Lake Eyre Basin Rivers Monitoring Project

Knowledge Review

DEWNR Technical report 2015/20

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

Funding for these projects has been provided by the Australian Government through the Bioregional Assessment Programme.

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Summary

The key objective of the Lake Eyre Basin River Monitoring (LEBRM) project is to provide an advanced and up-to date platform of hydrological and ecological knowledge that can support the detailed modelling, impact and risk analysis needs of Lake Eyre Basin (LEB) bioregional assessments (see DEWNR 2014). The LEBRM project background, purpose, approach and links to the bioregional assessment are described in more detail in DEWNR (2014). The purpose of the LEBRM Knowledge Review is to provide an assessment of the current state of knowledge about the Lake Eyre Basin (LEB) aquatic ecosystems to inform application of the *Integrated Scientific Management Framework* (ISMF; McNeil and Wilson 2014) for LEBRM.

The literature review included pressure-stressor-response (PSR) and risk assessment frameworks that inform the *Integrated Strategic Management Framework* (McNeil and Wilson 2014). The LEBRM project will build on a PSR approach based on the Queensland work (Marshall et al. 2006a; Negus et al. 2009; DERM 2010a). The Australian and New Zealand Standard for risk management (AS/NZS ISO 31000: 2009) provides for the management of any form of risk in a systematic, transparent and credible manner. This standard has been applied to water management in South Australia (DEWNR 2012) and has been used to assess risk from coal seam gas (CSG) in the Surat Basin (QWC 2012).

National and state-based systems for classifying aquatic ecosystems relevant to the LEB were reviewed. The extent of aquatic ecosystem mapping and level of attribution varies across the LEB; to date, no consistent aquatic ecosystem mapping and classification has been applied across the LEB. Conceptual modelling of aquatic ecosystem is a way to on build on classification to describe how different aquatic ecosystems may function. Conceptual models are being used in the LEBRM project to model how pressures and stressors impact on different aquatic ecosystems types. A number of conceptual modelling approaches have been reviewed and the approach adopted by the LEBRM project aligns with national frameworks (*LEBRM Conceptual Models and LEBRM Conceptual Modelling Approach (DEWNR, 2015*).

The LEB Rivers Assessment (LEBRA) is the primary program focussed on evaluating the health and condition of aquatic ecosystem across the LEB. The LEBRA methodology is presented and difficulties associated with evaluating such naturally variable systems discussed. Other condition assessments undertaken at the state level are the South Australian Monitoring, Evaluation and Reporting Program (Goonan et al. 2012) and Queensland Stream and Estuary Assessment Program (Negus et al. 2009).

The potential impacts of CSG and large coal mining (LCM) developments are described in terms of pressures and stressors. This review found there is little scientific information from Australia regarding pressures and stressors resulting from CSG developments; the majority of the literature draws on expert opinion and overseas experiences.

The current level of knowledge about aquatic ecosystem attributes in the LEB is very limited, with the Cooper, Georgina-Diamantina and Neales catchments most studied. However, even within these catchments, most studies have focussed on riverine waterholes and other more permanent aquatic ecosystem types. The review found little information is available for ephemeral aquatic ecosystem types such as floodplains and floodouts.

Literature for the components and processes of aquatic ecosystems are grouped under headings of hydrology, water quality and biota. The Cooper and the Georgina-Diamantina catchments are the only catchments in the LEB where long-term flow gauge stations exist and these are only sparsely distributed. Knowledge about the LEB hydrology has been supplemented with a network of stage-height loggers in the Neales, Cooper and Georgina-Diamantina catchments installed in the early 2000s. The network has been maintained and expanded, and contributed to a significant body of knowledge about the hydrology of these catchments. Salinity is the main water-quality attribute that has been monitored in the LEB, with very little information available on other attributes. Salinity is highly variable spatially and temporally; the main drivers are flow, location in the catchment and complex interactions with shallow aquifers. Surface water–groundwater interactions vary across the LEB, making it difficult to transpose the findings from one region to another.

Long term, standardised monitoring of fish and waterbirds at selected sites in the LEB has provided sufficient information to predict the response of fish populations to hydrological stressors. Invertebrate and waterbird studies have had varying success with regard to understanding population dynamics. The review found limited knowledge about other aquatic fauna, vegetation and riparian and floodplain biota of the LEB.

This review provides an overview of the ecological, conservation and cultural values associated with LEB aquatic ecosystems. Significant ecological and conservation values have been documented in the LEB that are associated with the boom and bust nature of the basin and its relatively intact condition. LEB aquatic ecosystems also have significant cultural values, often associated with the scarcity of water, and many sites of cultural value are also considered to have high ecological values.

1. Introduction

1.1. Context

The Bioregional Assessment (BA) Programme is a transparent and accessible programme of baseline assessments that increase the available science for decision making associated on potential water-related impacts of coal seam gas and large coal mining developments. A bioregional assessment is a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential direct, indirect and cumulative impacts of coal seam gas and large coal mining development on water resources. This Programme draws on the best available scientific information and knowledge from many sources, including government, industry and regional communities, to produce bioregional assessments that are independent, scientifically robust, and relevant and meaningful at a regional scale. For more information on bioregional assessments, visit <http://www.bioregionalassessments.gov.au

In addition, the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) is a statutory body under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) which provides scientific advice to Australian governments on the water-related impacts of coal seam gas and large coal mining development proposals.
Under the EPBC Act, the IESC has several legislative functions to:

- Provide scientific advice to the Commonwealth Environment Minister and relevant state ministers on the water-related impacts of proposed coal seam gas or large coal mining developments.
- Provide scientific advice to the Commonwealth Environment Minister on:
    - bioregional assessments being undertaken by the Australian Government, and
    - research priorities and projects commissioned by the Commonwealth Environment Minister.
    - Publish and disseminate scientific information about the impacts of coal seam gas and large coal mining activities on water resources.

1.2. The Lake Eyre Basin

The Lake Eyre Basin (LEB) is an internally-draining basin that takes up almost one sixth of Australia's land mass in the arid and semi-arid interior (Figure 1). It is unique in being one of the last unregulated dryland river systems in the world and the ecology cycles through massive 'booms' following large floods through to 'bust' in significant periods without flow (Bunn et al. 2006; Puckridge et al. 1998). While natural gas extraction has occurred in the LEB for a number of years, the coal-bearing Arkaringa, Pedirka and Galilee Basins (Figure 1) have been identified for potential coal seam gas and large coal mining developments.

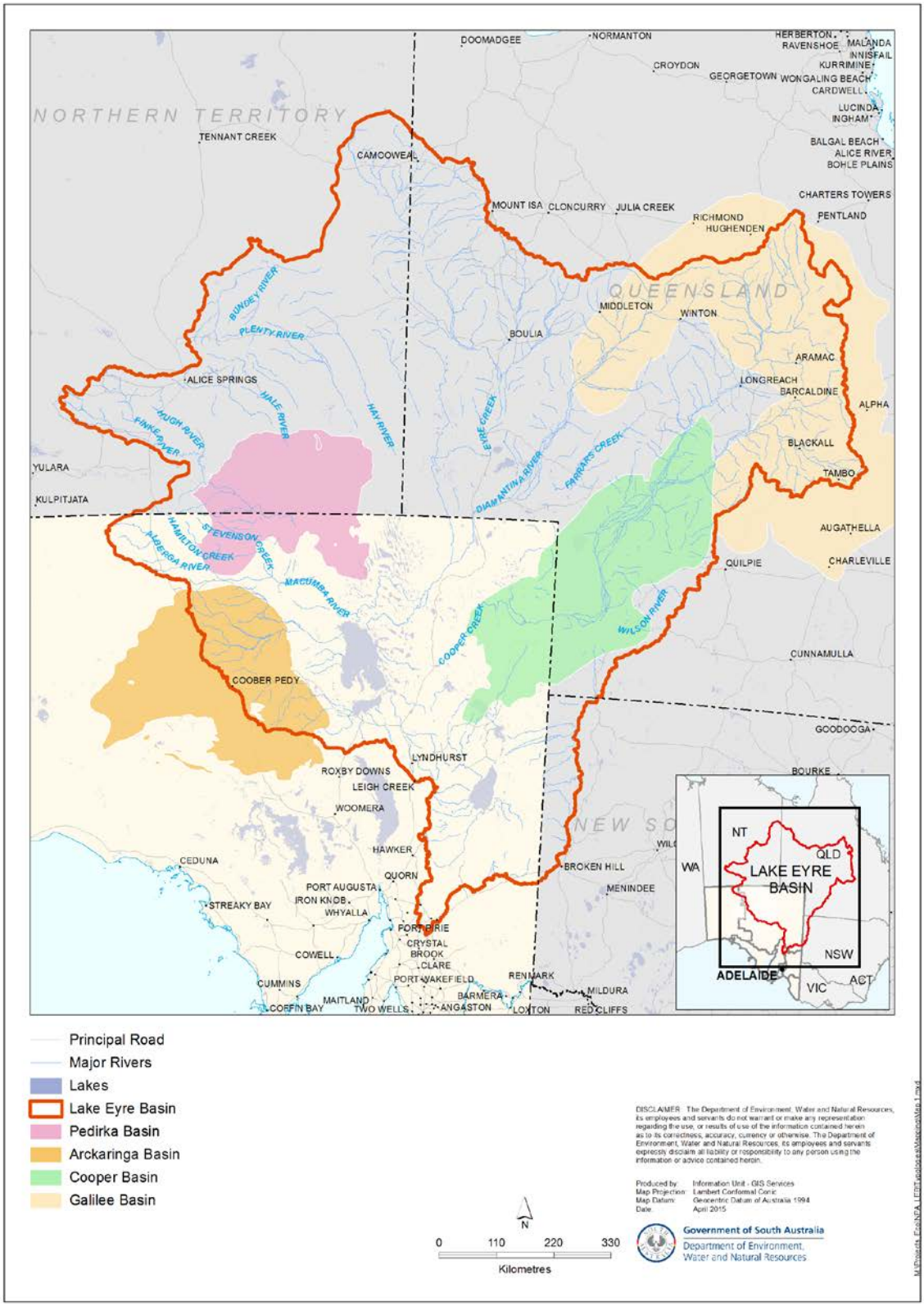

Figure 1.1 The Lake Eyre Basin, showing the major waterbodies and location of the coal-bearing basins (note that the LEBRM project is not covering the Bulloo River catchment)

1.3. Scope

This report is part of a series of studies forming part of the Lake Eyre Basin Rivers Monitoring (LEBRM). The LEBRM project is one of three water knowledge projects undertaken by the South Australian Department of Water, Environment and Natural Resources (DEWNR) to inform the Bioregional Assessment Program in the Lake Eyre Basin. The three projects are:

- Lake Eyre Basin Rivers Monitoring,
- Arckaringa and Pedirka Groundwater Assessment and
- Lake Eyre Basin Springs Assessment.

The LEBRM project was developed to collate a baseline of scientific knowledge around the hydrology and ecology of aquatic ecosystems in the LEB and to improve that knowledge in regions where coal-bearing deposits are located and therefore where CSG or LCM activities are most likely to occur in the foreseeable future. The overarching goal of the LEBRM project is to provide an advanced and up-to-date platform of knowledge about the hydrology, ecology and values of LEB surfacewater-dependent ecosystems that can support the detailed modelling, impact and risk analysis needs of LEB bioregional assessments (see DEWNR 2014). The LEBRM project background, purpose, other components and links to the bioregional assessment are described in more detail in DEWNR (2014).

The purpose of the LEBRM Knowledge Review is to provide an assessment of the current state of knowledge about the LEB aquatic ecosystems to inform application of the *Integrated Science and Management Framework* (ISMF; McNeil and Wilson 2014) and other components of the LEBRM project. As the LEBRM project is focussed on surface-water driven ecosystems of the LEB, the knowledge review is also focussed on surface-water driven ecosystems and the pressures and stressors that might impact on these. Groundwater-related pressures and stressors are being addressed through a complementary project, the LEB Springs Assessment. The LEB Springs Assessment is considering all groundwater-dependent ecosystems (GDE) including Great Artesian Basin springs and GDEs associated with alluvial aquifers (DEWNR 2014). Published papers, reports and books, as well as unpublished documents from government agencies, universities and non-government organisations available when the LEBRM project commenced were included in the Knowledge review.

The knowledge review consists of two parts, of which the first is further divided:

A. Literature review to inform the ISMF
   i. Overview of literature (Section 2) provides a summary of the literature against key headings (linked to the ISMF) highlighting major concepts and state of knowledge, existing approaches and methods
   ii. Annotated bibliography (Section 3) presents a summary of each document or website reviewed against each topic
   iii. References spreadsheet and document library (Section 4) contains a spreadsheet of all the references reviewed, with links to the document websites, links to the document in an electronic library of documents, and a spreadsheet identifying research data.
B. Data deliverables
   i. Data stack
   ii. Data register
   iii. Interactive GIS
   iv. Maps

The Literature Review is structured to reflect the ISMF (McNeil and Wilson 2014) as follows:

1. Strategic documents review: information to inform the overall approach taken in the LEBRM project including pressure-stressor-response frameworks, conceptual modelling and impact assessments, as well as the current state of monitoring and mapping in the LEB
2. Impacts of anthropogenic disturbance: provides a brief overview of the pressures that CSG and LCM developments may exert on aquatic ecosystem stressors
3. Aquatic ecosystems and their attributes: presents the current state of knowledge about componenets and processes that support LEB aquatic ecosystems (including floodplain systems)
4. Values: reviews the ecological, conservation and cultural values of LEB aquatic ecosystems.

This structure allows specific literature to be easily identified and accessed for relevant purposes throughout the project. The structure also enables the review to be easily accessed and interrogated for other programs such as the LEB Rivers Assessment (see Monitoring and condition).

2. Overview of literature

2.1. Strategic documents review

The LEBRM Integrated Science and Management Framework (ISMF) integrates a number of different management approaches into a holistic management model (see McNeil and Wilson 2014). The ISMF allows for the identification, classification and attribution of aquatic assets and the identification of impacts from anthropogenic disturbance, ecological responses and the mechanisms by which these responses impact on human values and NRM management activities. A goal in capturing the baseline knowledge for the LEBRM project, therefore, is to identify strategic documents that outline existing work on various aspects of the framework. This includes work on pressure-stressor-response and risk assessment, as well as other key components of the ISMF including asset identification, classification and mapping, conceptual model development and the identification of ecological monitoring and condition assessment approaches. The following section focusses on these strategic documents as well as identifying previous literature reviews that have aimed to collate information on various aspects of the ecology and management of LEB aquatic ecosystems. The documents discussed represent the key documents relevant to the LEBRM project and the section is not intended to provide a comprehensive history of each topic (i.e. documents that are incorporated in or superseded by more recent documents are not included).

2.1.1. Frameworks

The review focussed on frameworks that have been applied to assessing or describing how aquatic ecosystems may be affected by the types of water-related impacts likely to result from CSG and large coal mining developments.

2.1.1.1. Pressure-stressor-response frameworks

Pressure-stressor-response (PSR) frameworks are one approach that has been used to describe how human activities (pressures) result in changes in the biophysical conditions (stressors) that lead to a change in attributes, processes and conditions (response) (Marshall et al. 2006a). Climate, hydrology and geology are natural drivers at the landscape level that govern natural ecosystem functions by producing the variable biophysical conditions to which individual species, and hence ecosystems, are adapted.

PSR frameworks have been adopted in Queensland (earlier termed pressure-*vector*-response frameworks) in combination with risk assessment as they have been found to be effective for the selection of indicators for river health monitoring (Negus et al. 2009; DERM 2010a). Marshall et al. (2006a) identified stressors that are common to riverine ecosystems and developed generic PSR models for each stressor. The models were used to prioritise stressors for each of the major catchments, with an expert panel approach used in the Queensland LEB (Clifford et al. 2010). Mapping pressures by catchment identified priority catchments for waterway monitoring (DERM 2011a, b). More recently, the PSR approach has been adopted in Queensland for specific pressure sources. A PSR approach has been applied to evaluate the response in health of streams of the upper Murray-Darling Basin (MDB) to water releases from CSG developments (Takahashi et al. 2011b). McNeil et al. (2012) have used a PSR approach in determining criteria for fish refuge management in the MDB.

The LEBRM ISMF (Figure 2) built on the PSR approach to link it with risk assessment (McNeil and Wilson 2014) and the PSR was also used to build the conceptual models (Imgraben and McNeil 2013).

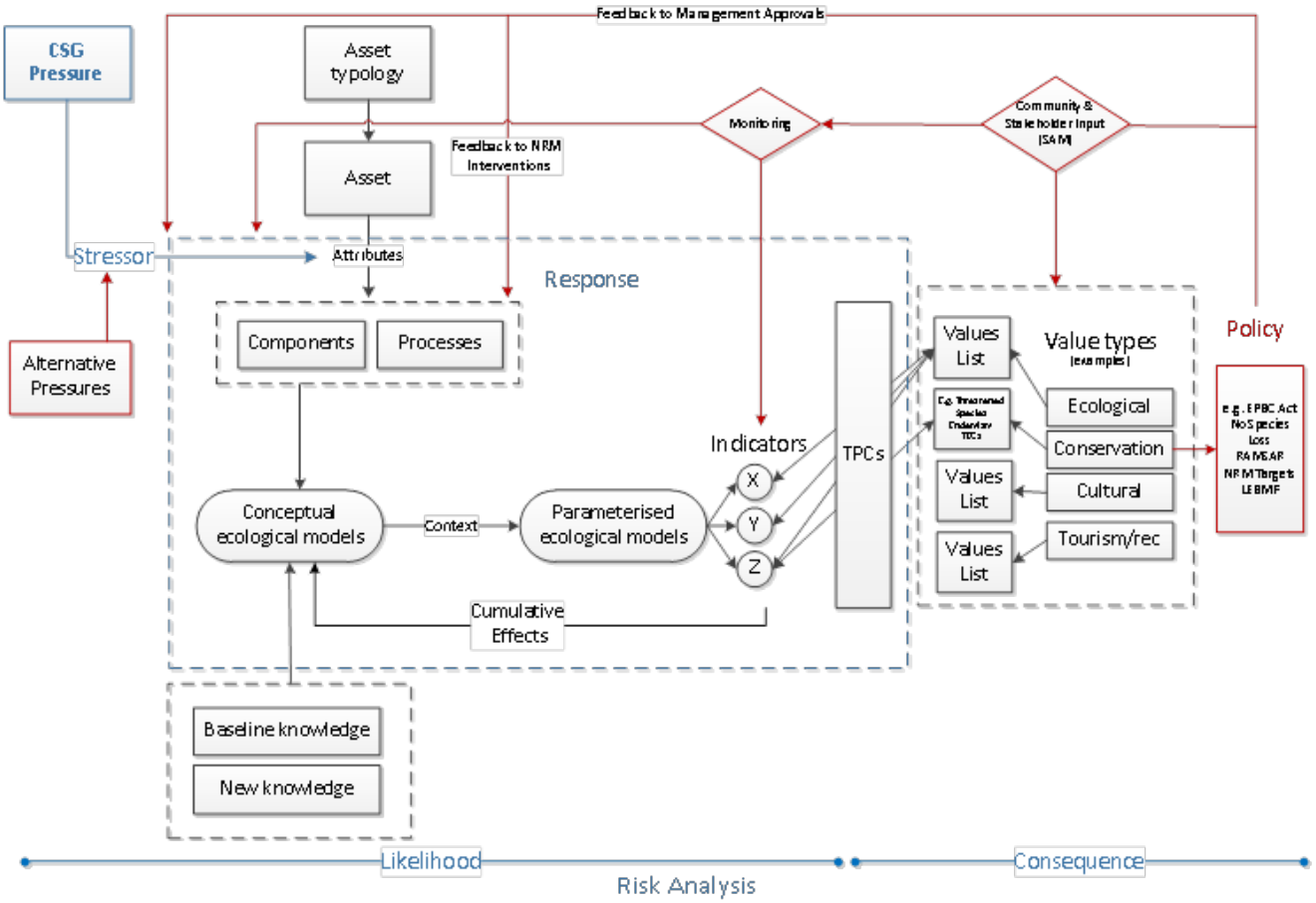

Figure 2-1 Showing how the pressure stressure response model was built into the integrated strategic management framework (from McNeil and Wilson 2014) (TPC = threshold of potential concern)

2.1.1.2. Risk and impact assessment frameworks

The Australian and New Zealand Standard for risk management (AS/NZS ISO 31000: 2009) provides for the management of any form of risk in a systematic, transparent and credible manner. This standard has been applied to water management in South Australia (DEWNR 2012), has been used to assess risk from CSG in the Surat Basin (QWC 2012), and is used to prioritise indicators in Queensland waterway monitoring (Negus et al. 2009; DERM 2011a, b).

Preliminary assessments of the vulnerability of water assets to CSG and LCM are currently being undertaken by regions, largely using existing data. In South Australia, the vulnerability assessments are based on a generic list of activities and effects and the degree of impact based on the water regime and source for each asset (Wilson et al. 2014). Knowledge generated through the regional vulnerability assessments will be incorporated into the bioregional assessment.

Research on the GAB in recent years has produced frameworks for assessing

- Risk to GAB groundwater dependent ecosystems (GDEs) from groundwater development in South Australia (Green et al. 2012)
- Cumulative risk to springs from CSG in the Surat area (QWC 2012)
- Impacts on GAB springs from climate change and development across the whole of the GAB (Miles et al. 2012).

Whilst the LEBRM project is not focussed on springs, the frameworks developed in these projects are relevant, particularly for considering changes in baseflow to watercourses.

The decision support system developed for determining stream ecosystem health response to releases of water extracted from coal seams in Queensland incorporates an ecological risk assessment framework (Takahashi et al. 2011). This system also brings together PSR and conceptual modelling.

Undertaking a risk assessment process is a requirement for development proposals; but they generally do not assess cumulative impacts of multiple developments (Williams et al. 2012; GA & Habermehl 2010). Several approaches have been developed for assessing cumulative risks:

- A GIS-based framework for assessing cumulative risk of mining on natural resource assets in the Namoi Catchment (Eco Logical Australia 2011, 2012)
- A framework for assessing potential local and cumulative risks of mining on groundwater, (although this does not include impacts from CSG; Howe 2011)
- Assessment of risks to springs in the Surat Cumulative Management Area (QWC 2012).

2.1.2. Aquatic ecosystem classification and mapping

2.1.2.1. Classification schemes

Aquatic ecosystem classification involves a systematic and often hierarchical approach to identifying the similarities and differences between aquatic ecosystems based on attributes relevant to ecosystem function. 'Typology is an extension to classification whereby those classified aquatic ecosystems are assembled into groups for a specific purpose i.e. a naming convention (AETG 2012a p. 3).' In the past, typologies have been developed without a supporting classification, leading to difficulties in attributing types and the potential for some types to be missed.

The ANAE classification framework was developed to provide a single national classification scheme for aquatic ecosystems in Australia (AETG 2012a). The framework is based primarily on a landscape function approach initially taken by Queensland (DSITIA in prep.) and is consistent with Queensland, South Australia and New South Wales classifications (e.g. Scholz & Fee 2008; DSITIA 2012 in prep.), although there are minor variations.

The ANAE takes a high level landscape approach to classification and is useful for integrating the more detailed but divergent jurisdictional aquatic ecosystem classifications to a uniform level. The LEBRM project has built upon the ANAE and South Australian Aquatic Ecosystem (SAAE) typologies (Scholz and Fee 2008; Fee and Scholz (unpublished)), intending to further develop sub-types incorporating attributes such as:

- Groundwater – surface water interactions (e.g. Green et al. 2012; Reid et al. 2009; Duguid 2013a)
- Hydrological regime (Duguid 2005; Kennard et al. 2010)
- Hydro-ecological processes (McNeil et al. 2011a; Robson et al. 2008)
- Geomorphology (e.g. Grimes 1984; Brierley & Friers 2005; Duguid 2005).

The modified SAAE aquatic ecosystem types are presented in the accompanying Conceptual Modelling report (Imgraben & McNeil 2013).

Application of aquatic ecosystem classification enables information that is known about a type in one location can be transposed to another aquatic ecosystem (AE) of the same type. Application of the ANAE classification to aquatic ecosystem mapping has been trialled in some regions, including the South East of South Australia (Butcher et al. 2011) and the MDB (in prep.), but it has not been comprehensively applied nationally nor in the LEB.

Because classifications are used to separate ecosystem types which are governed by differences in attributes and processes, classification is a form of conceptual modelling, with models developed for each type. Classification can be linked to risk analysis when conceptual models for different aquatic ecosystem types based on a classification inform the vulnerability analysis . If the spatial distribution of different aquatic ecosystem types is known, then vulnerability assessments may be spatially applied through a modelling approach; the accuracy is dependent on the scale of the typology, the natural variability of the aquatic ecosystem types and the data available. Classification can also be used to prioritise aquatic ecosystem types for management and/or conservation (e.g. ANAE 2012b; AETG 2012e).

2.1.2.2. Mapping and spatial assessments

Approaches to mapping and attributing aquatic ecosystems in Australia vary between the states, although work has recently been undertaken to develop national systems including:

- Guidelines for mapping Ramsar wetlands (DEWHA 2008)
- Delineating and describing aquatic ecosystems (AETG 2012c)
- Identifying and mapping GDEs (SKM 2012; Richardson et al. 2011a, b).

As discussed earlier, mapped aquatic ecosystems in the LEB have not been consistently assigned with types as proposed under ANAE (AETG 2012a) or other classifications, nor have the boundaries been delineated (AETG 2012c). The ANAE classification has been trialled in the South East of South Australia where it was found to work well, but it was noted that this was partially due to the region being relatively data-rich with experienced practitioners (Butcher et al. 2011). Work currently being undertaken at the regional level under NPA water asset database projects includes mapping aquatic ecosystems and attributing them. This may provide a useful data source which the LEBRM project could use to characterise or assign classifications; however a consistent approach has not been applied between jurisdictions.

Much work in the LEB has focussed on defining aquatic ecosystems by their degree of permanence (e.g. Tunn & Cameron 2008), with particular emphasis on determining refuge waterbodies (e.g. Silcock 2009a; Duguid 2013a). Remote sensing methods have been found to be effective at mapping wetland inundation frequency in the LEB (Wainright et al. 2006; Tunn & Cameron 2008), although the reliability of identifying permanent waterholes is limited because these are often small or narrow (Costelloe 2008; Tunn & Cameron 2008). Mapping of waterholes in the Cooper Creek and Georgina-Diamantina catchments combined remote sensing, historical records, expert knowledge and field surveys with existing literature and data reviews (Silcock 2009a). Remote sensing methods developed recently by White et al. (2013) and Lewis and White (2013) may assist; in particular they reviewed and trialled different methods for different spatial and temporal scales. Mapping of aquatic ecosystems in the Northern Territory portion of the LEB to date has been focussed on locating wetlands and waterholes, predominantly from remotely sensed information (e.g. Duguid 2011), with limited ground truthing and attribution of assets.

The Queensland wetlands program has undertaken a detailed mapping exercise covering much of the State using the EPA (2005) method. The wetland maps are presented on the Wetland *Info* website (EHP 2013). The LEBRM project will adopt the Queensland mapping methods (EPA 2005) where relevant.

2.1.3. Conceptual models, monitoring and condition

2.1.3.1. Conceptual models

As part of the LEBRM project, conceptual models for LEB aquatic ecosystems, highlighting their potential vulnerabilities to CSG and LCM development activities (see Impacts of anthropogenic disturbance), are being developed. This section presents a brief discussion about the conceptual model review; a more detailed discussion outlining the scope of the models, process for developing the models outputs and products is presented in the accompanying *LEBRM Conceptual Model Report*.

Conceptual models are a key element of many environmental monitoring and management programs. They may be used as a basis for discussion and planning, can help to identify gaps in knowledge, and prioritise areas that require further research or monitoring (Roman & Barret 1999). System scale models are integral in strategic adaptive management for setting objectives and identifying management options (Kingsford and Biggs 2012). Conceptual models provide a representation of the current knowledge of an asset, in this case an aquatic ecosystem, and should integrate the current understanding of system dynamics with the important processes and functions (Gross 2003). Fundamentally, they are working hypotheses about system components and processes, and should document key assumptions (Wilkinson et al. 2007). Through adaptive management, conceptual models can be tested and updated (Kingsford and Biggs 2012).

Conceptual models may be presented in many forms such as diagrams, tables and flow-charts, and may have accompanying narratives or contextual information. In many cases, it may be useful to use a combination of different conceptual model formats, which should be tailored to the objectives, audience and intended uses of the outputs (Hierl et al. 2007).

There are two types of conceptual models being developed for LEBRM:

1. Hydro-ecological control models describing the drivers, processes and functions of key aquatic ecosystem types (presented as flow diagrams and visual diagrams)
2. Pressure-stressor-response models identifying the ecological responses to key CSG/coal mining activities.

The Ramsar concept of 'Components, Processes and Services' (DSE 2005) will be used to structure the list of attributes. This ensures consistency with Ramsar and the National High Ecological Value Aquatic Ecosystems Framework (AETG 2012b), as well as with work that is being undertaken by the Aquatic Ecosystems Task Group, to develop an Integrated Ecological Condition Assessment Framework (AETG 2012d). The attribute classes also correspond with (or can be translated easily to) the Framework for the Assessment of River and Wetland Health indicators (National Water Commission 2007).

For the LEB, early conceptual models were developed as part of the DRY/WET (Puckridge et al. 1999) and ARIDFLO projects (Costelloe et al. 2004b). The ARIDFLO conceptual models describe the response of the river systems (floodplains, waterholes and wetlands), and their biotic and abiotic components, to different flow phases. Conceptual models were also developed to guide the first LEB river health assessment methodology (McKenzie-Smith et al. 2006). These models describe hydrologic and geomorphic processes at different geographic scales within the LEB and describe that variation from a temporal perspective. The models describe processes within headwater, channel, waterhole and terminating wetland areas, and during different hydrologic phases ('dry', 'wet' or 'flood'). Conceptual models focussing on fish have subsequently been developed and tested through the LEBRA project (Balcombe & McNeil 2008) with on-going review and refinement.

The Queensland Wetlands Program has developed a statewide series of wetland conceptual models that have been further refined at the catchment or basin level, including for the LEB (EHP 2012a). Queensland has also developed PSR models for key stressors resulting from a range of different pressures (Marshall et al. 2006a). Draft conceptual models have been developed for South Australian aquatic ecosystems (Fee & Scholz in prep.) linked to the SAAE types (Scholz & Fee 2008). Some preliminary conceptual-modelling work has been undertaken to describe key processes in mid-Finke waterholes, however, many aspects of the models require testing (Duguid 2013a). Some conceptual modelling work has also been undertaken for headwater springs in the Northern Territory LEB (Davis et al. 2013b).

Aquatic ecosystem models have also been developed for the semi-arid parts of the Murray-Darling Basin with four types of models presented for each aquatic ecosystem type: aquatic ecosystem component models, aquatic ecosystem inundation models, character description models and key driver models (Price & Gawne 2009). These models have been reviewed in the development of the LEBRM conceptual models.

Where classification typologies have been attributed to a spatial waterbodies layer, (see Classification schemes) the conceptual modelling can be spatially applied to aquatic assets.

2.1.3.2. Monitoring and condition

In Australia, monitoring of aquatic ecosystem health or condition has generally been conducted by state jurisdictions and is undertaken at the state and regional level, with each state and NRM region having their own regional priorities, creating difficulties in reporting at a national level due to variations in methods, indicators and interpretation. The National Water Initiative (NWI) baseline assessment of water resources in Australia (AWR 2005) highlighted the need to report on condition of rivers and wetlands at a national level, leading to the development of the framework for the assessment of river and wetland health (FARWH). The FARWH provides a flexible approach whereby different methods can be used in different regions, but are interpreted and reported under a common set of indices and standards (Alluvium Consulting 2011). FARWH is based around reference condition approach, but determining reference condition is a challenge for variable and modified systems (Alluvium Consulting 2011) and may be of limited use for management or impact assessment.

Sheldon et al. (2012) discuss early warning, compliance and diagnostic monitoring of ecological responses to human-induced changes in low flow (including no flow) conditions in Australia. The timing of monitoring indicators in relation to flow phase is acknowledged as a critical issue for the LEB (Thoms et al. 2009). Sheldon et al. (2012) recommend a 'filters approach' (Chessmen & Royal 2004 in Sheldon et al. 2012) over referential approach whereby expected conditions are derived from potential conditions and filtered by environmental conditions that are occurring at the time. This approach is intended to

overcome the issue of distinguishing where a change in an indicator is outside the range expected for a given set of environmental conditions and thereby takes into account natural variability. The emphasis of this work however is on detecting when low flows are longer than should 'naturally' occur, resulting in negative impacts on aquatic ecosystems. Impacts associated with low flows (and no flow periods) having a shorter duration than should 'naturally' occur are not dealt with.

In the LEB, maintaining the health of the rivers and wetlands is an obligation under the LEB Intergovernmental Agreement and therefore assessing the health of rivers and wetlands is mandated. Methods for condition assessment from other regions are difficult to apply in the LEB because natural variability and aridity may obscure changes caused by human activities. Determining when low flow conditions are outside the normal range of hydrological variation is one of the greatest challenges for monitoring the impact of low flows (Sheldon et al. 2012). For these reasons, determining guidelines for evaluating indicators such as water quality is difficult.

A river health assessment methodology was developed for the LEB (Sheldon et al. 2005) and a selection of the indicators trialled in the first phase of the LEBRA (LEBSAP 2009a). Data collected in the pilot studies, monitoring data collected by state and national programs and an expert panel approach were used in the first assessment of health of LEB Rivers (LEBSAP 2008; LEBSAP 2009a). The 2008 LEBRA found that LEB rivers were generally in good health but there were insufficient data to make an assessment of some indicators in some regions, particularly catchments in South Australia and Northern Territory.

A revised methodology for LEBRA was subsequently developed (Thoms et al. 2009). Under this method, physical habitat, fish, waterbirds, riparian vegetation structure, wetlands vegetation condition, water quality and pressure indicators were proposed as the indicators. The current LEBRA monitoring program (2010-2013) has focussed on a primary set of key indicators with annual monitoring plans for fish, water quality and hydrology developed through the LEBRA Operations Group (DSEWPAC 2011, 2012, 2013).

LEBRA monitoring is undertaken by the states and provides an annual snapshot of data across the LEB. The LEBRA methodology indicators are closely associated with refuge habitats as these are sensitive to threats at the Basin-scale, in particular low flow thresholds (McNeil & Cockayne 2011). The methodology (Thoms et al. 2009) focusses on using 'Thresholds of Probable Concern' (TPC) and work is currently underway to determine an approach for identifying TPCs through the LEBRA project. The TPC approach is intended to overcome the issue of determining at what threshold a change in an indicator or value should trigger a change in management intervention (Kingsford and Biggs 2012).

In South Australia, the Environmental Protection Agency conducts a statewide aquatic ecosystem condition monitoring program (Goonan et al. 2012), assessing each NRM region on a rolling basis approximately once every five years. This program undertakes an assessment of water quality, macroinvertebrate assemblages and a general assessment of ecosystem pressures. The latest assessment conducted in the South Australian section of the LEB (South Australian Arid Lands NRM region) was undertaken in 2012 (EPA 2012).

Queensland Integrated Waterways Monitoring Framework is highly targeted, with indicators based on risk assessments for each region (DERM 2010a; Negus et al. 2009), with a report on the health of the Queensland portion of the LEB in preparation (Negus et al. 2013).

Much LEB data are also collected from relatively short-term projects that may focus on a particular area and indicator. The LEBRM Knowledge review has identified these data-sets in the References spreadsheet (see References Spreadsheet and Document Library).

Both coal seam gas and other large coal mining development dewater aquifers as part of the extraction, potentially resulting in large volumes of discharge water being produced. Releasing discharge water into watercourses is one disposal option being considered. The question of how to detect stream ecosystem health response to water releases into watercourses has been the subject of work by DERM in Queensland ('Healthy Headwaters project') leading to the development of a decision support system (Takahashi et al. 2011c), biological monitoring guidelines (Takahashi et al. 2012b) and other guidelines. This work uses a PSR framework and Ecological Risk Assessment and is focussed on change in ecological values as opposed to condition. Because water releases are a relatively new problem, the project has identified indicators (such as ionic composition) and

ranges of indicators (such as lowered turbidity and lowered salinity) that are not usually considered in other monitoring programs.

2.1.4. Pre-existing literature reviews

As part of the first State of the Basin report for the LEB river health assessment a review of available literature and data to inform river health assessment was undertaken (LEBSAP 2009a). This report highlighted the key gaps in information, noting that even for the Cooper Creek, the most studied catchment in the LEB, the level of knowledge is still far below that for many coastal catchments in Australia. Hydrology and boom and bust cycles of aquatic ecosystems were highlighted as priorities for research. The Desert Rivers, Western Rivers and Frome catchments were areas with insufficient data on which to base an assessment for some indicators (refer to LEBSAP 2008 and 2009a for definition of these catchments). Table 2-1 presents a summary of other recent key literature reviews relevant to the aquatic ecosystems of the LEB.

Table 2-1 Recent literature reviews

References	Topic	Region
Davis et al. (2007)	Review of ecological and biophysical processes in Queensland (Qld) wetlands	Qld
Duguid (2005)	Includes a review and collation of literature and data for the wetlands of the arid Northern Territory (NT)	Area encompasses the NT portion of the LEB
Golder & Associates (2009)	Environmental water requirements (EWRs) based on available data and literature: focus on extraction and diversion as key threats to EWRs	Cooper Creek in Qld
Miles & Risby (in prep.)	EWRs based on available data and literature: focus on extraction and diversion as key threats to EWRs	LEB rivers in South Australia
Piddocke (2009)	Journals of three 19th century explorers and one early 20th century traveller were examined	Cooper and Georgina-Diamantina catchments
Rolls et al. (2012)	Ecological responses to low flows	Australia
Silcock (2009a)	Historical literature relating to permanent water sources	Cooper and Georgina-Diamantina catchments

The LEBRM literature review has highlighted the dearth of scientific literature documenting CSG and LCM impacts on aquatic ecosystems in Australia. What literature is available is largely focussed on the Surat and Bowen Basins in Queensland and impacts on groundwater dependent ecosystems. Key amongst these is a review by Shaw et al. (2010) that summarises available data for the examination of the physical-chemical and flow characteristics of proposed releases of CSG water to surface streams. A summary of research activities in Queensland CSG sector (GFCQ 2012) identifies many research projects currently underway that, when completed, should fill some of the gaps in knowledge. Due to the lack of scientific literature to review, current documents are based largely on expert opinion (e.g. RPS 2011; Moran & Vink 2010; Williams et al. 2012). Reddy (2010) presents a collation of literature on CSG and the environment predominantly from Wyoming, USA. The geology and hydrology of the American coal-bearing regions is different to Australia and more detailed analysis of the differences and similarities is required to determine how readily the observations in America can be transposed to Australia.

2.2. Impacts of anthropogenic disturbance

Understanding the linkages between anthropogenic disturbance and ecological impacts is critical to predicting ecological responses to coal mining activities and infrastructure. Under the ISMF (Figure 1) the LEBRM project aims to develop PSR models for various mining activities, assets and asset types in the LEB. The current understanding of Pressures (sources of disturbance) and stressors (mechanisms linking disturbance to ecological responses) related to coal mining activities is an important first step in developing accurate and well informed PSR models to underline the conceptual modelling framework. In addition, the identification of other pressures, often unrelated to coal mining developments, which may complicate, compound, or mask the impacts of these activities, is of vital importance to developing accurate PSR models.

The following section explores the various literature around pressure and stressor identification, modelling and prioritisation. The information in this section represents both the various jurisdictional approaches to pressure and stressor identification and a brief overview of coal-mining related pressures and stressors. How these impact aquatic ecosystems will be explored in subsequent components of the LEBRM project and the LEB bioregional assessment. The following sections attempt to summarise literature about the impacts of anthropogenic disturbance on aquatic ecosystems using the PSR framework, however it is outside the scope of this document to present the complex interactions and feedback loops that occur between pressures, stressors and responses.

2.2.1. Pressures

For the purposes of the ISMF, pressures are considered as human activities in the landscape that have the potential to adversely influence aquatic ecosystems (McNeil and Wilson 2014). Hydrological, climatic and geological factors outside of human influence are termed 'drivers' (Marshall 2006) and not discussed herein, however they act on ecosystems as pressures and are considered in the conceptual models (Imgraben and McNeil 2013) and ISMF (McNeil and Wilson 2014). For the purposes of the LEBRM project, the focus is on sources of risk to surface water-dependent aquatic ecosystems arising from CSG and LCM developments. The identification and characterisation of pressures will be integral components of the vulnerability assessment.

It is important to note that as the LEBRM project is focussed on the vulnerability of surface water-driven aquatic ecosystems (including floodplains) from surface water-driven stressors, several potential pressures to groundwater-driven aquatic ecosystems, such as hydraulic fracturing and drawdown in groundwater levels, are not a focus of this review. Issues of groundwater-dependency and groundwater-driven stressors will be the focus of the proposed LEB Springs project. The following discussion presents some of the key pressures to LEB aquatic ecosystems that have been identified to date. Non-CSG and LCM pressures are noted as these already exist in and have impacted on some of the LEB aquatic ecosystems (LEBSAP 2008).

2.2.1.1. Wholistic LEB pressures

Several projects to date have compiled lists of pressures to aquatic ecosystems of the LEB (e.g. Duguid et al. 2005; LEBSAP 2008; Clifford et al. 2010). Listing and ranking of pressures specifically resulting from CSG and LCM has not been undertaken for the entire LEB to date, but many of the existing lists identify pressures that may arise from CSG and LCM as well as from other land uses and may be considered as a starting point.

As part of the first assessment of river health in the LEB, the LEBSAP (2008) identified the following key threats to LEB rivers:

- Major water impacting developments, including mining and irrigation
- Cumulative impacts of minor water developments (including bores) and diversions
- Intensified land use around waterholes
- Isolation of floodplains through levee construction or roadway embankments
- Impacts of pastoral activities, tourism and mining
- Intensified surface water extraction and drawdown
- Impacts of climate change on water resources
- Modification of basin catchments, such as vegetation clearance and inappropriate grazing, soil management and cropping practices

- Presence and spread of introduced pest plants and animals, especially their impact on waterholes
- Stocking rivers and waterholes with non-local fish species.

A recent list of threats to LEB assets was compiled by the LEB Community Advisory Committee (LEBCAC 2012). The five highest ranked threats were (in order from greatest threat first):

1. Invasive pests and weeds
2. Altered hydrological regimes and excessive water extraction
3. Total grazing pressure
4. Reduced water quality
5. Tourism impacts.

Although CSG and LCM developments were not directly rated as significant threats, all these pressures (except grazing and tourism) are considered to be strongly associated with CSG and LCM developments.

Queensland has undertaken pressure identification as part of waterway monitoring to identify risks to waterway health at the catchment scale (Table 2-2). Expert opinion and spatial-data analysis were used to score pressures for each catchment (DERM 2011a,b). The most significant pressures identified as threatening a large proportion of priority species (terrestrial and aquatic) in the Queensland LEB are: invasive species (including pigs, gambusia and weeds), groundwater and surface water extraction and inappropriate fire and grazing regimes. The Cooper catchment was identified as having the most number of threats that scored greater than low threat (Table 2-2). A subsequent project in the Cooper catchment identified land use (i.e. grazing) and the introduction of feral animals as priority threats to the aquatic ecosystem (Negus et al. 2012).

,

Table 2-2 Pressures that scored greater than low threat for LEB catchments as part of the Queensland integrated waterways monitoring program (Negus et al. 2012).

Pressure	Cooper	Thompson	Barcaldine	Georgina	Eyre	Diamantina
CSG	✓					
Grazing	✓	✓	✓	✓	✓	✓
Major industrial sites	✓				✓	
Flow barriers	✓	✓	✓			
Metal mines					✓	
Feral pigs	✓	✓	✓			
Pest fish	✓	✓	✓			✓

No pressure or threat prioritisation specifically for surface-water driven aquatic ecosystems has been undertaken in South Australia and the Northern Territory. The South Australian Arid Lands Biodiversity Strategy (DEH & SAALNRMB 2009) identifies the following threats to biodiversity arising from mining:

- Mechanical disturbance
- Pollution
- Reduction in GAB pressure
- Alteration of natural water flows.

For the purposes of the LEBRM project, pressures are defined at the activity level, consistent with the approach used in the South Australian NPA data project, and are grouped by the land use type, termed 'pressure group' (either CSG or LCM).

Further work will be required to assess the relative impact of the pressures in relation to each other, mitigation measures and other, non mining-related pressures.

2.2.1.2. Specific CSG and LCM pressures

The South Australian water asset vulnerability assessment (Wilson et al. 2014.) identified the following list of CSG and LCM activities, which has been used as the basis of the water-related pressures for the LEBRM project:

- *Surface water extraction:* In arid regions of the LEB, surface water extraction for long-term uses such as town supply is limited because water quality is often unsuitable and the supply is insufficient, however, some exceptions exist, such as Innamincka. The characteristics of these surface waters make them more suited to short-term uses such as road construction, dust suppression and water supply for exploration camps. These activities, whilst not drawing large volumes of water compared with that used for longer term extractive purposes, can result in rapid drawdown of waterholes, accelerate the drying of waterholes and interruption of downstream flow. Many waterholes, including semi-permanent ones, also supply water for stock.
- *Surface water diversion and capture (no extraction*): Surface water diversion and capture may be required for flood prevention or water supply for some developments; however, surface water diversion may inadvertently occur through the construction of access and supply routes. In low relief landscapes such as the LEB, flow patterns and migration pathways may be easily disrupted, with parts of the floodplain becoming isolated and less frequently inundated whilst other parts become more frequently inundated.
- *Discharge to surface water*: Surface water discharge leading to altered hydrological regimes and hydrochemistry is considered one of the main pressures arising from CSG that is likely to impact surface water ecosystems (NWC 2010, 2012). Both CSG and usually LCM developments require dewatering of aquifers, either to release gas from coal seams or prevent flooding of coal mines, resulting in large volumes of generally low-quality water being produced (often referred to as co-produced water). Co-produced water may be excessively saline and contain high levels of some chemical components. Co-produced water generally requires treatment before it can be disposed of and the main disposal options are:
  - Discharge into watercourses
  - Re-injection into aquifers.

  Reuse options are limited because users generally require more reliable supply than CSG and LCM can deliver (RPS 2011), however, irrigation options are being used in some CSG operations. Discharge of large amounts of excess water into watercourses is a relatively new pressure in Australia and subject to water quality regulations in South Australia and Queensland. Impacts on flow regime and water quality have been a focus of recent research. The healthy headwaters CSG water feasibility study (Activity 4) in Queensland in particular has focussed on release of CSG water and the resulting reports are discussed further in this document.
- *Site runoff:* Surface run-off from hard, unprotected and compacted surfaces can carry sediment and other contaminants, can become acidic if it passes over sulfidic soils and can also cause erosion (Water & Rivers Commission 2000). Stormwater management is used to mitigate the risks.
- *Site establishment and traffic (vehicular and foot):* None of the documents reviewed contained specific information on mine-site establishment and traffic pressures. However, several reports note that CSG operations have relatively high amount of on-going site establishment and traffic over a large 'footprint' due to the number, density and short operational lifespan of wells meaning new wells are continually being opened (Williams et al. 2012). Wakelin-King (2011) reports on impacts of tourist traffic on refugia in the Neales catchment.
- *Overburden management*: Overburden is the soil or rock overlying a deposit that is displaced during mining without being processed (including rock storage facilities). This material needs to be stored on-site or deposited elsewhere. There is potential for leaching of toxicants into the ground and for surface erosion of the materials which may deposit in watercourses. Overburden placement can also re-direct surface run-off and may require surface water diversion (DITR 2008).
- *Hydraulic fracturing:* Hydraulic fracturing (fraccing) is a potential pressure for GDEs (Williams et al. 2012) and will be a focus for the LEB Springs project. However, there have been some instances documented in the media and community websites of fracturing causing the release of gases into watercourses (e.g. Carney & Agius 2013; Lock the Gate Alliance 2013). This topic requires further investigation to evaluate if it should be included in the LEBRM project risk analysis.
- *Evaporation ponds and tailings dams*: Brines, slurries and residual solids are a by-product resulting from co-produced water treatment and fraccing fluids. Evaporation ponds have been used in CSG developments in the past but in

Queensland and NSW these are now banned; other options are under review (Williams et al. 2010). Tailings dams for managing slurries present a risk to wildlife, especially waterbirds that may attempt to utilise the surface free-water. Other risks associated with evaporation ponds and tailings dams include groundwater contamination, seepage through the dam wall, dam wall failure and exposure of contaminants or toxicants to wildlife, with longer-term issues around maintaining the dam wall integrity (DITR 2007; Azam & Li 2007).

The following CSG and LCM development activities identified by Wilson et al. (2014) have impacts primarily on groundwater-related stressors and will be dealt with by the LEB Springs Assessment project (see DEWNR 2014):

- Unconventional gas activities
- Groundwater dewatering and extraction
- Managed aquifer recharge
- Well drilling (exploration and groundwater).

Additional pressures to those above that have been identified through the literature review include:

- Pest plants and animals (LEBSAP 2008): the pressures identified by DEWNR do not specifically include pest plants and animals as the spread of these species and new introductions are treated as a response to the human pressures and are dealt with through the aquatic ecosystem components and processes modelling
- Pressures arising from the population of mine workers and support personnel, including recreation impacts (Farag et al. 2012), water supply and effluent treatment and providing an amenable environment
- Clearance and alteration of vegetation (Wakelin-King 2010; Golder Associates 2009)
- Inter-basin transfer (pressures to macroinvertebrate communities) (Smythe-McGuiness et al. 2012)
- Climate change (LEBSAP 2008; Golder Associates 2009)
- Inappropriate fire regimes
- Accelerated erosion and sedimentation (Wakelin-King 2011; Golder Associates 2009)
- Accidental spills of toxic or saline waters (DITR 2007)
- Stocking waterways with non-local crustaceans (Redclaw crayfish *Cherax quadricarinatus*) (Duguid et al 2005; Cockayne et al. 2012, 2013).

DITR (2008) have listed activities that may impact on water quality by the following stages:

- Exploration
- Resource development and design
- Mining, minerals processing and refining
- Rehabilitation
- Closure and post-mining
- Shipping of products.

2.2.2. Stressors

Stressors are biophysical condition attributes that are modified by pressures and elicit ecosystem responses (Marshall et al 2006). There are often complex interactions betweens stressors, where a change in one stressor may trigger a change in another stressor.To date there have been two reports that aimed at identifying stressors resulting from water-related CSG and LCM development pressures in Australia relevant to the LEBRM project:

Takahashi et al. (2011b): identifies the following key stressors resulting from CSG water release:

- Decrease in dry spells
- Constant flow and decrease in seasonality
- Decrease in conductivity (salinity)
- Increase in transparency of the water
- Changes in ionic composition of the water
- Cumulative toxicological impacts from contaminants.

Wilson et al. (2014): lists the following effects (equivalent to stressors) of CSG and LCM developments on surface water assets:

- Surface water/groundwater connectivity
- Physical habitat (geomorphic structure and organic habitat components)
- Water quantity (volume available to an asset)
- Surface water regime (timing, duration, frequency, extent and depth)

- Water quality [and chemistry]
- Functional connectivity of surface water.

Wilson et al. (2014) also identifies groundwater-related effects that will be considered by the LEB Springs Assessment project.

Whilst the terminology and grouping differs, the stressors identified by the Wilson et al. (2014) encompass those stressors identified by Takahashi et al. (2011). The Wilson et al. (2014) stressors are being used as the initial list of stressors for the LEBRM project; as noted for pressures, the LEBRM project will focus on stressors that impact on surface water-driven aquatic ecosystems. Additional stressors may be included as a result of the expert workshop review of the conceptual models.

Subsidence has also been flagged as a potential impact of CSG and some coal mining practices (GA & Habermehl 2010, Williams et al. 2012). There has not been any confirmed subsidence as a result of CSG in Australia and the maximum predicted subsidence is 280mm (Commonwealth of Australia 2014b)

Sedimentation is another issue that may be considered a stressor.

The following is a brief outline of the major surface water stressors likely to result from CSG and LCM activities. As noted earlier this review has found very little research documenting the impacts of CSG and LCM on water dependent ecosystems in Australia, therefore the discussion presented is based on adapting research from other pressures and expert knowledge.

2.2.2.1. Surface water regime stressors

The timing, duration, frequency, extent and depth of flows, as well as the volume of water available to an asset are critical aspects of this stressor (Wilson et al. 2014). Based on these characteristics, flow events can be characterised, including periods of no flow (e.g. Duguid 2013a).

Low flows are likely to be altered by CSG and LCM related pressures, mainly as a result of:

- The addition of waste water leading to increased low flows, in particular increasing the duration of low flows and increasing longitudinal connectivity (Takahashi et al 2011b)
- Extraction from waterholes leading to decrease in persistence time of refuges and a reduction in number and connectivity of refuges (Bunn et al. 2006), as well as loss of the 'bath-tub' ring of algae that maintains primary production during periods of no flow (Bunn et al. 2003)
- Surface water-groundwater interactions (see 2.3.2.2).

Low flows have a significant impact on the extent and arrangement of aquatic habitats, the physical and biological conditions in remaining habitats, affect sources and exchanges of energy and restrict dispersal of biota (Rolls et al. 2012).

During subcatchment flood events (Costelloe 2011), floodplain flow and inundation patterns may be impacted through the construction of roads and other infrastructure. Infrastructure can cause the concentration of flows in some areas whilst isolating other parts of the floodplain, with impacts on geomorphology (Wakelin-King 2013).

Medium to large flood events are important for maintaining the variety of landforms and physical habitat, and for watering the more distal ecosystems (Costelloe 2011a). Water diversion or extraction that reduces flood peaks or reduces flood volumes will be detrimental to these processes. As discussed above, larger flow events are required to flush out accumulated sediments in waterholes.

If subsidence occurs as a result of depressurisation for CSG, although falls are likely to be relatively low (Commonwealth of Australia 2014b), the area impacted could be spatially extensive (Moran & Vink 2010; IESC 2014b) and may be significant in some circumstances with potential impacts on surface flow paths (Commonwealth of Australia 2014b). The likelihood of subsidence is lowest where gas recovery involves minimal volumes of co-produced water, there is limited connectivity between the coal seams and adjoining formations, and the overlying strata are dominated strong (competent) rocks (Commonwealth of Australia 2014b).

Changes in flow regime can alter the availability of habitats in many ways and this has been the subject of much research, including:

- Altering when and how long different habitats are available (submerged) to aquatic species (Smythe-McGuiness et al. 2012; Farag et al. 2010),
- Impacts on the growth patterns of the biotic components (Capon 2003; Bunn et al. 2006)
- Impacts on the geomorphological processes leading to changes in the geomorphic structures (Wakelin-King 2011).

2.2.2.2. Water quality and chemistry stressors

Mine waste water (including CSG-produced water) composition varies but may be different from the local watercourse water in turbidity, ionic composition, salinity, pH, organic components and toxicants (DITR 2008). Shaw (2010) reviewed the chemistry of CSG produced water which was incorporated in a direct toxicity assessment (Takahashi et al. 2011a) and salinity guidelines (Rogers et al. 2011) for water releases. Critical thresholds for some toxicants (including some used in fracing fluids) have not been established (Commonwealth of Australia 2014a).

Cases of release of methane into the air, shallow groundwaters and surface waters in Queensland and New South Wales have been documented in the media (e.g. Carney & Agius 2013) and by community groups (e.g. Lock the Gate Alliance 2013). The level of risk to human and environmental health and economic production is unknown. To date there has not been any documentation of methane release into water resources in the scientific literature in Australia; this is a subject that will require further research to determine the potential risks to water assets. A recent investigation at CSG wells in Australia found fugitive emissions into the air at most wells, but that the levels were within acceptable ranges for CSG industry for the purposes of reporting emissions under the National Greenhouse and Energy Reporting legislation (Day et al. 2014).

The water quality and chemistry parameters of LEB streams and rivers are naturally variable spatially and temporally, with the variability being primarily driven by flow (Sheldon & Fellows 2010). Sheldon & Fellows (2010) therefore recommend that any water quality guidelines need to be developed with respect to the current and preceding flow conditions. Spatial and temporal variation would also need to be considered in determining baseline water chemistry and quality.

The following water quality stressors have been identified as particularly relevant to CSG related activities in Queensland.

Turbidity

Produced water is likely to have very low turbidity and, while the review found no scientific literature documenting the impacts of artificially reducing the turbidity of naturally turbid waters, the increased light penetration is likely to alter primary production, food webs and habitats (Takahashi et al. 2011b).

Ionic composition

In the Murray-Darling Basin, treated waste water from CSG is typically higher in sodium and potassium compared with the naturally calcium and magnesium rich receiving waters, with negative impacts on the shell formation of invertebrates (Takahashi et al 2011b). Further investigation into the ionic composition of discharge and receiving waters and potential negative impacts is required (Shaw 2010).

Salinity

Alteration of salinity, which in the case of CSG produced water, can be either a lowering or increase of salinity, may result in physiological stress in species adapted to different salinity conditions. Upper tolerance limits for salinity levels have been the subject of considerable research, however further research is required to determine lower salinity thresholds (Rogers et al. 2011).

Toxicants

Returned fraccing fluids, brines from water treatment and slurries are likely to contain high levels of metals and radionuclides that, although naturally occurring in groundwater, are likely to be concentrated (Williams et al. 2012). Because the LEB is an endorheic system there is potential for cumulative impacts and build-up in downstream levels of toxicants, even if they are

below critical thresholds at the discharge sites (Takahashi et al. 2011b). As well as direct discharge, catchment run-off may also alter water quality where produced water is used for irrigation (Farag et al. 2010).

2.2.2.3. Functional connectivity of surface water

Fragmentation of floodplains through the construction of roads and other infrastructure may isolate portions of floodplain, reducing the area of floodplain and interrupting the movement of and area available for biota (plants, animals etc), energy and nutrients (Bunn et al. 2006). Changes in flow will also alter the permanency and connectivity of waterholes (Sheldon et al. 2010). Increasing flows through discharges may increase the functional connectivity providing opportunities for invasive species as well as triggering ecological responses in biota.

2.2.2.4. Other stressors affecting physical habitats

The physical habitats include both geomorphic structures such as different land forms (pools, floodplains etc.) and substrate types (rocks, gravel etc.) and biological components such as emergent vegetation and fallen wood.

Loss or alteration of vegetation

Loss or alteration of vegetation has commonly occurred as a result of increased grazing pressure, but may also occur as a result of altered hydrology or other pressures. Loss or change in vegetation will alter the range of microhabitats (e.g. fallen submerged timber, nesting hollows, surfaces for biofilms, shelter from predators) and may impact geomorphological processes and structures (Wakelin-King 2013), triggering responses in water regime stressors. Physical habitats are susceptible to many pressures and in most parts of the LEB are likely to have undergone some degree of anthropogenic alteration to date, including sedimentation of waterholes and erosion and compaction of the bed and banks.

Sedimentation of waterholes

As well as smothering submerged habitats, flora and fauna and reducing the depth of aquatic habitat, the sedimentation of waterholes leads to a reduction in the persistence of waterholes between flow events. The depth of a waterbody is the primary determinant of the length of time it takes for the water to persist between flows when evaporation is the only form of loss and there are no groundwater inflows (Hamilton et al. 2005). In the Neales River, up-valley floodplain gullying has substantially reduced depth in some waterholes (Wakelin-King 2010). Cendon et al. (2010) propose that the velocity of flows seen in the LEB during large flow events is sufficient to flush the waterholes of sediment that builds up during low flows; riparian vegetation plays a critical role in that process (Knighton and Nanson 2000; Zong & Nepf 2010). Sediment flushing has been observed in the Neales catchment where the deepest waterhole, Algebuckina, decreased in depth by 1 m over a five-year period, but was subsequently scoured to its previous depth following a 1:10year flow event in 2011 (Costelloe 2011b). However, increased disturbance of the catchment and floodplain may occur from drilling, road construction or other land use pressures and may lead to excessive sedimentation (Eco Logical Australia 2011; Golder Associates 2009), requiring larger flow events to flush the sediments and place greater stress on aquatic ecosystems between major flood events. Inappropriate road, bridge or culvert design (Wakelin-King 2010, 2013) can also lead to erosion and waterhole sedimentation.

Erosion / compaction of watercourse bank / bed

Compaction and erosion around the banks of watercourses by foot traffic or stock can lead to gullying and impacts on riparian vegetation (Petit 2002), with stock particularly contributing to gullying up and downstream from waterholes and human visitation a factor on steep waterhole banks. Some river reaches are inherently more susceptible to erosion (Wakelin-King 2010).

Introduction and spread of invasive species

Invasive species are considered one of the greatest threats to LEB aquatic ecosystems (LEBCAC 2012, DERM 2011b; Clifford et al. 2010). Clifford et al. (2010) ranked in-stream pest fauna as the highest risk and riparian pest fauna as moderate risk. Invasive species may be introduced and spread accidentally in mud and soil attached to equipment and vehicles and their

establishment facilitated as a result of disturbance. It is possible that some species may also be intentionally introduced such as for recreational purposes (e.g. angling species of fish and crayfish). Many pest plants and animals are currently limited in their distribution by water availability; changes in flow regime that result in increased water availability may lead to increases in the abundance and distribution of pest plants and animals (DERM 2010c) including species that occupy riparian zones (e.g. pigs). This provides an illustration of how a change in one stressor (flow regime) leads to a change in another stressor (pest species), resulting in an ecosystem response to multiple stressor.

Invasive plants and animals can alter the biotic habitat through grazing on vegetation and changing its composition and structure (Pettit 2002). Pest animals may also cause compaction and erosion leading to altered flow paths and flow velocities that impact on geomorphic structures (Pringle & Tinley 2003; Wakelin-King 2011).

2.3. Aquatic ecosystems and their attributes

Under the pressure-stressor-response framework, aquatic ecosystem components and processes respond to stressors arising from anthropogenic pressures. Under a risk analysis framework, it is the attributes of a system and their vulnerabilities to pressures and stressors that determine the likelihood of any response occurring (*LEBRM Integrated Strategic Management Framework*). This section summarises current knowledge about the components and processes of the following key attributes:

- Physical habitat and geomorphology
- Water quality
- Hydrology
- Biota.

Catchment by catchment descriptions of aquatic ecosystem attributes focussing on environmental water requirements have been prepared for SA catchments (Miles & Risby 2010) and for the Cooper Creek (Golder Associates 2009).

2.3.1. Components

For the purposes of LEBRM, the term 'components' is used to describe the measurable attributes of an aquatic ecosystem, such as species present and water quality parameters. The components of LEB aquatic ecosystems vary spatially and temporally, with some components more variable than others. Key natural drivers are the hydrology, geology and climate, processes which operate over a range of spatial and temporal scales, from catchment-wide down to habitat components. Determining the components of aquatic ecosystem requires knowledge of how they vary spatially and temporally.

The following sections describe the known components of LEB aquatic ecosystems; whilst there is some over-lap in the listed components with the stressors listed previously, this section is focussed on describing the known attributes of LEB aquatic ecosystems.

Primarily information on the majority of aquatic ecosystems is on their spatial location and mapped extent, with some information on frequency of inundation and occaisional species records. More specific information about the attributes of aquatic ecosystems in the LEB has focused heavily on refuge waterholes, with less information available regarding lakes (Reid & Gillen 1998: Schmarr et al. 2013; Costelloe et al. 2004), palustrine ecosystems (Duguid 2013a; Timms 2007) and floodplains (Capon 2003, 2007).

2.3.1.1. Physical habitat components

The physical habitats of aquatic ecosystems are generally recognised as those areas that provide the living space of water-dependent biota (Maddock 1999) and yet methods for characterising physical habitat remain poorly documented for intermittent river systems internationally (Fernandez et al. 2011). The emphasis on the aquatic habitats and requirements of aquatic fauna (e.g. Parsons et al. 2002) fails to address the physical habitat components required to support the range of fauna that utilise arid river, wetland and floodplain environments.

Physical habitat assessment methods generally focus on identifying the habitats as they appear in the 'here and now' from the perspective of fauna requirements (e.g. MDBC 2003, Parsons et al. 2002), generally over relatively small spatial and temporal

scales. Geomorphological assessments consider the underlying processes driving the observed physical habitats and generally begin at broader spatial and temporal scales, working towards to finer scales (discussed below).

Most of the major catchments have had some work to identify the location of permanent and near permanent waterholes, as discussed in Section 2.1.2.2, however there has been little work to describe aquatic ecosystem habitats beyond their hydrological persistence. The Cooper, Georgina-Diamantina and Neales catchments are the most understood, with the ARIDFLO project having collected morphological data including bankfull depth, width and cease-to-flow depth for 56 study sites (Costelloe et al. 2004). Physical habitat data are limited in the Northern Territory, with the most comprehensive knowledge being from thirty waterholes in the mid-Finke catchment recently surveyed for HEVAE delineation and description (Duguid et al. 2013a). Field survey parameters collected included water depth. The LEBRA project has also expanded into the Macumba and Northern Territory catchments, with some morphological data collected for most sites and brief descriptions of physical habitat features. The Neales catchment critical refugia project collected information on the attributes of additional sites to the LEBRA and ARIDFLO sites, with the bathymetrical dimensions of all significant waterholes in the mid and upper reaches of the Neales and Peake catchment now characterised to some degree (Costelloe 2011a). Information on the attributes of aquatic ecosystems is almost non-existent for other western catchment rivers and the Lake Frome catchments. There is some knowledge about the distribution of some permanent waterbodies in the Flinders Ranges (Ehmann 2009; White & Scholz 2008; McNeil et al. 2011b) and western Frome region (Deane & Walters 2008). Permanent refuges in these regions are primarily groundwater dependent (Deane & Walters 2008, McNeil et al 2011b) and may therefore be addressed by the LEB Springs project. Data are limited on farm dams in the South Australian LEB.

ARIDFLO documented the vertical zonation of vegetation communities in relation to morphology, concluding that Coolabahs (*Eucalyptus coolabah*) typically occur at the top of bank and Lignum communities at and above cease-to-flow (Costelloe et al. 2004). As water level rises, the range and area of aquatic habitats increases, with more logs, rocks, and different types of vegetation becoming submerged (e.g. Arthington et al. 2005). Conversely, as the water levels decline, the range of aquatic habitats declines whilst non-aquatic habitats emerge and vegetation grows, becoming available to non-aquatic species. Several studies have sought to identify physical habitat indicators associated with biotic components; in the Cooper Channel Country, water bodies with shorter fetch length have been found to have lower turbidity and higher benthic production (Davis et al. 2002).

2.3.1.2. Water quality components

The term water quality is used in the context of the LEBRM project to describe the composition of water, such as its chemistry, conductivity and suspended sediments, and not to imply its value.

Knowledge of the water quality of LEB aquatic ecosystems is very limited, both in terms of spatial and temporal coverage as well as the range of water quality parameters. As for habitat components (above), most knowledge has been gained from the ARIDFLO project (Costelloe et al. 2004). Most attention was focussed on the salinity behaviour as this was found to vary over several orders of magnitude in the South Australian reaches of the LEB rivers (Costelloe et al. 2004). This is further described in the Section 2.3.2.1. Since ARIDFLO, limited water quality monitoring has been undertaken, with LEBRA gauge sites monitoring salinity (Costelloe et al. 2008) and some other parameters monitored during fish surveys (Cockayne et al. 2012, 2013). Some additional water quality information was collected in the Cooper Catchment in Queensland in the early 2000's through the Dryland River Refugium project (Sheldon & Fellows 2010).

In general, water quality varies in response to climatological drivers and groundwater interactions (as discussed below under Processes), however LEB waters are generally highly turbid, and salinity increases with distance downstream and time since flow (Costelloe et al. 2004, 2011; Sheldon & Fellows 2010). Bicarbonate is the dominant anion in freshwaters (Larsen 2012, Sheldon & Fellows 2010). Some water chemistry information was collected for mid-Finke catchment waterholes where salinity has been found to vary spatially from relatively fresh (530 µS/cm) to highly saline (>50,000 µS/cm) (Read 2011, Duguid 2013a, Cockayne et al. 2013). Major anion analysis in the Finke did not reveal any clear trends to enable the characterisation of aquatic ecosystem water quality components in relation to surface or groundwater hydrology (Read 2011).

2.3.1.3. Hydrological components

As for other components, the ARIDFLO project contributed significant knowledge about the hydrological components of LEB aquatic ecosystems (Costelloe et al. 2004). Many of the refuge waterhole sites, as well as some additional waterhole sites, have continued to be studied under the LEBRA project and critical refugia project (Costelloe 2011), providing a greater temporal extent to knowledge of baseline conditions. A range of long-term variables was calculated for these waterbodies, including frequency of flooding, drying and connectivity (Costelloe et al. 2004; Costelloe 2008).

Silcock (2009a) documented the location of waterholes in the Cooper and Georgina-Diamantina catchments using a range of methods and classed the waterholes into broad categories of degree of permanence. Remote sensing methods have been used in the South Australian Cooper and Warburton catchments to determine the degree of permanence of palustrine and lacustrine wetlands and lakes as well as floodplains (Wainwright et al. 2006; Tunn & Cameron 2008). Kingsford et al. (1999) calculated the frequency of inundation for some of the major terminal lakes in the Cooper Catchment.

Data are limited for the Northern Territory, with some information available on the location of permanent and semi-permanent waterholes (Duguid et al. 2005; Duguid 2005; Duguid 2013a; Brim Box et al. 2008). Historically there has been no long-term monitoring for any aquatic ecosystem sites and, while some flow monitoring sites existed, they had not been surveyed in relation to aquatic ecosystems (Costelloe 2008). However, the LEBRA has established hydrological monitoring at aquatic ecosystem sites since 2011 that will provide the first long-term hydrological data for the NT LEB (Cockayne et al. 2012, 2013).

2.3.1.4. Ecological components

The ecological attributes of LEB aquatic ecosystems are not static over time, nor are they consistent spatially with ecosystem types, instead they vary in time and space depending on the:

- Physical, chemical and hydrological attributes of the aquatic ecosystem
- Connectivity of the aquatic ecosystem to other aquatic ecosystems
- Current hydrological phase and antecedent hydrological conditions
- Life histories of the biota, in particular their strategies for recruitment, dispersal and the scale over which they function (i.e. waterbirds populations function at continental and intercontinental scales (Kingsford et al. 2010) whilst species such as Cooper Creek Catfish (*Neosiluroides cooperensis*) have localised distributions around deep permanent pools) and their trophic dependencies.

Long term studies in some regions of the LEB have provided valuable knowledge about the biotic components of some aquatic ecosystem types. As with the physical, chemical and hydrological attributes, knowledge about the biological attributes of LEB aquatic ecosystems is most comprehensive for refuge waterholes, mostly collected through major projects including the ARIDFLO project (Costelloe et al. 2004), LEBRA (Cockayne et al. 2012, 2013), Neales refugial waterholes project (McNeil et al. 2011a), Queensland dryland refugium project (Arthington et al. 2005, 2010) and Northern Territory mapping (Duguid et al. 2013a; Brim Box et al. 200) and inventory work (Duguid et al. 2005). Information for a range of semi-permanent and intermittent palustrine and lacustrine aquatic ecoysystem types has also been collected for waterbirds (e.g. Kingsford and Porter 2008; Jaensch 2009b).

Aquatic fauna

The existing literature for aquatic fauna of the Cooper Creek provides a strong fundamental knowledge base to build upon; however, these data are fish-orientated and other LEB catchments (and their associated floodplains) require more attention. Models of fish distribution and behaviour have been developed and tested under the LEBRA project (McNeil et al. 2008; Balcombe & Kerezy 2008; Balcombe & McNeil 2008). Together with a more detailed classification of refugia waterholes (McNeil et al. 2011a), these have provided a good understanding of the distribution of fish in the LEBRA study catchments.

Invertebrate studies have been undertaken in many parts of the LEB and knowledge of macroinvertebrate distribution is considered good in some regions, including headwater aquatic ecosystems of the Northern Territory (Brim Box et al. 2009) and in upper Queensland catchments (Choy et al. 2003). However, most macroinvertebrate studies have been short-term (three years or less) and patchy. Using the AusRiVAS method (where sites are compared to reference), the invertebrate fauna was

found to be diverse (Goonan et al. 2003); the species are highly responsive to environmental variables and can respond rapidly and in high abundance. Assemblage diversity and abundance are dependent on water quality, habitat connectivity and the availability of submerged habitats, driven by the current and preceding hydrological conditions (Choy et al. 2002; Costelloe et al. 2004; Sheldon & Thoms 2006; Marshall et al. 2006b).

Numerous investigations into genetic traits of fauna populations have been undertaken within the Queensland LEB, particularly in Cooper Creek (including fish, turtle, mollusc and crustacean species). Generally, biological attributes and historical ecological processes are inferred from this genetic knowledge, including some evaluations of species sensitivity to habitat and flow disturbance (e.g. Carini and Hughes 2004). For fish species, effective population sizes were small in comparison to other Queensland catchments, with limited population connectivity and large variations in dispersal abilities and patterns within the LEB drainages (e.g. Huey et al. 2008; Hughes & Hillyer 2006). Distinct populations of turtle have been discovered (Goodsell 2002) but not confirmed and the freshwater mussel fauna in Cooper Creek include unidentified species, some of which may once have been more widespread (Baker et al. 2003).

Waterbirds

Knowledge about the distribution of waterbirds based on long-term studies is good for the eastern, central and southern parts of the LEB, and many important aquatic ecosystems for waterbirds have been identified (Kingsford et al. 1999; Kingsford & Porter 2008; Jaensch 2009; Kingsford et al. 2011). However, the Northern Territory is not covered by the East Australian Waterbirds survey and there is little information regarding waterbirds.

Flora

There is detailed information documenting flora species (native and exotic aquatic) and assessments of rarity and threats within the Queensland LEB (Silcock et al. 2011; DERM 2013, EHP 2012a). This includes at least one historical survey (Roberts et el. 1976) which may provide useful an ecological benchmark for terrestrial and floodplain vegetation composition and structure. A study by Pettit (2002) is one of the few Queensland studies that have specifically targeted riparian vegetation, whilst Capon (2003, 2007) has undertaken research into floodplain vegetation. Assessments of riparian condition have been included in larger scale projects (e.g. Moller 1999; DERM 2013) and represent a reasonable baseline and methodology approach.

Duguid et al. (2005) undertook detailed wetland vegetation surveys in the NT arid zone, with the water dependency of these species subsequently classified for AETG (2012e). Detailed studies of aquatic ecosystem vegetation have not been undertaken in the South Australian LEB. However, the broad distribution of common perennial vegetation and its lateral and longitudinal zonation in relation to water levels and environmental water requirements is understood (e.g. Tunn & Cameron 2008, Costelloe et al. 2004). A survey of riparian vegetation was undertaken in the Neales and Macumba catchments (Arid Rivers Survey 2005) and, whilst the results have not been reported on, these data may provide a useful historical dataset for future studies. Perennial riparian and floodplain vegetation identified at some key waterholes in the Neales catchment is presented in Scholz & Deane (2011).

The value of wetlands is consistently highlighted as critical habitat for rare aquatic flora (e.g. DERM 2010c, 2013; DEH & SAAL NRMB 2009) and, within broader terrestrial ecosystems, the conservation value of wetland and riparian vegetation is noted (e.g. Walsh 2009), due to the vegetation's function in sustaining other species (e.g. koala, cockatoos, bats). The detrimental impact of grazing on riparian and wetland (including spring) vegetation is well represented (e.g. Roberts 1993; Pettit 2002). The long-term, post-European settlement changes in aquatic flora diversity and cover have not been comprehensively quantified on a broad scale in the same fashion as for terrestrial flora.

Floodplain and terrestrial

The riparian and floodplain environments of the LEB provide a unique environment within the central Australian desert, with higher soil nutrients, soil water holding capacity and soil moisture than surrounding environments (Briggs et al. 2000) and different temporal productivity patterns. These factors support higher productivity, as well as exclusive habitats and resources,

with distinct and often more diverse and abundant assemblages of flora and fauna (e.g. Brandle et al. 2005; Briggs et al 2000; Read 1992). In central Australia, woodlands and forests are almost exclusively restricted to riparian and floodplain environments. These provide hollows and sites for nest-building as well as often more complex and diverse habitats and resources. Floodplain environments comprise two key functional ecological groupings: woodland specialists that could not otherwise exist in the desert environments and drought refuge for what are normally dryland terrestrial species. The species composition of these environments is consequently highly variable temporally, being driven by both the flow regime of the floodplain (which is often the result of climatic conditions hundred of kilometres upstream) and the local climatic conditions. Therefore knowledge about the species components of floodplain environments is limited due to the one-off or short term duration of most studies.

Gillen and Reid (2013) document the change in vegetation composition laterally and longitudinally on the Cooper Creek in SA: species with higher water requirements occur in more reliably watered riparian zones being replaced downstream with species from the floodplains of the wetter reaches. The density of overstorey species decreases downstream, as does the diversity of species. As the frequency of inundation decreases, local soil variations exert a stronger influence on vegetation species distribution (Gillen and Reid 2013).

The importance of Coolabah and lack of knowledge about its recruitment and other requirements make it a priority for further research (Gillen and Reid 2013). Coolabah is the most common woodland tree species found in riparian zones and floodplains, decreasing in density with decreasing flood frequency (Gillen and Reid 2013). Several surveys have found higher bird diversity in woodlands compared with surrounding dryland areas (Reid and Gillen 2013; Neagle & Armstrong 2010; Brandle et al 1998). Many species of raptors are restricted to riparian zones for nesting (Aumann 2001). Bats are also associated with riparian and floodplain habitats (Brandle et al. 1998).

The distribution of River Red Gums is thought to be associated with reaches receiving annual flow and/or fresh groundwater (Costelloe et al. 2004; Gillen and Reid 2013). Red Gums produce larger hollows than Coolabahs and hence are important for larger hollow-nesting species such as the Barking Owl, which on the Cooper Creek in SA, are restricted to locations in the upper reaches where Red Gums occur (Reid and Gillen 2013).

Unique microhabitats occurring on floodplains and infrequently wetted ecosystems include:

- Cracking clay soils that provide shelter from dessication and predators and trap seeds and other plant material (these are used by a number of small mammals and lizards) (Brandle 1998, 1999),
- Mounds of windblown soil accumulated at the base of trees and shrubs used for burrowing by Slater's Skink (Pavey et al. 2010), and
- Litter mats beneath trees and shrubs that provide habitat for small lizards (MacDonald et al. 2012).

The geographical isolation of floodplains and other highly ephemeral aquatic ecosystems results in range restrictions and isolation of fauna and flora populations dependent on these habitats (Pepper et al. 2011) such as Slaters Skink (Pavey et al. 2010). Pepper et al. (2011) propose that such population isolation may be leading to the evolution of new species of Beaked Geckos.

The presence of water, shade and higher productivity of floodplains are also attractive to introduced fauna, and higher numbers of cattle and mice occur than in surrounding environments (Brandle et al. 2005). This has resulted in impacts on these ecosystem including increased grazing pressure, soil disturbance and weeds (Neagle 2003).

There is also very little information regarding bird species and other terrestrial fauna that utilise riparian and wetland habitats. Riparian fauna are generally not included in aquatic ecosystem studies, despite some being entirely dependent on riparian and wetland habitats, such as the nationally vulnerable Grey Grasswren (Amytornis barbatus barbatus) (DEH & SAALNRMB 2009) and hollow-nesting fauna.

Gilgais

Gilgais are one of the unique aquatic ecosystems of the region. These are shallow depressions that form in certain shrinking and swelling soil types and are filled from rainfall alone. They are therefore hydrologically isolated from other aquatic

ecosystems. Gilgais support long-lived chenopod shrubs and a suite of short-lived flora and fauna capable of responding to irregular rainfall events, including a high proportion of endemic species (DEH & SAAL NRMB 2009).

2.3.2. Processes

The following is a discussion of some of the key known processes operating in the LEB, presented by attributes. There are strong links between the processes across the attributes, for example geomorphology is important for fish dispersal through determining the range and distribution of habitats, whilst hydrology influences the timing and persistence of the connectivity. These linkages are identified in the discussion.

2.3.2.1. Water quality processes

Water quality variations are considerable in the LEB catchments. Most is known about the salinity variation and the associated effects on the biota (e.g. Hudson et al. 2003; Costelloe et al. 2005c; Shiel et al. 2006; McNeil et al. 2011). However, much less is known about temperature, pH, dissolved oxygen and temperature effects, particularly temporal variation in these factors.

The salinity of the LEB rivers can vary over several orders of magnitude, but the largest variations are confined to the lower reaches of the major catchments (in South Australia) and to the mid-lower reaches of the western catchments (Costelloe et al. 2005a). The salinity variations are greatest during periods of no flow and in the low flow recession of large floods (Sheldon & Fellows 2010; Costelloe et al. 2005b). Salinity variations are less complex in the Thomson River but are a significantly highly variable in the western catchments where salinity is interlinked with interactions with shallow groundwater (Costelloe et al. 2005a,b, 2007b; Irvine et al. 2006). Changes in the flow regime (e.g. decreases in flow events due to water extraction or diversion; increases in flow due to discharging of co-produced groundwater) are likely to have different impacts on the salinity regime of reaches and individual wetlands in different catchments (Costelloe pers. comm. 1st May 2013).

2.3.2.2. Hydrological processes

Hydrological proceses are grouped into four broad themes:

- Flow regime (river reach) processes
- Water regime (waterbody scale) processes
- Climate
- Surface water – groundwater interactions

Flow regime (river reach) processes

Hydrological modelling is critical for the bio-assessment of the study catchments as it provides one of the few mechanisms to investigate effects of any development on the flow regime of these rivers (Costelloe et al. 2003a). Understanding the flow regime is also critical for understanding the ecology of these rivers (Costelloe et al. 2004) and modelling provides the only means for generating flow data for different reaches within these poorly gauged catchments (Costelloe et al. 2005a).

The modelling requirements of the LEBRM project catchments are:

- Distributed discharge data are required rather than just end-of-catchment output. Analysis and assessment will be required at a number of sites (e.g. prominent waterholes) in the catchment. This will require the capacity to rout flow due to the size of the catchments. This requirement argues for a distillated grid-based (e.g. Costelloe et al. 2005, 2006) or link-node (e.g. Harding 2010 or the eWater Source platform) model structure.
- Channel and hill-slope land-types need to be separately modelled. This adds to the model parameterisation but the channel typically has much greater storage capacity than the hillslope. Channel flow processes, particularly transmission losses, need to be modelled in addition to run-off generation processes (Costelloe et al. 2003a, 2005a, 2006a).
- Rainfall variability (spatial and temporal) is likely to be a major contributor to model uncertainty (Costelloe et al. 2005a) and further work is required to investigate optimal rainfall products to use in the modelling. Studies have

shown that using satellite-based rainfall time-series (e.g. from TRMM) can improve hydrological modelling performance at monthly and seasonal time-scales (e.g. Khan et al. 2011), but further research is required into the performance at a daily time-step to better model individual flow events.

- Calibration of the models will be difficult in all but the Thomson catchment. In the Neales catchment, the Algebuckina record has some gauging, but none are from high flows and the medium flow gaugings have a high level of uncertainty. Model calibration will require less traditional means, using 'soft data' (Wagener & Montanari 2011), such as evaluating the occurrence, timing and relative size of flow events at the sites of the water level logger network (e.g. Costelloe et al. 2005a). Modelling will also require a probabilistic approach as available data will not be sufficient to identify an optimum parameter set. This approach will require a Monte Carlo type method so that the model runs using a range of parameter sets generated in order to find a suite of parameter sets that generate 'behavioural' discharge data (i.e. are best able to replicate the spatial and temporal behaviour of the flow regime of the river, see Wagener & Montanari 2011).

Water regime (waterbody scale) processes

The literature indicates the importance of maintaining the long-term water regime (e.g. depth, connectivity, frequency of inundation and drying) of individual waterbodies (Puckridge et al. 2010). In addition, individual waterbodies can have very high ecological values at the reach and catchment scale due to their persistence characteristics (McNeil et al. 2011). For waterbodies with little groundwater interaction, their persistence once flow ceases is primarily a function of their depth and evaporation rate (Hamilton et al. 2005; Costelloe et al. 2007a; Costelloe 2011). This means that the consideration of flow regime change at the reach or catchment scale in response to anthropogenic developments is not sufficient but that water regime changes at the scale of individual waterbodies need to be considered.

Climate

The climatic conditions of the LEB have varied widely in the past decade or so. The effects of climate change, particularly over the western catchments, are highly uncertain. The Murphy and Timbal (2007) study shows that the last 15 years in the western LEB was wetter than average, notwithstanding periods of significant drought, and this supports the Costelloe et al. (2005a) modelling suggesting that the post-2000 period experienced more flow events than the previous 20 years.

Surface water–Groundwater interaction

River-groundwater connectivity is a major process that needs to be considered in the assessment of the study catchments, but is hampered by a lack of data. The Neales is known to have shallow, very saline alluvial groundwater in its mid to lower reaches that shows recharge-discharge processes following flow events (Costelloe et al. 2005b, 2006b, 2007a). The lower Macumba has no reported groundwater data but the higher reported salinity in the river (Cockayne et al. 2012, 2013) suggests it may behave similarly to the Neales. Tributaries in the upper Macumba (e.g. Hamilton Creek) have relatively low salinity alluvial groundwater in the sandy channel sediments (Costelloe pers. comm. 1st May 2013). The Finke has limited groundwater data but seems to be a zone of net recharge with deeper and fresher groundwater than the Neales (Read 2011) as well as discharge of highly saline regional groundwaters at some waterholes (Duguid 2013a). The status of shallow groundwater in the Thomson is unclear. In the uppermost reaches it shows recharge-discharge processes with relatively fresh groundwater (Kellet et al. 2003). In the middle reaches, the groundwater is likely to be relatively deep and fresh around the river system (Cendon et al. 2010).

Based on the review of literature, the following pressures need to be considered:

- Reductions in stream flow (i.e. due to damming, diversions, water resource use) are likely to result in more saline alluvial groundwater and river-lake sediments in the Neales and similar systems. This is likely to have major detrimental implications for riparian vegetation. Major reductions in flow may decrease recharge to the GAB in the Finke but that is less likely as the recharge only occurs during large floods (Fulton et al. 2013).
- Increases in stream flow (i.e. due to release of co-produced water from gas-coal extraction) could result in rising saline water tables in the Neales and Macumba (and potentially the Thomson) with detrimental impacts on deep rooted riparian vegetation. This may be less of a problem for the Finke, depending on the depth of the water table.
- Extraction and use of unconfined groundwater (i.e. due to open pit pumping) will have different effects depending on the salinity of the groundwater. Reductions in relatively fresh groundwater levels are likely to place stress on phreatophytic riparian trees and may increase streamflow transmission losses.

2.3.2.3. Ecological processes

Ecological processes for the purposes of this review include intra and inter species dynamics and energy and nutrient transfer and cycling. The ecological processes occurring in the LEB river systems are driven by highly variable hydrology and climate, and the hydrological and geomorphological processes that determine the range of aquatic ecosystems and the connectivity of habitats. Ecological processes are influenced by high levels of disturbance and variability. To survive in the LEB, species have evolved life strategies relating to resistance and/or resilience capabilities that enable them to survive long periods of little to no flow, harsh environmental conditions and unpredictable flow events. Large floods trigger spectacular booms in biotic production in the LEB (e.g. Kingsford et al. 1999), however periods of no flow are as critical in dictating the biotic assemblages that exist in arid environments (Rolls et al. 2010). The longer periods of no flow last, the fewer submerged habitats exist and the more saline and oxygen depleted they become. Species must be able to survive by having desiccation resistant life stages (i.e. survive as eggs or seeds in dry soil), migrating to other areas, become temporarily locally extinct and re-populating during the next flow events, or be able to survive in refugia. Small flow events sustain species which are entirely dependent on permanent water by freshening refuges, extending their duration and providing short term connectivity that enables migration between refugia. Whilst small and no-flow phases exert stresses on the biota of aquatic ecosystems, they are the unique conditions that LEB biota have adapted to and any disruption of these flow phases (including artificially increasing or regulating flows) would disrupt the natural ecological processes and provide opportunities for introduced species.

For fish species, their links to ecological processes are particularly well represented in the literature. The crucial role of fish in contributing to carbon fuelled production in waterholes is quantified (Burford et al. 2008). Population dynamics of fish within the LEB are documented, with the recruitment strategies of the majority of native species being investigated in some part. Some species possess highly adapted physiologies (e.g. diet switching - Balcombe et al. 2005; flexible spawning – Kerezsy et al. 2011), and a wide ranging dependency on differing components of the flow regime for reproduction and recruitment (e.g. Kerezsy et al. 2011), migration (e.g. Balcombe et al. 2007) and colonisation (e.g. Huey et al. 2011). The critical dependency of species on physical habitat is clear at the waterhole scale (e.g. for refuge) (Arthington et al. 2005; McGregor et al. 2006) and floodplain scale (e.g. for spawning, recruitment, migration) (e.g. Balcombe et al. 2007); although the nature of the dependency/relationships varies greatly as the flow regime shifts seasonally.

The role of fish in influencing other processes and components (e.g. through trophic structures, predator – prey relationships) in the LEB has been less well documented. Food webs and nutrient cycling have been investigated for Cooper Creek waterholes. Multifaceted relationships between floods and floodplains and waterholes as carbon sources are evident; generally, food webs exhibit a highly dynamic nature, as productivity sources shift throughout boom and bust cycles. Fish (Burford et al. 2008), benthic biofilms (Fellows et al. 2009) and algae (Bunn et al. 2006) play crucial roles in driving waterhole production. Beyond the Cooper Creek waterholes this review found there has been very little investigation into food webs and nutrient cycling. Bunn et al. (2006) found that littoral filamentous algae were the major source of energy for aquatic consumers, and zooplankton were the other major source, however Burford et al. (2009) demonstrated fish transport carbon from the flooplain into waterholes.

Detailed ecological processes for other biota are comparatively less well represented: Marshall et al. (2006b) found macroinvertebrate assemblages in the Cooper Creek were linked to the 'connectivity potential' of waterholes; and a number of reports document the utilisation of floodplain and wetland habitats by migrating and nesting waterbirds (e.g. Kingsford and Porter 1994; Jaensch, 2003). .

The importance of understanding underlying genetic and, therefore, biological and ecological processes when evaluating risk to species, and designing conservation management plans is consistently emphasised (e.g. Bailey 2003; Huey 2007). Similarly, selecting an appropriate spatial scale for management is imperative, as some species are capable of crossing drainage boundaries of the LEB while others are not (e.g. Hughes & Hillyer 2003). The complex biological adaptations of the fauna to the unique flow regime (particularly, boom-bust patterns) are highlighted in the majority of the literature (e.g. Sternberg et al.

2008), although the drivers behind the adaptations and ecological traits/patterns are not always clear and warrant further, dedicated research.

Recent research has begun elucidating the role of waterholes in sustaining aquatic fauna by indicating, for example, that some species do not maximise dispersal opportunities, remaining within origin waterholes during boom phases; again, the precise drivers are unclear (Carini & Hughes 2004; Cook et al. 2002). Critical correlations between flow regime, waterhole persistence, habitat connectivity and faunal species diversity have been demonstrated for fish (e.g. Balcombe & Kerezy 2008; McNeil et al. 2008) and invertebrates (e.g. Carini et al. 2006; Choy et al. 2003).

Miles and Risby (in prep.) present a summary of the ecological processes supported by different components of the LEB flow regime, as summarised in Table 2-3 below.

Table 2-3 Relationship between ecological processes, aquatic ecosystem attributes and hydrology (adapted from Miles & Risby in prep. with additional information for 'disco', 'polo club' and 'stepping stone' refugia)

Environmental water requirement	Influence on aquatic ecosystem conditions	Ecological processes supported
Flow Events		
Basin-scale floods	Inundation of all habitats and vegetation and hydrological connectivity between all habitats and some catchments.	Massive booms in waterbird populations spanning several years (see antecedent floods below) Booms in fish populations with breeding and migration by all species up and downstream, most across floodplains and some potentially between catchments.
Catchment-scale floods	Inundation of and connectivity between most habitats within catchments	Massive booms in waterbird populations in Cooper and Georgina-Diamantina catchments. Booms in fish populations with breeding and migration by all species up and down-stream and most across floodplains. Inundation of riparian, wetland and floodplain vegetation, probably triggers recruitment of most water-dependent plants
Regional flows	Inundation of and connectivity between in-channel habitats, may not extend to terminal lakes.	Low level 'bridging' recruitment and migration of some fish species. Inundation of riparian vegetation
Local rainfall events	Short-term inundation of and connectivity between in-channel habitats in localised areas	Migration by a few fish species. Probably more ecologically important in catchments and reaches where larger flow events occur infrequently.
No flow	Habitats become disconnected and dry-up, with the time to dry up primarily dependent on depth	Different refuge types develop supporting different suites of species and inter-species competition and predation processes dominate in waterholes. Contains the spread of alien species.
Flow Regime		

Environmental water requirement	Influence on aquatic ecosystem conditions	Ecological processes supported
Duration of flow	The longer the duration of flow the longer habitats are inundated and connected	Increased distance fish can colonise and trigger for more species migrate. Increased range of waterbird guilds breed and increased probability of breeding success.
Duration of no flow	The longer the duration of no flow events, the more habitats dry-up, depending on their cease-to-flow depth: shallower habitats dry-up sooner than deeper habitats Conditions in refugia become increasingly harsh (e.g. increased salinity and temperature, decreased oxygen)	Increasingly harsh conditions in remaining refugia combined with inter-species competition and predation pressures results in local extinctions of water-dependent species reliant on refugia
Annual flows to key sites	Key sites are filled and connected to upstream refuges annually	The terminus point for annual flow events marks a change in the habitat characteristics and biota in catchments from up to downstream
Antecedent floods	Result in extended duration of flooding and increased extent of second and subsequent floods	Cumulative recruitment of fish species with short generation times, colonisation of more distant waterholes.
Variability	Conditions within and connectivity between habitats are unpredictable	Native biota in the LEB are adapted to the extreme variability in flow
Aquatic Refugia[1]		
Permanent water in 'ark refugia'	Waterholes remain permanently inundated to sufficient depth for wholly aquatic species to survive	During extended periods of no flow, ark refugia contain the entire diversity of fish and other water-dependent species in catchments and are the point from which they will re-colonise following flows
Semi-permanent water in 'Disco refugia'	Waterholes remain inundated for periods long enough for species to recolonise, reproduce and disperse to other refugia	After periods of flow, disco refugia provide habitat for water dependent species to recolonise, reproduce and redisperse. Extent, duration and repetition of flow along with the resilience of species determine how many species will recolonise these habitats. Extended periods of no flow reduce the number of these habitats until they eventually all dry.

[1] Definitions as per McNeil et al. (2011) which, except 'disco' refugia, are based on Robson et al. (2007)

Environmental water requirement	Influence on aquatic ecosystem conditions	Ecological processes supported
Permanent water in 'Polo Club refugia'	Waterholes remain permanently inundated to sufficient depth with conditions suited to exclusive species	During extended periods of no flow, Polo Club refugia contain only species adapted to harsh conditions (such as high salinity) in catchments and are the point from which they will re-colonise following flows.
Semi-permanent water in 'Stepping Stone refugia'	Waterholes remain inundated for periods long enough for species to recolonise and disperse to other refugia	After periods of flow, stepping stone refugia provide habitat for water dependent species to recolonise and redisperse on repeated and longer flow durations. Infrequent flows and extended periods of no flow reduce the opportunity for species to disperse to 'disco' or 'ark' refugia.
Rate of draw-down in waterholes	Rate of draw-down in most waterholes is equivalent to evaporation rates	The 'bath-tub ring' of algae is known to support the food web in deep and turbid waterholes; if the rate of draw-down is too fast, these algae may be stranded resulting in a loss of biological production.

Floodplain and terrestrial

Terrestrial fauna of ephemeral aquatic ecosystems have varying dependencies on floodplain environments, including:

- Species that are almost entirely restricted to the floodplain environment to supply all their resource requirements, such as Slater's Skink (Fenner et al. 2012) and Brushtail Possums (Kerle et al. 1992).
- Species that require unique habitats found only within floodplains for some but not all essential requirements, utilising surrounding terrestrial zones for their other needs (generally food). These include hollow nesting species such as bats and some birds, as well as raptors that require large trees to nest in. Several studies support the theory that some bird populations in arid zones are constrained by habitat availability and therefore responses to 'good' seasons may be depressed (Pavey and Nano 2009; Aumann 2001).
- Species that reside predominantly in the drylands but use floodplains as a refuge during droughts for food, moisture and shelter from the heat (e.g. Red Kangaroos, Newsome 1965)

Species that reside in both dryland and aquatic ecosystems where the populations in the wetter sites are able to survive droughts and are 'source' populations for surrounding areas such as Desert Mouse (Read et al. 1999) and Plains Rat (Brandle et al. 1999). MacDonald et al. (2012) propose that the ephemeral watercourses and rocky escarpments of central Australia support terrestrial species once more widespread under wetter climates. Hence these highly ephemeral desert aquatic ecosystems may provide evolutionary and ecological refugia for terrestrial species in a similar fashion to the desert's permanent aquatic refuges (as per Davis et al. 2013). These multiple ecological roles of floodplain environments makes them a critical landscape element in arid Australia and therefore lack of knowledge about both their internal dynamics and broader landscape scale dynamics is a key knowledge gap. Floodplain plant communities are highly structured by flow regime: wet and dry phases provide crucial triggers for ecological processes (germination, colonization, growth) (Capon 2003), and structure the seed bank composition (Capon 2007). However, in the lower catchment of the Cooper Creek, where inundation occurs infrequently, local variations in soil characteristics exert a stronger influence on vegetation distribution compared with upper reaches where flooding is more frequent (Gillen & Reid). Other localised effects may also drive the distribution of some species, for example healthy Coolabahs commonly occur on the outer floodplain at the base of sand dunes and are likely to be sourcing local fresh groundwater from the dunes (Gillen 2010).

Morphological microhabitats such as mounds and clay cracks are vulnerable to damage by introduced herbivores through trampling (MacDonald et al. 2012), heavy rainfall (Fenner et al. 2012) and presumably floods. For terrestrial species occupying floodplains, whilst the flood regime provides for the unique habitats and resources on which they depend, the flood events

themselves may exert short term stresses on populations. Therefore the patterns of distribution of small vertebrates within the floodplain and floodout environments may be explained by their capacity of fauna to survive flood events, although this has not been specifically investigated.

2.4. Values

Risk assessment includes an assessment of the consequence of impacts; under the *Integrated Strategic Management Framework*, consequence is determined through consideration of values that humans place on ecosystem and their components and processes. It is these human values that influence the political, policy and management environments through which ecological assets are prioritised for protection and monitoring and through which mining approvals and impacts are managed. Therefore this section provides an overview of the ecological, conservation and cultural values associated with aquatic ecosystems.

2.4.1. Ecological and conservation values

For the purposes of this report, ecological values are those values that are important as part of a greater ecosystem function, such as important breeding or refugia sites, or biota that have a critical role in the function of an ecosystem. Conservation values are those values associated with unique, representative, rare or threatened species and ecological communities, such as are commonly identified through biodiversity planning processes. This report does not seek to make any assessment of conservation values, instead reiterating previously defined conservation values. Frameworks for identifying conservation values are relatively advanced, with Australia's first biodiversity conservation strategy published in 1996. The current national framework for biodiversity conservation (NRMC 2010) includes increasing ecosystem resilience through restoring ecosystem function as one of the key priorities, indicating a potential synchronicity in thinking around conservation and ecological values. The identification of ecological values is less well-structured but has become a focus in aquatic ecosystems management, with the development of interim national guidelines for identifying High Ecological Value Aquatic Ecosystems (HEVAE) (AETG 2012b).

An assessment of the 'natural heritage' values in the LEB showed that the surface water systems of the LEB were unique in being one of the world's largest unregulated arid river basins (Morton et al. 1995). The Warburton and Cooper drainage systems, Coongie Lakes, Goyder Lagoon and Kati Thanda-Lake Eyre were found to meet three criteria for World Heritage listing (Morton et al. 1995):

1. Outstanding examples of physiographic features
2. Outstanding examples of significant on-going ecological and biological processes
3. Superlative natural phenomena and areas of exceptional natural beauty and aesthetic importance.

The LEB Community Advisory Committee (LEBCAC 2012) undertook a process to identify the assets of the LEB and the results include a range of themes, with naturally variable flow in rivers, floodplains and waterholes identified as the highest priority asset. However, the types of assets identified were broad ranging, including processes such as natural hydrology as well as culturally valued sites and GAB springs (LEBCAC 2012). Similarly, a literature and knowledge review of the environmental and cultural values of water resources and water-dependent ecosystems in the South Australian LEB showed a diverse range of environmental values were identified in an expert workshop. The values identified included ecological, hydrological and geomorphological processes, listed sites, biological diversity and endemism (MacDonald & McNeil 2012).

As discussed above, the LEB is one of the few remaining unregulated river systems in the world and as such has inherent ecological and conservation value on a global scale (Morton et al. 1995; Puckridge et al. 1998). It also possesses a unique assemblage of fauna that are highly evolved to the conditions of the LEB (Davis et al. 2013a). The LEB catchments have the most variable hydrology in the world (Puckridge et al. 1998), unregulated flows and low levels of water extraction (Costelloe et al. 2003). Most of the catchment landscapes are relatively unaltered (compared with other parts of Australia), with the major stressors resulting from pastoral grazing, tourism and pest plants and animals (LEBSAP 2008). These features (variable and 'natural' hydrology and low impacted landscapes), coupled with the extreme 'boom and bust' cycles of the LEB (Bunn et al.

2006) provide the backdrop to the biota and ecosystems of the LEB and therefore are of significant ecological and conservation value in the LEB (LEBCAC 2012; Costelloe et al. 2003).

2.4.1.1. Ecological values

The Lake Eyre Basin High Conservation Value Aquatic Ecosystem (HCVAE) Pilot Project trialled the draft national guidelines for identifying HCVAEs (AETG 2012e). Since that project, the term 'conservation' has been replaced with 'ecological'; hence the national guidelines refer to High Value Ecological Aquatic Ecosystems (HEVAEs) (AETG 2012b). The criteria for HCVAEs used in the LEB trial were based on the draft national criteria of diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness (AETG 2012e). The final criteria for HEVAEs do not include evolutionary history (AETG 2012b).

The LEB trial used existing datasets to trial the method for determining HCVAEs, and, whilst the results were consistent with current expert knowledge of HCVAEs, the report notes that further work should be undertaken to identify HCVAE in the LEB (AETG 2012e). Using the draft criteria and existing datasets, the trial identified two assessment units that scored very high in three categories (these units contained Kati Thanda-Lake Eyre and Dalhousie Springs), seven units that scored very high in two categories (containing Cullyamurra Waterhole, Goyders Lagoon, Coongie Lakes, Edgbaston Springs and Lake Mueller, Dalhousie Springs, Lake Eyre Mound Springs and Palm Valley Area Springs) and 49 that scored very high in one criterion (see Table 4, AETG 2012e).

The ecological values of aquatic ecosystems in the Cooper Creek are discussed in Negus et al. (2012) where the national framework for ecological condition framework has been trialled. Different ecosystem types generally have different ecological values associated with them. Palustrine and lacustrine wetlands are recognised for their significance for waterbird breeding and feeding, with significant LEB wetlands nominated in Kingsford et al. (2010) and Kingsford & Porter (2008). Permanent riverine waterholes are recognised for providing refuges for fish and other obligate aquatic fauna. A recent trial of the HEVAE guidelines in the Mid-Finke catchment identified riverine waterholes of high ecological importance in that region (Duguid 2013a). Algebuckina Waterhole in the Neales Catchment and Cullyamurra Waterhole in the Cooper Creek Catchment are recognised as critical 'Ark' refuges (after Robson et al. 2008) in the South Australian LEB, whilst the floodplains are important for fish recruitment (McNeil et al. 2011a, Schmarr et al. 2012).

LEB rivers possess a relatively low total number of native fish species, (thirty-three (Wager & Unmack (2000), approximately half of the number found in the MDB), but very high abundances of fish. Importantly, only three introduced fish species occur in LEB rivers, Goldfish (Carassius auratus) and Plague Minnow (Gambusia holbrooki), Sleepy Cod (Oxyeleotris lineolatus) and these make up only a tiny proportion of the overall fish numbers (less than one percent of the fish caught during the ARIDFLO study (Costelloe et al. 2004)). This is in contrast to the Murray-Darling Basin, where introduced fish made up forty-three percent of fish numbers caught for the Sustainable Rivers Audit (MDBC 2008).

2.4.1.2. Conservation values

The *Environment Protection and Biodiversity Conservation Act 1999* (EBPC Act) lists national conservation priorities including a number of aquatic species that are present in and around aquatic ecosystems of the LEB. However, very few of the LEB riverine species are listed as threatened or endangered because it is a relatively intact system compared with other regions in Australia (LEBSAP 2008a). Therefore systems of prioritisation based on conservation significance tend to assign a lower level of conservation value to LEB aquatic ecosystems. The EPBC Act does however recognise the value of the LEB wetlands for migratory waterbirds under international agreements such as Ramsar (see http://www.environment.gov.au/biodiversity/legislation/index.html).

Terrestrial and aquatic species and ecosystems or communities of conservation significance in the LEB have been defined at a regional or state level for each of the states (DEH & SAALNRMB 2009; Ward & Harrison 2009; DERM 2010c). Within these regions, aquatic ecosystems are recognised for their significance to aquatic species and communities but also as providing water, food, habitat and refuge for terrestrial species in an arid region. Queensland is also currently undertaking work to define the conservation priorities for aquatic ecosystems in the LEB (DERM 2013).

LEB rivers are recognised for the spectacular booms in waterbird populations that occur in response to large floods. Wetlands are considered to be of international importance for waterbirds if they regularly support at least 20,000 individual waterbirds and over one percent of the total population of a species. Kingsford & Porter (1993) estimated that over 100,000 birds visit Kati Thanda-Lake Eyre on average every second year, with much larger numbers when major floods occur. At least half a million waterbirds visited LEB sites in response to the 1989/1990 floods (Kingsford et al. 1999) and the 2009 flood (Reid et al. 2010), and nearly 100,000 visited the Coongie Lakes complex in 2002 (Costelloe et al. 2004). Even small floods can generate significant responses, for example, flooding from the Neales and Macumba catchments in 2000 resulted in an important breeding event of 18,000 pairs of endemic and vulnerable[2] Banded Stilts (*Cladorhynchus leucocephalus*), with over 50 000 successful fledglings (Costelloe et al. 2004). Kati Thanda-Lake Eyre, Cooper Creek and Lake Hope are among ten eastern Australian highest-ranked wetlands by abundance of waterbirds (1983–2009) (Kingsford et al. 2012). Coongie Lakes is listed as a Ramsar Wetland.

The LEB is an important site for waterbirds that migrate along the East Asian-Australasian Flyway, with species coming from as far away as Mongolia and Siberia. Over one percent of the entire population of some 29 Australian and four internationally migratory species utilised the LEB in 2009; this included two species listed under CAMBA, JAMBA and ROKAMBA[3] and one species only listed under JAMBA (Reid et al. 2010). Channel Country wetlands are critical for the recruitment of the majority of inland Australian waterbirds, especially through the deterioration in MDB habitats and drought conditions in south-eastern Australia (Reid et al. 2010). Food resources include fish, invertebrates and plants, while nesting resources include flooded trees and shrubs, sedgelands, and vegetated and un-vegetated islands. These biotic resources are supported by the variable water regime, which includes periods of no flow as well as the large floods (Kingsford et al. 2010).

Determining the conservation status of fish and other biota is difficult where survey data are sparse. For example, the Finke Goby (*Chlamydogobius japalpa*) was listed as endangered ten years ago based on very limited survey (Duguid pers. comm. 30th May 2013). It is now known to be much more widespread within the Finke River Catchment and has probably been subject to natural boom bust cycles (based on Cockayne et al. 2012, 2013 and related surveys).

2.4.2. Cultural and social values

2.4.2.1. Overview

Cultural value is an overarching term that embraces many perspectives and definitions. This section seeks to define the term in the context of water, landscape and human involvement with and occupation of arid environments. The literature review includes a number of national and international perspectives on values as applied to many cultures and also determines links between natural and cultural values. Beyond definitions, the cultural values literature also includes methods and guidelines for establishing cultural values in relation to heritage, natural systems and rights to water. Assessment procedures for recording and documenting landscape systems from cultural, social and aesthetic perspectives aid in signifying the ways in which water landscapes are valued (UNESCO 2003).

In analysing landscape values a number of basic concepts arise including; cultural landscapes, cultural flows (in relation to water and Aboriginal people's perspectives), water landscapes and statements of cultural significance. Cultural significance is defined as 'aesthetic, historic, scientific or social values for past, present, and future generations' and 'the physical location of a place and the maintenance of visual settings and landscape relationships contribute to the cultural significance of places' (Burra Charter 1999, Articles 1.4 8, 9 & 13).

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[2] Listed under the *National Parks and Wildlife Act (1972)*

[3] Bilateral migratory bird agreements: CAMBA (China-Australia Migratory Bird Agreement), JAMBA (Japan-Australia Migratory Bird Agreement), ROKAMBA (Republic of Korea-Australia Migratory Bird Agreement)

The overlap between non-aboriginal values regarding landscape qualities and use, and the Aboriginal concept of country is particularly pertinent to arid landscapes. 'Country is not a generalised or undifferentiated place…rather country is a living entity… (Bird Rose 1996, p7).'

Values based registers, conventions and heritage studies confirm the intrinsic relationships and interdependencies between natural and cultural values and recommend assessment methods for heritage and conservation management. Effective landscape indicators used in the assessment of landscape values combining ecological (science) and visual (aesthetic) methods are recommended as important components of landscape planning and management (Fry et al. 2009).

Many researchers (e.g. Australian Heritage Council 2002; Hopkins 2005; Lee 2010; Macdonald & McNeil 2012; Swaffield 2005; Taylor et al. 1987) note the importance of using conceptual themes to support the analysis of landscape systems and their assets. Such themes include physical and temporal landscape qualities. For example, conceptual themes derived from landscape ecology include: stewardship, coherence, disturbance, historicity, visual scale, imageability, complexity, naturalness and ephemerality (Fry et al. 2009). Three cultural landscape-derived themes are determined by the World Heritage Convention (1992) to assist in landscape evaluation and management processes:

1. Clearly defined landscape designed and created intentionally by man (sic)
2. Organically evolved landscape
3. Associative cultural landscape.

Swaffield (2005) posits that knowledge collected in the field can be broadly grouped under a range of conceptual themes including: science, process and pattern of landscape, design and management interventions, social and political relationships and cultural readings of the landscape.

The attachment to place and the right to access water for human sustenance, cultural and spiritual purposes are examples of water values that are intrinsically linked to cultural landscape values. The spatial dimensions and typologies of water assets link to the patterns of settlement and development across Australia, particularly in the inland areas (Cathcart 2009; Gibbs 2009; Harris 2001; Macfarlane 2005; Piddocke 2009; Ridgway 2008; Tolcher 1986; Yelland 2002). Cultural values of water are also influenced by water use, water scarcity, and major infrastructure within the context that 'water will determine the future of Australia' (Cathcart 2009).

On-the-ground (deep) mapping methodologies that survey, document and communicate landscape values over time are important to enable overlapping values to be captured and defined (Corner 1997; Fry 2009; Lee 2010; Mcdonald &McNeil 2012; McClucas 2001; Shanks & Pearson 2001; Yu 1999). The identification of these values is informed by documented histories and spiritual, social and ecological stories gained from local experience. Douglas (2010) suggests that fieldwork is critical to enable negotiations between 'science data, landscape data and values for particular sites'. Observation and experience of landscape can also be determined through personal narratives recorded on site (Taylor et al. 1987; Birckhead et al. 2011).

2.4.2.2. Aboriginal cultural and landscape values and methods

The interconnectivity of Aboriginal peoples to water in arid areas is regarded as inseparable from their connectivity to and the concept of Country and the ongoing physical and spiritual health of the land and its peoples. 'Water in the living cultural landscape is inseparable from land, people, ancestors and social relations' (Altman 2009). Throughout the literature the predominant Aboriginal and cultural values include:

- Ancient to present day lineage of creation stories and pathways across the land focussed around landscape features including water places and
- The link between daily practices and Aboriginal economies, rights to water, identities and ways of life, (Ah Chee 2002).

The literature includes a number of direct links to the spiritual knowledge of named and located water assets in the LEB and the Arckaringa, Pedirka and Galilee Basins (Austral Archaeology Historical Research 2001; Hercus 1990; Kimber 1992; Mulvaney 2001; Silcock 2010). Cultural values for many other water places are so far unreported in published literature due to either remoteness or the need for cultural clearance or determination as to whether stories and locations can be divulged. Responsibilities for care of Country and its water assets reside with the local Aboriginal people and protocols for negotiation

with industry, pastoral, government, tourist and conservation interests and programs are under development across regions. A number of published protocols for engagement and research into landscapes (and by association their water assets) are in the public arena, often negotiated through mining interests and/or government agendas based upon jurisdictional boundaries (Australia ICOMOS 1999; Australian Heritage Commission 2002; Birckhead et al. 2011; Jackson et al. 2012; Lee & Morris 2005; RAMSAR 1999; Rea et al. 2008; UNESCO 2003).

The nomination of tracks and communication routes across country, linked to various water resources, by Aboriginal people is necessary to gain understanding of the dynamics of water use during different climatic conditions over time (Ah Chee 2002; Hercus 1990; Hercus et al. 2002; Kimber 2011; Mcfarlane 2005; Maclean et al. 2012; McBryde 1997; Yu 1999). Traditional practices of water conservation in arid areas through farming and trapping, well-making and use of simple hydraulic structures to satisfy food and water needs in times of drought are well documented alongside the practices of moving from waterplace to waterplace when sources dry up (Hercus 1990; Kimber 2011; Macfarlane 2005). The occupation and traditional use and naming of 'natural' water sources and types (mound springs, rock pools, springs, native wells, floodplains, wetlands, waterholes and rivers) have been increasingly supplemented over time by pastoral and mining water infrastructure such as dams, bores and pipes with non-Aboriginal names applied to the same area.

The concept of cultural water attached to place, networks and customary practice adds to the cultural mapping of LEB landscapes. Cultural flows mean having sufficient volume and quality of waters to support and improve traditional, healthy and economically beneficial lives (Collings & Falk 2008; Duff 2011). Cultural flows include, but are not limited to; periodic flooding, recognising the primacy of the river, respecting connectivity between water, country and life, caring for places (Duff 2011) and using water for economic purposes (NWC 2012). The definition and management of cultural flows need ongoing custodianship and input of Aboriginal people on their country. Environmental flows are defined using scientific approaches, however the concept of cultural flows must be regarded as overlapping rather than distinct qualities (NWC 2012).

Across Australia, research indicates that Aboriginal people's access to and ownership of water is an issue of human rights in relation to customary and commercial opportunities (NWC 2012). The protection of these rights and Aboriginal traditional knowledge is also connected to issues of climate change, biodiversity conservation and Aboriginal engagement and participation in water management, particularly in the Great Artesian Basin (GAB) (Ah Chee 2002). National principles for protection of water include consent for access onto Aboriginal lands and use of waters (Australian Human Rights Commission 2008). Gaining informed consent in remote landscapes is often facilitated by meeting representatives on country and at water places, where storytelling, mapping and walking sites can provide for cross-cultural consultation (Lee & Morris 2005; Rea and Anmatyerr Water Project Team 2008).

The literature reviewed identifies the broad range of Aboriginal, government, industry, environmental and cultural organisations working with Aboriginal presence and perspectives on Country. These organisations recognise water as an intrinsic component of the spiritual, social and economic lives of Aboriginal peoples (Ramsar 1999; Santos 2007; National Water Commission 2012). Protocols for operating on Aboriginal country stress the need for early and continuing meaningful engagement with Aboriginal people (Lee & Morris 2005; SAAL NRM 2013). In summary, meeting on country in appropriate ways includes:

- Respect for important sites and artefacts,
- Negotiation regarding access to and collecting or extraction of resources, and
- Specific projects and agreements in relation to water and its cultural and economic value.

Water values have been recorded and are observable on site and in the surrounding landscapes of the rivers, waterholes, creeks and springs all over the LEB study area, including Dalhousie, Witjira, the Lower Finke River and Simpson Desert areas (Ah Chee 2002; Badman 2000; Bandler 2007; Bayly 1999; Bird Rose 1996; Gibbs 2006; Harris 2001; Kimber 1992; Lee 2010; Gibbs 2006; Macdonald & McNeil 2012; Macfarlane 2005; Silcock 2009a & 2009b). However, a comprehensive fieldwork study to work on the ground with traditional owners and custodians of the water systems and places has not been undertaken in the designated LEBRM study areas.

2.4.2.3. Historical non-Aboriginal landscape and cultural values

Non-Aboriginal values and perceptions of the landscape are traced from early explorer accounts and then through the histories of opening up the land to development of large-scale industries including pastoralism, mining and tourism. Historically, small communities developed in sparsely located places adjacent to natural water supplies initially drawn from springs and permanent and semi-permanent waterholes. With increasing industrialisation of remote, arid landscapes, the GAB became a source of reliable and permanent water supply through bores and water storage systems (Yelland 2002). The critical aspect of water drawn from aquifers is that the water source is invisible, resulting in the expectation that an unending supply of water to sustain industry is available. Despite scientific and anecdotal reports of lowering water tables, these assumptions are also recorded in similar conditions across other areas of arid Australia (Harris et al. 2002; Lloyd et al. 2013) and the mid- and south-west of the USA (Osborne 2011).

The primacy of water and the locations of places where water can be accessed structured the original routes and pathways explored across the LEB. Since the mid-1960's, the geological riches of the oil and coal basins have provided the modern framework for the development of roads, infrastructure and temporary settlements in resource-intensive areas (Lee 2010; Santos 2007). Patterns of mining and exploration development industrial infrastructure can be seen in the Cooper Basin (Tolcher 1986).

The historical literature covers a wide range of accounts regarding the methods and processes used by early settlers and pastoralists to open up the country based upon water supplies (Gibbs 2009; Silcock 2009). The concept of historical ecology is concerned with understanding ecological variation from the past to enable greater understanding of present and future water systems (Piddocke 2009). Other writers reveal the human values placed on water through association with the natural systems of rivers, waterholes, mound springs and soaks through aesthetic experiences linked to nature narratives regarding human, animal and plant life and survival strategies (Harris, 2001).

The range of explorer journals and historical reports (e.g. Mitchell 1847; Stuart 1865; Babbage 1858) are an invaluable resource for research into both non-Aboriginal and Aboriginal occupation of water places across the LEB including:

- Patterns of use
- Water networks
- Infrastructure development
- The cultural and social lives of communities and settlers.

Through explorer and settler stories, the condition and degree of change of water places and systems is mapped for the large western and northern river systems (Lee 2010; Piddocke 2009; Silcock 2009) and networks of mound springs (Badman 2000; Harris 2001; Mulvaney 2002). Many places are named and oral accounts are recorded, particularly around the trade, train and explorer routes such as the Oodnadatta Track and the Ghan Railway, and also through the stock routes that followed the rivers and waterholes of the Neales, Macumba and Finke Rivers (Austral Archaeology Historical Research 2001; Bayly 1999; Kimber 1992; Kinhill et al. 1986; Lee 2010; Litchfield 1983; Macfarlane 2005; Piddocke 2009; Schmiechen 2004; Silcock 2009b; Tolcher 1986; Yelland 2002).

Water histories are beginning to be told across certain areas of the LEB, such as the western Simpson Desert, which reveal the location of old water places and document the new sources and methods of water gathering and extraction (Macfarlane 2005; Smith & Hesse 2005). The point is well made in a number of accounts that non-Aboriginal people also have strongly held values for water places as sites for memory, identity and spiritual health (Burmill et al. 1999; Gibbs 2009; Lee 2010; Macdonald & McNeil 2012; Silcock 2009b). Through collating these historic accounts regarding the visible condition and use of the range of waterbodies in the study area, the degree of change in the system can be either measured or assumed based upon the range of different stories recorded. Fieldwork towards landscape assessment of the disparate surface waterbodies across the LEB will provide an overview of the qualities inherent in early 21st century water systems subject so far to minimal industrialisation of the landscape and its waters.

2.4.2.4. Contemporary values in the Lake Eyre Basin

The community values literature presents a range of issues and dynamics around water quality, supply and conservation in a period of potential expansion of mining and exploration activities in remote places with scarce permanent water supplies. These can be broadly grouped into the following subjects:

- Community engagement and management regimes
- Tourism, landscape, water and management
- Aboriginal perspectives and methods
- Mining and exploration production
- Cultural heritage values including media and social commentary on CSG mining
- Government policy and management.

In times of water scarcity there are competing demands for water, resulting in the need for policy and management regimes to focus on both surface and ground water assets from social, cultural and economic perspectives (Leek 2001). The relationships between land use and associated social systems need to be documented to gauge the impacts of changing water regimes upon the landscapes and social lives of people in the LEB. Increasing knowledge of the impacts and benefits of resource extraction requires a community focus on the major issues surrounding the conservation and management of water supplies, water quality and water sustainability (Leek 2001). Local knowledge regarding changes over time in both water systems but also in communities and industries shows very dynamic economic, social and ecological systems in place (Desert Channels Qld Inc. 2004; Measham et al. 2009; Rickson 2012; Storey 2010). Social media platforms (e.g. Western Downs Alliance 2012) record great uncertainty regarding ongoing community access to water assets, water rights and ownership. While aspects of the water assets of the LEB are known from a scientific perspective (as outlined in previous sections), all three LEBRM priority areas have not so far undergone a cultural landscape assessment with a primary focus on water assets.

Contemporary knowledge and information systems that convey the results of research into the natural and cultural systems of the LEB enable locals and visitors to have the ability to be well-informed about the interconnections between ecological systems and human induced impacts and developments. The key drivers of the future use of the LEB will be continued pastoralism and increasing mining and industrial infrastructure, with conservation and tourism regarded as the new economies (Read 2003; Schmiechen 2004). These larger scale economies have the potential to require far greater volumes of water than existing land uses and will draw on water assets for both industrial and recreational pursuits. Community concern is increasing regarding the ability of policy, management and regulatory regimes to enable wise and conservative use while supporting new economies (e.g. Western Downs Alliance).

The capture and communication of community water values and the ways in which communities and industries develop methods that support the maintenance of such values is a critical aspect for research and community engagement on the ground and at the scale of local systems and networks (Macdonald & McNeil 2012). From an Aboriginal perspective, the link between values, spiritual relationships, rights to water and economic development and caring for country are the main issues (Altman et al. 2009; Australian Human Rights Commission 2008; Duff 2011). Documentation of agreed approaches to maintaining important sites for water landscapes and their assets is critical to sustainable management (Birckhead et al. 2011). A number of protocols are in place and managed by mining companies for procedures to record and protect Aboriginal cultural heritage sites including: procedures for access to artefacts and reduction of impact through improved exploration and mining operations techniques (e.g. Santos 2007). The involvement of Aboriginal people in these procedures with the ability to monitor effects over time is important. Participatory management practices enable broad benefits to local people and the maintenance of sustainable livelihoods to be achieved. These practices can be applied to activities such as water farming, recreation, wetland use and ecotourism, and thereby maintaining spiritual and cultural values, equitable access to water assets and reduced conflict between competing stakeholders (Davies & Holcome 2009; Measham et al 2009).

The cultural and economic value of the various 'natural' water sources is widely acknowledged by the range of people who access these assets for livelihood, recreation or spiritual uses and values (Macdonald & McNeil 2012). Some generalisations can be made regarding water as the primary magnet for occupation of arid places. For tourism, the apparent naturalism of water resources, preferably associated only with small settlements and/or heritage sites, is the paramount experience of being in the outback (Silcox 2009b). For pastoralists, reliable water, drawn from a range of sources over times of climatic change,

frames their response to working with and on the land (Ah Chee 2002; Gill 1997; Piddocke 2009). For industry, the scale of both development and the need for water of sufficient quantity results in increasing industrialisation of remote landscapes (AGL 2013; RPS Ecos 2007). It is clear that identifying locally these competing uses and perceptions around the type, condition, quality and degree of naturalness of water assets is critical to gain understanding of the values that people hold for inland waters. Ah Chee (2002) recognises 'the different values and priorities for water within the GAB for Aboriginal and non-Aboriginal people and how it must now be managed to allow for wise use to achieve a better outcome for future generations'.

Communication protocols across all stakeholders are required to ensure access to available and current information regarding: mining exploration, discovery and future development, tourism developments and communication networks, conservation and Aboriginal native title priorities (Lloyd et al. 2013). Recognising the larger LEB water systems as a whole in government policy is one method to enable effective engagement across communities (Bellamy et al. 2012). Forums where people from the LEB and those with interests from outside are able to meet and exchange knowledge and processes for the wise use of water assets, is supported by community (Western Downs Alliance 2012).

Mining, exploration, production and cultural heritage values

Information produced by both mining companies and the various organisations involved with and impacted upon by mining exploration and production is summarised in the accompanying Annotated Bibliography. This also includes references to a number of websites, which produce a range of information on CSG and other mining operations in the study area and from a national perspective. The reports and information sheets are in some instances reviewed and alternatively the website links to their entire reports are included without review. The intent has been to identify the range of operators and companies in the study area to date.

Media and social commentary CSG mining

The range of commentary on CSG and other mining operations is substantial from international to local opinions and information sharing. While not formally reviewed for accuracy, these social networking sites provide insight into community opinion and concerns regarding CSG andcoal mining, their benefits and impacts. For the purposes of this review only one of the numerous sites (Western Downs Alliance 2012) has been selected for inclusion in the Annotated Bibliography, demonstrating the types of networks and commentary posted.

2.5. Conclusion

This review has collated 558 published and unpublished information sources to present the state of knowledge about the LEB aquatic ecoysystems at the beginning of the LEBRM projet. As stated in the scope, the review focusses on surface-water driven aquatic ecosystems as groundwater-dependent ecosystems are the subject of another LEB water knowledge project. This summary presents and overview of the information, whilst the following section (3) presents more detailed summary of each document as they relate to the topics.

The literature review included pressure-stressor-response (PSR) and impact assessment frameworks that inform *Integrated Strategic Management Framework*. PSR approaches have been used in Queensland to guide waterway monitoring (DERM 2010a) and evaluate the potential impacts of CSG water releases (Takahashi et al. 2011b).

National and state-based systems for classifying aquatic ecosystems relevant to the LEB were reviewed. The extent of aquatic ecosystem mapping and level of attribution varies across the LEB; to date, no consistent aquatic ecosystem mapping and classification has been applied across the LEB. Aquatic-ecosystem conceptual modelling builds on classification and is being used in the LEBRM project to model how pressures and stressors impact on different aquatic ecosystems types. A number of conceptual modelling approaches have been reviewed and the approach adopted for LEBRM aligns with national frameworks (DSE 2005; AETG 2012b,d).

The extreme natural variability of the LEB provides a challenge for monitoring and assessing the health of the system. The LEB Rivers Assessment program has developed a methodology (Thoms et al. 2009) over a number of years and monitors fish, water quality and hydrology as indicators (DSEWPAC 2011, 2012, 2013).

This review found that, at the commencement of the LEBRM project, there was little scientific information from Australia regarding pressures and stressors resulting from CSG and LCM developments, and the majority of the literature draws on expert opinion and overseas experiences (e.g. Moran and Vink 2010; Williams et al. 2012). The potential response of aquatic ecosystems may be in changes to their attributes, components and processes (McNeil and Wilson 2014). The current level of knowledge about aquatic ecosystems in the LEB is very limited, with the Cooper, Georgina-Diamantina and Neales catchments most studied. However, even within these catchments, most studies have focussed on riverine waterholes and other more permanent aquatic ecosystem types. The review found little information is available for other aquatic ecosystem types such as floodplains and floodouts.

The Cooper and the Georgina-Diamantina catchments are the only catchments in the LEB where long-term flow gauge stations exist, and these stations are only sparsely distributed (Costelloe 2008). Knowledge about the LEB hydrology has been supplemented with a network of stage-height loggers in the Neales, Cooper and Georgina-Diamantina catchments installed in the early 2000s. The network has been maintained and expanded and contributed to a significant body of knowledge about the hydrology of these catchments.

Salinity is the main water quality attribute that has been surveyed or monitored in the LEB, with very little information available on other attributes. Salinity is highly variable spatially and temporally and the main drivers are flow, location in the catchment and complex interactions with shallow aquifers (Sheldon & Fellows 2010; Costelloe et al. 2005a,b, 2007b; Irvine et al. 2006). Surface water–groundwater interactions vary across the LEB, making it difficult to transpose the findings from one region to another.

Long term, standardised monitoring of fish and waterbirds at selected sites in the LEB has provided sufficient information to predict the response of fish (Balcombe & McNeil 2008) and waterbird populations (Kingsford & Porter 2008) to hydrological stressors. Waterbird responses are, however, complicated by the fact that they are able to move between basins and continents, and therefore reflect influences at broader scales than the LEB alone (Kingsford et al. 2010). Studies about invertebrates to understand their population dynamics have had varying success. The review found limited knowledge about other aquatic fauna, vegetation, and riparian and floodplain biota of the LEB. In particular, improving understanding of Coolabah, including hydrological and geophysical requirements is a priority for floodplain and riparian environments.

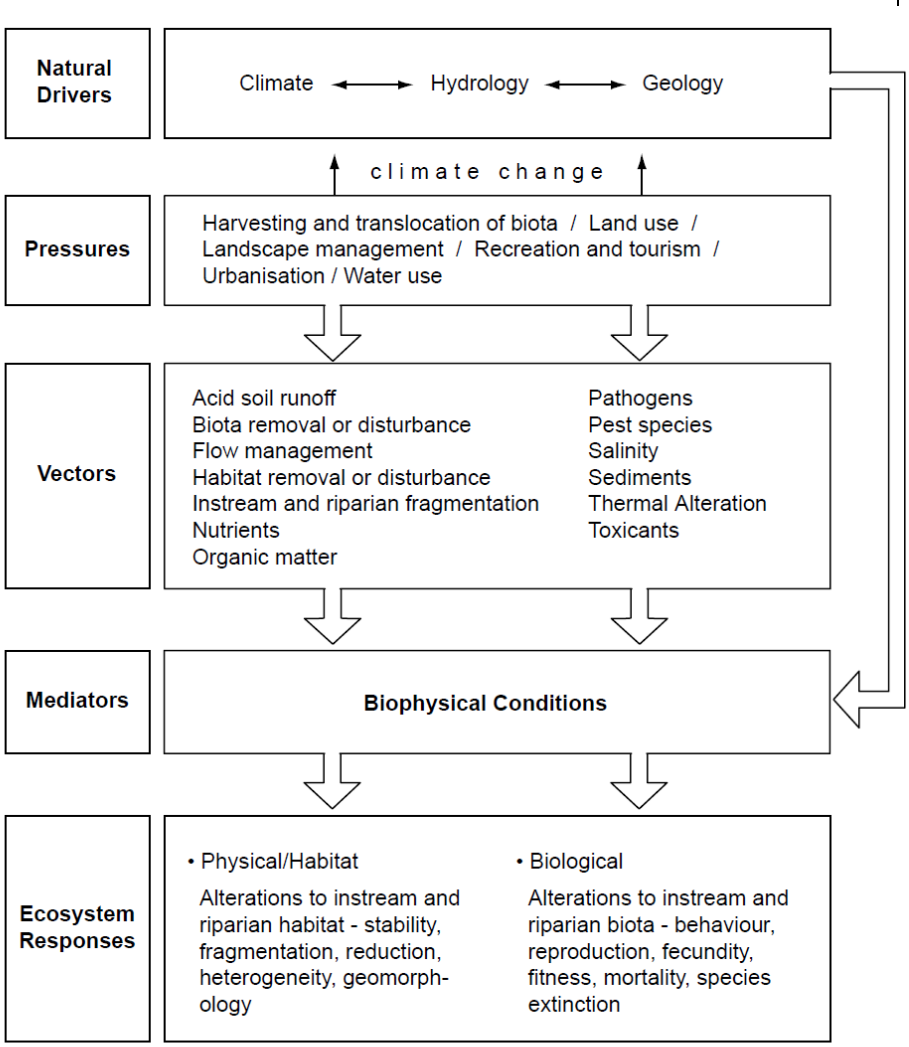
The LEB has significant ecological and conservation values that are associated with the boom and bust nature of the basin and its relatively intact condition (Morton et al. 1995). LEB aquatic ecosystems also have significant cultural values, often associated with the scarcity of water, and many sites of cultural value are also considered to have high ecological values.

3. Annotated bibliography

3.1. Strategic documents review

3.1.1. Frameworks

3.1.1.1. Pressure-stressor-response frameworks

Reference	Region	Summary
Marshall et al. (2006a)	Qld	Development of conceptual PVR models for Qld's riverine ecosystems. Use 'vector' as precursor to 'stressor': vectors are biophysical condition attributes modified by pressures to produce ecosystem responses. Pressures are associated with land uses and therefore can use the Australian Land Use and Management Classification as its basis. Developed generic base models for each vector based on diagram p. 6: 
McNeil et al. 2012	MDB	The protection of drought refuges for native fish in the MDB Criteria for refuge management incorporates PSR thinking:

Reference	Region	Summary
		• Refuge values – aspects important to protect/restore, e.g. species, communities, habitats • Characteristics and their attributes - Physical habitat (structural nature of refuges) e.g. o Intact riparian zones o Presence of deep holes - Hydrological processes (persistence and behaviour of surface water) e.g. o Permanence of water o Groundwater inputs - Spatial [hydrological] connectivity (between refuges and other habitats) o Lateral connectivity and o Longitudinal connectivity - Biological integrity e.g. o Intact ecological processes o Diverse and abundant/intact riparian vegetation • Functions – provide ecological services and/or processes essential for maintaining attributes at a sustainable/adequate level • Threats (direct impacts) and pressures (often indirect anthropogenic impacts) to values, characteristics, attributes and functions • Management strategies – mitigate threats and pressures and maintain refuge characteristics, functions, attributes and values.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek Catchment trial A report detailing the application, development and trial an Integrated Ecological Condition Assessment (IECA) for High Ecological Value Aquatic Ecosystems (HEVAE) in the Cooper Creek catchment. Five HEVAE units (CAT 500 polygons) were selected for assessment. Aquatic ecosystems were identified and listed for each hydrological unit, and HEVAE criteria relevant for each unit were determined. Sampling of targeted indicators was undertaken to validate threat risks and to gather information for knowledge improvement. Results indicate the PSR for each of the areas sampled, and provided criteria within the HEVAE and current management controls. Priority threats to the Cooper Creek aquatic ecosystem were land use (i.e. grazing) and introduction of feral animals (i.e. cattle, pigs and fish) Relevance: Presents a method for assessing HEVAE in the LEB.
Sheldon et al. (2012)	National	Early warning, compliance and diagnostic monitoring of ecological responses to low flows Uses pressure and response terminology however it is not consistent with PSR as used by above references.
Smythe-McGuiness et al. (2012)	Qld	Macroinvertebrate responses to altered low-flow hydrology in Queensland rivers Utilised a PSR model, with the five main pressures associated with flow alteration: Dams and weirs, water extraction, interbasin transfer, disposal of industrial wastewater (CSG) and climate change; links to all identified stressors; and expected responses (as illustrated by conceptual models).

<table>
<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td></td><td></td><td>Outcomes indicated that significant shifts in macroinvertebrate communities would occur in response to alterations to the low-flow regime.

Relevance: Potential for utilising macroinvertebrates in monitoring as indicators of hydrological regime change.</td></tr>
<tr><td>Takahashi et al. (2011b)</td><td>Qld (MDB)</td><td>Stream ecosystem health response to CSG water release: biological monitoring guidelines

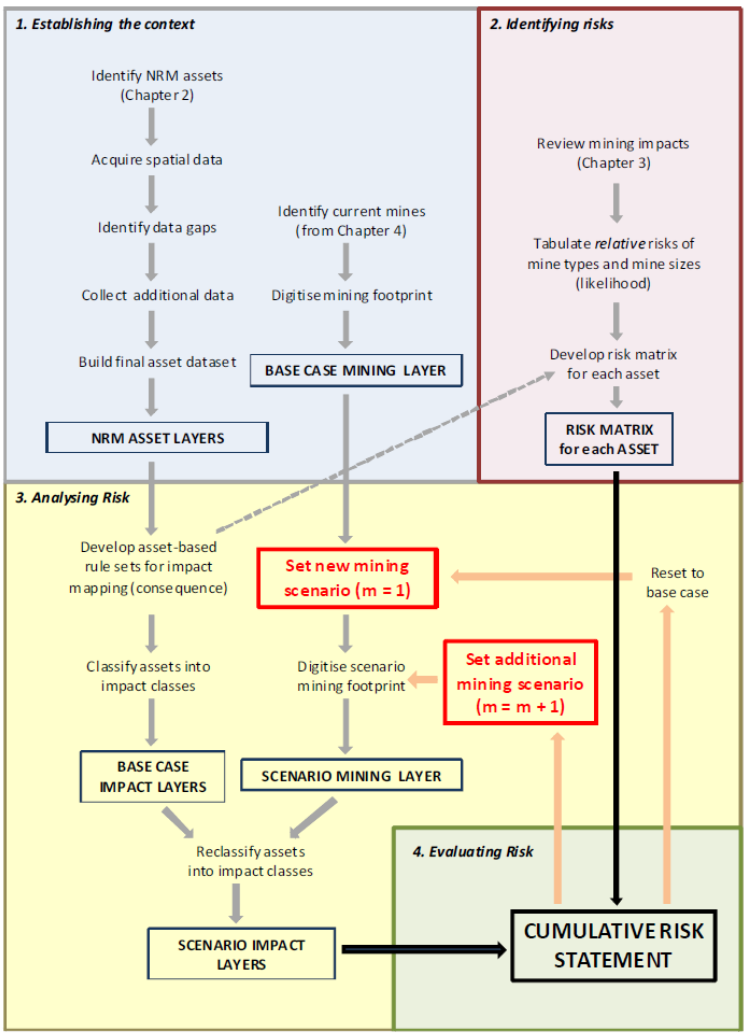
Pp 17-18 Stressor-response table including measurements for stressor and possible response indicators.

Table 3. Applying PSR approach to CSG scenarios. The pressure in this case is the release of CSG water into the surface water. The Monitoring and Sampling Manual (2009) is recommended for sampling of the indicators.
<table>
<tr><th>Stressors</th><th>Measurement of stressor</th><th>Potential responses</th><th>Possible indicators</th></tr>
<tr><td>Alteration to hydrology leading to decrease in dry spells</td><td>▪ Days of 'no flow' compared to previous 100 + years</td><td>▪ Decrease in ephemerality. For example, some macroinvertebrate that inhabit the ephemeral streams may not be able to survive in the altered system.
▪ Increase in connectivity may encourage selected species of fish to migrate into the streams where they previously could not inhabit. This has the potential for an increase in invasive species.
▪ Increase in aquatic macrophytes in permanent pools and backwaters.</td><td>▪ macroinvertebrates
▪ macrophytes
▪ fish species
The potential fish species that can be selected as indicators are listed in Table 2.</td></tr>
<tr><td>Constant release of water leading to constant flow and decrease in seasonal flow</td><td>▪ Days of 'no flow' compared to previous 100 + years
▪ Seasonal variations in flows</td><td>▪ Decrease in species that rely on seasonal cues for breeding
▪ Increase in invasive species due to decreases in native species and alterations to the food web and the ecosystem.</td><td>▪ macroinvertebrates
▪ macrophytes
▪ flow dependent fish
▪ exotic species of fish
▪ riffles
The potential fish species that can be selected as indicators are listed in Table 2.</td></tr>
<tr><td>Decrease in EC due to constant RO water being released</td><td>▪ EC level in water</td><td>▪ Decrease in macroinvertebrates that are sensitive to low EC, especially below thresholds of 120 µS/cm.
▪ Increase in invasive species due to decreases in native species and alterations to the food web and the ecosystem.
▪ Increase in tolerant family groups which will dominate the community structure
▪ Decrease in PET richness and SIGNAL scores following disturbance.</td><td>▪ macroinvertebrates
▪ macrobrachium
▪ exotic species of fish</td></tr>
<tr><td>Alteration to ionic composition due to constant RO water being released</td><td>▪ Ionic concentrations and composition of water
• Na
• Mg
• Ca
• Cl
• SO4
• HCO3
• K</td><td>▪ Decrease in species of macroinvertebrates, fish and algae may be sensitive to such a change as altered ionic composition is known to be toxic to certain species.
▪ Decrease in macroinvertebrates that rely on Ca for their physiology as RO permeate can strip Ca from its surroundings.
▪ Increase in invasive species to increase in number due to decreases in native species and alterations to the food web and the ecosystem.</td><td>▪ macroinvertebrates
▪ algae
▪ macrobrachium
▪ aquatic plants</td></tr>
<tr><td>Decrease in turbidity leading to increase in transparency of the water, which subsequently leads to higher light penetration</td><td>▪ Turbidity of water
▪ Light penetration of water</td><td>▪ Increase in algal blooms especially if the nutrient levels are high.</td><td>▪ algae
▪ primary production</td></tr>
<tr><td>Cumulative toxicological impacts from contaminants</td><td>▪ Toxicant</td><td>▪ Increase in acute and chronic toxicity on various sensitive organisms.</td><td>▪ fish
▪ algae
▪ aquatic plants
▪ macroinvertebrates
▪ crustaceans</td></tr>
</table>
</td></tr>
</table>

3.1.1.2. Risk and impact assessment frameworks

Reference	Region	Framework summary	Application results
DERM (2011a,b)	Qld	Assessment for integrated waterway monitoring in Qld A whole-of-state prioritisation of catchments for waterway monitoring using a risk based approach combining spatial data analysis and scientific expertise. Risk is determined based on spatial analysis of human-induced pressures, with each pressure being scored based on an appropriate indicator (e.g. number of mines in a catchment for the pressure mining). Consequence is based on a weighting being applied to each pressure for each of four ecosystem types, with confidence levels scored. Risks are separately assessed for ongoing risks and incident-based risks. Technical Report (DERM 2011b) Overall, LEB catchments' aquatic and riverine ecosystems rank low levels of ongoing and incident-based human activities. No LEB catchments ranked >low for coal mining but for CSG pressure Cooper (lower only) ranks moderate (6-200 wells).	Applied at whole of catchment scale (see DERM 2011b): Cooper
DERM (2010c)	Qld (LEB)	Desert Channels Back on Track Actions for Biodiversity Utilised DERMs 'Back on Track' species prioritisation framework to identify species that are in decline on a whole-of-state scale, but which also have a good chance of recovery. Framework involves scoring and ranking against seven criteria, then progressing through community, stakeholder, expert consultation process. The overall purpose of the actions indicated is to achieve greater conservation benefit for invested resources, and to encourage an ecosystem approach to conservation management. Relevance: Potential monitoring parameters (i.e. monitor for change to threats).	The tables developed for all major threats include actions relevant to the recovery of multiple species.
DEWNR (2012)	SA	Risk management framework for water planning and management Framework is focussed on the risks to values: natural resources, community values and management actions. Consistent with AA/NZ ISO 31000. The risk assessment requires: • Risk identification – risks that may cause an event which results in a consequence • Risk analysis – likelihood and consequence of risk, generally using a risk matrix; include controls analysis • Risk evaluation – is the level of risk acceptable or does it require treatment	

Reference	Region	Framework summary	Application results
Eco Logical Australia (2011)	NSW (Namoi)	Proposed Framework for Assessing the Cumulative Risk of Mining on NR Assets in the Namoi Catchment Framework for quantifying cumulative risk impacts on: soils, land use, surface water, groundwater, vegetation type, vegetation condition, landscape connectivity and threatened species. Basis of the spatial tool (Eco Logical Australia 2012). Adopts AS/NZ ISO 31000:2009. Considers open cut, long wall and CSG mining. 'The proposed framework is spatial in nature (i.e. is operated within a Geographic Information System) and involves the following: - identification of the major types of impact associated with mining; - derivation of a catchment-wide map of each type of impact using one or more baseline asset maps, using explicit rule sets underpinned by published science and expert advice; - derivation of a risk matrix for each type of impact that relates the mine types and size classes to the projected magnitude of impact; - linking the impact mapping and risk matrix to establish risk maps; and - preparation and input of a base case mining layer and a scenario mining layer (p. iv).' Uses risk statements for any mining scenario that show the single impact of each mine, cumulative impact of all mines, and the associated levels of risk on each NR asset. Risk statements supported by layers showing change in impact zones before and after a scenario. From p. 75.	See Eco Logical Australia 2012

Reference	Region	Framework summary	Application results
		 Figure 14. Proposed framework for cumulative risk assessment in the Namoi	
Eco Logical Australia (2012)	NSW (Namoi)	Assessing the cumulative impact of mining scenarios on bioregional assets in the Namoi Catchment – development and trial of a GIS tool Developed a spatial tool that has been designed to report the cumulative risk of any mining scenario constituting a combination of one or more mines. Tool designed to: '- analyse the cumulative impact of a scenario (input by the user) across a number of asset sensitivity surfaces; - call on respective risk tables that associate sensitivity and likeliness/magnitude with risk; and - produce a risk report that includes maps, area statistics, single and cumulative risk diagrams, and statements about specific assets impacted (p ii).'	No
Green et al. (2013)	SA (GAB)	AWMSGAB: Risk assessment process for evaluating water use impacts on springs of the western GAB	

<table>
<tr><th>Reference</th><th>Region</th><th>Framework summary</th><th>Application results</th></tr>
<tr><td></td><td></td><td>
Provides a framework to analyse and evaluate risk factors associated with reductions in groundwater pressure in the GAB.

Whilst the framework was developed for GAB springs of the artesian GAB it is suitable for springs in the non-artesian parts of the basin provided similar standards of data are included. GAB springs also include watercourse springs and potentially ecosystems supported by diffuse discharge (see Kellett et al. 2012).

The assessment includes the following steps:
<table>
<tr><th>Risk assessment step</th><th colspan="2">Component</th></tr>
<tr><td>Likelihood assessment</td><td colspan="2">1a. Aquifer pressure above spring level versus predicted drawdown (number of spring vents in each rating category)</td></tr>
<tr><td></td><td colspan="2">1b. Spring flow reduction likelihood matrix (number of spring vents in each rating category)</td></tr>
<tr><td>Vulnerability assessment</td><td colspan="2">2a. Surface water salinity</td></tr>
<tr><td></td><td colspan="2">2b. Acid sulfate hazard</td></tr>
<tr><td></td><td colspan="2">2c. Morphology (typology)</td></tr>
<tr><td></td><td colspan="2">2d. Wetland extent (number of spring vents in each rating category)</td></tr>
<tr><td></td><td colspan="2">3a. Ecological focal zone</td></tr>
<tr><td></td><td colspan="2">3b. Wetland connectivity vulnerability</td></tr>
<tr><td>Consequence assessment</td><td>4a.</td><td>Diversity</td></tr>
<tr><td></td><td></td><td>Distinctiveness</td></tr>
<tr><td></td><td></td><td>Vital habitat</td></tr>
<tr><td></td><td></td><td>Evolutionary history</td></tr>
<tr><td></td><td></td><td>Naturalness</td></tr>
</table>
An assessment of the controls and uncertainty are also part of the framework.

The framework requires a level of data that is not currently available across the entire GAB.
</td><td></td></tr>
<tr><td>Wilson et al. 2014</td><td>SA</td><td>Assessment of vulnerability of water assets to hydrological change caused by coal seam gas and large coal mining development in South Australia

Identified CSG & LCD activities that may affect hydrological character of water assets (which is used as basis for list of pressures below (Section 2)). List of potential effects which may occur and with each combination of activity and effect</td><td>Project undertook assessment</td></tr>
</table>

Reference	Region	Framework summary	Application results
		rated consistently. Based on the water regime and source for each asset, the vulnerability of assets are determined. Framework consistent with DEWNR's risk management framework (DEWNR 2012).	
Howe (2011)	National	Framework for assessing potential local and cumulative effects of mining on groundwater – project summary report Focusses predominantly on groundwater impacts but includes a framework for impact assessment with accompanying software tool. Eromanga region in SA was used as one of the case studies. Notes that CSG needs to be brought into the framework.	
Kingsford and Biggs (2012)	Inter-national	Strategic Adaptive Management Guidelines For Effective Conservation Of Freshwater Ecosystems In And Around Protected Areas Of The World The framework involves the identification of asset values (including ecological and human) and indicator rules to inform the development of Thresholds of Potential Concern (TPC) that identify potential tipping points beyond which ecosystem function, resilience or viability are threatened.	
Lobegeiger (2011)	Qld (MDB)	Refugial Waterholes Project: Research Highlights Documents the processes utilised in determining the refugial qualities of waterholes, by assessing risk to aquatic biota. The Moonie was the focus catchment for this study, although data from five other Qld catchments were used to test the transferability of relationships. The project addressed the following topics for the Moonie, and assessed the applicability of methods/results for use in other catchments: • Persistence time of waterholes • Parameters required to estimate persistence • Impacts of sedimentation on waterhole morphology and persistence • Impacts of resource availability on resident biota • Resident fish ecology • Critical depth thresholds • Spatial connectivity of waterholes • In systems that experience temporary flow, refuge waterholes provide critical habitat for obligate aquatic biota. Relevance: Method for identifying important waterholes.	Results used directly for WRP reviews; not all models developed were transferable for use in other catchments
Marshall et al. (2006a)	Qld	Development of conceptual PVR models for Qld's riverine ecosystems Pressures associated with land uses and therefore can use the	

Reference	Region	Framework summary	Application results
		distribution and intensity of the land uses based on the Australian Land Use and Management Classification as a quantitative basis for the likelihood of a vector (/stressor) occurring. Consequence based on ranking ecosystem responses on a five point scale semi-quantitative. This gives a ranked list of vectors for each region. The risk rankings can then be taken to regional expert panels and reviewed, supporting information identified and confidence rankings applied (i.e. as per Clifford et al. 2010).	
McGregor et al. (2012)	Qld (MDB)	Stream ecosystem health response to coal seam gas water release: guideline for managing flow regimes. Provides a framework to assess risk to flow dependent ecosystem components and processes, using an eco-hydraulic modelling approach based on the principles of ecological risk assessment. The report discusses the following process: 1. Identification of the hazards related to the disposal of CSG water. This requires an understanding of the hydrological characteristics of the receiving environment. 2. Selection of ecological assets which represent the ecological values of the system, to be used as indicators of hydrological alteration of the flow regime. Knowledge of biota relying on aspects of the flow regime needs to be considered when discharging large volumes of water. 3. Development of CSG water disposal hydrology scenarios using existing knowledge on discharge volume and timing. 4. Analysis of the potential risks associated with disposal of CSG water. 5. Characterisation of the risks and incorporation of these into a management framework. The seasonality and timing of flows must be explicitly considered. Monitoring should focus on measures of ecosystem condition and response which are sensitive to the altered hydrological regime at relevant spatial and temporal scales in order to evaluate the effectiveness of the water disposal regime. Relevance: Guidelines of methods for monitoring aquatic ecosystems in relation to CSG water.	Although the framework was developed for CSG discharge scenarios in the Qld MDB, the process could be suitable for managing flow regimes in LEB rivers.
Miles et al. (2012)	GAB	GABWRA: Assessment of the impacts of future climate and groundwater development on GAB Springs The GABWRA spring impact assessment framework was developed concurrently with Green et al. (2012) but is a simplified approach to suit data available at the whole-of-GAB scale. In particular the GABWRA framework does not include an assessment of vulnerability. The GABWRA framework does	Evaluation of impacts from climate change and future groundwater use across the whole GAB

Reference	Region	Framework summary	Application results
		include assessments of opportunity for recovery of ecological values resulting from improved groundwater management.	
Takahashi et al. (2011c)	Qld (MDB)	Stream ecosystem health response to CSG water release: decision support system Structured around an ecological risk assessment framework where likelihood is based on hazard characterisation and consequence based on ecological response characterisation. 'A stressor is a physical chemical or biological component of the ecosystem that is controlling biological populations and ecosystem values (the ecological responses). A hazard is the change in that stressor, due to a human pressure, that is likely to induce an unnatural ecological response. Natural drivers also have an influence on stressors but would not be considered a hazard (p. 19).'	
Williams et al. (2012)	National	An analysis of CSG production and NRM in Australia Emphasise the importance of cumulative risk analysis and impact assessments of multiple land use developments. Social, economic and environmental impact assessments need to be brought together for whole-of-system approach.	

3.1.2. Aquatic ecosystem classification and mapping

3.1.2.1. Classification schemes

Reference	Region	Summary
AETG (2012a)	National	Interim Australian National Aquatic Ecosystem Classification Framework (V1) Three levels of classification, Levels 1 & 2 are large scale and provide a regional context for the classification whilst Level 3 identifies major classes and attributes used to classify these into habitats.

Level 1	Regional scale (Attributes: hydrology, climate, landform)	
Level 2	Landscape scale (Attributes: water influence, landform, topography, climate)	
Level 3 Class	Surface Water	Subterranean

<table>
<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td></td><td></td><td>
<table>
<tr><td>System</td><td>Marine</td><td>Estuarine</td><td>Lacustrine</td><td>Palustrine</td><td>Riverine</td><td>Floodplain</td><td>Fracture</td><td>Porous/Sed Rock</td><td>Unconsolidated</td><td>Cave/karst</td></tr>
<tr><td>Habitat</td><td colspan="2">NA</td><td colspan="4">Landform</td><td colspan="4">Confinement</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="4" rowspan="2">Confinement (riverine only)</td><td colspan="4">Dominant porosity</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="4">Saturation regime</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="4">Soil / substrate</td><td colspan="4">Residence time</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="4">Vegetation / Fringing vegetation</td><td colspan="4">Dominant recharge sources</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="4">Water source (SW/ GW/ SW-GW, local)</td><td colspan="4">GW-SW connectivity regime</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="4">Water type (chemistry)</td><td colspan="4">Water type (chemistry)</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="4">Water regime</td><td colspan="4">Hydraulic conductivity</td></tr>
</table>
</td></tr>
<tr><td>AETG (2012b)</td><td>National</td><td>Guidelines for identifying HEVAE

Describes the criteria and workflow for identifying HEVAEs. Identification of HEVAEs is linked to Clause 25(x) of the NWI in relation to identifying HEVAE at a national level but may have other applications at state and regional level. Engaging expert knowledge is a critical step to help overcome data limitations and develop criteria relevant to region and purpose.

HEVAE criteria:
1. Diversity
2. Distinctiveness
3. Vital habitat
4. Naturalness
5. Representativeness</td></tr>
<tr><td>Brierley & Fryirs 2005</td><td>All</td><td>Geomorphology and River Management: Applications of the River Styles Framework

Outlines River Styles®, a process-based classification and assessment scheme for river geomorphology.</td></tr>
<tr><td>Claus et al. (2010)</td><td>Other (NSW)</td><td>Assessing the extent and condition of wetlands in NSW: Supporting report A – Conceptual framework

A review of existing classification systems is included. Attributes used to classify NSW wetlands included: wetland system, climate, water source, water regime, water type, vegetation.

Consistent with DSITIA (2012)</td></tr>
<tr><td>Davis et al.</td><td>National</td><td>Evolutionary refugia and ecological refuges: key concepts for conserving Australian</td></tr>
</table>

Reference	Region	Summary
(2013a) (this work is under-pinned by work in Davis et al. (2013b)		arid zone freshwaterbiodiversity under climate change Present a conceptual model that characterises evolutionary refugia and ecological refuges based on a review of the attributes of aquatic habitats and freshwater taxa. Evolutionary refugia: permanent, groundwater-dependent habitats (subterranean aquifers and springs) supporting vicariant relicts and short-range endemics. Ecological refuges: can vary across space and time, depending on the dispersal abilities of aquatic taxa and the geographical proximity and hydrological connectivity of aquatic habitats. The most important are the perennial waterbodies (both groundwater and surface water fed) that support obligate aquatic organisms.
DERM 2011c	Qld	Queensland wetland definition and delineation guideline Part A: A guide to existing wetland definitions and the application of the Queensland Wetlands Program definition Provides guidance on the range of wetland definitions in Qld; provides guidance on interpretation and use of the Qld Wetlands Program definition and how it relates to other wetlands program tools. Relevance: Determination of sites, and use for consistency of definitions and terms.
DSITIA (2012)	Qld & SA	DRAFT An adaptive, attribute-based classification scheme for lacustrine and palustrine habitats Classification scheme developed collaboratively/concurrently (?) with ANAE and SAAE, between SA, Qld and NSW for wetland mapping. The attributes are more or less consistent with ANAE with the exception that the DSITIA classification includes a 'local hydrology modifier' as an attribute to describe modified systems and splits vegetation attribute into structure and community. Note good definition to differentiate classification from typology (p. 8): Classification '… a scheme or framework for applying attributes within a database and the process of establishing and applying decision rules to obtain a typology. Whilst a typology refers to the types or list of types that are produced through the application of classification scheme decision rules or criteria, or derived by other means.' i.e. typologies are not always based on clear classification scheme and these are more difficult to apply.
Duguid (2005)	NT (LEB)	Wetlands in the arid Northern Territory Classification for wetlands (including springs) proposed based on attributes of: • Landform • Wetland size • Water regime • Water salinity and chemistry • Vegetation • Spatial arrangement.
Eamus et al. (2006)	National	A functional methodology for determining the groundwater regime needed to maintain the health of groundwater-dependent vegetation Provides a step-by-step theoretical and practical framework for determining

Reference	Region	Summary
		groundwater requirements for GDEs. Identifies 3 classes of GDEs of which class 2 & 3 are relevant: Class 2: includes all systems dependent on the surface expression of groundwater, including baseflow to rivers and streams, wetlands and some floodplains. Class 3: all ecosystems dependent on the subsurface expression of groundwater, includes terrestrial ecosystems such as River Red Gum forests.
Fryirs & Brierley (2009)	All	An example from the Hunter River. (across the catchment) ' … the underlying causes of geomorphic adjustment have been similar… ' (but at a reach level) ' … a range of effect(s) … the sequence and timing of which vary depending on (the reach's) inherent sensitivity …'
Green et al. (2013)	GAB (SA)	AWMSGAB: Risk assessment process for evaluating water use impacts on springs of the western GAB Includes a classification scheme for GAB dependent ecosystems including SW systems dependent on baseflow based on: • Wetland type: palustrine for most springs • Water source: GW / SW / GW-SW • Hydraulic environment: artesian / non-artesian • Structural linkage: includes surface depressions and outcropping aquifers • Surface morphology: Seven types for artesian springs.
AETG (2012e)	LEB	LEB HCVAE Pilot Project Presents a classification for the LEB using: landform, connectivity, water source, water regime, water type. This was applied for the LEB however the classification is probably now superceded by AETG publications and state-based classifications. A range of other background data were compiled and used as part of the HCVAE trial but are not presented in the report.
Kennard et al. (2010)	National	Classification of natural flow regimes in Australia to support environmental flow management
McNeil et al. (2011)	Western Rivers (Neales)	Climate variability, fish and the role of refuge waterholes in the Neales River catchment Develops a classification system for refuge habitats Defines the ecological role of refuge habitats with regards to fish Grades the importance of the different refuge classifications and their conservation values. Takes into account the functions of these refuge types during and after times of drought
Reid et al. (2009)	National	Catalogue of conceptual models for groundwater–stream interaction Includes a framework for classifying GW-SW interaction based on clear attributes: • Aquifer system (fractured rock, layere/complex, contained alluvial valley,

Reference	Region	Summary
		regional) • Aquifer scale (local, intermediate or regional scale based on maximum flow path length) • Aquifer width (narrow (<5 km), broad or variable) • Recharge (process/location) • Discharge (process/destination) • Floodplain (narrow/incised, broad, terraced, variable) • Stream flow (regulated, unregulated, mostly reliable, variable, intermittent). • Stream–aquifer relationship (gaining / losing) • Aquifer connectivity or confinement status • Hydraulic conductance • Long-term pumping impact on stream flow.
Robson et al. (2008)	National	Identification and management of refuges for aquatic organisms This report provides background information to consider whether and how particular types of refuge should be given specific protection in management plans to enable ecosystems to persist through and recover from disturbance. 'The essential components of a refuge are: it is a physical place secure from one or more disturbances and it is a source of colonists for the wider landscape after disturbance has ceased.' Presents the following classification for refuge types: • ''Ark-type' refuges occur where species are broadly adapted to a disturbance and most species actively use refuges; these refuges contain an assemblage of species that is representative of aquatic biodiversity at the landscape scale. • 'Polo club–type' refuges eventuate where the refuge is suitable for use by only a subset of the regional biodiversity because particular biological and ecological traits are required to persist in the refuge. • 'Casino-type' refuges consist of areas that have, by chance, been left untouched by a disturbance that affects surrounding areas. These vary in their level of representativeness of local biodiversity. • 'Stepping-stone' refuges become vital to an organism when they support some stage in dispersal process that cannot otherwise occur, but their use as a refuge is intermittent or ephemeral. • Anthropogenic refuges are refuges formed by artificially created habitat such as drains or farm dams (p. vi).'
Scholz & Fee (2008)	SA	A framework for the identification of wetland condition indicators: a national trial – SA: Developed an interim wetland classification for SA from an expert panel workshop. The classification is consistent with Cowardin (1979) and site below the palustrine and lacustrine typology level. Seventeen wetland types were identified with the following wetland attributes: • Climate • Wetland class (palustrine, lacustrine, riverine) • Water regime (permanent / non-permanent) • Water type (saline / non-saline) • Substrate type (rock, mineral, peat) • Seasonality of water (for non-permanent wetlands) • Vegetation type (tree, shrub, sedge, samphire).

Reference	Region	Summary
		Also developed conceptual models for ten of the 17 wetland types. Note that the GAB spring types have been further developed (eg. Green et al. 2013 and Miles et al. 2012). The typology was further developed in Fee & Scholz (draft) but has not been applied.

3.1.2.2. Mapping and spatial assessments

Reference	Region	Summary
AETG (2012c)	National	Aquatic ecosystem delineation and description guidelines Aquatic ecosystems are delineated as a nested set of zones of different sizes and complexities: • Core element: an aquatic ecosystem (e.g. a lake, river or estuary) as identified through the ANAE Classification Scheme. • Ecological focal zone (EFZ): a single or aggregation of core elements that contains the key ecological values and functions, and the surrounding areas that support and maintain those values. • Zone of influence: area surrounding the ecological focal zone in which pressures and management actions could impact on the state and /or condition of the asset. • Catchment zone: wider surface-water catchment of the EFZ; in some cases the catchment zone may be the same as the Zone of Influence. Description 'documents the critical components and processes that underpin the ecosystem values of the site, and develops conceptual model(s) and identifies threats.'
Barnetson & Duguid (2008)	NT (LEB)	NT-LEB Wetland Mapping: Revised Mapping of Wetland Extent in the Northern Territory Portion of the Lake Eyre Basin Documents a revision of existing mapping of wetlands in the NT LEB using satellite imagery, including: include riverine waterholes, springs, swamps, saline playas (salt lakes) and non-saline playas (claypans) (Duguid et al. 2005). This project used better imagery and mapped to a higher level of accuracy than Duguid et al. (2005), however it was not possible to determine areas of deep water using TM imagery. Similarly, it was not possible to reliably distinguish areas with emergent vegetation (swamps). Information on the extent and longevity of major waterholes of the Finke River were determined using images from various dates from 2002 to 2008.
Barnetson & Duguid (2010a)	NT (LEB)	Revised Wetland Mapping for the NT-LEB (Interim Documentation) A preliminary description of the methods and results of wetland mapping for the NT LEB, from December 2009 to April 2010. This follows from previous work (see Duguid et al 2005 and Barnetson & Duguid 2008). Done as part of the trial of the criteria for identifying LEB HCVAE (AETG 2012e). DEM was used to help overcome issues with shading. HCVAE classification was then applied to wetlands.
Barnetson & Duguid (2010b)	NT (LEB)	Wetland Mapping in mountainous terrain: a tough nut to crack Discusses the challenges of mapping wetlands using Landsat^{TM} in the NT LEB in

Reference	Region	Summary
		mountainous areas, where challenges included shadowing. Further work required to map wetlands in upland areas, in particular long-term waterholes.
Bryant et al. (2010)	Qld (inc. LEB)	Soil indicators of Queensland wetlands: Statewide assessment and methodology Sampled nine sites within the Qld LEB to validate proposed wetland soil indicators. Soil profiles were described and sampled to 1 m depth; and a key to identify wetlands using soil indicators was developed. Soil indicators for a number of arid climate wetlands in the LEB (palustrine and lacustrine) are discussed. Indicators outside of the LEB are relatively uniform, however within the LEB, due to the fluctuation of flows, these indicators can be less pronounced. Within semi arid and arid areas of the state, one of the most useful identifiers was the presence of depleted soil matrix chroma. Relevance: Contains methods for the identification of wetlands and methods for the assessment of their soil and hydrology.
Butcher et al. (2011)	SA (South East)	An integrated trial of the ANAE classification scheme in the SE SA Trial based on the draft ANAE classification (Auricht 2011). Found that the ANAE worked well in the region but noted that it was a data-rich region with experienced practitioners and it may be more difficult to apply in data-poor regions or with less experienced practitioners.
Deane & Walters (2008)	SA (Lake Frome)	Baseline survey of refugia pools in the north-eastern Willochra Creek and western Lake Frome Catchments Baseline mapping of permanent aquatic refugia habitat within the Willochra Creek Catchment and the Lake Frome Basin, as far east as the South Australian Arid Lands region. Nineteen permanent pools were identified through consultation, then mapped and surveyed during autumn 2006. Surveys collected data on environmental and biological variables enabling the broad ecological character of pools to be described.
DEHP (2013)	Qld	WetlandSummary—facts and maps, WetlandInfo. Webpage which contains background summary of all information provided by the WetlandSummary tool, and links to all the wetland mapping and spatial metadata (including links to associated reports and publications).
DERM (2013)	Qld (LEB)	Lake Eyre Basin and Bulloo Catchments: Aquatic Conservation Assessments Draft Expert Panel Report Documents the process, findings and recommendations from an expert panel, for prioritising areas of aquatic conservation importance using the Aquatic Biodiversity Assessment and Mapping Method (AquaBAMM) approach. The process utilises maps to interrogate data in the assessment phase, and produces a map/data output in a GIS environment based on spatial mapping units that describe conservation significance or value for planning and assessment purposes. Relevance: Selection of monitoring parameters (larger scale, e.g. naturalness, diversity, connectivity).
DERM	Qld	Queensland wetland definition and delineation guidelines Part B: Delineation and

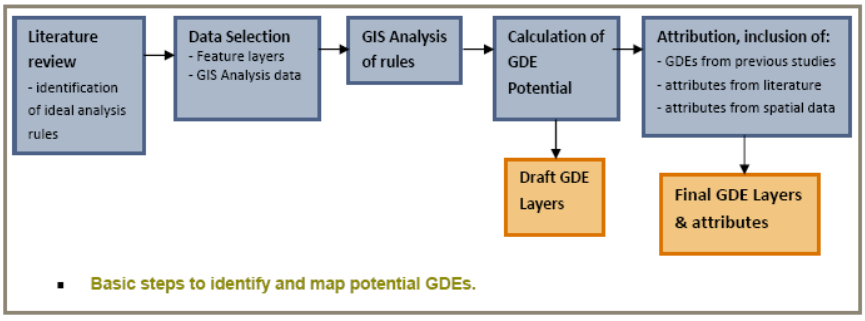
Reference	Region	Summary
(2011d)		mapping guidelines Provides detailed information on how to apply the Qld Wetlands Program Definition to delineate a map boundary of a wetland; and contains detailed methodologies for wetland survey and delineation. Provides detailed procedures to establish if an area is a wetland or not and if so to describe, to a specified accuracy, where the boundary between the wetland and non-wetland is, resulting in usable maps. Relevance: Presents a method for mapping wetlands and thus potential for use as a site selection tool
DEWHA (2008)	National	Mapping Specifications for Australian Ramsar Wetlands This document provides background information and specifications for mapping Australian Ramsar wetlands as developed by the Wetlands and Waterbirds Taskforce. Also describes the standards to be used for a consistent approach to delineation of boundaries, data capture and management, and map production for Ramsar wetlands. Specifications are given for: • Delineation • Data capture • Data custodianship, access and storage • Data management • Map format • Information to be included on maps and source data to be used • Size and number of maps • Cartographic standards.
Duguid (2011)	NT (GAB)	Wetlands of the GAB Water Control District (Northern Territory) Describes wetlands of the NT that overlie the GAB aquifers consistent with the classification developed in Duguid et al. (2005). The geography, climate and hydrology of the area are described here to assist in understanding the ecology of the wetlands. The variety of wetland types known from the Water Control District are described with comments on their abundance and ecological characteristics. No natural perennial waterholes or springs are known from the area; there is one lake/swamp inundated by artesian bore water. Major wetland types include floodouts of major watercourses, in inter-dune claypans and swamps. There are also many wetlands in the claypans between dunes filled from local rainfall events and not river flow. No natural GDEs are documented but localised groundwater systems (in adjacent dunes) are thought to sustain some wetlands for longer periods than rainfall or river flow alone would. This report includes descriptions of selected wetlands and wetland aggregations; however, is not a comprehensive wetland inventory of the area, or the identification of wetland values. Likewise, the report does not provide a rigorous treatment of the hydrological processes. The report includes: • An overview of the landscape and hydrological process • a description of the main wetland types in the district • a summary of known biological characteristics, where various types occur and their relationship to the river systems

Reference	Region	Summary
		• the conservation significance of individual wetlands and groups of wetlands • descriptions of each major river and its floodout • information compiled for individual wetlands • recommended priorities for further work.
Duguid (2013a)	NT	Delineation and Description of Ecological Character of the Mid-Finke Waterholes: A Trial of Guidelines for High Ecological Value Aquatic Ecosystems This report describes ecologically significant waterholes in the middle section of the Finke River in the Northern Territory in order to test draft guidelines for delineating and describing the ecological character of High Ecological Value Aquatic Ecosystems (HEVAE). The report includes a bio-physical description of the Mid-Finke and describes methodology used for, and results of: • Mapping the location of long-term waterholes with improved accuracy • Identifying permanent and near-permanent waterholes • The assessment of the role of groundwater systems on ecological character (longevity and salinity) • Consultation with landholders to identify permanent and near-permanent waterholes • Collecting field information at waterholes for depth, salinity, surface extent (size), terrain, substrates and vegetation • Trial of the HEVAE guidelines through the Delineation and Description of Ecological Character of the Mid-Finke Waterholes • Incorporating expert knowledge on fish, plants, surface hydrology and groundwater (hydrogeology) • Results of a workshop on surface and groundwater hydrology of the waterholes. This version of the report is currently being reviewed by the Aquatic Ecosystems Task Group; a final version will be published by SEWPaC once reviews are complete.
Duguid (2013b)	NT LEB	*MAPPING* *Wetlands of the Alice Springs Water Control District (ASWCD)* Area mainly comprises upper catchment of Todd River in west MacDonnell Ranges and part of the floodout; also includes part of the Hugh River, a tributary of the Finke. Used remote sensing imagery gathered from previous projects along with Google Earth mapping and topo. Notes that mapping of permanent and semi-permanent waterholes not adequate and information on springs is collated from existing sources. Classification based on Duguid et al. (2005) and Duguid (2013a). Includes descriptions of various wetland types and their locations in the ASWCD. Includes a number of GDEs. A couple of potentially permanent riverine waterholes. The artificial wetland of Alice Springs sewerage ponds are the largest permanent water source in the region and has high bird diversity. There are also some stock dams. Provides an overview of the flora and fauna (the latter based on Cockayne et al. 2012, 2013).

Reference	Region	Summary
Duguid et al. (2005)	NT	Wetlands in the arid Northern Territory This report describes the wetland values of the arid southern part of the Northern Territory based on information collected as part of a two year survey. The Inventory uses ground and aerial surveys with remote sensing and GIS to define and describe the types of wetlands that exist, assess their general biological attributes, and to improve mapping of their distribution. Mapping included, for some sites, recording the inundation patterns and the extent of connectivity between many rivers and water bodies. The report also includes a review of existing wetland classification and proposes a classification system for describing the wetland types in the arid NT. The system is semi-hierarchical and follows the principles of the Semeniuk Geomorphic Classification. The proposed classification results in 71 wetland types, assigned to six groups based on major landform, hydrological function and origin: • basins (17 types) • flats (4 types) • channels (21 types) • springs (18 types) • subterranean (1 types) • artificial (10 types). This report is in two volumes. Volume 1 is the main part and is for general public access. Volume 2 contains information collated about individual wetlands. It includes descriptions of important wetlands in the format required for inclusion in *A Directory of Important Wetlands in Australia*. Negotiations with landholders are ongoing for some sites and these are not to be included in the Directory without landholder permission. Accordingly Volume 2 is not for public access.
EPA 2005	Qld	Wetland Mapping and Classification Methodology – Overall Framework – A Method to Provide Baseline Mapping and Classification for Wetlands in Qld Outlines the methods used to map Queensland wetlands, as per the WetlandInfo website (EHP 2013). The report includes the following definition of wetlands: 'Areas of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m. To be a wetland the area must have one or more of the following attributes: 1. at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle, or 2. the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers, or 3. the substratum is not soil and is saturated with water, or covered by water at some time.' The report includes decision rules and detailed steps. The methods combine existing GIS datasets with remote sensing methods. There is some level of attribution of wetlands, with inland wetlands classified as either palustrine, lacustrine of riverine, and

Reference	Region	Summary
		further attribution including salinity category, frequency of inundation and degree of hydrological disturbance.
AETG (2012e)	LEB	Trialling the guidelines for the delineation of HEVAE in the LEB Central to the draft guidelines is a nested set of zones as per AETG (2012c). Report focusses on identifying core elements and EFZ's, trialled for four AEs in the LEB. Recommend the EFZ the finest scale of a HEVAE; also, that the size and area of EFZ may be different for different values, but the boundary of the HEVAE is the sum of all the areas to maintain all the HEVAE values.
Kellet et al. (2012)	GAB	GABWRA: Regional watertable Potential SW-GW dependent ecosystems
Lewis & White (2013)	SA (GAB)	Evaluation of remote sensing approaches Based on the results of the remote sensing research, recommendations are provided as to which techniques and technologies are suitable for characterisation and monitoring of GAB springs at different temporal and spatial scales. • MODIS suited for seasonal and longer-term changes in wetland vegetation at large spring complexes • Very high resolution satellite imagery suited to quantify wetland vegetation extent (i.e. to measure spring flow rates) • Hyperspectral airborne imagery suited for mapping different wetland characteristics • Visible & NIR colour aerial photography still important for validating mapped outputs.
Neave et al. (2004)	NT	A Resource Assessment Towards a Conservation Strategy for the Finke Bioregion This report covers the Northern Territory portion of the Finke Bioregion. This report provides a set of conservation options and recommendations, which will ensure that the species, ecosystems and ecological processes in the Finke Bioregion are conserved, whilst also considering the social and economic needs of the bioregion's residents. Specifically the report aims to: • determine (using existing and new data) what plant and animal species are present in the Finke Bioregion; • identify significant species and ecological communities in the Finke Bioregion (e.g. those that are rare, threatened, endangered or endemic); • determine patterns in the distribution of wildlife assemblages in the Finke Bioregion; identify threatening processes in the Finke Bioregion which impact on significant species and ecological communities; • identify other values in the bioregion (in addition to significant biodiversity values), including cultural heritage and aesthetic/recreational values (i.e. social values); • determine which of the values in the Finke Bioregion require conservation management; • apply assessment criteria to determine priorities for off-reserve conservation management of identified values, or should the opportunity arise, for the establishment of conservation reserves which would contribute to the comprehensive, adequate and representative reserve system in the Northern Territory. • prepare a report for the Finke Bioregion in consultation with stakeholders,

Reference	Region	Summary
		which includes recommendations and options for the conservation management of identified biodiversity and social values.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial A report detailing the application, development and trial of an Integrated Ecological Condition Assessment (IECA) for High Ecological Value Aquatic Ecosystems (HEVAE) in the Cooper Creek catchment. Five HEVAE units (CAT 500 polygons) were selected for assessment. Aquatic ecosystems were identified and listed for each hydrological unit, and HEVAE criteria relevant for each unit were determined. Ecological risk assessments were used to prioritise potential threats to each ecosystem type, and conceptual models were developed for each threat; presenting human pressures, the physical, chemical and biological stressors; the ecological responses to these threats; and the HEVAE values that are met by each unit. Sampling of targeted indicators was undertaken to validate threat risks and to gather information for knowledge improvement. Priority threats to the Cooper Creek aquatic ecosystem were identified as: land use (i.e. grazing) and introduction of feral animals (i.e. cattle, pigs and fish). Relevance: Potential use as a site selection tool and identifies potential monitoring parameters.
Richardson et al. (2011)	National	Australian groundwater-dependent ecosystems toolbox part 1: assessment framework Presents a suite of practical and technically robust tools and approaches that allow water resource, catchment and ecosystem managers to identify GDEs, determine the reliance of those ecosystems on groundwater, and determine possible changes to ecosystem state or function due to changes in the groundwater environment. Part 1 provides an assessment framework which guides users to determine environmental water requirements and translate these into water provisions. Part 1 of the toolbox includes the following: recommended GDE typologies, the GDE assessment framework (including key questions, approaches and tools), specific issues regarding implementation of the framework, the importance of conceptualising GDEs, guide to developing a monitoring program for adaptive management purposes, extrapolation of information to data-poor areas, challenges presented by change (including climate change) and GDE case studies from implementation of the framework around Australia.
Richardson et al. (2011)	National	Australian groundwater-dependent ecosystems toolbox part 2: assessment tools Part 2 of the toolbox focuses on the presentation of a suite of practical and robust tools which are referenced throughout the assessment framework and may assist with its implementation. These tools can help water managers to identify GDEs and determine environmental water requirements within the constraints of technology, budgets and time frames. The tools consider data requirements and indicate the level of effort and expense required to employ them and analyse associated results. The tools are based on a review of established methods reported in national and international literature. Fourteen tools are presented and are associated with each of

Reference	Region	Summary
		the major aspects of the assessment framework (i.e. tools for GDE classification and identification, tools for verification of groundwater use, and tools for understanding GDE response to change).
Silcock (2009a)	Cooper Creek and Georg-ina-Diamanti na	Identification of Permanent Refuge Waterbodies in the Cooper Creek & Georgina-Diamantina River Catchments for Queensland and South Australia Identification of permanent and semi-permanent waterbodies in the Channel Country. Combines satellite imaging, landholder interview, review of historic records and site visit to list the permanence of waterbodies in SA and Qld Cooper and Georgina-Diamantina. 1367 permanent and semi-permanent waterbodies were mapped across the study area, including 532 that were considered permanent. For each mapped waterbody, the spatial database contains information on name, location, naturalness, permanence (including water-holding capacity, frequency of drying and timeframe of observations) and other information relating to the hydrology, ecology or cultural significance of that particular waterbody. Classifies permanence in objective terms (e.g. Almost Permanent will be wet 97–99% of the time and will dry 1–2/50 to 1/130 years)
SKM (2012)	National	Atlas of Groundwater Dependent Ecosystems (GDE Atlas), Phase 2 Task 5 Report: Identifying and mapping GDEs Documents the methods applied to identify and map GDEs across Australia for the National GDE Atlas. The atlas is a management tool that enables the presence and the water needs of GDEs to be brought into the water planning and allocation process. Mapping outputs developed for the Atlas include: • GDEs that rely on the subsurface presence of groundwater • GDEs that rely on the surface expression of groundwater • subterranean GDEs • inflow dependent ecosystems (IDEs) • inflow dependence • remote sensing data (MODIS and Landsat). The layers were created from GDEs included in previous studies (fieldwork or desktop) as well as GDEs derived from spatial analyses (these have H, M, L classifications for potential for groundwater interaction). The GDE Atlas also contains contextual information that informs an understanding of the possible groundwater use for each potential GDE. This information describes the ecosystem's landscape setting, climate, geology, hydrology, ecology and hydrogeology.  ▪ Basic steps to identify and map potential GDEs. The method was applied to eight work package areas identified for Australia (areas of

Reference	Region	Summary
		similar hydrogeology, ecology and climate). A set of rules describing the potential for groundwater/ecosystem interaction was developed for each work package. Weightings were applied to each rule to allow effective rules to have a greater influence on the overall GDE potential result. Results were validated using GDEs that had been identified in previous studies, which were assumed to reliably identify interaction between groundwater and ecosystems.
Sparrow and Leitch (2009)	NT & SA	Vegetation Survey and Mapping of the Eastern and Southern Finke Bioregion and the NT Stony Plains Inliers, NT & SA This report summarises the results of mapping in the eastern and southern portions of the Finke Bioregion in the Northern Territory and South Australia. It gives a brief background on the physical characteristics, climate, soils, and geology of the Bioregion. The survey resulted in 43 mapping groups and 100 floristic group definitions. The report covers: • descriptions of existing data (specifically vegetation-related data) • methods used for the collection of new field data (field and remote sensing methods • a description of the resulting mapping groups and their floristic components • information on the applications of the data • recommendations for future mapping. A set of twelve Appendices are available at: http://www.territorystories.nt.gov.au/handle/10070/232791
Tunn & Cameron (2008)	Cooper & SA (G-D)	Wetland Mapping in the Lower Cooper and Georgina-Diamantina Catchments, LEB Extended wetland mapping work of Wainwright et al. (2008) to lower Cooper and Georgina-Diamantina catchments in South Australia.
Wainwright et al. (2006)		Wetland mapping, Channel Country bioregion, South Australia Used a remote sensing method developed in Queensland to map the maximum extent and frequency of inundation of wetlands in the upper Cooper and Georgina-Diamantina catchments in South Australia.
White et al. (2013a)	SA (GAB)	Characterising spring groups Developed remote sensing techniques to characterise GAB spring groups. Characterisation provides a baseline for these groups for the following attributes: • Spring-fed wetland extent • Dominant vegetation types • Surface evaporative crusts and their minerology • Wetted areas • Standing water. Results provide a baseline for these wetlands against which change can be measured. The methods may also be applied to other springs (and aquatic ecosystems).
Duguid (2013b)	NT LEB	Wetlands of the Alice Springs Water Control District (ASWCD)

Reference	Region	Summary
		Area mainly comprises upper catchment of Todd River in west MacDonell Ranges and part of the floodout; also includes part of the Hugh River, a tributary of the Finke. Applied a classification based on Duguid et al. (2005) and Duguid (2013a). Includes descriptions of various wetland types and their locations in the ASWCD. Includes a number of GDEs and a couple of potentially permanent riverine waterholes. The artificial wetland of Alice Springs sewerage ponds are the largest permanent water source in the region and has high bird diversity. There are also some stock dams.
Duguid et al. (2013)	Finke	*Drought Refuges for Native Fish in Parts of Central Australia* Aim of study to identify drought refuges for native fish in Finke River and Dulcie Ranges (flowing north to the upper Diamantina catchment and south to the hay and plenty Rivers), both of which support high fish diversity for arid Australia. Project included identifying and mapping sites and their habitats, surveying for fish and salinity testing. For most sites this was the first fish surveys. Provides descriptions of refuge sites and their habitats and reports on fish survey results. Recommends further surveys in Palmer and Dulcie areas. Results of salinity testing support previous insights into complexity of groundwater-surfacewater interactions in the Finke. More saline sites have less impacts from herbivores.

Geomorphological mapping

Reference	Region	Summary
Anand & de Broekert (2005)	All	A compilation of case studies carried out by the CRC LEME (Cooperative Research Centre for Landscape Evolution and Mineral Exploration). Examines regolith and discusses landscape evolution in sites across the whole continent. The work of the CRC LEME is extremely valuable because of its scale, and the detail and experience brought to the study of an otherwise-neglected topic.
Craig (2005)	All	Describes the practice of regolith mapping. Regolith (sediments and other non-rock) is a dominant factor in this mapping so it would not be directly usable by ecologists, however its approach to understanding landscape evolution is valuable.
Edgoose (2005)	Cooper Creek	Regolith evolution of the black-soil plains – one of the CRC LEME case studies.
Fagan & Nanson (2004)	Cooper Creek	In those rivers where vertic sediments occupy the floodplain (the Channel Country to north and east of Kati Thanda-Lake Eyre, but not the Neales Catchment), the floodplain channel type is dependent upon the inundation regime (and therefore can be used to map floodplain inundation patterns (pers. Comm. G Wakelin-King).
Grimes (1984)	All	Describes a scheme for mapping geomorphology based on process as well as landform taxonomy. Though this scheme is designed to integrate with geological mapping (therefore its map labelling protocols are not suitable for ecology studies), its approach would be very suitable to adapt for modern geomorphic mapping.

Reference	Region	Summary
Pain et al (2011)	All	Physiographic mapping of Australia – boundaries are based on characteristics (regolith, river networks and slope character) that reflect surface lithotypes and geological history. These boundaries therefore also reflect important habitat-defining features. – note that this citation merely refers to the explanatory notes of a GIS dataset – it's the dataset's attribute tables that have the most information.
Wakelin-King (2010)	Neales	Geomorphological assessment and analysis of the Neales Catchment Assesses fluvial function in Neales catchment (including Arckaringa Creek).
Wakelin-King (2013)	Cooper Creek	Geomorphological assessment and analysis of the Cooper Creek catchment Assesses fluvial function in Cooper Creek (SA).
Walker (1991)	None	The Land Unit mapping in the Western Catchment of New South Wales was very detailed with coverage over many 1:250 000 sheets. Though geomorphology is only addressed as part of a wider information set, its level of landform detail is low and there is no process description. However its consistency of approach and wide coverage make it a valuable resource for the area. Other Land Unit mapping, for example SA, is harder to find, and was done in less detail over a smaller area.

3.1.3. Conceptual models, monitoring and condition

3.1.3.1. Conceptual models

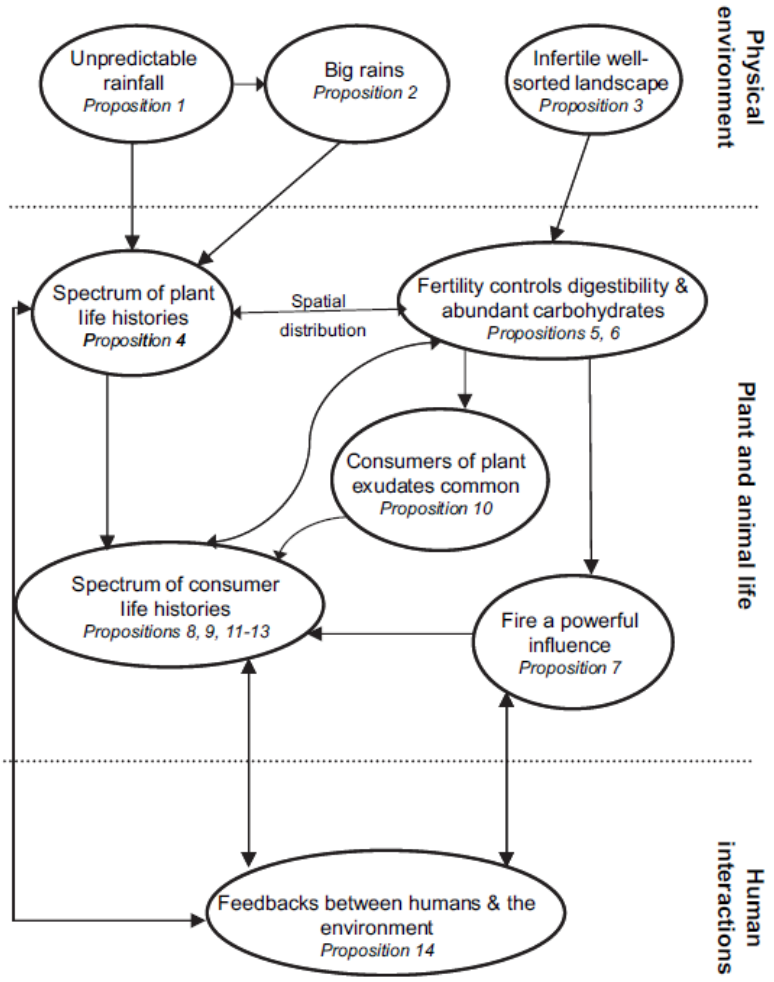
Reference	Region	Summary
Balcombe & Kerezy (2008)	Qld (LEB)	Preliminary Fish Sampling for the LEBRA: Testing of the Fish Trajectory Model in Qld Discusses the usefulness of the fish trajectory model in Queensland
Claus et al. (2011)	NSW	Assessing the extent and condition of wetlands in NSW: Supporting report A – Conceptual framework Steps for developing conceptual models: • State goals and objectives • Identify audience • Identify bounds of the system of interest • Identify critical model components, subsystems and interactions within the system of interest • Develop control models of key systems • Identify natural and anthropogenic stressors and pressures • Describe the relationship between ecosystem components/processes and stressors • Develop stressor models • Identify data gaps and assumptions • Review, revise and refine models. Models were developed to correspond to wetland types. Models exist for: inland floodplain swamp, inland rainfall/runoff swamp, inland billabong, inland GAB spring, inland freshwater lake, inland saline lake, inland clay pan, coastal floodplain swamp, coastal rainfall/runoff swamp, coastal heath swamp, coastal dune swamp, coastal

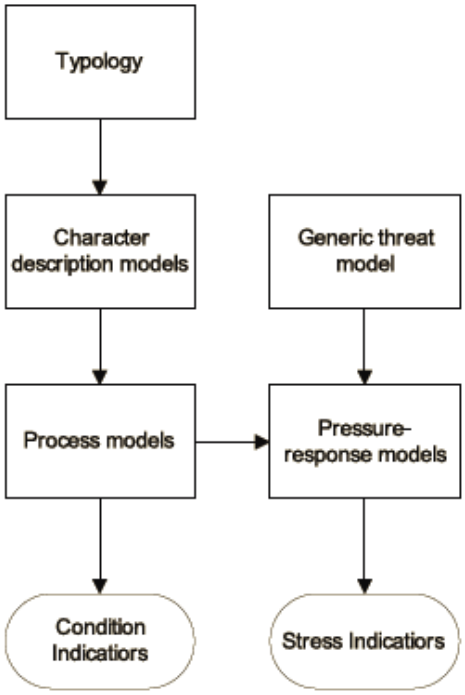
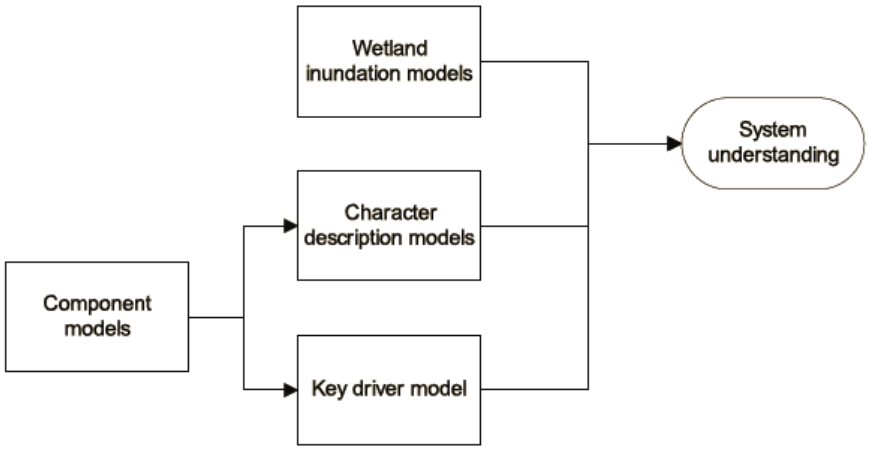
Reference	Region	Summary
		freshwater lagoon, coastal dune lake/lagoon, alpine bog and fen, alpine glacial lake, upland bog and fen, upland hanging swamp, upland freshwater lake. Disturbance indicators included catchment, hydrological and habitat disturbance. Pressures included climate change, urbanisation, infrastructure, clearing, grazing, agriculture, recreation, barriers to fish passage, rainfall/runoff diversion, surface and groundwater extraction, river regulation, point source, fire. Stressors included sediment, nutrients, salinity, pH, and pest species. Wet and dry phase models are presented.
Costelloe et al. (2004)	LEB	ARIDFLO ch.6: Interpretation and discussion Developed graphical models conveying the relationships between hydrology, ecology and water quality at different flow phases (pp. 709–726). Ecological responses to hydrological phases are described in terms of life history adaptations, critical thresholds and typical assemblages.
Duguid (2013a)	NT (Finke)	Delineation and Description of Ecological Character of the Mid-Finke Waterholes: A Trial of Guidelines for High Ecological Value Aquatic Ecosystems Conceptual models developed depicting key processes operating in waterholes: • Alluvial aquifer • Alluvial aquifer dynamics • Geological control of alluvium depth and groundwater flow • Fish movement and refugia • Scouring and deposition. The conceptual models are presented as diagrams. The hydrological conceptual model for mid-Finke waterholes is a preliminary hypothesis-based model. It could be tested by reconvening an expert panel, and in the longer-term by scientific research. Hypotheses used in the conceptual models requiring testing are listed.
EHP (2012a)	Qld (LEB)	Webpage providing brief intro and summary for the Lake Eyre and Bulloo Freshwater Biogeographical Province, according to the WetlandInfo criteria. Presents Key Ecosystem Drivers for the catchment in a visual conceptual model, and an accompanying table populated with summaries of local climate, geology and topography, hydrology, water quality and habitat features. Includes links to all data sources utilised to make the conceptual model, and provides simple descriptions of how data was derived. Relevance: conceptual model of system as it is now and methods for its production, could lead to the reproduction of other models under different future scenarios (i.e. altered flow regimes, water quality……)
EHP (2012b)	Qld	Walking the landscape - A whole-of-system framework for understanding and mapping environmental processes and values Describes the process used by the Groundwater Dependent Ecosystem Mapping and Classification Project, to develop and validate conceptual models and maps. WTL is a framework that integrates existing data with expert and local knowledge through hands-on workshops to create a common understanding among

Reference	Region	Summary
		multidisciplinary teams. It incorporates the available knowledge on landscape flora, fauna, water, soils and ecosystem processes and uses the information to develop conceptual models which link to a map. These models then help answer questions like how the landscape contributes to flood behaviour or why groundwater dependent ecosystems occur in certain locations. The primary aim of the method is to improve evidence-based decision making for the sustainable management and restoration of ecological systems. Relevance: Completion of the method will enable understanding and present mapping of environmental processes and values.
Fee & Scholz (2010 / in prep)	SA	Development of a South Australian Aquatic Ecosystems classification and its potential applications This report focusses on the theory and consultation underpinning the SAAE Classification – based on ecosystem, landscape and hydrogeological processes. The SAAE Classification allows coordination and scaling (aggregation) of information within and across jurisdictions (and nations). Translation tables are provided for classifications that are important to South Australia. Critical contextual, knowledge management and environmental management tools follow from the identification of AE types; such as conceptual models and diagrams of ecosystem functions and processes, management guidelines, conservation values, indicators for measuring condition, and so on. Conceptual models and diagrams of AE types have been developed for many AE types to simplistically represent complex ecosystem dynamics, and to clarify key elements for measurement and management of AEs. A detailed example of how these conceptual models and diagrams can be applied is provided for Artesian springs. Conceptual models and diagrams were developed either in-house, or through identifying existing models that equate to SA AE types (via translation tables). The conceptual models and diagrams may be used to identify AE indicators – generally ecosystem drivers of ecosystem function and threats to ecosystem processes are used. These indicators provide a means to 'measure' condition of the AE site or overall AE type.
Green et al. (2012)	SA (GAB)	AWMSGAB: Risk assessment process for evaluating water use impacts on springs of the western GAB Presents conceptual models of groundwater hydraulic processes including for SW systems receiving baseflow from GAB
Gross (2003)	Inter-national	Developing Conceptual Models for Monitoring Programs This is a non-peer reviewed discussion paper describing the principles behind developing conceptual models for monitoring programs, the different types of models that may be used, and the steps that should be taken to develop useful and robust models. It includes guidance for both 'control models', which describe the key processes, interactions, and feedbacks of a system, and 'stressor models', which are developed to describe the relationships between stressors, ecosystem components, effects, and (sometimes) indicators.

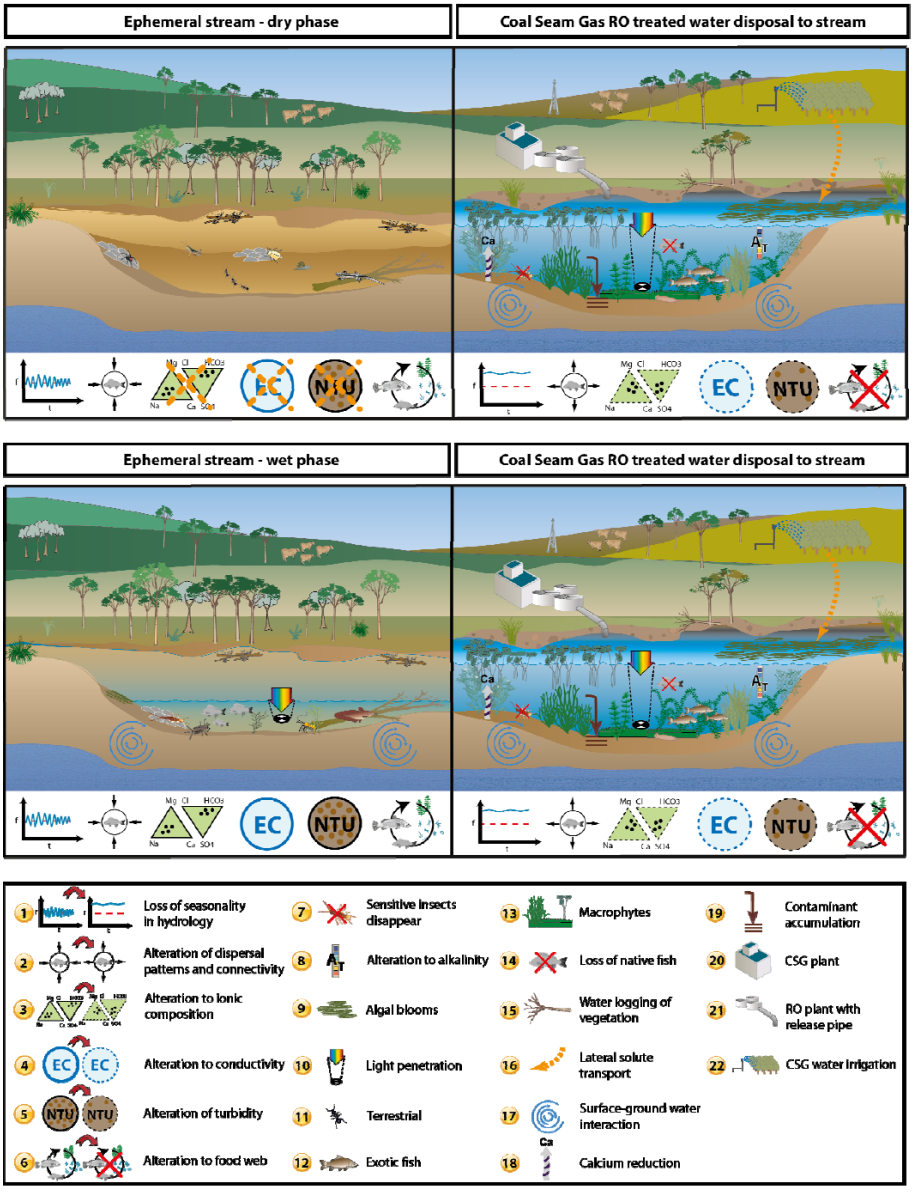
Reference	Region	Summary
Hierl et al. (2007)	Inter-national	Developing Conceptual Models to Improve the Biological Monitoring Plan for San Diego's Multiple Species Conservation Program This document describes the framework used for building conceptual models for species, communities, and landscapes in San Diego's Multiple Species Conservation Program. The report presents four major steps in conceptual model development of conceptual models as well as four case studies which illustrate the construction of models and their utility in identifying components for monitoring. The models are not specifically related to aquatic ecosystems and aquatic species, however the report contains principles which may be applied when developing any type of conceptual model.
Marshall et al. (2006a)	Qld	Development of conceptual PVR models for Qld's riverine ecosystems PVR (PSR) models for each of the vectors (stressors) identified statewide using flow diagram format.
McKenzie et al. (2006)	LEB	Conceptual models for LEB rivers (LEBRA methodology report) Conceptual models developed for LEB rivers to describe hydrologic and geomorphic processes at different geographic levels within the catchment and describe that variation from a temporal perspective. The models describe processes within headwater, channel, waterhole and terminating wetland areas, and during different hydrologic phases ('dry', 'wet' or 'flood')Models presented as interactive CD-ROM package.
McNeil et al. (2008)	SA (LEB)	Preliminary Fish Surveys for the LEBRA: Testing the Fish Trajectory Model in SA Fish trajectory model less usefull in the variable habitats that characterise the SA LEB than in the higher flow Qld LEB: • Provides a tabled conceptual model for the response of fish to various hydrological regimes • Develops a framework for grading and rating the status and conservation value of various refuge habitats throughout the Lake Eyre Basin. • Can be used to develop frameworks for similar studies within arid catchments.
McNeil et al. (2011)	SA (LEB, Neales)	Climate variability, fish and the role of refuge waterholes in the Neales River catchment Provides a potential conceptual model for the ecology of fish species within the Neales River catchment: • Defines the ecology of varying habitat types and their roles within aquatic ecosystems • Develops models for analysing and categorising refuge habitats • Can be used to analyse similar catchments in arid environments and determine the role and conservation value particular refuge habitats hold within the ecosystem.
Moran & Vink (2010)	MDB	Assessment of impacts of proposed CSG operations on surface and groundwater systems in the MDB Conceptual diagram below shows pathways for impacts to occur relative significance

Reference	Region	Summary
		of impacts: <table><tr><td></td><td></td><td colspan="5">To</td></tr><tr><td></td><td></td><td>Surface water</td><td colspan="3">Groundwater</td><td>Mixed S/G</td></tr><tr><td></td><td></td><td>Rivers</td><td>Alluvium</td><td>WCM</td><td>GAB</td><td>Other uses</td></tr><tr><td rowspan="5">From</td><td>Rivers</td><td></td><td>14. recharge from losing streams</td><td>15. recharge from losing streams into outcrop intake beds</td><td>16. recharge from losing streams into outcrop intake bed</td><td>12. crops, forestry, municipal</td></tr><tr><td>Alluvium</td><td>17. discharge (gaining streams)</td><td>3. redistribution potentially with water quality change</td><td>7. redistribution potentially with water quality change</td><td>10. redistribution potentially with water quality change</td><td>12. crops, forestry, municipal</td></tr><tr><td>WCM</td><td>1. discharge of associated water (with treatment if required)</td><td>2. reinjection of co-produced water via surface bores 5. redistribution potentially with water quality change</td><td>8. reinjection of co-produced water via surface bores</td><td>6. reinjection of co-produced water via surface bores</td><td>13. crops, forestry, municipal</td></tr><tr><td>GAB</td><td>11. discharge (gaining streams)</td><td>9. redistribution potentially with water quality change</td><td>4. redistribution potentially with water quality change</td><td>redistribution potentially with water quality change</td><td>12. crops, forestry, municipal</td></tr><tr><td>Other Uses</td><td>Discharge (Municipal effluent)</td><td>recharge (Drainage below root zone)</td><td></td><td>recharge (Drainage below root zone)</td><td></td></tr></table>Blue= significant and/or local risk; Green = intermediate changes; Yellow = minor changes; White = no change. Note that understanding of SW-GW connectivity in this region was updated under GABWRA, however, conceptually this is may be a useful way of looking at impacts.
Morton et al. (2011)	Central Australia	A fresh framework for the ecology of arid Australia In Australia's arid zone, highly variable rainfall, characterised by long periods of no rain and occasional heavy rainfall events, coupled with low soil fertility and localised soil differentiation are the dominant physical environmental drivers of (terrestrial) ecosystem composition:

Reference	Region	Summary
		
Price & Gawne (2009)	MDB	The development of wetland conceptual models for the semi-arid zone Conceptual modelling is currently being undertaken collaboratively by New South Wales, Queensland and South Australian agencies and the MDBA. The conceptual models being developed by these jurisdictions are aimed at identifying the key components, processes and drivers of the different wetland types and will form the basis for indicator selection/development for future monitoring programs. Models will be used for: • Synthesis of knowledge and to identify knowledge gaps • Identification of key links between drivers, stressors, and system responses • Understanding of how the processes, threats and system dynamics differ between wetland types • Facilitate in the selection and justification of indicators • Interpretation of monitoring data (specific to different wetland types) and identification of acceptable levels of change • Education and communication tools.

Reference	Region	Summary
		 For the semi-arid zone, seven wetland types were developed: commonly wet freshwater lakes, periodically-inundated floodplain freshwater lakes, periodically-inundated non-floodplain freshwater lakes, floodplain freshwater swamps, non-floodplain freshwater swamps, saline lakes, saline swamps. Box and arrow and pictorial models were developed to achieve objectives of communication and indicator selection. Four types of model were produced:  Wetlands component models were developed for wetlands types and included: wetland geomorphology, hydrology, water quality, nutrients, vegetation, primary production, microbial production, invertebrates, fish, waterbirds and frogs. The character description models consist of an annotated diagram describing the essential features and processes for each wetland type. Wetland inundation models are designed to illustrate the changing condition of a specific wetland type as they undergo cycles of filling and draining or drying. The models were reviewed by an

Reference	Region	Summary
		expert panel at a workshop.
Reid et al. (2009)	National	Catalogue of conceptual models for groundwater–stream interaction Presents conceptual models of GW-SW interaction processes, mostly as block diagrams but also includes descriptive concepts; also use maps and graphs to illustrate GW–SW concepts. The principles and information requirements for developing conceptual models are outlined. Conceptual models are a pre-requisite for predictive numerical models, integrated NRM and water allocation planning. 10 case studies are included, all are from SE Australia.
Rolls et al. (2012)	National	Review of literature quantifying ecological responses to low flows Pages 16 & 17 present a conceptual diagram of the four principles that outline the broad mechanistic links between low flow and processes and patterns in riverine ecosystems. These links do not operate in isolation, and many ecological pathways that are affected by low flows are likely to occur simultaneously, potentially resulting in similar or synergistic and complex consequences. Another model shows expected response based on habitat changes.
Roman and Barret (1999)	Inter-national	Conceptual Framework for the Development of Long-term Monitoring Protocols at Cape Cod National Seashore This document presents a conceptual framework for the development of monitoring protocols for the Long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore. Conceptual models were developed for four major seashore ecosystem types: • Estuaries and salt marshes • Barrier islands/Spits/Dunes • Ponds and Freshwater wetlands • Coastal uplands The models describe the relationship between stressors and ecosystem responses, and the report then describes how these elements might best be incorporated into a monitoring program. The document includes the conceptual framework and models, as well as the development and implementation of the monitoring program. The models are specifically related to seashore/estuarine ecosystems, however the report contains principles which may be applied when developing any type of conceptual model.
Smythe-McGuiness et al. (2012)	Qld	Macroinvertebrate responses to altered low-flow hydrology in Queensland rivers Utilised conceptual models to illustrate how stressors were likely to be intermediating the impact of low-flow alterations on aquatic biota. This assisted in overcoming difficulties in identifying general low-flow ecology relationships where data pertaining to specific species were lacking. Conceptual models are presented for: impacts of surface water extraction on aquatic ecosystems, downstream impacts of dams and weirs on aquatic ecosystems, and impacts from coal seam gas wastewater disposal on aquatic ecosystems. Key recommendation from the report was: advocating the development of conceptual understandings of flow-related conditions required for the identification

Reference	Region	Summary
		of biological responses. Relevance: Presents conceptual models, and how some species respond to selected flow regimes.
Takahashi et al. (2011b)	Qld (MDB)	Stream ecosystem health response to CSG water release: biological monitoring guideline  **Figure 1. Conceptual model of the ecological effects of CSG-related water entering the ephemeral stream during the dry and wet phase.**
Wilkinson et al. (2007)	SA	Best Practice Framework for the Monitoring and Evaluation of Water-Dependent Ecosystems 1: Framework This document is a guide for developing robust monitoring programmes, using an adaptive management framework. The document includes a description and examples of four components that should be established when developing a monitoring program:

Reference	Region	Summary
		• *Rationale and priorities:* This includes identifying the nature of the problem, the type of monitoring required, the physical and biological characteristics of the WDE/s of interest and the nature of the risks and threats. • *Conceptual understanding:* This section provides the fundamentals underlying the development of conceptual models, and overview and examples of different types of models and the steps that should be used to construct them. • *Monitoring program:* Provides guidance on how to choose methods, techniques and instrumentation to collect data necessary for a monitoring program. • *Implementation and assessment:* This provides information on how to successfully implement a monitoring program, how to collect and store data and how to evaluate and review your results. Specifically, this provides guidance on maintaining an adaptive management approach.

3.1.3.2. Monitoring and Condition

Reference	Region	Summary
Alluvium Consulting (2011)	National	FARWH: findings from the trials and options for uptake The FARWH aims to provide a framework that allows for different jurisdictions to report on a national level on river and wetland health using different methods but a common condition ranking system. Two-tiered approach recommended: Tier 1: broadscale assessment of an entire region – using more of a desktop and expert knowledge approach to identify areas at high threat or of high value to be the focus of the more resource intensive detailed assessments, may only use the first three indicators. Tier 2: detailed assessments at reach or site scale, full suite of FARWH indicators. Conceptual models used to link indicators with change in condition, with different models for different AE types and therefore different indicators for different AEs. Indices of river and wetland health: • Catchment disturbance • Hydrological disturbance • Fringing zone • Wetland extent • Water quality and soils • Physical form • Aquatic biota.
Balcombe & McNeil (2008)	Qld (LEB) & SA	Joint Recommendations for Fish Monitoring in LEB Rivers: Testing the Fish Trajectory Model in Queensland and South Australia Fish trajectory model developed to examine river health; following trialling of the methodology, this report discusses indicators' usefulness and modifications to the original indicators.
Brim Box	NT	Central Australian Wetlands Monitoring Framework: Water Quality and Aquatic

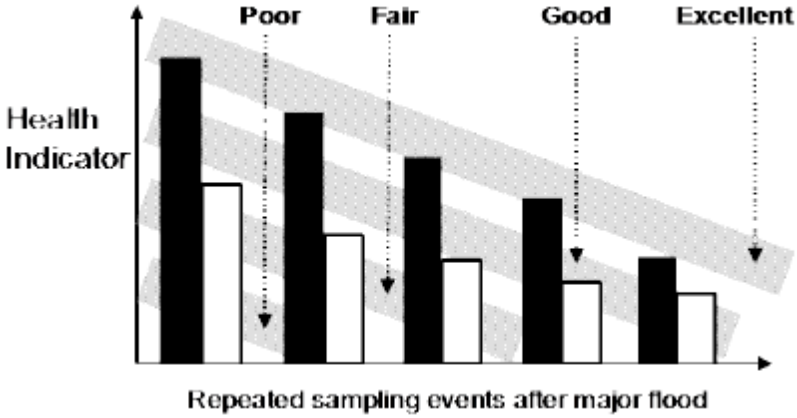
Reference	Region	Summary
(2010)		Fauna Sampling Outlines a monitoring methodology for macroinvertebrate and water quality monitoring. Provides a summary of monitoring indicators and methods but does not cover interpretation of results or contextual information relating to why monitoring should be undertaken or site selection.
Bunn et al. (2010)	Qld (South East)	Integration of science and monitoring of river ecosystem health to guide investments in catchment protection and rehabilitation Describes the development, implementation and key outcomes of the SEQ Healthy Waterways monitoring programme undertaken in SEQ catchments from 2001 onwards. Discussed in detail is the process utilised to determine indicators of ecosystem health, and measures of disturbance. Relevance: Discusses methods for determining monitoring and assessment parameters/indicators.
Chessman et al. (2010)	NSW (Upper Darling)	Assessing effects of flow alteration on macroinvertebrate assemblages in Australian dryland rivers Examines the effects of anthropogenic flow alterations on macroinvertebrate assemblages in arid environments. This article uses richness, density, abundance and composition as variables for analysis. The study found no difference between overall macroinvertebrate density or Observed vs. Expected indexes, however it did find one particular species specific difference in the community assemblages. Lack of taxonomic identification of macroinvertebrates and limited success whilst using one particular standardised sampling method reduced the ability to draw meaningful conclusions from these data. Significant environmentally sensitive 'indicator species' were not discussed and could have possibly been used as an effective condition gradient when analysing the effects of flow alteration on macroinvertebrate communities.
Choy et al. (2002)	Qld (LEB)	Ecological condition of central Australian arid-zone rivers Assessment of ecological condition for Georgina, Diamantina, Cooper-Thomson and Bullo Rivers, based on: • Level of human influence • Habitat condition • Water chemistry • Macroinvertebrate composition. 75% of sites were considered to be in good condition, with the remainder being mildly impaired; however, temporal and spatial variability for criteria was high. Key impacts were due to riparian and bank damage from stock. Relevance: Presents topics for consideration during selection of monitoring sites and parameters.
Claus et al. (2010)	NSW	Assessing the extent and condition of wetlands in NSW: Supporting report A – Conceptual framework

Reference	Region	Summary
		Information collected to inform a condition assessment includes: Wetland type, water source, water regime, water quality (temperature, pH, turbidity, salinity), fringing zone and catchment mapping, site description, photos, hydrology, physical modifications, change in inundation, presence of drains, soil erosion, pugging, soil surface, land use, vegetation (plant types and cover), tree health, waterbirds, soil pH and salinity, soil moisture, ASS. Methods for collecting data on each of these attributes are presented.
Clifford et al. 2010	Qld (LEB)	SEAP Lake Eyre and Bulloo Province Stressor Prioritisation Workshop Report Documents use of PSR models to prioritise indicators for waterway monitoring
DERM (2010a)	Qld	Queensland Integrated Waterways Monitoring Framework Aim to align SEAP with other waterway monitoring programs. More of a policy level document of intent than Negus et al. (2009). Key features of the framework are: • Prioritisation of catchments based on risk assessment (see Clifford et al. 2010) • Indicators for each catchment selected based on PSR framework • Improved access to waterways monitoring through the *Qld Waterways Monitoring Portal*
Jaensch (1999)	Qld (LEB)	The status and importance of Queensland's south-western wetlands Reviews existing data to classify wetlands, present summary information on wetland biodiversity, status and importance, and analyse threats for wetlands in south-western Qld. Report is supplemented by individual 'factsheets' or each wetland type. Seven wetlands were reported to meet the criteria of Ramsar (with two of these already being listed). The greatest threat to these wetlands was reported to be reduction of inundation resulting from water removal. Relevance: Presents a wetland classification scheme and method for creating a classification scheme, and potential use for site selection.
Kingsford & Porter (2008)	LEB	Scientific Validity of Using Waterbird Measures to Assess River Condition in the LEB Discusses the usefulness of using waterbirds to assess river health in the LEB. Review of known LEB waterbird studies and their methods. Concludes that: 'Waterbird indicators (species richness, abundance, breeding) complement other indicators (e.g. flow, fish, vegetation). Waterbirds integrate food webs across the entire floodplain. Waterbirds are also predominantly at the top of the food chain and so they can track changes in other indicators (e.g. invertebrates, vegetation, fish) providing an additional indirect measure of these indicators. Waterbirds can track ecosystem health at the landscape scale, including the key wetland and entire catchment of a river and even basin. Hydrology indicators are primarily used as a surrogate for ecological health and waterbirds can provide added information about the adequacy of such indicators.' Designed for aerial bird surveys in the LEB including strengths, weaknesses and potential outputs.
Kodric-	NT	Incomplete datasets in community ecology and biogeography: a cautionary tale

Reference	Region	Summary
Brown and Brown (1993)	(Dalhousie Springs)	Examines the risks associated with making inferences and conclusions derived from incomplete datasets and other compiled literary sources. The report uses datasets of native fish communities in the Dalhousie Basin as one of two examples. Discusses the limitations of field sampling and in drawing conclusions derived from an incomplete sample set of a population. Highlights the importance of sampling bias in revealing patterns of species distribution and community structure. Emphasises the scalar nature of species distribution in isolated habitats. Re-enforces the need for further monitoring where gaps in datasets are present, particularly where sampling efforts may have been biased.
LEBSAP (2008, 2009)	LEB	State of the Basin 2008: Rivers Assessment and Background & reference The assessment is a broad assessment based on available data and expert knowledge: • 5 reporting regions/catchments: Cooper Creek, Georgina-Diamantina, Desert Rivers, Western Rivers and Lake Frome • 3 reaches per catchment: headwaters, channels and waterholes, terminating wetlands • 5 Indicators: hydrological condition, landscape stress, water quality, fish and waterbirds. Findings are that the rivers are generally in good health, with some rivers lacking sufficient data to make an assessment. Catchment landscape stress is moderate to high in some reaches.
Moller (1999)	Qld (LEB)	State of the Rivers Cooper Creek and Major Tributaries An assessment of the physical and environmental condition was conducted for 273 sites on the Thompson River, Barcoo River, Cooper Creek and their tributaries. Parameters were assessed against presumed natural condition by comparison to remnant sites. Measures were recorded for the following: reach environs (i.e. how remnant/unmodified); bank erosion; bank stability; bed and bar stability; channel diversity (i.e. diversity of habitats, waterhole , riffle, and run); riparian habitat; aquatic habitat; and scenic, recreation and conservation value. Generally 'moderate' to 'good' conditions are present results, though threats to the ecology and habitats are present. Most of these threats are due to vegetation clearing close to waters and ease of stock access. It is noted that with certain management practices and time these can be rectified. Relevance: Describes the state of rivers in the Cooper catchment, discusses method for monitoring. There is potential for identification of temporal changes if monitoring the same parameters occurs.
Negus et al. (2009)	Qld	Stream & estuary assessment program (SEAP) – an assessment framework for riverine ecosystems Using PSR models developed by Marshall et al. (2006a), provides framework to assess condition of AEs within a risk framework, evaluate trends, improve

Reference	Region	Summary
		understanding and guide NRM decisions. Referential approach to assess indicators, with reference condition developed using 20th and 80th percentile ranges for data from sampled reference sites (sampled at same time as monitoring sites).
Negus et al. (2013, Draft)	Qld (LEB)	Riverine Assessment in Queensland's Kati Thanda-Lake Eyre and Bulloo catchments: Stream and Estuary Assessment Program 2012 An assessment of the condition and threats to permanent riverine waterholes in the Kati Thanda-Lake Eyre and Bulloo catchments was undertaken using desktop and field analyses under SEAP (Streams and Estuary Assessment Program). The assessments conducted confirmed that pigs, cattle and riparian weeds are widespread and common, and present a significant risk to riverine ecosystems in the LEB and Bulloo catchment. The current distribution of introduced fish and redclaw was reportedly patchy; however these species have the ability to disperse throughout the system and impact on native species. Several key recommendations have been made for future monitoring and include: carp and cane toads as potential future threats of importance; management of weeds and introduced riparian fauna; and alignment and coordination of monitoring and assessment activities. Relevance: Notes the importance of coordination of projects with current/future monitoring projects. Details monitoring methods and parameters.
Parsons et al. 2002	National	The AUSRIVAS Physical Assessment Protocol presents a nation-wide methodology for assessing river physical habitat. However, the parameters it seeks to measure and its tools (datasheets, user guides) are not as universal as the authors intend, and are not very applicable to LEB rivers. Also the parameters do not measure the integrity of geomorphic processes, nor do they provide information that will reveal the nature and vulnerabilities of the geomorphic processes at the place being assessed. This is not a conceptual tool for assessing geomorphology, it is a tool for documenting the physical components of habitat, a very different thing.
Parsons et al. 2004	National	Development Of A Standardised Approach To River Habitat Assessment In Australia The AUSRIVAS Physical Assessment Protocol presents a nation-wide methodology for assessing river physical habitat. However, what is actually being measured (as is clear from this paper) is the suitability of the habitat for macroinvertebrates. As most river networks in drylands Australia aren't dominated by water-retaining landforms, this protocol is not widely applicable, and its widespread acceptance implicitly excludes a range of other types of drylands HEVAE.
Pringle & Tinley 2003	NT & SA (Neales, and Finke)	Are we overlooking critical geomorphic determinants of landscape change in Australian rangelands? There's no point monitoring vegetation plots while ignoring valley-floor incision. The true indicator of local range condition is the gully network. (based on exclusion plots in WA)
Rogers et al. (2011)	Qld (MDB)	Stream ecosystem health response to coal seam gas water release: Salinity guidelines

Reference	Region	Summary
		Used guidelines derived from toxicity tests on aquatic organisms recorded in the national salinity sensitivity database and ANZECC, and ecosystem condition to determine trigger values for water quality and the level of protection to apply in different sub-basins. Discusses how guidelines for CSG salinity should be developed and utilised for best management. Relevance: Presents methods for study design and identification of monitoring parameters, and identifies the need for studies in CSG related ecotoxicology.
Scholz & Fee (2008)	SA	A framework for the identification of wetland condition indicators: a national trial – SA: Wetland condition indicators should be identified per wetland type and recommends indicators should focus on drivers of ecosystem function.
Sheldon & Fellows (2010)	Cooper Creek	Water quality in two Australian dryland rivers: spatial and temporal variability and the role of flow Spatial and temporal variability makes it difficult to develop water quality guidelines, guidelines need to be based on flow phase.
Sheldon et al. (2012)	National	Early warning, compliance and diagnostic monitoring of ecological responses to low flows Uses pressure and response terminology to group indicators. Indicators are ranked for their suitability for early warning, compliance and diagnosis for low flows - 'to determine when AEs are at risk of future change and establish when an ecosystem has either permanently shifted to a new state or has recovered to pre-low flow conditions.' Pressure indicators: • Hydrological change • Physical condition – notes changes to physical form better captured within metrics that reflect habitat availability and condition • Habitat condition Response indicators: • Vigour indicators – e.g. nutrient cycling, ecosystem metabolism and decomposition • Organisation indicators – macroinvertebrates (eg AUSRIVAS, SIGNAL), fish (e.g. IBI), diatoms and other algae • Water quality – often seen as explanatory variables for other response indicators (*because should be separately classes as a stressor!*) Remotely sensed indicators • NDVI used for low flow hydrological classification • NDVI anomalies from average to detect drier than normal was unsuccessful but recommend going to more regional scale Detecting impact: monitoring needs to consider flow phase (see below); reference condition doesn't work well for systems that are highly variable temporally and spatially; recommend filters approach whereby expected conditions for site are derived from potential and filtered by environmental conditions such as water quality.

Reference	Region	Summary
		 Indicators for detecting onset of low-flow impact: 'One of the most challenging tasks when monitoring the impacts of low flow is detecting the onset of low-flow conditions that are outside the range of normal hydrological variation for a given site (p. 26).' Indicators for detecting impact of low flow; indicators to detect recovery from low flow – difficulty in predicting recovery trajectory.
Sheldon et al. (2005)	LEB	Methodology for assessing the health of LEB rivers Original assessment methodology now replaced by Thoms et al. (2009)
Smyth et al. (2009)	National	*A framework for assessing regional biodiversity condition under changing environments of the arid Australian rangelands* Arid rangelands are also difficult to assess in part due to climate driven variability. Have developed a framework for assessing rangeland biodiversity condition using an adaptive management approach The first step is to define biodiversity condition. The framework is designed to inform management and therefore indicator choice follows on from determining the management questions. In the case study, biodiversity values were used as the basis for defining the management objectives, with values including natural surface flows and drainage lines. Framework has been trialled in the Stony Plains bioregion but unable to interpret condition because of the absence of long term monitoring.
Stewardson et al. (2009)	Cooper Catchment	Using Remote Sensing to Monitor Hydrological Change in the Lake Eyre Basin Landsat and MODIS data were analysed to determine if they could be used to detect changes in flood inundation totals and patterns in response to changes in the flow regime. Floods of similar recurrence intervals were used in the analysis. It was found that the uncertainty in the mapping of flood patterns by remote sensing exceeded the expected range in flow regime change. As a result, mapping by remote sensing was relatively insensitive to small-medium sized changes in the flow regime for a given flood recurrence interval.

Reference	Region	Summary
Takahashi et al. (2012)	Qld (MDB)	Stream ecosystem health response to coal seam gas water release: Direct toxicity assessment. Risks to aquatic organisms (macroinvertebrate, fish, algae & macrophyte) associated with discharging CSG water to receiving waters were analysed, under laboratory conditions. Results indicated that water quality interactions (alkalinity, turbidity, EC and ionic composition) significantly influenced toxicity of the water; and highlighted the importance of site-specific studies when assessing risks to organisms. Relevance: Identifies monitoring parameters, and presents a potential tool for site selection (in proximity to CSG sites).
Thoms et al. (2009)	LEB	Proposed LEB Rivers Assessment Methodology The LEB River Assessment Plan Methodology presents a plan for assessing river condition in the LEB. Recommendations for LEBRA indicators: physical habitat, fish, waterbirds and riparian vegetation structure and wetlands vegetation condition (DIWAs), water quality and pressure indicators. Recommend Strategic Adaptive Management system recommended, with resilience of the LEB natural resources as its aim and Thresholds of Potential Concern the focus over 'trend' assessments, however, TPC yet to be determined for LEB. Provides detailed and costed monitoring methods for each indicator. The sections dealing with assessment of physical form recommend using the protocols outlined in Parsons et al. (2002, and 2004). These protocols are inappropriate for use in the LEB. The Thoms et al. (2009) methodology is not appropriate for mapping geomorphology in catchments like the LEB, where so much baseline work is yet to be done.
Wakelin-King (2010)	NT (Neales)	Geomorphological assessment and analysis of the Neales Catchment Mapping spatial relationships of landforms and sediments uncovers the process relationships. Assessments of condition and causality are made on the basis of processes in reference landscapes or landforms, and comparing landform distribution with distribution of human vs. geological factors.
Goonan et al. (2012)	SA	The South Australian monitoring, evaluation and reporting program (MERP) for aquatic ecosystems: context and overview Report outlines changes to the EPA's water quality monitoring approaches used in SA. The change is in part due to difficulties in applying a reference condition method due to the level of land use modification in SA. The new approach focusses on the direct measurement of important biological groups and related indicators of condition and risk rather than the use of chemical surrogates as in most monitoring programs. Multiple lines of evidence are used to assess the condition and the pressures that impact on ecosystems. A tiered approach enables assessments at different scales, which, from broadest to finest scale are: 1. A land use risk characterisation identifies the major human disturbances likely to be impacting on different waters, and provides a coarse, desktop

Reference	Region	Summary
		assessment of the likely condition of specific waterways in a region 2. A description of the biological condition and environmental risks at the local scale, (e.g. a stream reach, lake or groundwater body) 3. An assessment of the source of specific problems at the site scale may also be applied as a third layer of investigation, either for unexpectedly impacted sites or for issue-based studies Rolling regional sampling programs will be incorporated to ensure that each region of the state is comprehensively sampled at least once in every five years as part of the state of environment reporting cycle. The results are communicated via the online 'Aquatic Ecosystem Condition Reports, however no reports are currently available for the LEB region.
DSEWPAC (2011, 2012, 2013)	LEB	Annual project plans for LEBRA monitoring Plans outline the annual monitoring programs for LEBRA developed by the LEBRA Operations Group. The plans build on Thoms et al. (2009), but due to resource limitations, only a subset of 'no regrets' condition indicators, as chosen by the LEBRA Operations Group, are selected for monitoring: hydrology, fish and water quality. Includes McNeil & Cockayne (2011) as an appendix outlining fish sampling methods.
McNeil & Cockayne (2011)	LEB	Proposed Guidelines for Fish Monitoring LEBRA Outlines the methods used for fish sampling in LEBRA, broadly based on Thoms et al. (2009) and Balcombe & McNeil (2008). Methods include small and large fyke nets and seine nets.
Smyth et al. (2009)	National	A framework for assessing regional biodiversity condition under changing environments of the arid Australian rangelands Arid rangelands are also difficult to assess in part due to climate driven variability. Have developed a framework for assessing rangeland biodiversity condition using an adaptive management approach The first step is to define biodiversity condition. The framework is designed to inform management and therefore indicator choice follows on from determining the management questions. In the case study, biodiversity values were used as the basis for defining the management objectives, with values including natural surface flows and drainage lines. Framework has been trialled in the Stony Plains bioregion but unable to interpret condition because of the absence of long term monitoring.

3.1.4. Literature reviews

Reference	Region	Summary
Bunn et al. (2006)	Qld (Cooper Creek)	Flow variability in dryland rivers: boom, bust and the bits in between Review of studies from the Cooper exploring the consequences of extreme natural flow variability for river ecosystem processes. Topics include: persistence and distribution of waterholes as refugia, boom and bust, flow pulses and flow regulation. A key proposition is that limitation of flooding flows and an increase in

Reference	Region	Summary
		flows will stress dry land river systems, and could help explain the state of dry land river systems with extensive water resource development. Relevance: Indicates changes that may occur from flow regulation (dam and release gradually for downstream consumption).
Conrick, (2007)	Qld	Scoping Study for Monitoring Wetland Extent and Condition Review of relevant national and international literature on wetland condition and extent indicators, and methodology, as they relate to monitoring. Includes reviews of wetland classification and monitoring frameworks, and how these are being applied in Qld. Summarises current monitoring programs being undertaken for riverine, lacustrine and palustrine wetlands in Qld (SEAP, SRA, LEBRA, EHMP, ABMAP, SWAN, Dryland Refugia and AquaBAMM), by listing the variables, indicators and measures involved in each program as well as brief outcomes to date. A series of general conceptual models are presented for Qld Lacustrine and palustrine wetlands and sub-types, as developed through the Wetland Indicators Workshops. Relevance: Use for definition consistency, methodologies, and presents conceptual models.
Davis et al. (2007)	Qld	Understanding Ecological and Biophysical Processes in Queensland's Wetlands: Literature Review and Gap Analysis A statewide review of wetland-related literature. There are some sections relevant to the LEB in Chapter 2: Wetland Ecosystems. The report also summarises literature regarding functions attributed to wetlands (using an ecosystem services-type approach) and threats to wetland ecosystems: • Changes to water regime • Habitat modification • Pollutants • Weeds & feral animals • Climate change. Notes that information relating to ecosystem responses to these threats (and how to manage them) is largely unknown.
DCQ Inc. (2004a)	Qld (LEB)	Our Country: Our Community – A community information paper for the Queensland section of the Lake Eyre Basin Information paper that provides details about issues relating to current and future natural resource management issues in Qld LEB. A wide range of topics are covered including: geological, hydrological, and eco/biological processes, historical and current human occupation and their associated land uses. This document was prepared for use with the reference: (Desert Channels Queensland Inc. 2004b). Relevance: Details environment of and threats to the environment in the LEB.
DCQ Inc. (2004b)	Qld (LEB)	Protecting Our Assets - A natural resource management plan for the Queensland section of the Lake Eyre Basin (2004–2009) Four Assets were identified; land, water, biodiversity, and community; and information presented relating to them in addition to gaps. Proposed actions are

Reference	Region	Summary
		presented. Threats to these assets are discussed and resource condition targets and management action targets are discussed. Threats included: introduced species and anthropogenic influenced factors (e.g. grazing). Abatement actions include: pest removal/management and changes to land management practices. Relevance: Details threats to LEB environment and abatement actions in a plan.
Duguid 2005, Duguid et al. (2005)	NT	Wetlands in the arid NT Includes review and collation of literature and data relating to wetlands in arid NT including the NT LEB.
GFCQ (2012)	Qld	Collation of Water-Related Science and Research Activities in the Queensland Coal Seam Gas Sector Summarises the science and research activities into CSG in Qld: identified 188 activities or research projects. The majority of the work is being undertaken in the Surat Basin and focussing on hydrogeology, groundwater impacts and injection activities. Surface water management, including irrigation, discharge and water treatment is the second major area of research. At least half of the activities are yet to be completed and 7% had not yet started, highlighting that there is currently a lack of scientific literature but the situation should begin to improve as these projects are finished and published.
Golder Associates (2009)	Qld (Cooper Creek)	Cooper Creek Water Resource Plan: Environmental Discussion Paper A summary of current environmental information and needs (1998 to 2009) relevant to the Cooper Creek catchment for use as a guide to the development of water management provisions, and for consideration in the review of the Cooper Creek WRP 2000. Specifically, the paper summarises: • key scientific studies undertaken in the catchment (inc. key findings) • hydrological requirements of species, ecosystems, ecological processes, biodiversity and ecologically significant areas • future impacts of water resource development, climate change and other pressures • assessment of the provisions of the current WRP (inc. LEBA) • recommendations on water resource management strategies • key knowledge gaps. Direct alterations to the system as a result of water resource development include loss of longitudinal and lateral connectivity and the modification and loss of habitats, both riparian and instream. Relevance: Future monitoring should be catchment wide and should contain a long term perspective of flow history, due to flow variability.
Larson (2006)	Qld (LEB)	Analysis of the water planning process in the Georgina and Diamantina catchments: An application of the Institutional Analysis and Development (IAD) framework. A review was conducted of water planning processes and a survey was conducted for how resulting plans are received by communities and the impacts of these plans.

Reference	Region	Summary
		Information was presented for the production of plans, involvement of stakeholders at all levels and stages and how topics should be addressed. Stakeholders need to be involved in water planning processes. In addition the importance of 'government' staff in regional areas is highly important due to the low populations and the knowledge of a 'local'. Relevance: Highlights the need for stakeholders at all levels to be involved in the development of a resource plan.
LEBSAP 2009	LEB	State of the Basin 2008: Rivers Assessment – Background and reference Literature and other data supporting the findings of the LEBRA 2008
Miles & Risby (2010 / in prep)	SA (LEB)	LEB Strategy Scientific Report On a catchment by catchment basis draws together existing literature and data for the SA LEB on: - LEB hydrology (surface and groundwater) - Aquatic conservation assets - Environmental water requirements.
Morton et al. (1995)	SA (LEB)	Natural Heritage Values of the Lake Eyre Basin in South Australia:World Heritage Assessment Literature review documenting natural heritage values for possible (but ultimately unsuccessful) World Heritage listing.
Nanson (2010)	LEB	The rivers, floodplains and fluvial-wetland characteristics of the Lake Eyre Basin A summary of existing information on the geomorphology of LEB aquatic ecosystems, dividing the Basin into five major geomorphological regions.
Nanson et al. 2002	All	A review of drylands rivers. Describes flashy and non-flashy hydrographs, and relationships to catchment size. Explores the increased understanding of diversity in drylands rivers (including difference between braiding and anabranching).
Piddock (2009)	Qld & SA (Cooper Creek & G-D)	Historical collation of waterbody information in the Lake Eyre Basin catchments for Qld and SA The journals of three nineteenth century explorers and one early twentieth century traveller were examined, and references to waterbodies and other environmental phenomena extracted and geo-referenced. Explorer observations of a range of mammal species are also presented and their ecological significance discussed.
Reddy (2010)	USA	Coalbed Natural Gas: Energy and Environment Comprehensive reference covering CBNG (aka CSG) and its environmental impacts Chapter on Aus/NZ CSG development
Rolls et al. (2012)	National	Review of literature quantifying ecological responses to low flows undertaken at beginning of Low Flows project (therefore mostly pre-2010). Summarises literature quantifying the ecological response to, and recovery from, low-flow events in streams and rivers. Focusses on the low-flow responses of macroinvertebrates and fish, and sought to identify potential ecological indicators and thresholds useful for

Reference	Region	Summary
		low-flow planning and management. The report concludes it is difficult or impossible to use the available literature to identify thresholds of low-flow stress that can be generalised across geographic regions due to differences in climate, land use and both antecedent flow regime and water quality conditions. Research indicates that the ecological effect of reduced flow depends on the interaction with the antecedent flow history and the antecedent water quality conditions that are driven by climate, flow regime and the surrounding landscape. Poor knowledge of the basic ecology and biology of many groups of biota in large regions of Australia, combined with high variation in traits among taxa that are taxonomically similar, is likely to hinder the broadscale assessment of ecological responses to low flows.
Shaw et al. (2010)	Qld	Stream Ecosystem Health Response to Coal Seam Gas Water Release: Hazard Characterisation Summarises available data to allow examination of the physical-chemical and flow characteristics of proposed releases of CSG water to surface streams. These data examined provided a basis on which to assess the potential benefits/hazards posed by CSG water discharges to aquatic ecosystems in surface streams and will assisted with directed guideline development through the Healthy Headwaters Project.
Silcock (2009a)	Qld & SA (Cooper Creek & G-D)	Identification of permanent refuge waterbodies in the Cooper Creek and Georgina-Diamantina river catchments for Queensland and South Australia Presents a summary of historical literature on permanent waterbodies in the Cooper and Georgina-Diamantina catchments including: • Studies on Aboriginal occupation • Explorer/ surveyor journals • Early settlers/ scientists accounts • Local/regional histories. Sections on: • Human importance of water (indigenous and European) • Human impacts • Ecology • Anthropogenic alteration of the ecosystem and hydrology.
Tooth 2000	All	Process, form and change in dryland rivers; a review of recent research A review. Drylands rivers have extremely variable flows, and according to catchment context may or may not develop equilibrium landforms. Generally channel networks increase with size down-valley, but only as far as tributaries bring new water to the main channel: away from the uplands, channel size decreases as transmission loss becomes a dominant factor.
Tyler et al. (1990)	SA (LEB)	Natural History of the North East Deserts Comprehensive literature review for entire NE corner of SA with some overlap with Arckaringa and Pedirka Basins: • Geology

Reference	Region	Summary
		• Hydrology • Biology • Climate • Anthropology • Zoology • Palaeontology • Conservation.
Walker et al. (1997).	Qld (Cooper Creek)	Viewpoint: Irrigation development on Cooper Creek, central Australia – prospects for a regulated economy in a boom-and-bust ecology A discussion regarding the ecological impacts of a proposed irrigation scheme in the headwaters of Cooper Ck, including consequences for hydrology, geomorphology and biology. Presents the opinion that the Cooper cannot accommodate such development. Relevance: The biology/ecology of the Cooper has adapted to and for 'boom and bust' hydrological regime and would not sustain a change away from this.

3.2. Impacts of anthropogenic disturbance

3.2.1. Pressures

Reference	Region	Summary
Azam & Li (2010)	Inter-national	Tailings dam failures: a review of the last 100 years Reviewed causes of tailings dam failures internationally. Main causes of dam failure were found to be 'unusual rain' and 'poor management'. Note implications of 'unusual rain' events may be more likely under climate change scenarios. 'Poor management' includes poor monitoring and maintenance to maintain structural integrity.
Badman (1989)	Cooper Creek	*The birds of the middle and lower Cooper Creek in SA* Notes that windrows that form along seismic lines and access tracks on floodplains can alter flow paths and prevent inundation of large areas. Also that seismic tracks on stony plains country takes a long time to repair and can cause erosion when constructed using graders, but notes more recent practice of using rollers has less impact. Documents an attempt was made to dam the Lake Hope channel to divert floodwaters down the lower cooper, however this was removed before any floods occurred. At Embarka Swamp levee banks are used to connect a network of production wells, maintaining water at constant levels. Also notes the unintended consequence of exploration being to open up areas for tourism.
Commonwealth of Australia (2014a)	National	Co-produced water – risks to aquatic ecosystems, background review Volumes and quality of co-produced water varies between operations. Elevated salts commonly occur and other water quality parameters require management

Reference	Region	Summary
		attention. Management options include re-use (agriculture or other industries), injection and discharge to surface waters.
DAFF (2008)	Qld	Petroleum Industry – Pest Spread Minimisation Advisory Guide A set of guidelines were prepared developed to enable the petroleum industry, (Including coal seam methane developers) to assist operators to develop systems to minimise the spread of pests (primarily weeds and insects). Topics which need to be addressed in such plans are training, managing spread, managing infestations and monitoring/reviewing the effectiveness of actions (includes appendices). Relevance: Details methods for reducing pest spread by the petroleum and CSG industry/resource development
Davis et al. (2010)	USA	Effects of coalbed natural gas development on fish assemblages in tributary streams of the Powder and Tongue rivers Case study of CSG impacts on Northern USA fish assemblages.
DEH & SAALNRMB (2009)	SA (LEB)	SAAL Biodiversity Strategy Outlines threats to biodiversity conservation priorities

<table>
<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td></td><td></td><td>
Table 2: Threatening processes affecting the biological diversity of the Australian rangelands
<table>
<tr><th>Threatening process[viii]</th><th>Category of threat</th></tr>
<tr><td>Damage to key sites by grazing animals</td><td>• Excessive total grazing pressure</td></tr>
<tr><td>Displacement of native perennial grasses and palatable shrubs through grazing</td><td>• Excessive total grazing pressure</td></tr>
<tr><td>Feral herbivores</td><td>• Excessive total grazing pressure
• Competition for resources by pest plants and animals</td></tr>
<tr><td>Climate change</td><td>• Alteration of natural water flows
• Competition for resources by pest plants and animals
• Altered fire regimes
• Direct impacts on populations</td></tr>
<tr><td>Changed water regimes</td><td>• Reduction in Great Artesian Basin water pressure
• Alteration of natural water flows</td></tr>
<tr><td>Introduced predators</td><td>• Competition for resources by pest animals
• Predation</td></tr>
<tr><td>Invasion of exotic plant species</td><td>• Competition for resources by pest plants</td></tr>
<tr><td>Unsuitable fire regimes</td><td>• Altered fire regimes</td></tr>
<tr><td>Disease</td><td>• Direct impacts on populations</td></tr>
<tr><td>Mining</td><td>• Mechanical disturbance
• Pollution
• Reduction in Great Artesian Basin water pressure
• Alteration of natural water flows</td></tr>
<tr><td>Hunting</td><td>• Direct impacts on populations</td></tr>
<tr><td>Commercial harvest</td><td>• Direct impacts on populations
• Habitat degradation for non-target species</td></tr>
<tr><td>Tree clearing</td><td>• Mechanical disturbance</td></tr>
</table>
</td></tr>
<tr><td>Department of State Development</td><td>SA</td><td>Department of State Development web page – Environment Register:

http://www.pir.sa.gov.au/petroleum/environment/register

This webpage has available for download all the industry-standard EIR for South Australia's hydrocarbon exploration operations.</td></tr>
<tr><td>DERM (2010c)</td><td>Qld (LEB)</td><td>Desert Channels Back on Track Actions for Biodiversity

Details actions to address individual threats towards 50 priority species within the Desert Channels NRM region, on a case-by-case basis.

For each species, the following threat information is presented:
• threat name
• importance of the threat to the species
• potential impacts on species
• threat detail
• actions to address the threat (inc. current actions, plans and strategies, on-ground works, community education, research and monitoring).

The major pressures threatening a large proportion of priority species identified in this report are:</td></tr>
</table>

<table>
<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td></td><td></td><td>• Feral/invasive species (inc. cats, pigs, gambusia and weeds)
• Groundwater and surfacewater extraction
• Inappropriate fire and grazing regimes.

Relevance: Details threats to species within the LEB and abatement actions.</td></tr>
<tr><td>DERM (2011b)</td><td>Qld</td><td>Assessment for integrated waterway monitoring in Queensland: Technical Report

Overall, LEB catchments aquatic and riverine ecosystems rank low levels of ongoing and incident based human activities compared with other Qld catchments. No LEB catchments ranked as being under greater than low level of pressure from coal mining but for CSG pressure the lower Cooper ranks moderate (6-200 wells). The following table summarises human pressures ranked > low in LEB catchments
<table>
<tr><th>Pressure</th><th>Coop.</th><th>Thom.</th><th>Barc.</th><th>Geor.</th><th>Eyre</th><th>Diam.</th></tr>
<tr><td>CSG</td><td>✓</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Grazing</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Major indust sites</td><td>✓</td><td></td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>Flow barriers</td><td>✓</td><td>✓</td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td>Metal mines</td><td></td><td></td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>Feral pigs</td><td>✓</td><td>✓</td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td>Pest fish</td><td>✓</td><td>✓</td><td>✓</td><td></td><td></td><td>✓</td></tr>
</table></td></tr>
<tr><td>DITR (2007)</td><td>National</td><td>Leading Practice Sustainable Development Program for the Mining Industry: Tailings Management

Water resource risks associated with tailings dams:
• Leakage through dam and from damage to infrastructure delivering tailings to dam – surface & groundwater quality impacts
• Failure – hydraulic impacts and water quality/pollution
• Exposure of contaminants/toxicants to wildlife
• Longer term closure issues of maintaining integrity.</td></tr>
<tr><td>DITR (2008)</td><td>National</td><td>Leading Practice Sustainable Development Program for the Mining Industry: Water Management</td></tr>
</table>

<table>
<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td></td><td></td><td>
Table 7. Typical water quality issues for the mining industry.
<table>
<tr><th>MINE-LIFE STAGE</th><th>WATER QUALITY RELATED ACTIVITY</th><th>ACTION</th></tr>
<tr><td>Exploration</td><td>Erosion from temporary roads
Runoff of drilling fluids, petroleum products from drill pad construction and operation, camp wastes.</td><td>Initial baseline monitoring program developed (weather station, several water quality/biology sites, water flows).</td></tr>
<tr><td>Resource development and design</td><td>Developing water management plan.
Preparing EIS.</td><td>Baseline inventory and monitoring at key sites, including those in reference catchment(s), implemented for water quality and ecological features.</td></tr>
<tr><td>Mining, minerals processing and refining</td><td>Discharge management.
Possible acid-rock drainage.
Tailings management.
Solid waste management.</td><td>On-site monitoring (discharges, storage and holding dams, groundwater).
Off-site monitoring of receiving system and reference sites (quality, flows, biology).
Water management plan implemented.</td></tr>
<tr><td>Rehabilitation</td><td>Management of onsite water.</td><td>On-going assessment of impacts.</td></tr>
<tr><td>Closure and post-mining</td><td>Considering all possible future impacts (e.g. acid rock drainage).</td><td>Continued off-site and onsite monitoring.</td></tr>
<tr><td>Shipping of products</td><td>Possible spillage, dust control</td><td>Monitoring of receiving system and reference sites (quality, flows, biology).</td></tr>
</table>

Changes to downstream flow regimes resulting from mine sites:

‘causing extended and/or elevated base flows due to relatively constant discharges, for example from mill operations or dewatering;
time shifting of rainfall-runoff flows and attenuation of flood flow peaks such as by capture of site runoff and treatment in retention ponds;
reduction in site runoff, for example by use of a zero-release strategy or enhancement of onsite evaporative losses of water from potentially contaminated areas;
increasing flood flow peaks and reducing base flows by reduced infiltration and/or increased runoff rates resulting from removal of natural vegetation and soil covers of areas or compaction of soils and subsoils;
disruption of existing relationships between surface and groundwater systems;
diversion of waters from one catchment to another;
altering the physical, chemical and/or biological characteristics of the water in flow events; and,
converting temporary waters to perennial waters or vice versa.’

Changes to flow may result in facilitating spread and establishment of pest species.

Barriers to biota can include chemical barriers as well as physical, i.e. from point disposal site, even if that disposal is diluted downstream.
</td></tr>
<tr><td>DMITRE Petroleum (2012)</td><td>SA</td><td>DMITRE Petroleum: Coal Seam Gas

Website providing an overview of CSG in SA including major coal formations: Arkaringa, Pedirka and Cooper Basins</td></tr>
<tr><td>Farag et al. (2010)</td><td>Inter-national</td><td>Potential effects of coalbed natural gas development on fish and aquatic resources</td></tr>
</table>

Reference	Region	Summary
		(Coalbed natural gas = CSG) Water quality impacts essentially depend on management of produced water, the choice of which may be influenced by the quality and volume of water: • Direct discharge – option for low TDS waters (in LEB this would need to consider evaporative impacts) • Off-channel impoundments – potential groundwater contamination • Reinjection – costly and therefore favoured only when GW quality too poor for other options; ensure not injected into drinking water supplies • Irrigation – if quality suitable but may still reach watercourse through catchment run-off • Stock watering and industrial uses (eg dust suppression). Other impacts: • Road & pipeline construction, crossings – disrupt flow patterns and also movement of migratory aquatic species • Invasive species spread by vehicles • Increased recreational impacts (ie from increased human populations, → increased recreational impacts including fishing).
Golder Associates (2009)	Qld (Cooper Creek)	Cooper Creek Water Resource Plan: Environmental Discussion Paper Summarises future impacts, from a number of pressures, on ecological assets identified within the Cooper Creek WRP area: • Future water resource development (i.e. diversion of water and flow regulation) • Climate change • Clearance and alteration of vegetation • Sedimentation • Invasive species. Direct alterations to the system as a result of water resource development include loss of longitudinal and lateral connectivity and the modification and loss of habitats, both riparian and instream. Relevance: Future monitoring should be catchment wide and should contain a long-term perspective of flow history, due to flow variability.
Goldstein et al. (2012)	SA	Roadmap For Unconventional Gas Projects In South Australia Provides an overview of different types of unconventional gas, including coal seam gas, and describes gas plays in SA, and current projects. The most advanced unconventional gas porjects in SA are in the Cooper Basin, where conventional gas is already produced. Other areas of interst (in the LEB) are the Arkaringa, Pedirka and Eromanga (overlying the Cooper Basin), with the Arkaringa in advanced stages of investigation. Outlines regulatory and approvals processes. The report discusses the importance of maintaining community trust by meeting community expectations.
Kimmel and	USA	Status of Fish and Macroinvertebrate Communities in a Watershed Experiencing

Reference	Region	Summary
Argent (2012)		High Rates of Fossil Fuel Extraction: Tenmile Creek, a Major Monongahela River Tributary Case study of CSG effects on fish and (briefly) macroinvertebrates. Considers salinity and finds these fish communities more robust than EPA regulations suggest.
LEBCAC (2012)	SA (LEB)	LEBRA SAM Workshop Draft LEB Objectives, highest priority LEB assets and threats, highest priority partners LEBCAC identified and ranked, in priority order, threats to LEB river assets and their values. The threats are a mixture of pressures and stressors as defined for the LEBRM project. The highest ranked threats were (in order from greatest threat first): • Invasive pests and weeds • Altered hydrological regimes and excessive water extraction • Total grazing pressure • Reduced water quality • Tourism impacts • Intensive land use and development. 'Extractive industries' were considered by the LEBCAC and not ranked as a threat, however, aspects of the altered hydrological regimes threat are relevant to CSG & LCM: boom-bust cycle; loss of connectivity; hydrological changes, specifically to springs, and redirection of river flows; altered hydrological regimes (flow, duration) due to: barriers, roading (linear infrastructure), inappropriate land management.
LEBSAP (2008)	LEB	LEB State of the Basin 2008: Rivers Assessment Threats to LEB rivers: • Major water development proposals including mining and irrigation • Cumulative impacts of minor water developments (including bores) and diversions • Intensified land use around waterholes • Presence and spread of introduced pest plants and animals, especially their impact on waterholes • Isolation of floodplains through levee construction or roadway embankments • Impacts of pastoral activities, tourism and mining • Intensified surface water extraction and drawdown • Impacts of climate change on water resources • Modification of basin catchments, such as vegetation clearance and inappropriate grazing, soil management and cropping practices • Stocking rivers and waterholes with non-local fish species.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial A report detailing the application, development and trial of an Integrated Ecological Condition Assessment (IECA) for High Ecological Value Aquatic

Reference	Region	Summary
		Ecosystems (HEVAE) in the Cooper Creek catchment. Five HEVAE units (CAT 500 polygons) were selected for assessment. Aquatic ecosystems were identified and listed for each hydrological unit, and HEVAE criteria relevant for each unit were determined. Ecological risk assessments were used to prioritise potential threats to each ecosystem type, and conceptual models were developed for each threat; presenting human pressures, the physical, chemical and biological stressors; the ecological responses to these threats; and the HEVAE values that are met by each unit. Sampling of targeted indicators was undertaken to validate threat risks and to gather information for knowledge improvement. Priority threats to the Cooper Creek aquatic ecosystem were land use (i.e. grazing) and introduction of feral animals (i.e. cattle, pigs and fish). Each site has specific threats defined. Relevance: Potential for use as a site selection tool and identifies potential monitoring parameters.
NWC (2012; 2010)	National	Coal Seam Gas Position Statement 2012 update Supports the earlier position statement including estimate of 300 GL/year of co-produced water from CSG (NWC 2010). Notes QWC's estimate of co-produced water in Surat Basin would be approximately 125 GL over the next three years and thereafter reduce to an average 95 GL. 2010 Position Statement Identifies the following potential risks to sustainable (surface) water management: • Extraction of large volumes of water will impact connected surface and groundwater systems • Impacts from depressurisation (impacts on adjacent aquifers, reduction in flows in surface water systems, land subsidence) • Large volumes that may be discharged in surface water systems, altering hydrology and hydrochemistry.
Pettit (2002)	Qld (Cooper Creek)	Riparian Vegetation of a Permanent Waterhole on Cooper Creek, Southwest Queensland Discusses direct impact of livestock/grazing on erosion/compaction of watercourse bank/bed, and the consequences for riparian vegetation on the Cooper Creek.
Reid et al. (2009)	National	Catalogue of conceptual models for groundwater–stream interaction Effect of GW pumping on streams – presentation of conceptual models describing general relationships: • GW pumping impacts both gaining and losing streams. For losing streams the rate of discharge to the aquifer is accelerated. For gaining streams the rate of discharge to the stream can be reduced, and in

Reference	Region	Summary
		severe situations the hydraulic gradient reversed so that water no longer flows into the stream. • Where GW is pumped from a semi-confined aquifer, leakage from aquifers above/below may also be induced. Also discusses effects of land use change, stream regulation, stream diversion and other pressures.
RPS (2011)	National	Onshore co-produced water: extent and management Volume of co-produced water declines over the life of well operation, therefore main supply point migrates with the development drilling activity. Options for management of co-produced water: • Reuse: options limited due to lack of industrial areas or large populations near to CSG operations and also that such user require continuity of supply that is not guaranteed from CSG with short supply periods and uncertainty of volumes. • Aquifer recharge: technically feasible although issues of geochemical compatibility and locations of acceptable aquifers; re-injection into depleted areas of coal seams or into coal measures some distance from the operations • Environmental releases need to avoid constant in-channel flows.
RPS Ecos (2008)	National	Australian Petroleum Production and Exploration Association Code of Environmental Practice This document gives guidance on objectives to be achieved when managing environmental impacts associated with petroleum exploration and production. It includes an overview of the legislative framework in Australia relevant to petroleum mining, industry policy and principles, and general environmental objectives as well as for objectives for onshore and offshore mining operations.
SANTOS (2003)	SA (Cooper Creek)	South Australia Cooper Basin Operators Lists risks and risk management strategies of explorations wells. A good example of industry standard (and best practice) but specific only to the Cooper. Key points are covered (contamination, flood, etc.) but focus is on hydrocarbon exploration drilling. This document is not intended to cover CGS production fields. Also they do not cover road construction disruption to flow paths (See Wakelin-King 2013, and note that the W-K2013 report has not yet been released publically or to SANTOS).
SCER (2012)	National	The Draft National Harmonised Regulatory Framework: Coal Seam Gas '… a guidance and reference tool for Australian federal, state and territory government regulators for the coal seam gas (CSG) industry. Its purpose is to provide a suite of national and global leading practices to consider and implement in the assessment and ongoing regulation of proposed projects for CSG exploration and production.' Core areas: Well integrity, water management and monitoring, hydraulic fracturing, chemical use. A (draft) document of Leading Practices for CSG operations. Doesn't go into infrastructure issues: specific to CSG issues. Covers

Reference	Region	Summary
		well integrity, water management, hydraulic fracturing, and chemical use.
Schmarr et al. 2013	Cooper	*Aquatic ecology assessment and analysis of the Cooper Creek, South Australia* Inappropriate obstruction or channelling of floodplains that would restrict the movement of fish into and out from these areas. Describe the hydrological changes brought about by two bridges, noting that the long levy banks leading to the bridges are a major contributor to the problem; in particular the velocity of water passing through culverts and bridges may be an impassable barrier. Gambusia and Goldfish found in large numbers but not appearing to impact native fish populations. Cane Toads not found but significant potential for them to move into the area.
Smythe-McGuiness et al. (2012)	Qld	Macroinvertebrate responses to altered low-flow hydrology in Queensland rivers Analyses flow-related pressures to macroinvertebrate communities in Qld: • Dams and weirs • Surface water extraction • Interbasin transfer • Disposal of industrial water (CSG) • Climate Change. Relevance: As above and details the likely influences of future changes related to the above.
Thoms et al. (2009)	LEB	Proposed LEBRA Methodology Monitoring pressure indicators
Wakelin-King (2010)	Neales	Geomorphological assessment and analysis of the Neales catchment Pressures that affect geomorphology of key waterholes include thinning of riparian vegetation, gullies initiated through riparian ridges by human foot traffic and rabbits, gullies initiated up- and downvalley at waterhole ends by stock pads. Devegetation and flow concentration along roads is a very destructive force. Establishment of connectivity between distant waterholes, along a valley with steep enough gradient to propagate gully networks, is an especially destructive force. Some river reaches are predisposed to gullying and entrenchment by their tectonic context.
Wakelin-King (2013)	SA (Cooper Creek)	Geomorphological assessment and analysis of the Cooper Creek catchment (SA) A key pressure that affects geomorphology of key lakes, swamps, and waterholes is a lack of understanding of what the main flow paths look like in this very diffuse system. As a result, infrastructure has been constructed (all-weather roads on raised bunds) which was occluding primary flow paths. Some ameliorative structures have been installed but the solutions are incomplete. Also, culvert and bridge design which concentrates flow creates erosion which can propagate along the river network – the design is based on temperate-zone river processes, is inappropriate for drylands rivers. Demonstrates impacts of oil and gas infrastructure on wetlands, floodplains and rivers. Aerial images show flow paths blocked and density of seismic lines

Reference	Region	Summary
		through wetlands. Notes the lack of documentation of infrastructure on the floodplains hampers best management.
Walsh (2009)	Qld (LEB)	Enhancing biodiversity hotspots along western Queensland stock routes: Desert Channels NRM Region Presents information for localised pest (i.e. weed and feral animal) threats and damage within biodiversity hotspots along regional stockroutes. Relevance: Lists threats to identified 'biodiversity hotspots' and management actions, and presents and suggests future actions, methods for the identification of the hotspots is described.
Water & Rivers Commission (no date)	WA	Water Quality Protection Guidelines No. 6 for Mining and Mineral Processing – Minesite stormwater Stormwater run-off may carry suspended solids to water sources. Stormwater management design should prevent contamination of water resources. This should include diverting run-off from surrounding areas around the mine site. Stormwater infrastructure design should also ensure there is no erosion due to run-off. Acidification is a risk if the water passes through sulfidic soils. Stormwater run-off should be used as a resource, such as for dust suppression and rehabilitation.
Williams et al. (2012)	National	An analysis of CSG production and NRM in Australia Surface-water and Groundwater Impacts • Potential impacts on water resources are most significant (*cf* other NRM issues). Priority issues for surface water systems are: • Impacts of de-pressurisation on groundwater movement between strata o Extraction is greatest at beginning of operations and then reduces, with most operations lasting 20-40 years • Replacement of extracted water once operations cease – source? • Disposal of extracted water during dewatering o Extracted water typically saline and alkaline therefore treatment often involves desalinisation; brines and 'fraccing fluids' still need to be managed • Management and disposal of 'fraccing' fluids and brines and slurries o Evaporation ponds were initially used in CSG operations but are now not allowed in Qld & NSW. o Most cost-effective disposal option is injection into suitable formations. Other NRM impacts: • Biodiversity & landscape (terrestrial) – further fragmentation • Impacts on productive landscape – irrigation and cropping poorly compatible • Air emissions – gas is cleaner energy, however potential for leaks and more whole of life energy analysis required; climate change with feedback via rainfall to water resources Economic and social impacts: • Economic – benefits skewed towards cities and large regional centres with costs borne by small regional centres, particularly Indigenous

Reference	Region	Summary
		people. • Social – much research into this topic Note: The comments are largely unsupported by references, and many statements (which are intended to be understood as observations) are unattributed. There are parts which mention subsidence but nothing at all meaningful. The report doesn't distinguish well between deep aquifers and groundwater, not does it adequately deal with connectedness or otherwise between aquifers. There seems to be little recognition of existing regulatory mechanisms, nor does it distinguish between lack of regulation, and lack of enforcement of existing regulations. The report is a valuable articulation of the things the wider community is concerned about.
Wilson et al. (2014)	SA	Assessment of vulnerability of water assets to hydrological change caused by coal seam gas and large coal mining development in South Australia The following CSG and coal mining activities (equivalent to pressures) are used in the vulnerability assessment: • Unconventional gas activities • Groundwater dewatering and extraction • Managed aquifer recharge • Surface water extraction • Surface water diversion and capture (no extraction) • Discharge to surface water • Site run-off • Site establishment and traffic (vehicular and foot) • Well drilling (exploration and groundwater) • Overburden management • Hydraulic fracturing • Evaporation ponds and tailings dams.

3.2.2. Stressors

Reference	Region	Summary
Blodgett & Kuipers (2002)	International	Technical Report on Underground Hard-Rock Mining: Subsidence and Hydrologic Environmental Impacts Subsidence an unavoidable consequence of mining. Types of subsidence are: • Cracks, fissures, or step fractures • Pits or sinkholes • Troughs or sags. Subsidence can impact groundwater aquifer integrity, SW-GW connectivity, SW flows, eg cause depressurisation of confined aquifers, cause SW systems to drain into ground. Subsidence is largely unavoidable consequence of hard rock mining. Dewatering may also lead to subsidence. Factors that affect subsidence include groundwater; nature of overburden; surface and near-surface geology; degree of extraction; surface topography; ground water; mining method; and backfilling.

Reference	Region	Summary
Box et al. (2008)	Central Australia	Central Australian waterbodies: the importance of permanence in a desert landscape Reviews the importance of permanent water in arid environments, contains chapters on factors that influence water permanence in central Australia. Covers: • Climate change • Invasive flora species • Invasive animal and domestic stock.
Bunn et al. (2006)	Cooper Ck	Flow variability in dryland rivers: boom, bust and the bits in between. Stressors covered : • Habitat removal or disturbance and fragmentation —in-stream • Surface water regime • Water quantity • Flow management • Surface water/groundwater connectivity • Connectivity • Biota removal/disturbance.
Clifford et al. 2010	Qld (LEB)	SEAP Lake Eyre and Bulloo Province Stressor Prioritisation Workshop Report Of 15 stressors identified under the SEAP framework (Negus et al. 2009), an expert workshop approach ranked riparian pest fauna as a moderate risk and instream pest fauna as high risk. All other stressors were ranked as low risk. Builds on the basic Vector/Stressor models developed by Marshall et al. (2006a).
Commonwealth of Australia (2014a)	National	Co-produced water – risks to aquatic ecosystems, background review Key risks associated with discharging co-produced water are salinity, toxicity and changes to flow regimes, especially for ephemeral streams. Treatment of co-produced water can result in it being of lower turbidity and salinity than naturally occurs in watercourses. The effects of multiple toxicants on biota are unknown and difficult to predict and water quality guidelines are not available for all contaminants.
Commonwealth of Australia (2014b)	National	*Subsidence from coal seam gas extraction in Australia, Background review* No cases of subsidence resulting from CSG have been documented in Australia however the maximum predicted subsidence is 280mm. Whilst this is small (especially compared with subsidence seen under long wall mining) it may occur over large areas with potential impacts on surface drainage in some situations. Subsidence is least likely least likely where gas recovery involves minimal volumes of co-produced water, there is limited connectivity between the coal seams and adjoining formations, and the overlying strata are dominated by sandstone and other more competent (strong) rocks.
Costelloe (2011a,b)	SA (LEB, Neales)	Hydrological assessment and analysis of the Neales Catchment (and update) The main refugia waterhole in the Neales, Algebuckina Waterhole, was shown to have experienced significant variations in its cease-to-flow depth due to sedimentation and scouring processes. During a relatively dry period with mainly small flow events (2003-2009), the cease-to-flow depth of Algebuckina decreased from 4.4 m to 3.45 m. However, the approximately 1:10 year flood in February 2011

Reference	Region	Summary
		scoured the waterhole and the cease-to-flow depth increased again to approximately 4.7 m. Changes in the morphology of other significant waterholes was not observed but this involved a less robust dataset than available for Algebuckina Waterhole.
Costelloe et al. (2004)	LEB	ARIDFLO Various chapters: • Hydrology (hydro-chemistry, flow regime, waterhole morphology) • Biology (algae, invertebrates, fish, waterbirds) • Some information superceded by subsequent project reports.
Davis et al. (2010)	USA	Effects of coalbed natural gas development on fish assemblages in tributary streams of the Powder andTongue rivers Case study of CSG impacts on Northern USA fish assemblages.
Day et al. (2014)	National	Field measurements of fugitive emissions from equipment and well casings in Australian CSG production facilities Measured methane emissions from 43 CSG wells in NSW and Queensland. Methane emissions were recorded at 40 wells, but mostly emission rates were very low. The authors note that only a small number of wells were sampled and may have been too few to be representative. This was the first time methane emissions have been sampled in Australia.
DITR (2008)	National	Leading Practice Sustainable Development Program for the Mining Industry: Water Management Changes to downstream flow regimes resulting from mine sites. Changes to flow may result in facilitating spread and establishment of pest species. Barriers to biota can include chemical barriers as well as physical, i.e. from point disposal site, even if that disposal is diluted downstream.
Eco Logical Australia (2011)	NSW (Namoi)	Proposed Framework for Assessing the Cumulative Risk of Mining on NR Assets in the Namoi Catchment Identify impacts of mining: 'physical impact' = pressure, 'environmental impact' = stressor, 'ecological/agricultural impact' = response; primary and secondary impacts of the mine, primary and secondary impact zones. Water resource impacts of open cut coal mining (see Table 4, pp. 27–28): • Primary impacts: establishment of tailings dams • Secondary Impacts o Groundwater: depressurisation of confined aquifers, lowering of watertable, change in groundwater flow paths; management of water as per CSG o Surface water: alteration of land surface, altered hydrology/diversion, extraction for maintenance activities (e.g. dust suppression), erosion and sediment deposition, chemical pollution Water resource impacts of CSG (see Table 9, pp. 48–49)

Reference	Region	Summary
		• Primary impacts: groundwater drawdown and impacts on inter-aquifer connectivity • Secondary impacts: o Groundwater depressurisation and drawdown o Groundwater contamination (low risk based on GA & Habermehl (2010) and Moran & Vink (2010) but this assessment disputed by DEA (2011)) o Fraccing: fluid leakoff (contamination if using chemicals; gas leakage into adjacent aquifers; liberation of natural chemicals, greatest risk is from well failure; well failure which is more likely under repeated fracturing o Surface subsidence (as per Moran & Vink 2010) o Surface water flow (extraction, SW-GW connectivity & disposal) o SW contamination – flowback following fraccing carries fraccing fluids which are usually higher in TDS, BTEX, ions than co-produced water; risks of releases, leaks, spills resulting in SW contamination from storage and transport water ➔ Qld govt banned use of evaporation CSG dams in 2011; risks of stored chemicals spilled during transport, fires, vandalism, impoundment failures o GDE impacts discussed.
Farag et al. (2010)	Inter-national	Potential effects of coalbed natural gas development on fish and aquatic resources (Coalbed natural gas = CSG) Water Quality Issues: Quality of groundwater water being extracted – varies and depends on source and capacity to treat; Deeper older waters tend to have higher TDS. Water quality impacts on fish and aquatic resources include: • direct toxicity issues (mostly due to salinity) if discharged into watercourse or irrigation run-off • indirect impacts from irrigation such as altering soil properties (i.e. sodicity arising from irrigation leading to soil degradation and erosion) • Potential for bioaccumulation of trace elements especially where migratory birds utilise impoundments where trace elements levels may increase over time • Species may be more susceptible at certain life history stages (larval/juvenile) • Potential for contamination of water resources from drilling fluids. Water Quantity Issues • Alteration of surface hydrology altering seasonality and connectivity, shift from ephemeral to perennial systems • altered range of habitats and vegetation of habitats; reduced diversity of habitats • cooler water temperatures (due to increased depth) • non-native species may be favoured.
GA & Habermehl (2010)	Qld	Summary of advice in relation to the potential impacts of CSG extraction in the Surat & Bowen Basins Reviewed EIS's for three proposed CSG developments.

Reference	Region	Summary
		Highlight the uncertainty around cumulative, regional-scale risks of multiple developments. Low likelihood of cross-contamination because depressurisation will draw water from any connected aquifers into the coal measures. Consider risks of fraccing impacting structural integrity of aquifers is low. Consider risks to SW & GW from subsidence is low based on estimated magnitude in order of a few to tens of centimetres. Note many of the GW issues and recommendations have in part been addressed by QWC risk assessment for Surat and Bowen
Kimmel & Argent (2012)	USA	Status of Fish and Macroinvertebrate Communities in a Watershed Experiencing High Rates of Fossil Fuel Extraction: Tenmile Creek, a Major Monongahela River Tributary Case study of CSG effects on fish and (briefly) macroinvertebrates. Considers salinity and finds these fish communities more robust than EPA regulations suggest.
Kingsford et al. (2010)	National	Australian waterbirds – time and space travellers in dynamic desert landscapes Two most important things for waterbird conservation are the rehabilitation of flows in regulated rivers and protection of naturally flowing rivers in arid regions
Leigh et al. (2010)	LEB	Sequential floods drive 'booms' and wetland persistence in dryland rivers: a synthesis Flood clusters - Disruption of clusters would reduce the frequency and duration of inundation, impacting biota/ecological processes that depend on longer duration/higher frequency flows. Conceptual diagram showing impact of extraction on flows.
Marshall et al. (2006a)	Qld	Development of conceptual PVR models for Qld's riverine ecosystems Identifies 15 'common' vectors (=stressors) for Qld riverine ecosystems for which PSR models are developed. The vectors relate to pressures from all potential stresssors and are therefore are broader than those used in the LEBRM.
McNeil et al. (2011)	SA (LEB, Neales)	Climate variability, fish and the role of refuge waterholes in the Neales River catchment Details the role of refuge habitats with regards to fish within the Neales River catchment during drought and post drought periods. Outlines climatic stresses upon aquatic ecosystems during times of drought. Describes pest fish species in and around the Arkaringa and Pedirka basins. Details fish response to variable flow and their tolerance to salinity.
Moran & Vink (2010)	MDB	Assessment of impacts of proposed CSG operations on surface and groundwater systems in the MDB Where water flows have been reduced through extraction/diversion (i.e. for agriculture), discharges into watercourses may return parts of the EWRs although

Reference	Region	Summary
		water quality issues remain. Impacts to SW systems via alluviums overlying aquifers where extraction occurs, causing watertables drop in the alluvium. Notes drawdown from CSG may be significantly less than has resulted from extraction for agriculture. Subsidence resulting from depressurisation could be important where low relief systems (eg floodplains) are impacted; expected that the depth of subsidence may be small (relative to long-wall mining) but spatial extent significant.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial Stressors discussed: • Feral species • Weeds • Surface water regime • Water quantity • Flow management • Surface water / groundwater connectivity • Connectivity • Biota removal / disturbance.
NSWDP (2008)	NSW	Impacts of underground coal mining on natural features in the Southern Coalfield: strategic review Subsidence land surface impacts may include buckling, troughs, cracking of rock strata. Environmental consequences of subsidence impacts include loss of surface flows to the subsurface or redirection, loss of standing pools, adverse water quality impacts, development of iron bacterial mats, cliff falls and rock falls, damage to Aboriginal heritage sites, impacts on aquatic ecology, ponding.
Piddocke (2009)	Qld & SA (Cooper Creek)	Historical Collation of Waterbody Information in the LEB Catchments for Qld and SA Anecdotal and empirical evidence strongly suggests that deposition of eroded regolith resulting from overgrazing in the late nineteenth century, has resulted in localised reductions in waterbody permanence.
Reid et al. (2009)	National (Eastern Australia)	Catalogue of conceptual models for groundwater–stream interaction Pressure-stressor relationships
Rogers et al. (2011)	Qld (MDB)	Stream ecosystem health response to CSG water release: salinity guidelines The 75th percentile level of electrical conductivity recorded for the relevant sub-basins is recommended as appropriate upper limit guideline until such time as more relevant local information becomes available. There is a lack of information on which to base a lower salinity guideline, but the 25th percentile level from the Queensland Water Quality Guideline is recommended as an interim guideline.
Rolls et al. (2012)	National	Review of literature quantifying ecological responses to low flows Developed principles to describe the effects of low flow on aquatic ecology that can be used to predict ecosystem responses – both as a result of altered flow regimes

Reference	Region	Summary
		and naturally through the onset of drought – and include recognition of the response with the initial onset of low flows, along with longer-term effects and the process of recovery (Figure 5). The principles are: • Ecological low-flow principle 1: Low flows control the physical extent and arrangement of aquatic habitat, therefore influencing ecological patterns and processes. • Ecological low-flow principle 2: Low flows influence physical and biological conditions in remaining aquatic habitats, which drives changes in ecosystem patterns and processes. • Ecological low-flow principle 3: Low flows affect the sources and exchange of energy in aquatic ecosystems, altering ecosystem production and biotic composition. • Ecological low-flow principle 4: Low flows restrict dispersal, influencing multi-scale ecological patterns and processes and increasing the importance of refugia to sustain biota.
Scholz & Deane (2011)	SA (LEB, Neales)	Prioritising waterholes of ecological significance in the Neales and Peake catchments Vegetation at several major water holes assessed. Results showed that, superimposed on the main ecosystem drivers of hydrology and salinity, sites were found to have varying impact levels depending largely on grazing and tourism history. Grazing was observed to impact on the vegetation structure and species diversity (with less-palatable species dominating). Visitation to the sites had a greater impact on the landscape through compaction and soil erosion from vehicular and traffic access, while the overstorey species *Eucalyptus coolabah* were impacted from being selectively cut for fire wood.
Sheldon & Fellows (2010)	Cooper	Water quality in two Australian dryland rivers: spatial and temporal variability and the role of flow Found that the greatest spatial variability in water quality occurred during no flow and that temporal changes in water quality driven by flow. Compared bicarbonates/sodium chloride dominated systems.
Sheldon et al. (2010)	LEB	Any change in flow variability is likely to affect connection frequency and permanency of waterholes will impact diversity, resilience and capacity of biota to respond to floods. Small to medium flows important for maintaining waterholes between major flow events due to lack of groundwater inputs (Cooper Channel Country).
Smythe-McGuiness et al. (2012)	Qld	Macroinvertebrate responses to altered low-flow hydrology in Queensland rivers Identifies hydrological stressors associated with flow-related pressures, for macroinvertebrate communities in Qld: • Loss of riffle habitat • Replace low flows with high flows (i.e. dam releases) • Replace variable flows with stable flows • Interruption of baseflow • Reduced water quality • Loss of surface water volume • Interbasin transfer of biota • Additional water to temporary streams • Overall reduction in flows

Reference	Region	Summary
		• Increased frequency in extreme event s(i.e. flood, drought).
Takahashi et al. (2011a)	Qld (MDB)	Stream ecosystem health response to CSG water release: direct toxicity assessment A direct toxicity assessment (DTA) using laboratory organisms was conducted using both raw and treated CSG water. Most organisms were sensitive to raw CSG water whilst only macro-invertebrates were sensitive to treated CSG water with low EC of 50 µS/cm. Overall, the lowest EC threshold was estimated to be 120 µS/cm for laboratory organisms. It is speculated that ionic composition also affected the toxicity of the treated CSG water as the composition was skewed towards sodium. When water quality indicators, such as alkalinity and turbidity of the treated CSG water were compared to those of the receiving water, significant differences were apparent.
Takahashi et al. (2011b)	Qld (MDB)	Stream ecosystem health response to CSG water release: biological monitoring guidelines Key stressors identified from CSG operations include: • Decrease in dry spells • Constant flow and decrease in seasonality • Decrease in EC • Increase in transparency of the water • Changes in ionic composition of the water • Cumulative toxilogical impacts from contaminants. Recommendations include: • Conducting literature review to produce list of organisms, ecosystem processes and key places sensitive to stressors. • Produce conceptual models of effects of stressors on biological indicators. • Develop monitoring to incorporate duration, frequency etc. to capture effects of CSG operations.
Wakelin-King 2010, 2013	LEB	Geomorphological assessment and analysis of the Neales (2010) and Cooper (2013) Catchments Changes to landforms which disrupt the geomorphic processes that maintain landforms (and thus habitat). Riparian devegetation, other devegetation, construction of linear disturbances (fencelines, stock pads, tracks, roads, firebreaks), flow concentration (bridge abutments, culverts), occlusion or impoundment at the main flow path, flow diversion.
Williams et al. (2012)	National	An analysis of CSG production and NRM in Australia Surface water and groundwater impacts • Impacts of de-pressurisation on groundwater movement between strata: o Direction of flow will be towards de-pressurised aquifers from aquifers above/below (depending on permeability of aquitards) o Potential to increase loss from losing streams, reduce flow to gaining streams to extent of reversing and making losing o Because flow is towards coal measures little risk of GW contamination o Land subsidence is a risk and has occurred, potential to affect SW systems (gradients), irrigation, terrestrial ecosystems etc, projections for Surat were around 30 cm, drops of metres has been observed

Reference	Region	Summary
		around some wells • Disposal of extracted water during dewatering: o Altered hydrology o Water quality impacts including potential 'clean water' pollution to naturally turbid systems • Management and disposal of 'fraccing' fluids and brines and slurries: likely contaminants include heavy metals, radionuclides that are naturally present in GWs but become concentrated
Wilson et al. (2014)	SA	Assessment of vulnerability of water assets to hydrological change caused by coal seam gas and large coal mining development in South Australia Effects that are the potential hydrological changes to a water asset that may occur as a result of a CSG or LCM development: • Surface water / groundwater connectivity • Physical habitat (geomorphic structure and organic habitat components) • Water quantity (volume available to an asset) • Surface water regime (timing, duration, frequency, extent and depth) • Water quality [and chemistry] • Groundwater flow patterns • Groundwater pressure • Aquifer structural integrity • Functional connectivity of surface water

3.3. Aquatic ecosystems and their attributes

3.3.1. Components

3.3.1.1. Physical habitat and geomorphological components

Reference	Region	Summary
Arthington et al. (2005)	Qld (Cooper Creek)	Spatial and temporal variation in fish-assemblage structure in isolated waterholes during the 2001 dry season of an arid-zone floodplain river, Cooper Creek, Australia This study examined the spatial and temporal variation in fish-assemblage structure within isolated waterholes on the floodplains of Cooper Creek. Waterhole physical characteristics were measured as part of the study, with 38 variables measured across three scales (floodplain, waterhole, within waterhole). These variables were then linked to fish assemblage structure across different spatial and temporal scales.
Costelloe (2011a,b)	SA (Neales)	Hydrological assessment and analysis of the Neales Catchment This reports the findings of the SAAL NRMB 'Critical Refugia' project for the Neales River. All significant (i.e. named, known from previous studies, described by local landholders) waterbodies in the Neales (with the exception of the lowermost reach near Kati Thanda-Lake Eyre) were characterised by depth (including ARIDFLO and this study), width and legth. The waterbodies were categorised into fluvial (waterholes), springs (including spring-fed pools), bore drains and dams. Not all springs, bore drains and dams in the catchment were characterised. The persistence of waterholes was largely a function of its maximum cease-to-flow depth and the time since the last filling. The study showed that Algebuckina waterhole, which had been the deepest waterhole in 2003, had decreased in depth by a metre and was not the deepest waterhole in 2009. However, following a flood in early 2010, sediment was scoured out and the waterhole was slightly deeper than in 2003.
Costelloe et al. (2004)	LEB	ARIDFLO The ARIDFLO report provided morphological and hydrological information on the 56 waterbodies sampled by this project, spread across five river reaches. The morphological information included bankfull depth and width and cease-to-flow depth. The riparian vegetation was also found to show vertical zonation influenced by these measures. For instance, Coolabahs typically occurred near the bank-top position while the lignum typically occurred at and above the cease-to-flow point. These data indicate that deep waterholes are relatively rare in the LEB, with the deepest being Cullyamurra Waterhole on Cooper Creek. In terms of catchment-scale importance, Algebuckina Waterhole on the Neales River stands out as being substantially deeper than other waterholes in this catchment.
Costelloe & Russel (2014)	Neales	*Identifying conservation priorities for aquatic refugia in an arid zone, ephemeral catchment: a hydrological approach*

Reference	Region	Summary
		Provides an overview of the distribution of aquatic refugia in the Neales catchment and their hydrological and salinity characteristics and influences. No correlation between catchment position and refugia, rather this is a function of local geology. Notes that Algebuckina does not show any evidence of receiving groundwater and more likely to be losing.
Davis et al. (2002)	Cooper Creek	Physical and ecological associations in dryland refugia: waterholes of the Cooper Creek, Australia This paper explores how morphological features may influence ecosystem processes within waterholes. Fourteen waterholes along the Cooper Creek system were characterised using a suite of morphological variables at three scales (landscape, entire waterhole, within waterhole), using both field and remote sensing techniques. In particular, links between the morphology and water quality, biological productivity and aquatic food webs are discussed: 'it was found that the maximum fetch length was an important variable that separated waterholes into two groups. Water turbidity of these two groups of waterholes was different, as were rates of benthic production and respiration. Benthic production and therefore energy available to support the food webs of these waterholes was greater in the group of waterholes with shorter fetch lengths and lower turbidity.'
Deane & Walters (2008)	SA (Lake Frome)	Baseline survey of refugia pools in the north-eastern Willochra Creek and western Lake Frome Catchments Baseline mapping of permanent aquatic refugia habitat within the Willochra Creek Catchment and the Lake Frome Basin, as far east as the South Australian Arid Lands region. Nineteen permanent pools were identified through consultation, then mapped and surveyed during autumn 2006. Surveys collected data on environmental and biological variables enabling the broad ecological character of pools to be described. A conceptual landscape model predicting the bio-physical character and ecological significance of pools is discussed.
Duguid et al. (2013)	Finke	*Drought Refuges for Native Fish in Parts of Central Australia* Aim of study to identify drought refuges for native fish in Finke River and Dulcie Ranges (flowing north to the upper Diamantina catchment and south to the hay and plenty Rivers), both of which support high fish diversity for arid Australia. Project included identifying and mapping sites and their habitats, surveying for fish and salinity testing. For most sites this was the first fish surveys. Provides descriptions of refuge sites and their habitats and reports on fish survey results. Recommends further surveys in Palmer and Dulcie areas. Results of salinity testing support previous insights into complexity of groundwater-surfacewater interactions in the Finke. More saline sites have less impacts from herbivores.

Reference	Region	Summary
Fernandez et al. (2011)	International	A review of river habitat characterisation methods: indices vs. characterisation protocols This review uses the European Standard for Assessing the Hydromorphological Characteristics of Rivers as a reference benchmark for comparison with more than 50 existing methods of river habitat characterisation globally, included AusRivAS. Found riverine habitats the main focus of characterisation and that further work is required develop methods for describing the physical characteristics of intermittent rivers.
Hamilton et al. (2005)	Cooper	Persistence of aquatic refugia between flow pulses in a dryland river system (Cooper Creek, Australia) Waterhole persistence is largely governed by evaporation processes with mean losses of 2.1 m/y. These results indicated that these waterbodies were not receiving any significant groundwater inputs (in agreement with Cendon et al. 2010) and that waterhole volumes would fall to <10% of bankfull volumes in 6-23 months.
Maddock (1999)	International	The importance of physical habitat assessment for evaluating river health This paper reviews the need for physical habitat assessment and the range of physical habitat assessment methods that have been developed in recent years. It gives background information about physical habitat and its importance, the scale/s of assessment, and methods used.
Marquis & Roy 2011	International	Bridging the gap between turbulence and larger scales of flow motions in rivers ' .. turbulent flow structures ... embedded within increasingly larger flow scales in a self-similar manner ... clustering of turbulent events may be an important control in fish bioenergetics and feeding patterns.' Mechanics of flow turbulence is a factor in fish ecology.
MDBC (2003)	Murray-Darling Basin	Physical Habitat Theme Pilot Audit Technical Report - Sustainable Rivers Audit This document summarises the technical outcomes and development of the Physical Habitat Theme during the Pilot Sustainable Rivers Audit. It includes a description of methods, as well as an evaluation of the indicators used and suggestions for further development and improvement. This document is the Executive Summary only of the physical habitat technical report from the Pilot Sustainable Rivers Audit. The full technical report is available on CD by contacting the office of the Commission. Recommends the Physical Habitat theme be separated into the: • Physical Form theme • Riparian Vegetation theme • Floodplain theme.
Nanson 2010	LEB	The rivers, floodplains and fluvial-wetland characteristics of the Lake Eyre Basin Four dominant riverine regions: • 'Desert Rivers Region" in the northwest draining the central ranges (the

Reference	Region	Summary
		Northern Territory) • 'Channel Country" draining the northeast of the basin from the Barkly tablelands to the Eastern Highlands (western Queensland and eastern Northern Territory) • 'Western Rivers Region" immediately to the west of Kati Thanda-Lake Eyre • 'West of Lake Frome Region" with streams draining the Flinders Ranges (South Australia). Further subgroups are suggested within two of these regions. Geology and climate greatly differentiate the characteristics of these four extensive areas and therefore have an impact on the basin's riverine wetlands. Provides a description of the geomorphology in each region and level of understanding.
Parsons et al. (2002)	National	Australian River Assessment System: AusRivAS Physical Assessment Protocol AUSRIVAS physical assessment protocol is a method for assessing the physical condition of streams and rivers. This document presents the reference site selection and field collection methods. A large number of sites need to be sampled to generate reference condition data and predictive models to enable assessment of physical habitat condition. Data are collected at two spatial scales: a large catchment or segment-scale and a small sampling site scale; large-scale factors are then used to predict the occurrence of small-scale factors. As with the AUSRIVAS method, the methods is focussed around determining condition based on suitability for aquatic macroinvertebrates and is hence biased towards identifying those habitat features relevant for macroinvertebrates. As most river networks in drylands Australia aren't dominated by water-retaining landforms, this protocol is not widely applicable, excluding a range of other types of ephemeral HEVAE.
Parsons et al. (2004)	National	Development Of A Standardised Approach To River Habitat Assessment In Australia Review four physical habitat assessment methods to develop the AUSRIVAS Physical Assessment Protocol as national methodology for assessing river physical habitat. They concluded no single existing method met all the desired requirements for a standardised habitat assessment protocol. On this basis they developed a new methodology using reference condition and predictive models approaches (detailed in Parsons et al. 2002).
Schmarr et al. 2013	Cooper	**Ecological** *Aquatic ecology assessment and analysis of the Cooper Creek, South Australia* 25 sites from Cullyamurra to Kati Thanda-Lake Eyre. Recommend that the Cooper in SA be treated as 3 units for management: permanent refugia in the upper reaches, semi-permanent main branch and north-west branch refugia and ephemeral lower Cooper refugia. Contains brief descriptions of each site including depth, water quality (pH, temperature, turbidity, salinity and DO) and dominant vegetation.

Reference	Region	Summary
Timms (2009)	National	Geomorphology of Lake Basins This book chapter discussed the parameters used to describe lake geomorphology, and expands upon the role of lake geomorphology in limnology. It includes a description of morphometric parameters, as well as a classification of different geomorphic lake types.
Tooth (2000)	National	Process, form and change in dryland rivers: a review of recent research This review has global coverage, but has information relevant to Australian dryland rivers. It outlines the distinctive characteristics of dryland fluvial environments: hillslope and channel hydrological and sediment transport processes, river pattern and geometry, temporal and spatial aspects of channel change, sedimentary structures and bedforms. Key deficiencies in dryland fluvial research are identified.
Wakelin-King & Tooth (in prep.)	NT (Finke)	Floodouts in drylands: forms, processes, and management implications of major fluvial discontinuities. Analyses geomorphic processes of different types of floodouts, and their formative conditions, vulnerabilities, and management implications.
Wakelin-King & Webb (2007)	NT (Finke)	Threshold-dominated fluvial styles in an arid-zone mud-aggregate river: Fowlers Creek Describes floodouts as part of discontinuous fluvial systems, and the co-creative relationship between floodout hydrology and vegetation. These floodouts originate in very large to extreme flow events.
Wakelin-King (1999)	NT (Finke)	Banded mosaic ('tiger bush') and sheetflow plains: a regional mapping approach Banded vegetation is a non-channelled waterway, has no lotic biota but is very important to plant communities, their dependent animals, and also groundwater. Easily destroyed by gullying.
Wakelin-King (2010)	SA (Neales)	Geomorphological assessment and analysis of the Neales Catchment Describes waterholes, anastomosed channels, floodplains, splays; processes and threats. Covers both human-created and natural mechanisms of change.
Wakelin-King (2013)	Cooper	Geomorphological assessment and analysis of the Cooper Creek catchment Describes waterholes, anastomosed channels, floodplains, splays; processes and threats. Covers both human-created and natural mechanisms of change. Includes report on cane toad habitat in the Strzelecki Desert.

3.3.1.2. Water quality components

Reference	Region	Summary
Bailey (2001)	Qld (LEB) &	Western streams water quality monitoring project

Reference	Region	Summary
	Qld	Water was sampled from 1993–2000 in Qld LEB and 1994–95 in the Warrego/Paroo for physiochemical parameters in situ and in the lab. LEB Qld sites generally had low salinity, visual clarity, and dissolved oxygen, and high pH, nutrient and temperature. Similar results were observed in the Warrego/Paroo. Relevance: Project demonstrates the importance of local resident involvement. Surface water quality was noted to be important in a number of other referenced documents, though there are no long-term monitoring projects.
Cockayne et al. (2012, 2013)	LEB	Lake Eyre Basin Rivers Assessment (LEBRA) 2010/2011 & 2011/12 Annual Monitoring Reports Summary of data from spring 2011 and autumn 2012 LEBRA sampling. Water Quality findings summarised. No analysis of data.
Costelloe (2011a)	Neales	Hydrological assessment and analysis of the Neales Catchment This reports the findings of the SAAL NRMB 'Critical Refugia' project for the Neales River. All significant (i.e. named, known from previous studies, described by local landholders) waterbodies in the Neales (with the exception of the lowermost reach near Kati Thanda-Lake Eyre) were characterised. The salinity of fluvial waterholes was used to help identify if groundwater interactions with saline groundwater were significant. Waterholes that were connected with the saline, unconfined groundwater quickly became hypersaline, e.g. Peake Crossing channel where salinities in excess of 200 000 mgL^{-1} TDS have been observed forming within 200 days of the peak of the most recent flow event. These hypersaline conditions are likely to hinder the refugia potential for many of these saline waterholes, despite the groundwater discharge increasing the persistence of the waterbody.
Costelloe et al. (2004)	LEB	ARIDFLO The ARIDFLO report provided morphological and hydrological information on the 56 waterbodies sampled by this project, spread across five river reaches. A range of water quality parameters were measured by the ARIDFLO project at the sampled waterbodies. Most attention was focused on the salinity behaviour as this was found to vary over several orders of magnitude in the SA reaches of the LEB rivers. This is further described in the Water Quality section.
Costelloe & Russel (2014)	Neales	*Identifying conservation priorities for aquatic refugia in an arid zone, ephemeral catchment: a hydrological approach* Provides an overview of the distribution of aquatic refugia in the Neales catchment and their hydrological and salinity characteristics and influences.
Deane & Walters (2008)	SA (Lake Frome)	Baseline survey of refugia pools in the north-eastern Willochra Creek and western Lake Frome Catchments Baseline mapping of permanent aquatic refugia habitat within the Willochra Creek Catchment and the Lake Frome Basin, as far east as the South Australian Arid Lands region. Nineteen permanent pools were identified through consultation, then mapped and surveyed during autumn 2006. Water quality

Reference	Region	Summary
		was highly variable between sites and through time, but was generally of moderate to high salinity. Mean electrical conductivity (EC) observed at the autumn 2006 survey sites was 8812 EC. Acidity of pools ranged from neutral to moderately alkaline, a mean value of 7.5 observed for survey sites
DERM (2011e)	Qld (LEB)	Ambient Surface Water Quality in Queensland 2004–8 Summary Report Summarises water quality monitoring collected from July 2004 to June 2008 by catchment, with LEB and Bulloo presented. Data includes electrical conductivity (EC), total nitrogen (TN), total phosphorus (TP) and turbidity. For the LEB and Bulloo: data availability was poor, and no Qld Water Quality Guidelines exist. EC levels showed significant variability, and turbidity was generally higher in the lower reaches.
Duguid (2013a)	NT	Delineation and Description of Ecological Character of the Mid-Finke Waterholes: A Trial of Guidelines for HEVAEs Salinity of waterholes found to vary from below 1,000 µS/cm to over 50,000 µS/cm.
Eberhard (2003)	Qld (LEB, Georgina)	Nowranie Caves and the Camooweal Karst Area, Queensland: hydrology, geomorphology and Speleogenesis, with notes on aquatic biota. Discusses detailed surface drainage, groundwater flow, aquatic biota and physiochemical water quality associated with the Karst area in the NE Georgina Basin
Goonan et al. (2003)	SA (LEB)	River health in the far north Brief summary brochure for AUSRIVAS monitoring in the LEB rivers within SA. The brochure identifies the sampling sites and summarises results. Most LEB sites are in good 'reference' condition but the saline sites were outside the parameters of the AUSRIVAS models.
Humphery (1996)	Qld (LEB) & Qld	Western streams water quality monitoring project, Lake Eyre catchment and Warrego/Paroo catchment Physiochemical parameters of LEB and Warrego/Paroo Rivers were monitored. Results presented the variability of these systems, and the timing of sampling has a large potential to influence the results. Relevance: Baseline water quality.
Irvine et al. (2006)	Qld (Diamantina)	Salt and water flux in an intermittent arid zone river: the role of the floodplain environment Chemical and isotope data showed spatially variable recharge during flow events in the Warburton River.
Larsen (2012)	SA & Qld (Cooper Creek, Diamantina-Georgina)	Aspects of the contemporary and Quaternary hydrology of the Lake Eyre Basin A PhD thesis. Chapter 2 examines dissolved ion compositions in Cooper Creek and the Georgina-Diamantina catchment using DERM data. Analysis found that the total dissolved solids (TDS) of flow in the Queensland reaches of these rivers is low (<150 mgL^{-1}) in comparison to the Murray-Darling Basin and many other

Reference	Region	Summary
		dryland rivers of the world. Similar to Sheldon and Fellows (2010), the dominant anion was bicarbonate.
McNeil et al. (2011)	Western Rivers (Neales)	Climatic variability, fish and the role of refuge waterholes in the Neales River Catchment Provides water quality observations for the sampling in the Neales catchment and also on the responses of fish to salinity and hypoxia, based on field experimental data.
Read (2011)	NT (Finke)	Hydrogeology of the Finke River Report provides information on river salinities and chemical composition during low flows and cease-to-flow in the Finke River. Data on waterholes were found to be moderately saline (<10 000 mg/L TDS) and at its highest in the more downstream waterholes. The salinity of the standing waterholes does not appear to reach the very high levels seen in the Neales and this is likely due to the alluvial groundwater of the Finke only have low-moderate salinity (due to fluvial recharge) compared to the hypersaline conditions found in the saline reaches of the Neales. Major anion analysis in the Finke did not reveal any clear trends.
Sheldon and Fellows (2010)	Cooper Creek	Water quality in two Australian dryland rivers: spatial and temporal variability and the role of flow Water quality data from the Channel Country reach of Cooper Creek were analysed. While conductivity was low (mean<350 EC), particularly relative to lower reaches of LEB, the composition was variable, particularly between the flow and non-flow sampling times. The composition of the water was Na-Ca-HCO_3 dominant. The paper concludes that 'Such extreme spatial and temporal variability hampers successful derivation of water quality guidelines for these variable rivers and suggests such guidelines would need to be developed with respect to 'flow phase'.'

3.3.1.3. Hydrological components

Reference	Region	Summary
Bryant et al. (2010)	Qld (inc. LEB)	Soil indicators of Queensland wetlands: Statewide assessment and methodology Sampled nine sites within the Qld LEB to validate proposed wetland soil indicators. Soil profiles were described and sampled to 1 m depth; and a key to identify wetlands using soil indicators was developed. Soil indicators for a number of arid climate wetlands in the LEB (Palustrine and Lacustrine) are discussed. Indicators outside of the LEB are relatively uniform, however within the LEB, due to the fluctuation of flows these indicators can be less pronounced. Within semi arid and arid areas of the state, one of the most useful identifiers was the presence of depleted soil matrix chroma.

Reference	Region	Summary
		Relevance: Contains methods for the identification of wetlands and the assessment of their soil and hydrology.
Bunn et al. (2006)	Cooper Ck	Flow variability in dryland rivers: boom, bust and the bits in between. Review of the influence of flow variability on refugia waterholes within Cooper Creek Relevance: Indicates changes that may occur from flow regulation (dam and release gradually for downstream consumption)
Costelloe (2008)	LEB	Updating and analysis of the ARIDFLO water level data in the Lake Eyre Basin Hydrological attributes – for some catchments more up to date reports exist
Costelloe (2011)	Neales	Hydrological assessment and analysis of the Neales Catchment This reports the findings of the SAAL NRMB 'Critical Refugia' project for the Neales River. All significant (i.e. named, known from previous studies, described by local landholders) waterbodies in the Neales (with the exception of the lowermost reach near Kati Thanda-Lake Eyre) were characterised. The waterbodies were categorised into fluvial (waterholes), springs (including spring-fed pools), bore drains and dams. Not all springs, bore drains and dams in the catchment were characterised. The persistence of waterbodies was evaluated with the assistance of field data and evaporation modelling. The evaporation modelling confirmed an earlier study (Costelloe et al. 2007a) that water loss rates in most fluvial waterholes was governed by evaporation and so the persistence of the waterhole was largely a function of its maximum cease-to-flow depth and the time since the last filling. Some of waterholes were found to be leaky (i.e. South Stewart and Stewart) and their loss rates were significantly greater than the mean areal potential evaporation rate. This study shows the benefits of collecting time series of data for stage and salinity in key monitored waterholes and this is a key part of the LEBRA monitoring.
Costelloe et al. (2004)	LEB	ARIDFLO The ARIDFLO report provided morphological and hydrological information on the 56 waterbodies sampled by this project, spread across five river reaches. A range of long-term hydrological variables were calculated for these waterbodies, particularly the frequency of flooding and drying. These latter variables have been found to have strong predictive value for aspects of the fish and macroinvertebrate assemblages by Puckridge et al. (2010).
Costelloe & Russel	Neales	*Identifying conservation priorities for aquatic refugia in an arid zone,*

Reference	Region	Summary
(2014)		*ephemeral catchment: a hydrological approach* Provides an overview of the distribution of aquatic refugia in the Neales catchment and their hydrological and salinity characteristics and influences.
DERM (2011)	Qld	Ambient Surface Water Quality in Queensland: 2004-8 Summary Report Overview of results from DERMs Surface Water Ambient Network (SWAN), reported for aquatic environments in nine aquatic ecosystem provinces of Qld using water quality data collected from July 2004 to June 2008. Data includes electrical conductivity (EC), total nitrogen (TN), total phosphorus (TP) and turbidity. For the LEB and Bulloo: data availability was poor, and no QWQGs exist. EC levels showed significant variability, and turbidity was generally higher in the lower reaches. Nutrient data was not covered. Trends were associated with climatic influences and local impacts.
Eberhard (2003)	Qld (LEB, Georgina)	Nowranie Caves and the Camooweal Karst Area, Queensland: hydrology, geomorphology and Speleogenesis, with notes on aquatic biota. Discusses detailed surface drainage, groundwater flow, aquatic biota and physiochemical water quality associated with the Karst area in the NE Georgina Basin. Relevance: As above.
Kingsford et al. (1999)	LEB	Water flows on Cooper Creek in arid Australia determine `boom' and `bust' periods for waterbirds Used flow and rain data to predict the lower Cooper fills every 4.5 yrs, Kati Thanda-Lake Eyre filled 8 in 100 years (1:13), Lake Blanche 6 in 100 (1:17) and Lake Callabonna 4 in 100 (1:25). Some Lower Cooper lakes held water for 4-5 years.
Sheldon et al. (2010)	LEB	Ecological roles and threats to aquatic refugia in arid landscapes: dryland river waterholes A mosaic of refugia with different connection regimes are required to support full suite of species.
Silcock (2009a)	Cooper Creek, Georgina-Diamantina	Identification of permanent refuge waterbodies in the Cooper Creek and Georgina-Diamantina river catchments for Queensland and South Australia Most waterholes occur on major channels, but their distribution is patchy. Based on the density of permanent waterholes, the Cooper Catchment contains the six 'wettest' reaches in the LEB, including Cooper Creek below Windorah and the lower reaches of the Thomson and Barcoo Rivers. The Roxborough Downs-Glenormiston and Roseberth-Durrie channels are the most well-watered in the Georgina and Diamantina catchments, respectively. In contrast, the lower Cooper beyond Coongie Lakes is the driest reach in the study area, with no >70% waters along its entire 340 km length. All other very dry reaches (i.e. those with <1 permanent waterhole per 100 km) occur in the two western catchments. Long reaches with no permanent water include the Mulligan River/Eyre Creek system in the far west, the upper Georgina River, Warburton River after Goyder Lagoon and

Reference	Region	Summary
		most of Farrars Creek. Since European settlement, the distribution and permanence of water has changed dramatically. Some water sources have declined in abundance and/or permanence, primarily through silting of waterholes and loss of springs.
Timms (1998)	Qld (Western)	A Study of Lake Wyara, an episodically filled saline lake in southwest Queensland, Australia A 10 year study of detailed limnology for Lake Wyara, with focus on hydrological and biological conditions. Discussion with close reference and comparison to Kati Thanda-Lake Eyre. At 'full level' the lake is hyposaline and contains a number of freshwater species. As it dries salinity increases and fewer species remain, being zooplanktonic. Above 60 g/L salt no aquatic species are present within the water. Birds frequent the lake in wet periods. Relevance: Describes the limnology of an episodically inundated lake.
Townsend (2002)	Qld (Longreach)	Seasonal evaporative concentration of an extremely turbid water-body in the semiarid tropics of Australia Monitored water quality (turbidity, EC, DO, TP, TN, Chl.a,) in Longreach Waterhole over one dry season to measure the impacts of evaporative concentration. Evaporative concentration increased EC, total solids, phosphorus and nitrogen. Elevated nutrients were not accompanied by elevated phytoplankton biomass. The need to relate water quality monitoring and investigations to the hydrologic histories of other arid water-bodies is emphasised.

3.3.1.4. Biological components

Multiple biotic groups

Reference	Region	Summary
Bailey (2003)	Qld (LEB)	Biodiversity overview information for Desert Channels Queensland Biodiversity of the desert channels is discussed, listing species with legislative or other threatened recognition, protected areas and threatening processes to the environment in the area. Any threat to riparian and wetland areas is a threat to the survival of aquatic species. The major information gaps for the Desert Channels Queensland planning region are: ecological and life history data and systematic surveys. Both of which need more direct cost-effective investment in biodiversity conservation activities. Relevance: Highlights knowledge gaps, being ecological and life history data, in addition to the need for systematic surveys to direct cost effective management actions.

Reference	Region	Summary
Bailey et al. (2001)	Qld (LEB)	Wetland, fish and habitat survey in the Lake Eyre Basin, Queensland: Final Report Waterhole and surrounding selected biota was surveyed along with bank condition and physiochemical parameters of 12 LEB Qld sites. The distribution of the Emerald-spotted Treefrog (*Litoria peronii*) is under review and the range of the Northern Rosella was extended to within the LEB. Relevance: Presents trends in abundance and distribution of fish in Qld LEB
Box et al. (2008)	Central Australia	Central Australian waterbodies: the importance of permanence in a desert landscape This paper reviews the historical and current knowledge about the importance of permanent water in arid environments, including chapters on biological attributes. Includes a broad overview of the number and types of species throughout central Australia and their reliance on permanent water sources. These species groups include: • Macroinvertebrates • Fish • Fauna • Flora. The paper covers an area described as central Australia which is defined arbitrarily here as the Northern Territory south of 20 degrees. Posits that the isolation and unique hydrology water quality of waterbodies in Central Australia as well as their unique hydrological and physio-chemical conditions has contributed to high levels of endemism and unique communities.
Deane & Walters (2008)	SA (Lake Frome)	Baseline survey of refugia pools in the north-eastern Willochra Creek and western Lake Frome Catchments Midges (family: Chironomidae) were the dominant taxonomic grouping, comprising 40 of total abundance in survey samples. Other common taxa included amphipods, mayfly nymphs and mosquitoes. Lake Eyre hardyhead was the only fish species that was recorded from two sites on Boolcunda Creek. Although not widely dispersed, this population represents a significant biodiversity asset. Species richness and between-site diversity was high with, on average, only 17% of animals shared between survey sites. The main factors influencing pool-scale biodiversity measures of macroinvertebrate communities were the physical dimensions of the pool and its landscape position.
Duguid et al. (2005) & Duguid (2005)	NT (LEB)	Wetlands of the Arid NT Volumes 1 & 2: An inventory of wetlands in the Arid NT which includes the LEB including wetland classification and mapping and surveys of aquatic invertebrates, fish, birds and plants. *Vol 2:* Includes descriptions and biological survey data for all wetlands surveyed as part of the *Wetlands of the Arid NT* (Duguid et al. 2005). Notes that many descriptions are still preliminary and further work is required. Includes note on hydrology of the sites.

Reference	Region	Summary
Ehman (2009)	SA (Lake Frome)	Flinders Ranges Frogs & Fishes: Pilot Project A survey of frogs and fishes at twenty six sites in the northern Flinders Ranges in the SA Arid Lands NRM Region. Found seven species of fish and three frogs (although it was considered too dry for an adequate frog survey). Up to 250 potential habitats for frogs and fishes exist in the northern Flinders ranges (see p. 16).
Ehmann (2005)	SA	South Australian Rangelands and Aboriginal Lands Wildlife Management manual Description of habitat, biology, distribution, threats, conservation and management of most wildlife species in SA Rangelands. Comprehensive encyclopaedia of arid rangeland species including fishes, reptiles, frogs and birds. Does not include invertebrate species. Covers many species distributed in Arckaringa and Pedirka. Describes external physiology, breeding habits and habitat preferences of most species. Details invasive pest species throughout these areas, including invasive fish species.
Eldridge & Reid (1998)	Finke	A Biological Survey of the Finke Floodout Region An ecological survey of the Finke River floodout and adjacent land systems. Aim to assess the region in terms of its vertebrate fauna, environmental condition and conservation significance, and to investigate the importance of the area as refuge habitat for vertebrate fauna. The survey included (was predominantly?) terrestrial areas. Survey in April 1994. 30 distinct sites sampled. Mammals, reptiles, birds and vegetation were sampled using standard methodologies and also by opportunistic sampling. Potential threats to the conservation and long-term ecological integrity of the floodout include: pastoralism, feral animals, fire, weeds, mining and tourism. Historical records indicate that the region's fauna has declined since European colonisation, with small to medium sized mammals most severely affected. Despite these losses the region still boasts an impressive small mammal fauna indicative of its conservation and refuge values.
Golder Associates (2009)	Cooper Creek	Cooper Creek Water Resource Plan: Environmental Discussion Paper Summarises the environmental needs of the flora and fauna of the Cooper Creek catchment. Specifically, the paper details current knowledge regarding the relationships between species and ecosystems and the variable hydrological regime of the Cooper. Relevance: Future monitoring should be catchment wide and should maintain a long-term perspective of flow history, due to flow variability.
AETG (2012e)	LEB	LEB HCVAE Pilot Project Contains broadscale information on the biological attributes of LEB AEs compiled from other datasets, including list of AE dependent species: plants, birds, frogs,

Reference	Region	Summary
		reptiles and mammals.
Miles & Risby (2010)	SA (LEB)	LEB Strategy Scientific Report Summarises existing information about: • aquatic ecosystem assets on a catchment by catchment basis and for the entire LEB in SA • environmental water requirements for each catchment in SA.
Mitchell et al. (2002)	Qld (Upper Thomson Creek)	Biodiversity Audit – Bioregional Case Study: Desert Uplands bioregion, Queensland Report prepared for National Land and Water Audit; reviews existing biodiversity data for Desert Uplands Region. Presents information for wetlands, riparian zones, regional ecosystems, ecosystems at risk and threatening pressures, and condition assessments from an expert panel. Relevance: As above
Moller (1999)	Qld (LEB)	State of the Rivers – Cooper Creek and Major Tributaries An assessment of the physical and environmental condition was conducted for 273 sites on the Thompson River, Barcoo River, Cooper Creek and their tributaries. Parameters were assessed against presumed natural condition by comparison to remanent sites. Riparian vegetation and aquatic habitat was assessed [other parameters also]. Most vegetation rated well, lower ratings were attributed to poor structural diversity and narrow riparian vegetation (from clearing). Aquatic habitats rated lower due to the lack of a diverse range of habitats at individual sites. Relevance: Discusses a method for fast environmental condition assessment; describes the state of rivers in the Cooper catchment; describes a method for monitoring; and potential exists for identification of temporal changes if monitoring the same parameters occurs.
Morton et al. (1995)	SA (LEB)	Natural Heritage Values of the Lake Eyre Basin in South Australia (vegetation chapters) Provides a detailed history of vegetation in the Lake Eyre Basin in South Australia through time, describing main species present in wetter and drier phases. Many areas will be dated but reviews biotic knowledge of the area in the mid-1990s. The paper concentrates largely on the well-documented areas of the basin incuding Goyder Lagoon and Coongie Lakes. Summarises management of vegetation. Describes common species present in different communities across the Lake Eyre Basin, giving detailed descriptions of the different regions of the Basin. Lists factors that shape plant communities (soil type, salinity, frequency of flooding) and mentions past disturbances by agriculture. Discusses endemic and relict plant species.
Neave et al. (2004)	Finke	A Resource Assessment Towards a Conservation Strategy for the Finke Bioregion A collation of biological information for the Finke bioregion with a focus on conservation values.

Reference	Region	Summary
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial A report detailing the application, development and trial of an Integrated Ecological Condition Assessment (IECA) for High Ecological Value Aquatic Ecosystems (HEVAE) in the Cooper Creek catchment. Five HEVAE units (CAT 500 polygons) were selected for assessment. Aquatic ecosystems were identified and listed for each hydrological unit, and HEVAE criteria relevant for each unit were determined. Sampling of targeted indicators was undertaken to validate threat risks and to gather information for knowledge improvement. Relevance: Describes the distribution of species and the ability of introduced species to disperse.
Reid and Gillen (1988)	SA (Coongie Lakes)	*The Coongie Lakes Study*. Two year biological survey of the region. Broad focus: birds, terrestrial vertebrates (mammals, reptiles, frogs), vegetation, aquatic biota (fish and zooplankton). Contextual analysis of most taxa. Consideration given to the impacts of tourism on the biota. Alteration of floodplain habitat identified as a key impact on aquatic biota. This observation is directly applicable to floodplain alteration by mining development in the Neales Catchment.
Schmarr et al. 2013	Cooper	**Ecological** *Aquatic ecology assessment and analysis of the Cooper Creek, South Australia* Reports on results of assessments of aquatic ecology (mostly fish as well as turtles, large bodied invertebrates and water rats) following the 2010 floods at 25 sites from Cullyamurra to Kati Thanda-Lake Eyre. Found that the assemblages of the upper and lower reaches were quite different despite significant flooding connecting the entire length. The lower reaches were dominated by resilient species with a few resistant species. Less resistant species maintained their populations in the upper reaches. Freshwater Mussels, Water Rats and Turtles were also only found in the upper reaches, with Water Rats having the more restricted distribution (caught at 4 sites, Mussels at 5 while turtles were caught at 12 sites). Freshwater Crabs were found at one site only (Gidgealpa waterhole).
Tassicker et al. (2006)	Qld (Upper Thomson River)	*The effects of vegetation structure on the birds in a tropical savannah woodland in north-eastern Australia* Vegetation structure and habitat variables, and bird communities were recorded from 60 sites across the desert uplands region. Discusses the implications of vegetation clearance and modifications for faunal composition in the region. Relevance: Land clearing is to the benefit of some bird species and the detriment to others, though the gross effect is detrimental

Reference	Region	Summary
Timms (2007)	Australia	The biology of the saline lakes of central and eastern inland of Australia: a review with special reference to their biogeographical affinities Examines previous studies of Australian salt lakes and attempts to discuss biogeographical affinities through differences in the richness and distribution of species, salinity levels and the extent of habitat heterogeneity. This study compiles data from multiple sources comparing biota within salt lake habitats; the discussion has a particular focus on macroinvertebrates. Contains summaries on geographical, abiotic and biotic features of salt lakes throughout inland Australia, including those surrounding the Arkaringa basin. Limited conclusions with regards to potential biogeographical affinities of flora and fauna living within salt lakes.
Tyler et al. (1990)	SA (LEB)	Natural History of the North East Deserts Comprehensive literature review for entire NE corner of SA with some overlap with Arckaringa and Pedirka Basins. Reviews vertebrates (birds, frogs, reptiles mammals and fishes) and butterflies in the region.
Walsh (2009)	Qld (Desert Channels Region)	Enhancing biodiversity hotspots along western Queensland stock routes: Desert Channels NRM Region Lists 12 sites along the regions stock routes which were evaluated, according to selection criteria, as being 'biodiversity hotspots'. Seven sites are aquatic habitats and the following information is discussed for each site: location, priority species, threats, current management and recommendations for future management. Relevance: Lists threats to identified 'biodiversity hotspots' and management actions present and suggests future actions. Methods for the identification of the hotspots are also described.

Fish

Reference	Region	Summary
Cockayne et al. (2012, 2013)	LEB	Lake Eyre Basin Rivers Assessment (LEBRA) 2010/11 and 2011/2012 Annual Monitoring Reports Summary of data from spring 2010–11 and 2011–12 LEBRA sampling. Thresholds of potential concern in the LEB outlined. Fish and water quality findings summarised. No analysis of data at the present time, but a useful baseline for fish-species diversity in the basin and sites relevant to Arckaringa and Pedirka Basins. Increased sampling effort in the area has expanded the distribution records for many species and highlights the importance of monitoring to increase knowledge of LEB rivers. Indicates that baseline assessment and ongoing monitoring in understudied environments must be undertaken before development occurs.

Reference	Region	Summary
Costelloe et al. (2004)	LEB	ARIDFLO - Fish Whilst the sampling in the Neales catchment seems to have been quite extensive. Extracting specific information about biological attributes from the final report is quite difficult. Much of the fish data appears to have been aggregated and summarised. Our observations of the raw data indicate it is far more comprehensive than the final report suggests. Only two sites sampled within Arckaringa Basin, Cootanoorina and Birribiana. These sites indicate the use of these waterholes as 'stepping stone' refugia for highly resilient species, although there are no permanent refugia upstream to migrate to. It was proposed that successive floods allowed migrating species to move back downstream.
DPI (draft, late 90's?)	Qld (LEB)	Fishing guide to waterholes of the Lake Eyre Catchment Queensland A description of species with in the Qld LEB is provided in relation to fishing. All larger bodied species excepting Bony Herring are listed. Distribution and preferred habitats are discussed as is line capture technique for each of these species. Relevance: Large-bodied fish species description (non-technical).
Duguid et al. (2013)	Finke	*Drought Refuges for Native Fish in Parts of Central Australia* Aim of study to identify drought refuges for native fish in Finke River and Dulcie Ranges (flowing north to the upper Diamantina catchment and south to the hay and plenty Rivers), both of which support high fish diversity for arid Australia. Project included identifying and mapping sites and their habitats, surveying for fish and salinity testing. For most sites this was the first fish surveys. Provides descriptions of refuge sites and their habitats and reports on fish survey results. Recommends further surveys in Palmer and Dulcie areas. Results of salinity testing support previous insights into complexity of groundwater-surfacewater interactions in the Finke. More saline sites have less impacts from herbivores.
Glover and Sim (1978a)	Central Australia	A survey of central Australian ichthyology Historical account of ichthyological surveys from the 1840s to 1970s. Concludes that overall occurrence and incidence of fishes in central Australia known by this stage, but general biology and environmental adaptations not well known. Many observations of early explorers still ring true today, e.g. accounts of stranded bony herring and spangled perch, and the early recognition that fishes of central Australia do not aestivate.
Huey (2007)	Qld (LEB)	The effects of species biology, riverine architecture and flow regime upon patterns of genetic diversity and gene flow in three species of northern Australian freshwater fish Detailed examination of *N. hyrtlii, A. macleayi* and *A. sp.*, population genetics in the

Reference	Region	Summary
		LEB. Results emphasize the importance of understanding underlying genetic processes when designing management and/or conservation strategies for fish taxa; particularly the need to identify dispersal abilities and effective population sizes. Relevance: Identifies the need for knowledge of species biology and ecology; and identifies the lack of connectivity between the major LEB catchments.
Huey et al. (2008)	Qld (LEB)	The effect of landscape processes upon gene flow and genetic diversity in an Australian freshwater fish, Neosilurus hyrtlii Investigated genetic diversity and gene flow for *N. hyrtlii* between LEB and Gulf of Carpentaria. Revealed that effective population size was relatively small in the LEB due to extreme hydrological variability and boom-bust cycles; and that there was no evidence of current connectivity between the Georgina, Diamantina and Cooper catchments. Results highlight the importance of flow regime and riverine architecture on shaping fish population dynamics. Relevance: Discusses adaptation of a species to low flow, boom and bust hydrological regime; and the lack of inter-catchment connectivity.
Long (1995)	Qld (LEB)	Recreational fishing enhancement program, pre-stocking survey Jordan River Jericho Survey of fish in two weirs on the Jordan River, JERICHO and potential species for stocking. Yellowbelly (*Macquaria ambigua*) are the only species suitable for stocking (namely LEB strain) and is only to occur in waterholes >2 m deep for dry season persistence. Relevance: Species distribution baseline data.
Long et al. (1995)	LEB Qld	Information Series: Fisheries study Lake Eyre Catchment, Thompson Diamantina Drainages Waterhole survey of fish, riparian vegetation, water quality and some other waterhole measures. Species abundances and diversity was as expected with fish in reasonable to good condition. One of the few studies of its type at the time and previous, and suggests the need for future similar more in depth study. Relevance: Species distribution baseline data.
McNeil et al. (2011a)	Western Rivers (Neales)	Climate variability, fish and the role of refuge waterholes in the Neales River catchment List of native and invasive fish within the Neales River Catchment. Details the salinity tolerance of different species of arid zone fish. This information would inform future water quality impacts using site-specific data. Most sites were downstream of catchment area located above the Arckaringa Basin. The paper gives the most comprehensive assessment of the fish diversity and abundance that would be affected by development within the catchment and would be a vital reference point for risk assessment. At least one bore drain (One-Mile) and GAB spring (Old Nilpinna) are permanent refugia for invasive *Gambusia holbrooki* and native desert gobies (*Chlamydogobius eremius*) respectively. These lie within the Peake Catchment above Arckaringa Basin

Reference	Region	Summary
		and are hydrologically connected at an unknown frequency. The study also incorporates a period of climatic variability that will be useful for teasing apart the impacts of temporal variability in climate on fish populations from other impacts.
Sternberg et al. (2008)	Qld (MDB)	Food resource variability in an Australian Dryland river: evidence from the diet of two generalist native fish species *N. erebi* diet reflected strong 'boom-bust' patterns according to hydrological variability; *M. ambigua* diets did not reflected such a strong pattern, however, their dominant prey switched according to ambient productivity. The ability to 'switch' between prey concentrations of varying quality allows both species to persist throughout periods of high and low productivity. Relevance: Potential for inference of species population dynamics with changes of hydrological regime.
Unmack (2001a)	Finke	Fish persistence and fluvial geomorphology in central Australia Summary of composition and distribution of fishes in the Alice Springs region from historic fish records (to 1991) in the NT LEB. Nine native and six exotic species were recorded: most exotics no longer exist, except in Finke River, where only one or no native species were found.
Unmack (2001b)	National	Biogeography of Australian freshwater fishes Publication of a Master's thesis, this document examines Australian bioregions in terms of fish endemism and Paleohydrology. Dataset does not include all currently known LEB fishes. Bundles LEB into the Central Australian Province.
Unmack (2010)	National	Biogeography of the genus Craterocephalus (Teleostei: Atherinidae) in Australia Similar to Unmack 2001b but considers genetic data and only Craterocephalus. Similar conclusion.
Wager and Unmack (2000)	LEB	Fishes of the Lake Eyre catchment of central Australia Description of Habitat, Biology and Distribution of fish species in LEB. Includes species distributed in Arckaringa and Pedirka and brief summaries of habitats. Comprehensive descriptions of physiology, preferred habitat and distribution. (Distribution information is now slightly outdated). Discusses breeding ages, behaviours and some spawning habitats; this information is usually limited to common aquarium species. Limited information regarding biological interactions (such as mutualism etc), or trophic dependencies. Mentions the importance of uninhibited flow patterns, however, lacking detailed information regarding dependencies on flow regimes and refuge habitats.

Waterbirds

Reference	Region	Summary
Jaensch (2009)	Cooper & G-D	Floodplain Wetlands & waterbirds of the Channel Country Some basic description of waterbird ecology in the LEB.
Kingsford & Porter (2008)	LEB	Scientific Validity of Using Waterbird Measures to Assess River Condition in the LEB Priority sites for waterbird conservation significance.
Kingsford et al. (1999)	Cooper Creek	Water flows on Cooper Creek in arid Australia determine boom and bust periods for waterbirds. Estimated how often boom habitat is present for waterbirds in a 100-year period. Predicts the effects of diverting water from the system for irrigation and infrastructure and negative effects on survival and breeding of waterbird populations. Analyses waterbird numbers over wet and dry periods in numerous Lakes throughout the Cooper Creek region. Presents examples of negative ecological impacts of upstream water diversions that have caused collapses of aquatic ecosystems from rivers overseas. These have mainly been caused by drops in water levels.
Kingsford et al. (2004)	Arid Australia	Imposed hydrological stability on lakes in Arid Australia Explores the differences in waterbird densities between regulated and unregulated lakes. Assessed temporal variations in waterbird densities. Changes in natural disturbances of flooding and drying have negative effects on aquatic ecosystems by reducing numbers of species and densities. The results supported the intermediate disturbance hypothesis applied to drying.
Kingsford et al. (2012)	Australia	National waterbird assessment Waterbirds can be used as ecological indicators of wetland and river health, including human impacts. Established a national waterbird database for survey data. Identified important wetlands for waterbirds throughout eastern Australia and the LEB. Lists further analyses that could be done to help with management of rivers and wetlands in the LEB. Regulation of rivers in the region has reduced the area of wetlands, having negative effects on the areas for waterbird to utilize for breeding and feeding. Poor coverage of western and desert rivers catchments.

Other Vertebrates

Reference	Region	Summary
Goodsell (2002)	Cooper Creek	Gene flow in highly variable environments: Population structure of an Australian freshwater turtle, Emydura macquarii Investigated the levels of genetic divergence and gene flow for *E. macquarii* in the Cooper. Results showed that populations exhibited a moderate level of population differentiation within and between catchments, and gene flow patterns are apparent within catchments. Distinctive genetic characters were discovered for the Welford population. Implications for flow management for genetic conservation are discussed. Relevance: Implications of flow management/change.
Predavec & Dickman (1993)	Qld (South West)	Ecology of desert frogs: a study from southwestern Queensland Monitored an assemblage of frogs for 23 months in dune habitats of SW Qld: *Notaden nichollsi, Neobatrachus centralis* and *Clyclorana australia*. Associations with rainfall and habitats were investigated along with diet analysis. Relevance: Highlights the limited knowledge and apparent importance of frogs in arid Australia and the need to consider them in field studies.
Tyler & Knight (2011)	National	Field Guide to the Frogs of Australia Identifies and describes 17 species of frog from the Qld LEB region Relevance: As above.
Tyler & Walker (2011)	SA	Frogs of South Australia 3rd Edition Distribution and description of frogs in SA. At least seven species of frog coincide with Arckaringa and/or Pedirka Basins. Brief species lists. Describes behaviour, external physiology and calls. List of known habitats and statewide observed distributions. This book provides a useful list of potential species within the study area. Access to raw spatial data may be required for more identification of specific locations and habitats that may coincide with development. The biology of most of the relevant species listed rely on rainfall and at least ephemeral waterbodies for reproduction. Any activities that shorten the longevity of ephemeral waterholes or change their water quality may impact upon these species.
Tyler et al. (2009)	LEB	Frogs of the Lake Eyre Basin Identifies and describes 44 species of native frogs within the Lake Eyre Basin, with illustration and notes on ecology. Relevance: As above.
White (2002)	Cooper Creek	The Cooper Creek Turtle persisting under pressure: A study in arid Australia Investigated the population structure and growth of *Em. macquarii* in waterholes of the Cooper. Highly adapted biological features and dispersal mechanisms are

Reference	Region	Summary
		discussed, along with the impacts of illegal fishing on population structure.

Invertebrates

Reference	Region	Summary
Carini and Hughes (2004)	Qld	Population structure of Macrobrachium australiense (Decapoda: Palaemonidae) in Western Queensland, Australia: the role of contemporary and historical processes Investigated genetic diversity among *M. australiense* and contemporary patterns of dispersal in western Qld. Results suggest that the species do not maximise their potential for dispersal during times of flood/connectivity, instead remaining in origin waterhole; hence, the species chances of recolonisation after disturbance is low. Relevance: post disturbance recolonisation potential is likely to be limited; and populations were found to have limited gene flow even within catchments.
Cook et al. (2002)	Qld	Genetic structure and dispersal of Macrobrachium australiense (Decapoda: Palaemonidae) in western Queensland, Australia Used population genetics to investigate the dispersal and recolonisation mechanisms of *M. australiense* in western Qld. Results found no gene flow occurs *between* catchments but is present *within* catchments; therefore, flood flows are not providing connectivity or dispersal opportunities. Detailed hypotheses for gene flow within catchments, and inferred patterns of historical dispersal are discussed. Relevance: Genetic differentiation is high between catchments, and there is an apparent extensive dispersal ability within catchments (low differentiation within catchment).
Carini et al. (2006)	Qld (LEB)	The role of waterholes as 'refugia' in sustaining genetic diversity and variation of two freshwater species in dryland river systems (Western Queensland, Australia) Investigated genetic diversity and patterns of connectivity among waterholes for two species: *M. australiense* and *N. sublineata*. Results revealed a positive correlation between *N. sublineata* diversity and waterhole persistence time. Significant genetic differentiation was detected for both species in main and satellite waterholes, demonstrating that the processes of connectivity and/or colonization are effectively the same for both habitats. Discusses the value of waterhole refugia with respect to flow management. Relevance: Highlights the requirement of maintaining connectivity, to ensure the conservation of genetic diversity; and that equal conservation/protection priority should be applied to satellite waterholes as to main channel waterholes.
Baker et al. (2003)	Qld (LEB)	Cryptic species and morphological plasticity in long-lived bivalves (Unionoida: Hyriidae) from inland Australia Compared and contrasted molecular and morphological variations, and diversity in the freshwater mussel fauna from four rivers in SW Qld (inc. Cooper). Mitochondrial phylogeny revealed four distinct lineages in reproductive isolation, potentially representing four separate species. Rich mussel diversity was found for Cooper Creek,

Reference	Region	Summary
		which may contain species now extinct from the MDB. Relevance: Discusses population connectivity/separation.
Costelloe et al. (2004)	LEB	ARIDFLO - Macroinvertebrate Steep sided rivers with high flows displayed lower taxon richness. Appears to be a function of reduced favourable microhabitats (primarily Coolabah, Lignum and Cyperus). Invertebrates also adapted to utilise bare banks (prevalent in the SALEB due to variable waterlevels). Extensive analysis around indicator species (Sect. 4.4.6.2) with associations to; reach, macrohabitat, trip, season, microhabitat and conductivity. Floods are associated with a boom in diversity (and less so abundance?). Strong associations with salinity with the association especially strong in the Neales. Selection of indicator species based on this report must be carefully considered due to the number of variables correlated to each group (eg salinity, reach, microhabitat)
Davis et al. (1993)	Central Australia	Invertebrate communities of relict streams in the arid zone: the George Gill Range, Central Australia Study of invertebrate communities within isolated streams of southern NT. Discusses similarities found between streams throughout Australia. Speculates on possible reasons for differences in species composition, such as the absence of amphipods and isopods and the increased richness of non-insect taxa.
Goonan et al. (2003)	SA (LEB)	River health in the Far North Macroinvertebrate assemblage of the region considered diverse: common members include midge larvae, mayfly nymphs and oligochaetes (worms). Some rare and uncommon species found. A number of rare beetles, dipteran fly larvae, caddisflies species and crustaceans highlight the uniqueness of individual sites in the region in terms of biodiversity values and significance. Some unusual records for the area include the rarity of amphipod crustaceans that are common elsewhere in the state and the common occurrence of the freshwater prawn species in the region.
Hughes & Hillyer (2003)	Qld	Patterns of connectivity among populations of Cherax destructor (Decapoda : Parastacidae) in western Queensland, Australia Examined levels of connectivity among populations of *C. destructor* in central Australia. Findings showed high connectivity among populations in the same catchment, particularly in the Cooper, suggesting contemporary dispersal; and limited connectivity across draining boundaries suggesting restricted terrestrial dispersal. Detailed hypotheses explaining patterns within catchments, and inferred patterns of historical dispersal are discussed. Relevance: Genetic differentiation is high between catchments and low within catchments, indicating movement within catchment and not between them.
Hughes &	Qld	Mitochondrial DNA and allozymes reveal high dispersal abilities and historical

Reference	Region	Summary
Hillyer (2006)		movement across drainage boundaries in two species of freshwater fishes from inland rivers in Queensland, Australia Investigated levels of genetic differentiation among *N. erebi* and *R. semoni* to reveal strong dispersal abilities and historical patterns of dispersal. Results indicated that populations were not as 'connected' as predicted and genetic differentiation among waterholes within drainages was detected for both species. Relevance: Populations are genetically similar within catchment, and dissimilar to other drainages.
Madden et al. (2002)	SA (LEB)	Macroinvertebrates of watercourses in the Lake Eyre Basin, South Australia Study of macroinvertebrate populations using AUSRIVAS method in arid land South Australia, encompassing creeks and rivers throughout the Lake Eyre Basin including those within the Arkaringa and Pedirka basins. Provides a list of macroinvertebrates recorded throughout four geographic regions of the basin, during the study period. Identifies species of macroinvertebrates likely to inhabit temporary waterholes and inundated areas in addition to species which prefer flowing water habitats. Identifies halophilic macroinvertebrate species common in hypersaline waterbodies. No exotic invertebrate species were identified Draws general conclusions with regards to refuge habitats for some rare gastropod species. Factors influencing macroinvertebrate distribution and abundance are yet to be determined. Composition of major eastern rivers more similar than to more ephemeral western rivers.
Shiel et al. (2006)	LEB	Zooplankton diversity and assemblages in arid zone rivers of the Lake Eyre Basin Uses ARIDFLO data to create a more concise set of results. Covers endemicity, diversity and abundance of zooplankton observed during ARIDFLO. Understanding the role of zooplankton in arid rivers and their response to seasonal changes and irregular flood and drought patterns. Little research has been done on the microfauna of arid zones in Australia. First records of microfauna for the LEB concentrating on the three river systems; lower Cooper Creek, lower Diamantina and Neales rivers. Found patterns between abundance of zooplankton and flooding events highlighting the importance of flooding events and negative effects from changes in water regime due to decrease in flows and alterations to natural variabilities. Identifies future areas for experimentation to test their speculations and acknowledges difficulties in conducting experiments in arid environments.

Vegetation

Reference	Region	Summary
Costelloe et al. (2004)	LEB	ARIDFLO Chapter :Vegetation Sampled vegetation most representative of the riparian zone across the five reaches at 54 waterbodies. When no riparian zone was present woody perennial plants were identified. Only provides brief results on vegetation, lacking repeated observations. Discusses significant correlations between plant species and waterbodies in specific regions. Presents the most common plant species observed and their frequency.
Costelloe et al. (2008)	Australia	Water sources accessed by arid zone riparian trees in highly saline environments Identifies and discusses water sources for riparian trees. Identifies strategies used by riparian trees in highly saline and arid conditions. Looks at the relationship between the spatial distribution of riparian trees and the hydrology of surface water and groundwater. Therefore alterations to water flows could have major effects on tree health, regeneration and distribution. Considers the effect of changes in flow regime on tree health and survival. Discusses the use of stable isotopes to identify water sources used in riparian trees. This could then help predict how changes in certain particular water sources would affect trees.
Duguid & Albrecht (2007)	NT (Desert Rivers)	Botanical survey of the northern Simpson Desert July 2007: Hay River, Lake Caroline and Mount Tietkins areas Botanical survey of the group of Lakes near Lake Caroline and nearby Hay River (as well as adjacent terrestrial areas). Survey followed good flows in the Hay and some wetlands still held water. Used combination of quadrats and opportunistic survey. Quadrats include all species and abundance-cover (Braun-Blanquett style). Quadrats positioned to capture uniform veg. community and to capture zonation around wetlands; they used multiple quadrats at some sites. Wetter sites had higher species diversity.
EHP (2012a)	Qld (LEB)	Wetland Conceptual Models (Case Study Series – Queensland Lake Eyre and Bulloo) Brief summary of riparian vegetation and macrophytes for the whole of basin, using data from State of the Rivers project
Gillen & Reid (2013)	Cooper	*Vegetation and soil assessment of selected waterholes of the Main and Northwest channels of the Cooper Creek, SA* Fieldwork undertaken in Autumn 2012 following extended wet season and vegetation of the region generally in very healthy state. Surveyed at 14 waterholes, three 100 * 4m transects parallel to the direction of flow. Soil samples in 10cm increments to 50cm depth collected from mid point of each transect for pH and salinity, with additional 15 samples to 5cm collected and tested for total nitrogen and carbon. Appendix 4 includes data for each site including species and photographs

Reference	Region	Summary
		Total of 148 plant species recorded, 9% of which are introduced. Distribution of *E. camaldulensis* was correlated with soils with significantly lower salinity and pH than sites without *E. camaldulensis*.
Pettit (2002)	Qld (Cooper Creek)	Riparian Vegetation of a Permanent Waterhole on Cooper Creek, Southwest Queensland Documents major riparian vegetation community species, describes population dynamics and reproductive status of major overstorey species. Discussion of vegetation distribution as influenced by waterhole morphology, and assessment of detrimental impact from livestock on waterhole vegetation.
Roberts (1993)	SA (Cooper Creek)	Regeneration and growth of Coolabah Summary of Coolabah regeneration from differing water regimes, topographic features and soils. Determining if there has been any regeneration of Coolabahs within the last century by observing height classes and reproductive activity. Abundance of introduced herbivores has a major influence on regeneration of riparian plant species. This study gives an insight into the contrast of temporary and continual water supplies on the condition of floodplain Coolabahs and how changes would affect this species in the future.
Roberts et al. (1976)	Qld (Cooper Creek)	Quantitative floristic studies of the ground layer in some mulga and Mitchell grass communities in south-western Queensland Presents information on soil types, ground cover vegetation composition and percentage groundcover for transects within the upper Cooper floodplain. Relevance: Potential ecological benchmark of species present.
Scholz & Deane (2011)	Neales	Prioritising waterholes of ecological significance in the Neales and Peake Catchments Descriptive assessment of vegetation and habitat values for surveyed sites.
Silcock et al. (2011)	Qld (LEB)	Assessing rarity and threat in an arid-zone flora Compiled list of ALL flora occurring in western Qld, and applied a rarity index to determine 60 potentially threatened species which have been overlooked. Habitats of rare flora include springs and wetlands. Relevance: All flora in western Qld is presented: Rarity is discussed including its 'definition' and forms
Sparrow and Leitch (2009)	NT & SA	Vegetation Survey and Mapping of the Eastern and Southern Finke Bioregion and the NT Stony Plains Inliers, NT & SA This report summarises the results of mapping in the eastern and southern portions of the Finke Bioregion in the Northern Territory and South Australia. It gives a brief background on the physical characteristics, climate, soils, and geology of the Bioregion. The survey resulted in 43 mapping groups and 100 floristic group

Reference	Region	Summary
		definitions. The report covers: • Descriptions of existing data (specifically vegetation-related data) • methods used for the collection of new field data (field and remote sensing methods • a description of the resulting mapping groups and their floristic components • information on the applications of the data • recommendations for future mapping. A set of twelve Appendices are available at: http://www.territorystories.nt.gov.au/handle/10070/232791

Algae

Reference	Region	Summary
Costelloe et al. 2005	SA (LEB)	Algal Diversity and assemblages in arid zone rivers of the Lake Eyre Basin, Australia. Summarises and highlights microalgal findings from ARIDFLO Moderate algal diversity (identified to genus) Both halophillic and halophobic species Cyanobacteria not observed to dominate More comprehensive data in ARIDFLO main report

Floodplain and Dryland

Reference	Region	Summary
Aumann (2001)	NT LEB	*The structure of raptor assemblages in riparian environments in the south-west of the NT* Raptors in central Australia are concentrated along drainage lines, in particular River Red Gum habitats. This study surveyed raptor assemblages in ten riparian habitats (1995–97). Found raptor assemblages in riparian areas varied between seasons and between sites. Results suggested variation was mainly due to food abundance but differences in habitat and nesting sources may also have a role. Food and nesting sites are limiting resources. The availability of nesting trees restricts most species to mainly riparian zones and limits their densities, potentially also depressing breeding in good seasons.
Baulder-stone et al. (1999)	Frome	*Gammon Ranges National Park: Flora and Fauna Survey and Vegetation Monitoring* From Abstract on web: *"This paper reports on the findings of an ongoing vegetation monitoring program in the Gammon Ranges National Park, South Australia… This monitoring program aims to assess the effect of the removal of stock on changes in perennial vegetation and litter cover, and the extent of bare ground… Permanent monitoring sites for flora were established in 1983 and assessments have been undertaken several times since… A Biological Survey of plants, mammals, reptiles, amphibians and birds was carried out*

Reference	Region	Summary
		in 1993. *… Significant increases in ground cover were measured in the Mitchell Grass (*Astrebla lappacea*) plains; less increase in other plains sites; and little change in the hill sites. This appears to correlate directly with the total level of grazing pressure in these areas, namely kangaroos in the Mitchell grass plains, plus rabbits on other plains sites, plus goats and euros in the hill country."*
Brandle (ed. 1998)	SA LEB	*A Biological Survey of the Stony Desert, South Australia* Survey includes stony country of SA LEB. Use cluster analysis to identify groups and associations. Vegetation uses results of this plus 7 previous surveys, sites included riparian & FP; classified veg associations and these include floodouts and claypans. Mapped veg types and identifies those associated with watercourses Mammals: identified mammal groups associated with diff veg and landforms; of the species associated with floodplains, several require heavy cracking clays as part of their habitat. This group: • Paucident Planigale • Fat-tailed Dunnart • Stripe-faced Dunnart • Forrests Mouse • Long-haired Rat • Sandy Inland Mouse • Plains Mouse • Narrow-nosed Planigale The latter 2 also comprise a group associated with heavily cracking gypseous clay plains and drainage depressions in sthn and wstn Kati Thanda-Lake Eyre region. Long-haired Rat also dominant in NW swamp and floodout areas. Little Broad-nosed Bat (*Scoterepens greyii*) was abundant and usually associated with well wooded drainage lines. Birds (Brandle & Reid): Reid et al (1990) woodlands along drainage lines and floodouts generally support the most diverse species assemblage, including of birds that may shelter in the woodlands but feed in surrounding shrublands and grasslands. These observations supported by this study, which found the most diverse bird community in Coolabah riparian woodland. These habitats provide drinking water, nesting sites especially for hollow-nesting species; other assemblages were associated with more ephemeral waterbody types, including shrubby floodouts. Reptiles (Brandle & Hutchinson): as with other fauna, specific assemblages associated with watercourse and ephemeral habitats, with soil texture a strong determinant – cracking clays important habitat for some species but overall low diversity at these sites. Amphibians (Brandle & Hutchinson): Total 10 frog species, Innamincka region most diverse (7 spp.)
Brandle et	SA LEB	*The distribution, habitat requirements and conservation status of the plains rat*

Reference	Region	Summary
al. (1999)		Species only found in gibber desert from NT SA border NW of Kati Thanda-Lake Eyre to south of Kati Thanda-Lake Eyre south and near Lake Torrens, once a more widespread distribution and broader genetic complex. The species is abundant following good rains and declines during dry periods. Found in cracking clay areas associated with minor drainage lines and gilgais, with drainage lines supporting higher densities and therefore presumably a refuge during droughts; however not found long major drainage lines, presumably these flooded too often disrupting the populations. Propose that minor drainage lines are primary habitat ('source') and gilgais secondary ('sink') as per source/sink habitat model (Pulliam 1988) further explored in a subsequent article in the same issue (Brandle & Moseby 1999: not reviewed as it was not conclusive). Suggest that they prefer cracking clays because they are more productive and seed and other plant material is trapped in the cracks and less likely to be harvested by other species. Discussion of broader survey results on the values of these habitats: they support a higher abundance and diversity of small mammals in the arid zone, acting as a refuge.
Brandle et al. (2005)	Neales	*A Biological Survey of the Mt Willoughby Indigenous Protected Area, South Australia - October 2003* Property located north of Cooper Pedy with eastern half of property overlying the upper catchments of the Lora-Peake creek. Vegetation: included Coolabah & River Red Gums on watercourses. Associated fauna identified: • Group 2. *Maireana aphylla* (Cotton-bush), *Atriplex vesicaria* (Bladder Saltbush) Low Open Shrubland over grasses on drainage lines o Bird Group 1: Rufous Fieldwren, Richard's Pipit, Gibberbird, Inland Dotterel o Mammal Group 2: Stripe-faced Dunnart, House Mouse, Giles' Planigale o Reptile Group 2: Broad-banded Sandswimmer, Pink-blotched Gecko, Saltbush Ctenotus, Sand Goanna, Dwarf Three-toed Slider • Group 9. *Eucalyptus coolabah* (Coolabah) / *E. camaldulensis* (River Red Gum) Woodland over *Santalum lanceolatum* (Plumbush), *Senna* spp. (desert sennas), *Rhagodia spinescens* (Spiny Saltbush) shrubs and *Maireana aphylla* (Cotton-bush) low shrubs floodplains. o Bird Groups 2 & 4: White-browed Babbler, Black-eared Cuckoo, Weebill o Mammal Group 3: House Mouse and Cattle o Reptile Group 3: Tree Dtella, Bynoe's Gecko, Long-nosed Dragon, Common Snake-eye, Desert Whipsnake, Western Brown Snake, Purple Dtella, Centralian Striped Skink Watercourse fauna generally comprised a high proportion of introduced species (mice and cattle). Very low weeds, with only 3 species recorded at only 6 of 28 sites. Mapped vegetation associations – 4 watercourse and swamp associations. Also did invertebrates but no analysis by land form or veg type.

Reference	Region	Summary
Briggs et al. (2000)	W NSW	*Wildlife in dry lake and associated habitats in western NSW* Compared the reptile and small mammal fauna of a dry lake bed environment with surrounding Blackbox woodlands (in the Darling floodplain). Species showed specific habitat partitioning, with some species favouring the dry lake bed. Study showed that conservation of all habitats was critical to retain the suite of vertebrates in these landscapes. "The dry lake provided the main habitat for the two small mammals *Sminthopsis crassicaudata* and *Planigale gilesi*. Reptiles were most speciose and most abundant in the blue bush (*Maireana* spp.) shrubland, but some reptile species were mainly or entirely confined to the dry lake habitats, or to black box (*Eucalyptus largiflorens*) woodland." Birds were most abundant and diverse in the black box woodland, but some species were confined to blue bush shrubland.
Clarke et al. (2005)	NT	Long-term changes in semi-arid vegetation: invasion of an exotic perennial grass has larger effects than rainfall variability This paper examines the long-term change in the herbaceous layer of semi-arid vegetation since grazing has ceased. Measurements were made over a 28-year period to explore four questions: • Whether there were differences in the temporal trends of abundance among growth forms of plants • Whether season of rainfall affected the growth form response • Whether the presence of an invasive species, *Cenchrus ciliaris* (Buffel Grass), influenced the abundance and species richness of native plants relative to non-invaded plots • Whether the abundance of native plants and/or species richness was related to the time it took for an invasive species to invade a plot. Results showed changes in the composition of vegetation as a response to the removal of grazing pressure, fluctuations in rainfall and, presence of exotic grasses. Not specifically related to aquatic ecosystems, however the study looks at grass and forb species that may be present in areas of interest.
Fenner et al. (2012)	Central Australia	"The endangered Slater's skink (*Liopholis slateri*) is restricted to the river floodplain habitat of central Australia. It is an obligate burrower and creates complex, multi-entrance burrow systems in the mound of soil that builds up around the base of some shrubs and small trees. We provide detailed information about the behaviour and use of the burrow systems by Slater's skink." Burrow systems can be destroyed during heavy rainfall (and presumably during high flood events).
Free (2009)	Desert Rivers	*The role of the Field River as a refuge for small vertebrates in the Simpson Desert* Notes lack of studies from Australia on the role of riparian zones in arid areas for small vertebrates. Looked at soil factors: found higher clay, soil carbon and nitrogen in riverine corridor compared with dune habitats. Number of trees, tree cover, cover of non-spinifex grasses and cover of annuals and their persistence greater in riverine corridor than dunes. Sampled 7 times between March 2005 and May 2008 using pitfall traps. Little difference in invertebrate numbers between both habitats.

Reference	Region	Summary
		Found small vertebrate species diversity highest in river centre (48) than floodplain (30). Found some species exclusively inhabited riverine corridor while others were exclusive to dune habitats. Some of the fauna found in the latter are known to utilise spinifex habitat and therefore won't be found in the riparian corridor where there is insufficient protection from predators. Species exclusive to the riverine corridor were tree-dependent. Reptiles were the most diverse and conspicuous fauna along the riverine corridor. Species turnover higher in riverine corridor than dunes. Introduced House Mouse was the only species that was significantly more abundant in riverine habitats than dune, only appearing in the latter following rains. Compared body condition, abundance and reproduction: other than House Mouse, there was generally no difference between habitat and differences were more a function of time since last rain.
Kerle et al. (1992)	Central Australia	*The decline of the Brushtail Possum … in arid Australia* Brushtail Possums distribution in central Australia restricted to watercourses, as well as rocky ranges and outcrops. Distribution now much less than historically.
McDonald et al (2012)	NT LEB	*The lizard fauna of litter mats in the stony desert of the southern Northern Territory* Propose that desertification of central Australia stony deserts restricted the distribution of lizards from that time to ephemeral watercourses and rocky escarpments where trees and shrubs exist. Many of these lizards inhabit litter mats beneath trees and shrubs along watercourses, and are hence locally vulnerable to floods (citing Ehmann (1981, 1992)) (as well as trampling by stock). Surveyed litter mats at 85 sites and found 8 species, including the EPBC-listed nationally vulnerable *Ophidiocephalus taeniatus*. Lizards were located underneath mats produced from the litterfall of four species of Acacia shrubs, but distribution varied between mat types
Mollenmans et al. (1984)	Cooper	*Biological Survey of the Cooper Creek Environmental Association* Reports on a program of standardised point related sampling of the vegetation and vertebrate fauna in 1983/4(?) together with the compilation of all available biological information on the study area. The report contains a large amount of raw data. Raw data such as the base maps used on the survey, are held by the then Survey and Research Section NPWS. Classified land systems into habitats and describes a range of wetland habitats and flora and fauna associated with them.
Moseby et al. (1999)	SA LEB	*Distribution, habitat and conservation status of the rare dusky hopping-mouse* Species only found in dune country of arid Australia (?mostly SA) with disjunct populations. This species mainly inhabits dunes, but higher abundances were found in proximity to lakes and creeks; propose this is due to higher soil nutrient levels supporting food plants but no direct evidence to support this.
Moseby et al. (2006)	LEB	*Variation in population dynamics and movement patterns between two geographically isolated populations of the dusky hopping mouse* A semi-permanent waterhole site supported a lower but more persistent population

Reference	Region	Summary
		of Dusky Hopping Mice than at Montecollina Bore where the population was more variable but higher numbers. Propose that this is because of more persistent food sources at the waterhole site where there were more diverse habitats.
Neagle & Armstrong (2010)		*A Biological Survey of the Marqualpie Land System* Land system mostly within Innamincka RR and to north, mostly dune country but "Small claypans and lakes occur within swales and several watercourses draining gibber country to the north and east cut through the dunefield." Found a highest diversity of plant species in Coolabah woodlands associations along watercourses, floodouts and in swales, dominated by annuals, (area had had good winter rains prior). The least diverse community was also associated with swamps and dunes, being Lignum and Golden Goosefoot shrublands. Recorded five bat species, all of which are hollow-nesters. Highest bird diversity found in two Coolabah woodland sites, supporting previous findings: "Reid and Gillen (1988) who described five main habitat types within the nearby Coongie Lakes Study area, indicating that after Eucalyptus camaldulensis (River Red-gum) dominated riparian woodlands along the major creeklines (which do not occur within the MLS), the *Eucalyptus coolabah* (Coolabah) Woodland on floodplain areas support the highest diversity of bird species, whilst the dunefields have the lowest… Close to half of bird species inhabiting Australian deserts depend on the availability of free water (Reid 1990)." Reptiles on the other hand had lowest diversity at 3 sites in Coolabah woodland. Two frog species found.
Neagle (2003)	LEB SA	*An inventory of the biological resources of the rangelands of South Australia* Chapter 2 provides an overview of each bioregion: physical description, special biodiversity features, vegetation and land use. Describes data used in inventory, this includes Pastoral Lease vegetation monitoring and EPA Frog Census community monitoring.
Newsome (1965)	Central Australia	Surveys of Red Kangaroo in central Australia in drought and following good rains showed that: • During droughts, "67.4% of kangaroos were sheltering in woodlands within 1/3 mile of open plains and water-courses (where food persisted), and only 17.4% were further than 1 mile away." Suggest a relationship with cattle grazing: "Kangaroos were densest (seven-eight per square mile) during drought on land 2-4 miles out from bores and dams and within 2/3 mile of open plains because at that distance grasses on the plains respond to the grazing of cattle by sprouting green shoots which kangaroos prefer" • "After the rains, only 29.5% were within 1/3 mile of these drought refuges; 51.8 % were further than 1 mile away, but only 6% were beyond 6 miles out, i.e. beyond the mulga woodlands. " Kangaroos only drank at bores and dams during severe drought, suggesting they are able to obtain sufficient water from food most of the time.
Pavey et al. (2010)		*Foraging ecology and habitat use of Slater's skink (Egernia slateri): an endangered Australian desert lizard*

Reference	Region	Summary
		Slater's skink is nationally endangered and now only found in desert river floodplains of southern NT. They depend on the mounds that form from wind-blown soils at the base of shrubs (particularly *Eremophila* and *Hakea*) to burrow; found mainly on outer floodplains at base of stony rises Ants and termites were the main food source. Follows from Fenner et al. (2006).
Pepper et al. (2011)	Central Australia	*Ancient drainages divide cryptic species in Australia's arid zone: Morphological and multi-gene evidence for four new species of Beaked Geckos* (Rhynchoedura) Based on genetic analysis, identified 4-5 distinct species of this gecko, with distributions related to drainages: LEB, Bulloo, MDB, western plateau and desert uplands (Pilbara etc)
Playfair & Robinson (1997)	Frome	*A Biological Survey of the North Olary Plains, South Australia 1995-1997* Abstract from web: *"From July to September 1995, 381 sites were surveyed in the North Olary Plains area from Yunta in the south and Lake Callabonna in the north, and between the Flinders Ranges and the New South Wales border. General landform information and a complete plant species list was obtained at each site. Subsequent analysis resulted in the description of 29 floristically distinct plant communities in the region, and the production of a map showing their distribution… In September 1996, 48 of the above sites were revisited, and a survey of vertebrates was undertaken using pitfall, Elliot and cage traps, as well as foraging for reptiles and mammals and observing birds."*
Puckridge et al. (2000)	Diamantina	*Biological Survey of the Lower Diamantina Floodplain* From Abstract on web *"The project aimed to describe the natural heritage of the lower Diamantina floodplain [Goyders Lagoon], clarify the status of the region's aquatic fauna, provide a basis for assessment of the region for possible listing on the Register of the National Estate, and identify land use issues relevant to the conservation of the heritage values identified."* Survey undertaken in November 1993. Results from this survey incorporated into the Morton et al. (1995) assessment of World Heritage values
Read et al. (1999)	SA LEB	*The distribution, ecology and current status of Pseudomys desertor in SA* Desert mouse widespread but sparsely distributed in northwest and north central SA. It was found to be most abundant at samphire shrublands (e.g. on fringes of saltlakes), sedgelands (e.g. associated with moundsprings) and Nitrebush shrublands (also often associated with springs), as well as spinifex grassland. Believe this preference is for foraging species rather that drinking water or aquatic habitats per se. Propose that spinifex populations are maintained by populations in wetter sites.
Reid & Gillen (2013)	Cooper	*Riparian bird assemblages of Cooper Creek, SA* Surveyed riparian and floodplain bird assemblages along the Cooper from Cullyamurra downstream. Bird abundance and diversity highest in the upper

Reference	Region	Summary
		reaches and declined downstream. Species richness and community abundances were higher in riparian sites than non-riparian. Found upper reaches supported diverse bird communities and breeding raptor populations.
Slaytor (1999)	Kati Thanda-Lake Eyre	*Lake Eyre South* From Abstract on web *"Studies of the biological components of the Lake Eyre South Study (LESS) were initiated to identify key habitats, species and localities within the study region and to provide data for the South Australian Biological Survey Database."* Survey April 1995 to April 1996.

3.3.2. Processes

3.3.2.1. Physical habitat and geomorphological processes

General processes

Reference	Region	Summary
Craddock et al. (2010)	Finke	Topographic data reveal a buried fluvial landscape in the Simpson Desert The palaeorivers that went from the Central Australian ranges down to Kati Thanda-Lake Eyre, before the Simpson Desert's dunes. Likely to have an influence even today.
EHP (2012a)	Qld (LEB)	Webpage providing brief intro and summary for the Lake Eyre and Bulloo Freshwater Biogeographical Province, according to the WetlandInfo criteria. Brief summary of geology, topography and channel morphology for the whole of basin. All data sources are referenced therein.
Moller (1999)	Qld (LEB)	State of the Rivers Cooper Creek and Major Tributaries An assessment of the physical and environmental condition was conducted for 273 sites on the Thompson River, Barcoo River, Cooper Creek and their tributaries. Parameters were assessed against presumed natural condition by comparison to remanent sites. Bed, bar and bank stability was assessed [other parameters also]. These were affected primarily by natural processes with stock presence and vegetation cover adding pressure. Relevance: describes the state of rivers in the Cooper catchment; and describes a method for monitoring. There is potential for identification of temporal changes if monitoring the same parameters occurs.
Sandiford et al. (2009)	National	Tectonic framework for the Cenozoic cratonic basins of Australia Tectonic history creating the present fluvial context of the LEB.
Tweed et al. (2011)	Channel Country	Arid zone groundwater recharge and salinisation processes; an example from the Lake Eyre Basin Groundwater is mostly recharged by diffuse infiltration (possibly through gilgai macropores) during heavy local rainfall (c.f. Cendon et al. 2010, documentation of waterhole-driven recharge). Recharge by floodwaters does not seem to be a major

Reference	Region	Summary
		contributor.

Variability, floods and extreme flows

Reference	Region	Summary
BOM (2012)	National	Record-breaking La Niña events The recent (2010–12) rainfall event was an unusually large one, on a timescale of recent human experience.
Dunkerley & Brown (1999)	LEB	Flow behaviour, suspended sediment transport and transmission losses in a small (sub-bank-full) flow event in an Australian desert stream Measured variability related to transmission loss. Drylands rivers decrease in size downstream. Influencing factors include not only channel sediment but also abstraction into higher-level anabranches.
Finlayson & McMahon (1988)	Inter-national	Australia v. the world: a comparative analysis of streamflow characteristics Australian drylands rivers have some of the world's most variable discharges: flood sizes (expressed as 100-year return frequency compared to annual) are much larger than those of the non-drylands rivers upon which society's understanding of river processes is based. Variations in run-off coefficients are one factor, another is arid-zone rainfall variability.
Knighton & Nanson (2001)	Cooper Creek	An event-based approach to the hydrology of arid zone rivers in the Channel Country of Australia The Channel Country rivers are very long and bring monsoonal rainfall into the arid interior. Flow variability is described, especially the variable hydrographs.
Pickup (1991)	NT (LEB)	Event frequency and landscape stability on the floodplain systems of arid central Australia Infers deposition in the last 10,000 years has been dominated by a few gigantic floods, and that since the last of these, channel-levee systems have been growing up and out from the mountain ranges. The 1974 flood is estimated to be the largest in the upper Finke system for the last 850 years but that larger floods have previously occurred.
Reid & Puckeridge (1990)	Cooper Creek (Coongie Lakes)	Coongie Lakes The Coongie wetlands and other parts of the lower Cooper Creek rely on large flows coming down from the upper catchment.
Reid and Frostick (1997)	LEB	Channel form, flows and sediments in deserts. Patchy rainfall distribution and migrating weather fronts can lead to asynchronous tributary activity, a characteristic of drylands rivers.
Tooth & Nanson (2000)	LEB	Equilibrium and nonequilibrium conditions in dryland rivers Equilibrium and non-equilibrium landforms down Australian river networks, and

Reference	Region	Summary
		relationships to catchment size. Drylands rivers are held to be flashy but the larger rivers in Australia develop anabranching, which could be viewed as an equilibrium landform.
Tooth (2000)	LEB	Process, form and change in dryland rivers; a review of recent research Documents processes contributing to flow variability. Extreme behaviour is characteristic of some dryland rivers, and high absolute discharges (as well as high relative discharges) may occur.
Tooth (2005)	Finke	Splay formation along the lower reaches of ephemeral rivers on the northern plains of arid Central Australia. Describes the occurrence, context and processes of sand-bed river splays in floodout zones. The floodouts in the distal rivers – away from the uplands catchments - need floods to water them.
Wakelin-King (2010)	Neales	Geomorphological assessment and analysis of the Neales Catchment Differences in flow patterns between the adjoining Neales and Arckaringa rivers relates to contrasting runoff characteristics, and results in very different styles of channel type and waterhole distribution.

Extreme flows and today's landform

Reference	Region	Summary
Baker et al. (1983)	Finke	Palaeofloods in central Australia Slackwater analysis of the Finke palaeoflood record. This is one of a number of dated palaeoflood records in drylands Australia. Description of the slackwater deposits and their process of deposition.
Bourke & Pickup (1999)	Finke	Fluvial form variability in arid central Australia Very large floods are a key process in drylands fluvial geomorphology: they carve channels, scour valleys back to bedrock, and deposit sediments which are unlikely to be completely modified by smaller, more frequent flows.
Bourke 1994	NT (Finke)	Cyclical construction and destruction of flood dominated flood plains in semiarid Australia Very large floods are a key process in drylands fluvial geomorphology: they carve channels, scour valleys back to bedrock, and deposit sediments which are unlikely to be completely modified by smaller, more frequent flows.
Gibling et al. (1998)	Qld (LEB)	Anastomosing river sedimentation in the Channel Country of central Australia Detailed account of river sedimentation for the LEB floodplain channels, including a facies model for anastomosing rivers. Results from surface and subsurface observations throughout the channel country are presented. Present anastomosis results from the need for the system to move large volumes of water and moderate sediment loads across low-gradient topography.

Reference	Region	Summary
		Relevance: Describes processes operating on and within the lower catchments and the resulting geological features (i.e. anabranching, sediment aggregation, channel braiding etc).
Gupta (1983)	National	High-magnitude floods and stream channel response. Very large floods govern fluvial geomorphology, providing the context within which are set the deposits of smaller flows. Relates processes and landforms across a range of scales, and demonstrates the temporal relevance.
Knighton & Nanson (2000)	Cooper Creek	Waterhole form and process in the anastomosing channel system of Cooper Creek Waterholes form at places of localised increases in stream power. During moderate floods a narrow band of high-velocity flow penetrates deeply, and is a likely mechanism for depth maintenance.
Kochel & Baker (1988)	Finke	Paleoflood analysis using slackwater deposits Slackwater analysis of the Finke palaeoflood record. This is one of a number of dated palaeoflood records in drylands Australia.
Patton et al. (1993)	Finke	Holocene paleofloods of the Ross River, central Australia Palaeofloods of Central Australia and their formative role in the landforms of today. This paper, Baker et al. (1983), Kochel & Baker (1988), and Bourke & Pickup (1999) were part of a controversial (at the time) discussion in geomorphology about the relative importance of catastrophism vs. uniformitarianism, and the influence (or not) of extreme past events on the landscape of today.
Tooth & Nanson (2000)	All, Finke, Channel Country	Equilibrium and nonequilibrium conditions in dryland rivers Discussion of equilibrium and non-equilibrium landforms in Australian river networks, and their relationships to catchment size. Equilibrium landforms have clear process-landform relationships and non-equilibrium landforms less so. While drylands rivers are held to be dominantly non-equilibrium, this is not the case in some e.g. the Channel Country.
Tooth (2005)	All, Finke	Splay formation along the lower reaches of ephemeral rivers on the northern plains of arid Central Australia. Documenting evidence for process of floods creating some types of floodouts.
Wakelin-King & Webb (2007)a	NSW (MDB)	Threshold-dominated fluvial styles in an arid-zone mud-aggregate river: Fowlers Creek Flood processes are a key part of creating tributary-confluence floodouts in western New South Wales. Vegetation-landform process relationships in a positive feedback loop keep floodouts healthy, but a flip to the alternate state (valley-floor incision) destroys the biological productivity. Floodouts are valuable drought refugia.
Wakelin-King (2010)	Neales	Geomorphological assessment and analysis of the Neales Catchment Waterholes are created during very large to extreme flood events. Channel relocation, including change or loss of large waterholes, can occur as part of a flood event.
Wakelin-King (2013)	Cooper	Geomorphological assessment and analysis of the Cooper Creek catchment

Reference	Region	Summary
		During the recent geological past, avulsion at the head of the Cooper Creek Fan has relocated water (therefore productivity) away from previous lake wetlands. The Coongie Lakes are the most recent wetlands. Avulsion is a complex process, but is most likely during very large-scale flow events.
Zong & Nepf (2010)	Cooper	Flow and deposition in and around a finite patch of vegetation Riparian vegetation intercepting high-level flood flow creates a shear zone between bank and channel, maintaining the steep sides of waterholes and channels.

Floodouts

Reference	Region	Summary
Bull (1997)	Some parts of Channel Country	Discontinuous ephemeral streams Floodout formation and relationships with arroyos and discontinuous channel networks. Process-landform relationships and sedimentary record features are described
Duguid (2011)	NT (GAB)	Wetlands of the GAB Water Control District (NT) 'All the major rivers flood-out among sand-dunes of the Simpson Desert, and only the Finke River extends through the Water Control District, with one of its terminal floodouts being in SA. The floodouts are major landscape features of the Water Control District. All the floodouts contain areas where water ersists for weeks or months in swamps or pans, however, these wetland areas are a small proportion of most of the floodouts. In contrast to the floodouts of the other rivers, the Finke River floodouts include an extensive group of large swamps and lakes between sand-dunes. These fill when episodic large flows occur (e.g. every 10-20 years) and some can hold water for more than a year (p.ii).'
Duguid et al. (2005)	NT (LEB)	Wetlands in the arid Northern Territory List of wetland types includes 'flats' – some of which are floodouts.
Grenfell et al. (2012)	International	Morphodynamics of a gully and floodout system in the Sneeuberg Mountains of the semi-arid Karoo, South Africa: Implications for local landscape connectivity Description of an African floodout.
Gupta (1983)	All	High-magnitude floods and stream channel response. Very large floods govern fluvial geomorphology, providing the context within which are set the deposits of smaller flows. The process implications are that landform creation and change is nested in a range of scales, including very large scales outside ordinary human experience.
Tooth (1999)	Finke	Floodouts in central Australia This reference was the first to define floodouts in terms of geomorphology process. Floodouts are characterised by progressive decline in channel capacity, an increasing proportion of overbank flow, and an eventual disappearance of the

Reference	Region	Summary
		channel. Large floods continue to travel across the extensive floodplain as unchannelised sheet flow.
Wakelin-King & Tooth (in prep.)	LEB	Floodouts in drylands: forms, processes, and management implications of major fluvial discontinuities. Analyses geomorphic processes of different types of floodouts, and their formative conditions, vulnerabilities, and management implications.
Wakelin-King & Webb (2007a)	MDB	Threshold-dominated fluvial styles in an arid-zone mud-aggregate river: Fowlers Creek Flood processes are a key part of creating some floodouts. The floodouts are threshold-driven landforms, robust up to a point but then susceptible to sudden change. A floodout's vegetation is a key factor in floodout maintenance. It alters flow dynamics to promote sedimentation and discourage erosion. Floodouts are part of discontinuous ephemeral streams, disequilibrium landforms which fluctuate around a balance between valley-floor strength and channel incision.

Waterholes and their host rivers

Reference	Region	Summary
Cendon et al. (2010)	Cooper	Freshwater recharge into a shallow saline groundwater system, Cooper Creek floodplain Recharge of groundwater through waterholes during flood. Process is scouring of waterhole base. Documented effects on local groundwater salinity are scaled to waterhole size.
Corenblit et al. (2009)	All	Control of sediment dynamics by vegetation as a key function driving biogeomorphic succession within fluvial corridors Habitat and landform creation, maintenance and change are process-linked. Vegetation traps sediments and makes landforms. Succession in plant communities is linked to geomorphic evolution, and links back again to biological functions such as seed banks. The role of riparian vegetation in maintaining waterholes and floodouts is an example of this type of behaviour.
Davis et al. (2003)	Qld (Cooper Creek)	Physical and ecological associations in dryland refugia: waterholes of the Cooper Creek, Australia Investigated how the morphological features of waterholes can influence in-stream ecosystem processes (i.e. bottom up control). Results identified a strong association between waterhole fetch length, turbidity and productivity: morphology = fetch length = turbidity = primary production = resident species populations. Relevance: Discusses the possible connections between physical and ecological aspects in the Cooper
Dunkerley (2008)	Channel Country	Bank permeability in an Australian ephemeral dry-land stream: variation with stage resulting from mud deposition and sediment clogging

Reference	Region	Summary
		Sealing of waterhole banks by muds after flow; capacity for infiltration is decreased by fines carried into pore spaces by floodwaters. Likely one of the drivers of transmission loss rates varying with flood height.
Fagan & Nanson (2004)	Cooper	The morphology and formation of floodplain-surface channels, Cooper Creek, Australia Channels of the mud-aggregate floodplains. Relationships of floodplain types to frequency of floodplain inundation; distribution of braid-like, reticulate and featureless floodplains reflects balance between fluvial and pedogenic (gilgai) processes. Detailed account of floodplain-surface environments and corresponding pedological variations for a 370 km reach of Cooper Creek. Discussion of how channel morphology influences flood flows with respect to bank/floodplain inundation. The analysis reveals a strongly interconnected system of surface channelling and pedogenic characteristics responsive to the depth and frequency of overbank flow. Overbank flow characteristics for any given area are determined by event size, floodplain physiography (width, topography) and transmission losses. Relevance: Details current processes in the morphology and formation of floodplain surface channels in the lower Cooper.
Gibling et al. (1998)	Channel Country	Anastomosing river sedimentation in the Channel Country of central Australia. Documents the mud-aggregate floodplains and anastomosing channels of Cooper Creek. Experimentally determines robustness of vertic particles during fluvial transport. (GWK note: a ground-breaking observation which reversed some common ideas about processes of mud deposition. In turn this changes some common interpretations about the nature of drylands fluvial behaviour.)
Knighton & Nanson (2000)	Cooper	Waterhole form and process in the anastomosing channel system of Cooper Creek Waterholes of the Channel Country. Describes waterholes and their context in the Channel Country's anabranching mud-aggregate system. Documents observed flow velocity (therefore stream power) conditions, including low speed/power over the floodplain but higher speed/power directed to waterhole centres.
Knighton & Nanson (2001)	Channel Country	An event-based approach to the hydrology of arid zone rivers in the Channel Country of Australia Hydrology of the Channel Country. Describes the overall hydrology, and links drainage network size and disposition to flow variability, hydrograph variability, and reliability of water supplies to the Strzelecki Desert.
Wakelin-King (2010)	Neales	Geomorphological assessment and analysis of the Neales Catchment Describes waterholes, anastomosed channels, floodplains, splays; processes and threats. Covers both human-created and natural mechanisms of change.
Wakelin-King (2013)	Cooper	Geomorphological assessment and analysis of the Cooper Creek Catchment Describes waterholes, anastomosed channels, floodplains, splays; processes and threats. Covers both human-created and natural mechanisms of change.

Reference	Region	Summary
Zawada & Smith 1991	Channel Country	South Africa. Observation of waterhole formation by catastrophic valley-floor incision during a very large flood. Primarily descriptive but the description of the event allows interpretation of waterhole formative process.

Other fluvial processes

Fluvial geomorphology and processes of river types within the LEB, not including floodouts or waterholes.

Reference	Region	Summary
Amos et al. (2008)	National	A catchment-scale assessment of anabranching in the 143 000 km^2 Fitzroy River catchment, north-eastern Australia This catchment-scale remote study of anabranching, using DEM-derived river networks and other data, made interesting observations on types of anabranching but the scale was too coarse for process analysis and no causative factors could be identified. Detailed field work was identified as a necessary next step.
Cohen et al. (2010)	Channel Country	Late Quaternary aeolian and fluvial interactions on the Cooper Creek Fan and the association between linear and source-bordering dunes, Strzelecki Desert Multi-step creation of sand dunes in the Strzelecki Desert relates to palaeoclimate and palaeoflow conditions, and reveals long-term fluvial processes and landscape evolution.
Eaton et al. (2010)	all	Channel patterns: Braided, anabranching, and single-thread The difference between braided channels and anabranching channels, with respect to measurable boundary conditions.
English (1998)	NT (LEB)	Cainozoic geology and hydrogeology of Uluru-Kata Tjuta National Park Banded vegetation communities enhance penetration of water to depth, and therefore are an influence on recharge effectiveness.
Hollands et al. (2006)	Finke	Aeolian-fluvial interaction; evidence for late Quaternary channel change and wind-rift linear dune formation in the northwestern Simpson Desert Documents large-scale channel relocation just north-west of the Simpson Desert.
Jones (2006)	Qld (Upper Channel Country)	Cenozoic landscape evolution in central Queensland Development of the drainage network and stream capture processes that define present-day catchments in central to north-eastern Qld.
Marriott & Wright (1996)	Channel Country	Sediment recycling on Siluro-Devonian floodplains Cooper Creek mud-aggregate floodplains are almost the only modern analogue for a very important lithotype. This paper is an example of the use of a modern analogue to understand the geological record.
Stevens (1991)	Channel Country	Some aligned claypans in the Strzelecki dunefield Describes palaeodrainages on the Cooper Creek Fan, providing important clues to

Reference	Region	Summary
		local landscape evolution.
Wakelin-King (1999)	Finke; portions of all	Banded mosaic ("tiger bush") and sheetflow plains: a regional mapping approach Banded vegetation is a non-channelled waterway characterised by alternating bands of vegetation and bare ground. The run-off patch promotes vegetation in the downslope vegetated patch; the process is a vegetation: landform co-relationship. Banded vegetation is very important to plant communities, their dependent animals, and also groundwater.
Wakelin-King (2010)	Channel Country, Arckaringa	Geomorphological assessment and analysis of the Neales Catchment Describes waterholes, anastomosed channels, floodplains, splays; processes and threats. Covers both human-created and natural mechanisms of change.
Wakelin-King (2013)	Channel Country	Geomorphological assessment and analysis of the Cooper Creek Catchment Describes waterholes, anastomosed channels, floodplains, splays; processes and threats. Covers both human-created and natural mechanisms of change. Includes report on cane toad habitat in the Strzelecki Desert. Notes the importance of the key landform elements that direct flow (and are therefore critical to the dependent ecosystems) such as sills, swamps and numerous small channels. Riparian vegetation has a role in maintaining channel integrity and waterhole depth.

Geomorphology and ecology links

Reference	Region	Summary
Bunn et al. (2006)	All	Flow variability in dryland rivers: boom, bust and the bits in between Flooding at a range of scales is the key process in drylands river ecologies. Reductions in flow volumes or modifications to delivery patterns are detrimental to ecosystems.
Cohen et al. (2011)	Frome	Continental aridification and the vanishing of Australia's megalakes Lake Mega-Frome comprised Lakes Frome, Blanch, Callabonna and Gregory and was last connected to Kati Thanda-Lake Eyre 50 to 47ka.
Costelloe et al. (2004)	LEB	ARIDFLO Various chapters: Hydrology: waterhole morphology
Leigh et al. (2010)	All	Sequential floods drive 'booms' and wetland persistence in dryland rivers: a synthesis Flooding at a range of scales is the key process in drylands river ecologies. Reductions in flow volumes or modifications to delivery patterns are detrimental to ecosystems.
Morton et al. (1995)	SA (LEB)	Natural Heritage Values of the Lake Eyre Basin in South Australia: World Heritage Assessment

Reference	Region	Summary
		Literature review documenting natural heritage values for possible (but ultimately unsuccessful) World Heritage listing. Sections 4.3 and 4.4 cover geology and geomorphology.
Nanson et al. (1998)	LEB (SA)	Hydroclimatic interpretation of Quaternary shorelines on South Australian playas Undertook an analsys of ancient beach ridges to identify periods of filling and drying of Kati Thanda-Lake Eyre. Found that under maximum filling, Kati Thanda-Lake Eyre has been at least 27m above the current lake bed. Filling since approximately 111 ± 18 to 89 ± 16 ka is unable to exceed 12m AHD due to a 'spillway' (Warrawoocara overflow channel) connecting Kati Thanda-Lake Eyre to the Lake Gregory - Frome complex.
Magee and Miller (1998)	LEB (SA)	Lake Eyre palaeohydrology from 60 ka to the present: beach ridges and glacial maximum aridity At its maximum during the last 60ka Kati Thanda-Lake Eyre has been up to 25m deep. Between 30000 – 12000 BP Kati Thanda-Lake Eyre at least as dry as today. Minor permanent inundation period after about 10000 BP and current ephemeral hydrology has been in place since approximately 4000 - 3000 BP.
Tyler et al. (1990)	SA (LEB)	Natural History of the North East Deserts Comprehensive literature review for entire NE corner of SA with some overlap with Arckaringa and Pedirka Basins. Covers: • Geology • Hydrology • Soils • Limnology
Unmack (2001a)	Finke	Fish persistence and fluvial geomorphology in central Australia Summary of Historic Fish Records (to 1991) in the NT LEB. Some discussion of Geomorphology The presence of surface water in regional river channels is controlled by geomorphology. To survive fish must disperse into other geographic regions through connectivity.
Unmack (2001b)	Australia	Biogeography of Australian freshwater fishes Publication of a Masters thesis this document examines Australian bioregions in terms of fish endemism and Paleohydrology. Dataset does not include all currently known LEB fishes. Bundles LEB into the Central Australian Province.
Unmack (2010)	Australia	Biogeography of the genus Craterocephalus (Teleostei: Atherinidae) in Australia Similar to Unmack 2001 but considers genetic data and only Craterocephalus. Similar conclusion.
Wakelin-King (2011)	Western Rivers	Geomorphological assessment and analysis of the Neales Catchment Landscape processes

Reference	Region	Summary
	(Neales)	Geological influences

3.3.2.2. Water quality processes

Reference	Region	Summary
Bailey, et al. (Draft, 2002)	Qld (LEB)	The Longreach Town Weirs - Environmental Issues Discussed the development of potential strategies to limit fish kills and other problems associated with water extraction from the Longreach Weir. Options discussed were retaining environmental water levels with aeration and removal of fish biomass at certain drawdown levels. Relevance: Highlighted the need to develop operational plans for weirs that involves stakeholders and takes into account social, economical and environmental issues.
Costelloe (2011)	Neales	Hydrological assessment and analysis of the Neales Catchment Describes the distribution of saline waterholes observed in the Neales catchment and provides some data on temporal variability of salinity fluctuations. Also provides some commentary on processes driving salinity fluctuations.
Costelloe et al. (2004)	LEB	ARIDFLO Report contains extensive water quality data from five reaches of the LEB (Thomson River and Coongie Lakes (Cooper), upper and lower Diamantina, Neales). Much of these data have been further summarised and analysed in publications listed below. The responses of some of the biotic groups to changes in water quality, particularly salinity, have been further published (e.g. algae, zooplankton, macroinvertebrates (partly)) but further information is contained in the ARIDFLO report for macroinvertebrates, fish and waterbirds. Not many analyses were done on other aspects of water quality, such as dissolved oxygen, pH or temperature.
Costelloe et al. (2005a)	Neales, Diamantina, Cooper	Modelling streamflow in a large ungauged arid zone river, central Australia, for use in ecological studies Summarises the distribution of saline waterholes from the ARIDFLO dataset and speculates on the main processes controlling this distribution, including surface water – groundwater processes. The most saline waterholes are those in the lower reaches of the Neales and Diamantina while the waterholes in the Queensland reaches are consistently fresh (<1000 EC).
Costelloe et al. (2005b)	Neales	

Reference	Region	Summary
Costelloe et al. (2005c)	Cooper, Diamantina, Neales	Algal diversity and assemblages in arid zone rivers of the Lake Eyre Basin Describes the main drivers of the algal composition during the ARIDFLO project (2000–02) in the SA reaches of the LEB. Salinity was found to be a significant driver of algal composition but diversity only markedly declined at very high salinity levels. At lower salinities there were changes between halophobic and halophilic species within the same phyla.
Costelloe et al. (2013)	Cooper	*Hydrological assessment and analysis of the Cooper Creek Catchment SA* Water salinity <1mS/cm at all sites. Salinity higher in downstream lakes than main channel, indicating these lakes contribute salt to the main channel during flow. A groundwater monitoring bore at Lake Toontawaranie was sampled in November 2011 and groundwater found to be 1.5 below ground level and salinity slightly more saline than seawater. The groundwater level was far higher than previously measured during the Aridflo project although slightly less saline. The groundwater is expected to have been recharged from the 2010 flood. Algae samples were also collected and analysed with some interpretation provided.
Duguid (2013a)	Finke	Delineation and Description of Ecological Character of the Mid-Finke Waterholes: A Trial of Guidelines for HEVAE The very high spatial variation in salinity of mid Finke waterholes is assumed to be related to inputs of various groundwaters (local alluvial and deeper regional) interacting with evaporation and transpiration by vegetation.
Dunlop et al. (2013b)	Qld (MDB)	Coal seam gas water use proposals in the Queensland Murray–Darling Basin: Approaches to the assessment of cumulative water quality impacts from coal seam gas water discharge on aquatic ecosystems Assessment of cumulative impacts of CSG discharge on the water quality of streams and rivers. Found that the impact of treated CSG water on overall water quality and salt load was low but did not investigate the effect on saline systems or the effects on groundwater – river interaction and consequent water quality implications. The report makes recommendations on appropriate chemical and biological (e.g. diatoms, macroinvertebrate assemblages) indicators for assessing the effects of CSG discharge. They recommend that indicators need to take into consideration existing longitudinal gradients. The report also investigated the effects of CSG discharge on bank stability and found there was no significant effect when evaluated using field data.
EHP (2012a)	Qld (LEB)	Webpage providing brief intro and summary for the Lake Eyre and Bulloo Freshwater Biogeographical Province, according to the WetlandInfo criteria. Very brief summary of turbidity, photic depth and benthic metabolism for the

Reference	Region	Summary
		whole of basin. All data sources are referenced therein.
Goonan et al. (2003)	SA (LEB)	River Health in the Far North Brief summary brochure for AUSRIVAS monitoring in the LEB rivers within SA. The brochure identifies the sampling sites and summarises results. Most LEB sites are in good 'reference' condition but the saline sites were outside the parameters of the AUSRIVAS models.
Hudson et al. (2003)	Neales	Aquatic macroinvertebrate biodiversity in the western Lake Eyre Basin: the role of naturally fluctuating salinity Macroinvertebrate diversity was found to remain relatively high up to salinities of 2000 EC. Beyond this threshold, the diversity decreased with increasing salinity. However, the presence of species intolerant and tolerant of salinity at intermediate levels can maintain diversity.
Irvine et al. (2005)	Cooper	Modelling solute transport through an arid zone ephemeral lake system: joint use of geochemical and hydrological techniques The salinity of the Coongie Lakes showed moderate increases in EC during a flow event in 2004–05 and evapoconcentration, soil water mixing and mineral precipitation-dissolution were required to explain salinity changes. In combination with Costelloe et al. (2009), these findings indicate that the groundwater interaction during dry periods can significantly affect water quality during flow events.
Irvine et al. (2006)	Diamantina	Salt and water flux in an intermittent arid zone river: the role of the floodplain environment. Chemical and isotope data showed spatially variable recharge during flow events in the Warburton River, with little recharge implied through the floodplain but more through the banks and in sand dunes adjacent to waterholes.
Larsen (2012)	Cooper, Georgina-Diamantina	Aspects of the contemporary and Quaternary hydrology of the Lake Eyre Basin, central Australia A PhD thesis. Chapter 2 examines dissolved ion compositions in Cooper Creek and the Georgina-Diamantina catchment using DERM data. Analysis found that the total dissolved solids (TDS) of flow in the Queensland reaches of these rivers is low (<150 mgL^{-1}) in comparison to the Murray-Darling Basin and many other dryland rivers of the world. Similar to Sheldon and Fellows (2010), the dominant anion was bicarbonate. Most ions did not show significant increases in concentration between upstream and downstream gauging stations, although this was only measured on a mean basis – not for individual flow events. This implies that some flow paths are delivering water very efficiently (i.e. no significant evapoconcentration) and that the large transmission losses in these rivers are driven by losses to terminal storages (such as wetlands on the floodplain) and infiltration – recharge processes.
Prichard, et al. (Draft, 2002)	Qld (LEB)	Discussion of the implications of biomanipulation in the Longreach Weir to control phytoplankton blooms during drought periods Methods of control of phytoplankton in the Longreach Weir during drought by

Reference	Region	Summary
		biomanipulation are discussed. Two main options exist: food web alterations; and resource alterations (i.e. alter required resources available to phytoplankton). A number of conceptual models are associated with this report linking management options and potential outcomes. Relevance: Discusses methods for and implications of altering a waterhole for avoiding undesirable phytoplanktonic blooms.
Read (2011)	Finke	Hydrogeology of the Finke River Report provides information on river salinities and chemical composition during low flows and cease-to-flow in the Finke River. Data on waterholes were found to be moderately saline (<10 000 mg/L TDS) and at its highest in the more downstream waterholes. The salinity of the standing waterholes does not appear to reach the very high levels seen in the Neales and this is likely due to the alluvial groundwater of the Finke only have low-moderate salinity (due to fluvial recharge) compared to the hypersaline conditions found in the saline reaches of the Neales. The salt flux analysis also showed that low to moderate flows (<50 m^3/s) had elevated salinities (900–1300 mg/L) but no data is available on the salinity behaviour of high flows. Appendix C provides information on depth and water quality variations in some mid Finke waterholes (Snake, Two Mile and Boggy Hole). These three waterholes show stratification with more saline water at depth (significantly so in the case of Two Mile waterhole). This has implications for the ecological functioning of the waterholes and may suggest the inflow of saline surface water or saline groundwater.
Sheldon and Fellows (2010)	Cooper	Water quality in two Australian dryland rivers: spatial and temporal variability and the role of flow Water quality data from the Channel Country reach of Cooper Creek were analysed. While conductivity was low (mean<350 EC), particularly relative to lower reaches of LEB, the composition was variable, particularly between the flow and non-flow sampling times. The composition of the water was Na-Ca-HCO_3 dominant. The paper concludes that 'Such extreme spatial and temporal variability hampers successful derivation of water quality guidelines for these variable rivers and suggests such guidelines would need to be developed with respect to 'flow phase'.'
Shiel et al. (2006)	Cooper, Diamantina, Neales	Zooplankton diversity and assemblages in arid zone rivers of the Lake Eyre Basin Describes the drivers of the zooplankton composition during the ARIDFLO project (2000–02) in the SA reaches of the LEB. Salinity was found to be a significant driver of zooplankton composition with significant changes occurring at salinities between 8000–120 000 EC.

3.3.2.3. Hydrological processes

Flow regime (river reach) processes

Reference	Region	Summary
Barma & Varley (2012a)	National	Hydrological modelling practices for estimating low flows – stocktake, review and case studies Hydrological modelling practices for estimating low flows – stocktake, review and case studies. Reviews modelling approaches and performances in the different states to dealing with low flows. Generally low flow performance was poor and several states developed models to better replicate low and/or intermittent flows. The models' capacity to deal with transmission losses and other groundwater – surface water interactions was often found to be a cause of poor performance in modelling the low flow spectrum of the flow regime. In the LEB, only the performance of hydrological modelling in the Queensland reaches of Cooper Creek are reported. In the Cooper the overall model performance and also performance at low flows was generally poor.
Barma and Varley (2012b)	National	Hydrological modelling practices for estimating low flows – guidelines Provides best-practice modelling guidelines for estimating low flow characteristics using rainfall-runoff modelling. The report provides the following 12 principles grouped under four headings (taken directly from the report) with comment provided below each group: <u>Data</u>: 1. The model used to estimate low flows should contain sufficient data of adequate spatial and temporal coverage to describe the major physical processes that influence the generation of low flows. The data period should be sufficient to represent climate variability and in particular include low-flow and cease-to-flow periods. 2. Data should be checked for outliers, trends and errors that need to be corrected or removed. 3. Uncertainties associated with the data should, if possible, be determined before use. These data requirements are only available at the long-term gauging stations, such as those in the Thomson catchment. The western rivers are characterised by limited data (Neales) to virtually no time-series of data (Macumba). The water level logger data available for the Neales may be able to match some of the above requirements. In particular, the period of data (2000–12) covers a range of climatic conditions and demonstrates the highly ephemeral nature of the catchment. <u>Model selection and configuration</u>: 4. The hydrological characteristics important in generating and describing low flows should be identified before selecting a model(s). Ecologically-relevant hydrological characteristics should be included. 5. Models should be configured to ensure these important hydrological characteristics are adequately represented. 6. Models best able to represent the identified low-flow hydrological characteristics should be selected for use in estimating low flows. Model selection should be based on the simplest model that will satisfy

Reference	Region	Summary
		the representation of important low-flow hydrologic characteristics, as well as overall modelling objectives and project requirements. In the context of the catchments under consideration, models need to be able to simulate flow and cease-to-flow characteristics at various points in the catchment (i.e. refugial waterholes or ecological sampling points). This requires a distributed to semi-distributed model structure (i.e. grid-based or link-node). Due to the large size of the catchments, this also requires some capacity to rout flow. The lack of groundwater discharge supporting low flows in these catchments means that groundwater connectivity does not need to be accounted for in the model structure (but see water quality section). Point 6 emphasises the need for the most parsimonious structure possible and this would be a conceptual structure in the LEB rather than a physically based model. There is discussion of the required elements of a conceptual model for the Neales River in Costelloe et al. (2005a). JC Model calibration: 7. The calibration period should be sufficient to represent climate variability and in particular include low-flow and cease-to-flow periods. 8. Where possible, validation using separate sets of data and appropriate criteria should be used to assess and report calibration robustness. 9. Consistent calibration processes should be applied when calibrating a model to observed flows. Objective functions used for automatic calibration should provide suitable weighting to the low-flow portion of the flow regime. Manual calibration should adopt suitable low-flow metrics (e.g. Tables 2 and 3 in Section 4). 10. Uncertainty analysis should be undertaken to evaluate the reliability and robustness of the model, particularly its ability to estimate low flows. These are sound model calibration processes. As for the Data grouping, these principles would be best addressed for the Thomson catchment which has the longest and highest quality flow record of the study catchments. The Neales record is probably not long enough foreffective split period calibration and evaluation but the 2000–05 and 2006–12 periods could be used, as both periods cover relatively wet and dry periods (albeit 2009–11 is the wettest period in this record). The Macumba and lower Finke provide modelling challenges due to the lack of data. The available data for the Macumba would need to be reserved for evaluation of model results. Due to the paucity of available data for the western rivers, the best calibration procedure may be to run a Monte Carlo type suite of model runs and use these to investigate the range of low flow behaviour using a range of non-traditional performance measures (i.e. measures of no flow and ranking of flow event size rather than automatic optimisation to a time-series). Model transposition: 11. Flows in ungauged catchments should be estimated using data from gauged catchments in the region. Information from more than one regional gauging station should be used in deriving the estimate. 12. The reliability of flow estimates in ungauged catchments should be tested by applying the method adopted to gauged catchments in the region and assessing the quality of calibration using suitable objective

Reference	Region	Summary
		functions and low-flow metrics. This may include testing different methods and selecting the one that performs best. These are again sound modelling strategies. For the western rivers it will be necessary to calibrate models on the Neales and upper Finke data and then apply a range of model sets to the ungauged Macumba and lower Finke. Modelling of ungauged tributaries of the Thomson will be able to use a range of model sets calibrated on gauged tributary and main-stem gauging records.
Bunn et al. (2006)	Cooper Ck	Flow variability in dryland rivers: boom, bust and the bits in between. Review of the influence of flow variability on riverine ecosystem processes in Cooper Creek Relevance: indicates changes that may occur from flow regulation (dam and release gradually for downstream consumption)
Costelloe (2004)	LEB	PhD thesis providing hydrological analysis and modelling of the five ARIDFLO study reaches in the LEB (Thomson and Coongie Lakes, upper and lower Diamantina and Neales Rivre). Much of the material is contained in the more accessible ARIDFLO report (Costelloe et al. 2004) and subsequent journal publications (Costelloe et al. 2003; 2005a, b; 2006; 2007).
Costelloe (2008)	Cooper, Diamantina, Neales	Updating and analysis of the ARIDFLO water level data in the Lake Eyre Basin Report summarising the data obtained from the on-going ARIDFLO water level logger network for the period 2000–08. This provides the most up-to-date report for the Diamantina but the Neales data are more recently summarised in Costelloe (2011) and the Cooper in Costelloe (2012).
Costelloe (2011)	Neales	Hydrological assessment and analysis of the Neales Catchment Summarises ten years of hydrological data collected in the Neales catchment. A short update was also provided following the collection of further data in April 2011. The monitoring found that the frequency of flow events could vary markedly between La Niña – associated wet periods, and the longer-term drier periods (see below). In addition, modelling of the catchment using the same model described in Costelloe et al. (2005) suggests that even the period since 2000 shows a higher frequency of flow events compared to the 1979–99 period. 'Over the period of 2000–11 (11 years), 46 flow events were monitored in the Neales catchment in at least one reach, indicating that approximately 4.2 flow events occur in the catchment per year. However, this frequency was highly skewed by the large number of flow events in the period November 2009 to April 2011. In this latter 18-month period, 22 of the flow events occurred, while the annual frequency of flow prior to November 2011 was 2.5 events. The number of flow events at any one site over 2000–11 varied between 28 and 38, resulting in approximately 2.5 to 3.5 flow events occurring per year at any one location, but with a frequency of only 1.0 to 1.9 flow events prior to November 2009.' Data summarised in this report will provide the basis for modelling the Neales

Reference	Region	Summary
		catchment.
Costelloe et al. (2003a)	Diamantina	Modelling the flow regime of an arid zone, floodplain river, Diamantina River Introduces a grid-based, conceptual model for the Channel Country reach of the Diamantina River between Diamantina Lakes and Birdsville. Further refinements to this model are presented in Costelloe et al. (2006a).
Costelloe et al. (2004)	LEB	ARIDFLO ARIDFLO report details hydrological analysis and modelling for the five ARIDFLO study reaches in the LEB (Thomson and Coongie Lakes, upper and lower Diamantina and Neales Rivre). The modelling of the Neales River is also reported in Costelloe et al. (2005a) and the upper Diamantina in Costelloe et al. (2003; 2006). Water level data were collected during the ARIDFLO project (2000–03) and these stage data provided some of the only hydrological monitoring in the ARIDFLO SA reaches. Grid-based, conceptual rainfall - run-off - routing models were developed for the five reaches with the aim of providing a time-series of modelled discharge data at each of the ARIDFLO sampling sites. The discharge data were then used to calculate a range of parameters that described the short-term and long-term flow regime at the sampling sites. In terms of flow regime modelling of the LEBRM target catchments, the description of the Thomson modelling in Costelloe et al. (2004) and Costelloe (2004) has the most relevance. The Thomson reach that was modelled covered the Longreach to Stonehenge reach and contributing catchment. Model performance for the reach was reasonable with some spurious small modelled events being generated.
Costelloe et al. (2005a)	Neales	Modelling streamflow in a large ungauged arid zone river, central Australia, for use in ecological studies Summarises results from the application of a grid-based, conceptual hydrological model to the Neales catchment. The model was calibrated on a short discharge time-series (2000–02) estimated for the Algebuckina Waterhole site. The emphasis of the modelling was to generate discharge data to characterise the flow regime at specific ecological sampling locations, rather than simulating the mean catchment - scale behaviour. The study made the following conclusions: • Larger flows were modelled with more confidence than smaller flow events. The model often produced spurious flow events or did not effectively simulate small, actual flow events (i.e. false positives and negatives for smaller flows). • The spatial accuracy of rainfall fields was considered a major contributor to the uncertainty in modelling flow events. • A relatively complex model structure was required to optimise model performance. This included routing of flows, allowing channel flows to cover different grid cell widths, differentiating between channel and hillslope cells, and allowing quick runoff (or having hillslope classes with varying soil moisture storage depths). This model approach has not been further investigated using a longer data series for the model calibration.

Reference	Region	Summary
Costelloe et al. (2006a)	Diamantina	Modelling streamflow in a large anastomosing river of the arid zone, Diamantina River Presents a grid-based, conceptual model for the Channel Country reach of the Diamantina River between Diamantina Lakes and Birdsville. Analysis of streamflow data from this reach showed similar behaviour to that identified by Knighton and Nanson 1994, 2001, 2002) for Cooper Creek. Costelloe et al. (2006a) considered that the variation in spatial distribution of streamflow for floods of varying sizes controlled the transmission loss and flow timing behaviour of the floods. The contribution of run-off from within this reach was also considered to be important during the larger flood events. The modelling approach was found to simulate the transmission losses and flow behaviour of large floods reasonably well but model performance decreased for small to medium sized floods. In particular, the incorrect modelling of flow paths was considered to be a major reason for the less effective modelling of smaller flows. The paper recommended further detailed mapping of flood patterns for a range of flood sizes in order to improve the flow routing capacity of the model. The Diamantina Lakes to Birdsville reach of the Diamantina River presents a more complex example for modelling than the comparatively simpler western river catchments, or even for the Thomson. However, this paper identifies that accurate simulation of flow paths and flood extents are likely to be very important characteristics that hydrological modelling needs to address in the LEB study catchments.
Costelloe et al. (2013)	Cooper	*Hydrological assessment and analysis of the Cooper Creek Catchment SA* Identifies 4 reaches: 1. Cooper main channel (Nappa Merrie to NW Branch-Main Branch junction): contains the deepest (>25m) waterhole (Cullyamurra), and most other waterholes >5m deep and highest density of ark refugia in the Channel Country. Section receives annual flows from a combination of catchment and local rainfall events. 2. Northwest Branch (Junction with Main Branch to Coongie Lakes): contains some waterholes. The smallest annual flows terminate at Coongie Lake therefore this is an important point to identify changes in flow regime. 3. Main Branch (junction w NW Branch to junction with Northern Overflow at Deparanie Waterhole) requires a discharge of 1200ML/d for flow to occur. Few deep refuges or open lake environments. Annual flows do not exceed past Embarka Swamp. Significant infrastructure for oil and gas in this reach. 4. Lower Cooper (Main Branch – Northern Overflow junction to Kati Thanda-Lake Eyre North) does not contain any ark refugia and receives flow on average 3-4 years. Study provided improved understanding of flow thresholds for different flow paths and proportion of flow down each and losses. Recommend the development of a new rainfall-runoff hydrological model capable of simulating the complex flow paths.

Reference	Region	Summary
Dunlop et al. (2013a)	Qld (MDB)	Coal seam gas water use proposals in the Queensland Murray-Darling Basin: Assessment of cumulative hydrologic pacts from coal seam gas water discharge on aquatic ecosystems Report summarises methods and outcomes of assessment of various coal seam gas (CSG) water discharge scenarios in the Condamine-Balonne catchment of the MDB. The report provides a very useful summary and framework for this exercise and summarises most of the main ecological and geomorphic effects of CSG discharge. The report demonstrates the need to have an adequate hydrological model of a catchment in order to effectively analyse effects of water discharge on an ephemeral river. In the case of the Condamine-Balonne this is the IQQM model. In addition, the report advocates the collection of data on the distribution and morphology of fluvial waterholes in affected catchments. The report is thorough in its analyses, but does not consider the effects of CSG water discharge on the alluvial aquifer of the river or on consequent effects on river-groundwater interactions and potential salinity effects. This is likely to be a significant interaction in the western LEB rivers where the water table is quite shallow and extremely saline. In addition, the effects of CSG water storages (for pulsed releases of water) are not investigated and these could have significant effects in arid catchments. It is recommended that this report be used as a basis of evaluating the effects of potential CSG discharges in LEB catchments.
EHP (2012a)	Qld (LEB)	Webpage providing brief intro and summary for the Lake Eyre and Bulloo Freshwater Biogeographical Province, according to the WetlandInfo criteria. Very brief summary of typical flow regime for the whole of basin. All data sources are referenced therein.
Harding (2010)	Cooper Creek	Cooper Creek daily flow model Powerpoint presentation summarising modelling of Cooper Creek catchment using the IQQM link-node model for flow routing and the Sacramento rainfall-runoff model for run-off generation. The presentation provides some information on the Cooper Creek modelling by Queensland but does not thoroughly describe the calibration and evaluation performance of the model. This modelling is the most detailed large catchment-scale modelling exercise in the LEB.
Hughes (2005)	International	Describes South African experience of determining environmental water requirements for ephemeral rivers. He states 'The most obvious impact of water resource developments on ephemeral rivers may be a reduction in the number and size of flow events. However, delays in the onset of flow in seasonal rivers and changes in the duration, quantity and quality of in-channel pool storage may be of equal importance. In a number of South African ephemeral channels the major impacts have been caused by the importation of water from elsewhere and a consequent reduction in streamflow variability.' These South African observations may be useful when assessing environmental flow requirements of LEB rivers
Jolly (1975)	Finke	Hydrological Information for Proposed Bridges Over Hugh River and Finke River

Reference	Region	Summary
		Study used cross-sectional surveys and roughness estimates as input to Manning's Equation to estimate peak discharge at water level monitoring sites in the Finke catchment. These provide useful estimates of the peak size of the larger floods in the Finke compared to the better gauged rivers of the LEB, such as the Diamantina and Cooper. The morphology from the surveyed cross-sections may also have value for fluvial geomorphological studies.
Kennard et al. (2010)	National	Classification of natural flow regimes in Australia to support environmental flow management Classification of flow regimes measured at unregulated gauging station based on ecologically relevant hydrological measures. The classification includes the longer-term gauging station records from the Cooper and Georgina-Diamantina catchments but ungauged catchments cannot be classified due to the absence of streamflow data. Not surprisingly, the LEB rivers were classified as 'summer–highly intermittent' and with varying degrees of variability in their flow regime. The reaches were placed in a similar grouping demonstrating that flow behaviour was relatively consistent across the major catchments of the eastern LEB.
Khan et al. (2011)	International	Hydro-climatology of Lake Victoria region using hydrologic model and satellite remote sensing data Study used the TRMM satellite rainfall product for hydrological modelling of a semi-arid area in east Africa. The rainfall data and hydrological model were found to adequately simulate seasonal to monthly time-steps flow behaviour.
Knighton and Nanson (1994)	Cooper	Flow transmission along an arid zone anastomosing river, Cooper Creek This was the first study to examine and characterise the very high transmission losses from flow events in the Channel Country of Cooper Creek. The study identified the non-linear nature of these transmission losses and suggested possible mechanisms – infiltration/recharge, evaporation and pooling of water in terminal storages.
Knighton and Nanson (2002)	Cooper	Inbank and overbank velocity conditions in an arid zone anastomosing river Analyses velocity conditions within waterholes during sub-bankfull and overbank flood events. These are the only in-depth analyses of velocity distributions at varying flood levels in channels of the LEB river and have important geomorphological implications for waterhole maintenance by the current flow regime.
Kotwicki (1987)	LEB	Floods of Lake Eyre The Kotwicki (1987) book provides the first attempt at basin and catchment scale modelling in the LEB. A summary of the material in the book can be found on the following website; http://www.k26.com/eyre. Kotwicki (1987) used the simple RORB model to estimate run-off and rout streamflow into Kati Thanda-Lake Eyre North through a series of cascading catchment models. By necessity, the models were at the catchment scale (i.e. Neales represented by a single RORB model). The approach gave the first

Reference	Region	Summary
		indication of the scale of inflow into Kati Thanda-Lake Eyre and also which were the most significant contributors to the Lake. In addition, this reference also collates useful information on previous floods in the catchments. For instance, Kotwicki (1987) references Bonython (1963) as indicating that the Finke may have contributed to the Macumba (and Kati Thanda-Lake Eyre) during floods in 1909, 1938 and 1945. The Kotwicki (1987) modelling approach has limited application for the more detailed sub-catchment modelling required for the western rivers but remains the only whole of basin approach to modelling in the LEB.
Leigh et al. (2010)	LEB	Sequential floods drive 'booms' and wetland persistence in dryland rivers: a synthesis Flood clusters are important for driving the booms in arid zone rivers and wetland persistence and transmission of flows to downstream wetlands: • the first flood saturates the channel and wetlands/floodplain, so subsequent floods are able to transmit further than if they occurred after a long period of no flow • subsequent floods top-up wetlands, increasing the duration of inundation. Therefore, medium-sized floods can have a greater extent and magnitude than larger floods if they occur after a large flood. The paper largely reviews existing data in the Cooper and MDB but also puts forward a conceptual model of how flow regulation in the MDB has decreased sequential flows and end of catchment flows.
Mackay et al. (2012)	National	Low-flow hydrological classification of Australia Classification of catchments/regions in Australia based on indices measuring aspects of low flow hydrology as measured at gauges. LEB catchments are represented by 12 gauging stations but with only one from the western rivers (upper Finke). The catchments are characterised as highly to moderately ephemeral using the full range of 35 indices. A subset of four dominant indices characterised the gauging station sites as highly to weakly ephemeral. The weakly ephemeral sites were the lower Cooper (Nappa Merrie and Cullyamurra) and the shorter period of no flow days at these sites reflects the considerable attenuation of flow events as they move through the Channel Country. The weakly ephemeral sites are considered to be 'at risk' to change as moderate water extraction could considerably increase the period of no flow. The western rivers would all be classified as highly ephemeral rivers.
McGregor et al. (2013)	Qld (MDB)	Stream ecosystem health response to coal seam gas water release: guideline for managing flow regimes Report summarises approaches to defining framework for determining the cumulative impacts of a process on the environment. It provides a literature review and then a framework based on the six principles defined below that should be used to determine the cumulative impacts of the discharge of CSG water into streams and rivers. The framework was then used by Dunlop et al. (2013a) for a quantitative scenario assessment of the effects of CSG discharge

Reference	Region	Summary
		into the Condamine-Balonne river. The six principles are: 1. Assessment of cumulative impacts must consider past, present and reasonably foreseeable future coal seam gas water discharges to surface waters that may interact within a stream network at a range of spatial scales 2. Assessment of cumulative impacts must include direct and indirect effects of the coal seam gas water discharges on a given ecosystem 3. Cumulative impact assessments must have clearly delineated spatial and temporal boundaries and be relevant to the ecosystem being affected 4. Cumulative impact assessments must focus on the risks and impacts that are relevant to the activities being carried out and which are considered important by stakeholders 5. Cumulative impact assessments must consider the independent and combined effect of stressors in the receiving environment 6. Cumulative impact assessments must incorporate measures of assimilative capacity, ecosystem resistance and resilience.
McMahon et al. (2008b)	LEB	Understanding the surface hydrology of Lake Eyre Basin - Part 2 Streamflow Summarises streamflow characteristics at gauged sites within the LEB. No gauged sites were available in the western rivers and so the analysis is not as relevant to those catchments. The study compared the characteristics of the LEB rivers to other arid zone rivers from around the world and the LEB rivers were found to be approximately twice as variable. The study also found that run-off coefficients for the rivers were low and transmission losses typically very large. These characteristics of the flow regime demonstrate that the LEB catchments are very challenging to effectively model.
Puckridge et al. (1998)	LEB and International	Flow variability and the ecology of large rivers Used hydrological metrics from gauging station data from large rivers to classify their flow regime. Found that the Cooper and Georgina-Diamantina had the most variable flow regimes of all of these large rivers. The paper argues that flow variability is an important ecological aspect of LEB rivers and needs to be maintained for their healthy ecological functioning.
Puckridge et al. (2000)	Cooper	Hydrological persistence and the ecology of dryland rivers Analysed fish response to a sequence of floods from 1988–92 and found that sequential floods (termed 'flood clusters') are important for the capacity of fish to ramp up their recruitment and potentially outcompete alien fish. This has implications for reducing the magnitude of flood clusters through water resource development and that connectivity is important to maintain during the wet periods.
Wagener and Montanari (2011)	International	Convergence of approaches toward reducing uncertainty in predictions in ungauged basins Advocate the use of a range of approaches in trying to predict (model) flow in ungauged basins. They argue the emphasis should be on trying to understand the behaviour of the flow regime in the catchment rather than trying to reduce the uncertainty around the model parameter values.

Reference	Region	Summary
Williams (1970)	Finke	The central Australian stream floods of February-March 1967 Provides some rare detail on the a large flood in the Finke River in 1967 along with detailed eye-witness accounts of the extent of this flood and that it did not reach the Macumba catchment. Also provides some data on sedimentary processes resulting from the flood.

Water resource management

Reference	Region	Summary
Marsh et al. (2012a)	National	Guidance on ecological responses and hydrological modelling for low-flow water planning Summarises the products of the low flow project and how they might be used in the management, monitoring and protection of low flows. They provide seven steps to consider in this process: 1. Describe the water resource – this would use the Mackay et al. (2012) classification system. In the case of the western rivers, these are highly ephemeral while the Thomson catchment is ephemeral and may be more susceptible to water resource use making the system more ephemeral. 2. Set high level objectives and outcomes – the low flow project did not provide much material on highly ephemeral systems so some additional material would be required to set high level objectives and outcomes for protection of the flow regime of the western rivers. 3. Set quantitative objectives – Marsh et al. (2012a) provide seven key findings on how ecological communities respond to changes in low flow. Objectives or monitoring considerations for the LEB study catchments should consider these seven findings. The unusual salinity behaviour of the western rivers during low flows also needs to be taken into consideration. 4. Develop water management strategies – this can involve monitoring for change or developing rules that minimise the effects of water resource development on low flows: 4.1 Across the board restrictions in water abstraction 4.2 Limiting abstractions to specific threshold flow events or times 4.3 Limiting extractions during no-flow periods 4.4 Scaled extractions depending on the location within the water source 4.5 Water releases from storages to provide required low-flow thresholds 4.6 Implementing management arrangements – generally beyond the scope of the bioassessment. 5. Implementing monitoring, compliance and enforcement – the low flows project provides a range of potential indicators (e.g. changes to four low flow metrics, changes to NDVI, changes to water quality). The monitoring requirements of the LEB rivers need to be specifically considered. 6. Reporting and review.

Water regime (waterbody scale) processes

Reference	Region	Summary
Costelloe	Neales	Hydrological assessment and analysis of the Neales Catchment

Reference	Region	Summary
(2011)		Collected morphological data from most named waterholes in the Neales catchment and also investigated connectivity processes during flow events. The evaporation modelling of Costelloe et al. (2007a) was updated for two instrumented waterholes (Algebuckina and South Stewart) and loss rates were found to be consistent with evaporation (Algebuckina) or evaporation plus additional leakage (South Stewart). Thus the maximum depth of the waterhole once flow had ceased was the best predictor of the persistence of most waterholes. Modelling indicated that a 24 month period without flow would result in all riverine waterholes being dry leaving only GAB spring environments to sustain some of the fish assemblage.
Costelloe et al. (2007a)	Cooper, Diamantina, Neales	Determining loss characteristics of arid zone river waterbodies Used stage data and open water evaporation modelling (Penman combination) to identify causes of waterhole persistence in monitored waterbodies (ARIDFLO project) of the lower Cooper (Coongie Lakes), lower Diamantina and Neales catchments. They found that evaporation losses mostly explained loss rates and there was limited evidence of significant groundwater contributions despite the large salinity variations observed in some waterholes (e.g. Costelloe et al. 2005).
Costelloe et al. (2009)	Cooper	Groundwater recharge and discharge dynamics in an arid zone, ephemeral lake system Demonstrated that lakes in the Coongie Lakes wetlands have differing lake sediment salinities depending on the water regime of the lake, with less persistent lakes having higher soil salinities. This was due to evaporation from shallow, saline groundwater through the dry lake beds. They speculate that this may have significant effects on vegetation and zooplankton and algal communities in these lakes. More persistent lakes have fresher unconfined groundwater immediately below because of the more consistent recharge, however, around the margins of these persistent lakes the groundwater can be highly saline.
Duguid (2013a)	Finke	Delineation and Description of Ecological Character of the Mid-Finke Waterholes: A Trial of Guidelines for HEVAE Data loggers were installed through the LEBRA program.
Hamilton et al. (2005)	Cooper	Persistence of aquatic refugia between flow pulses in a dryland river system (Cooper Creek, Australia) Used isotopic data to investigate causes of persistence in waterholes in the Channel Country reach of Cooper Creek in Queensland. The results showed that waterhole persistence was largely governed by evaporation processes with mean losses of 2.1 m/y. These results indicated that these waterbodies were not receiving any significant groundwater inputs (in agreement with Cendon et al. 2010) and that waterhole volumes would fall to <10% of bankfull volumes in 6–23 months.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial A report detailing the application, development and trial an Integrated Ecological

Reference	Region	Summary
		Condition Assessment (IECA) for High Ecological Value Aquatic Ecosystems (HEVAE) in the Cooper Creek catchment. Five HEVAE units (CAT 500 polygons) were selected for assessment. Aquatic ecosystems were identified and listed for each hydrological unit, and HEVAE criteria relevant for each unit were determined. Sampling of targeted indicators was undertaken to validate threat risks and to gather information for knowledge improvement. Distribution of species is described and the ability of introduced species to spread is indicated. Relevance: wetland risk analysis is presented.
Puckridge et al. (2010)	Cooper Creek	Ecological responses to variable water regimes in arid-zone wetlands: Coongie Lakes Identified the ecological importance of the 'water regime' of a wetland. The water regime refers to the long-term hydrological history of the wetland and particularly the frequency of inundation and drying (i.e. persistence) of a wetland. 'As water-retention time increased, fish species diversity (richness, evenness) and disease incidence rose, and fish species dominance and macroinvertebrate abundance decreased. The more mobile species of fish utilised the habitats and food resources provided by newly flooded waterbodies. We conclude that fish populations utilise wetlands with a variety of water regimes, and reductions in the frequency of inundation will decrease fish diversity with sequential losses of less mobile species.'
Silcock (2009a)	Cooper Creek, Georgina-Diamantina	Identification of permanent refuge waterbodies in the Cooper Creek and Georgina-Diamantina river catchments for Queensland and South Australia Report describing methods and results of mapping permanent waterbodies in the eastern LEB (Cooper, Diamantina-Georgina). Waterbody permanence was assessed using interviews with long-term land managers and a detailed inventory was produced along with large amounts of important anecdotal observations from land managers. This report provided the basis for the Fensham et al. (2011) paper which analysed the conservation significance of the various types of refugia.

Climate and paleohydrology

Reference	Region	Summary
EHP (2012a)	Qld (LEB)	Wetland Conceptual Models (Case Study Series – Queensland Lake Eyre and Bulloo) Webpage providing brief intro and summary for the Lake Eyre and Bulloo Freshwater Biogeographical Province, according to the WetlandInfo criteria. Very brief summary of typical rainfall, temperature and water balance for the whole of basin. All data sources are referenced therein.
Leon and Cohen (2012)	Kati Thanda-Lake Eyre	An improved bathymetric model for the modern and paleo Lake Eyre Present an improved bathymetric model for the current and paleo-Kati Thanda-Lake Eyre based on satellite data (altimetry and Landsat). The bathymetric model would

Reference	Region	Summary
		be useful for modelling the filling history and persistence of Kati Thanda-Lake Eyre and potentially to investigate when inter-catchment connection may have been possible through Kati Thanda-Lake Eyre in the recent past. Model results indicated that lake filling episodes occurring under wetter climates would have resulted in Kati Thanda-Lake Eyre and Lake Frome forming one large lake.
McMahon et al. (2008a)	LEB	Understanding the surface hydrology of Lake Eyre Basin - Part 1 Annual Rainfall Summarises the characteristics of annual rainfall across the LEB and compares the LEB to other arid zone rainfall characteristic. The paper has the following key conclusions: 'the variability of the annual rainfall (based on the coefficient of variation) in the LEB is approximately 60% greater than that found for stations located in arid regions in the rest of the world; there is a bias towards longer lengths of dry years than observed in the rest of Australia; and, there is a significant lag correlation between rainfall and ENSO, particularly in the east and in the latter part of a year.'
Murphy and Timbal (2007)	LEB	A review of recent climate variability and climate change in southeastern Australia Analyses possible causes for the Millenium Drought in south eastern Australia. Of interest to the LEB is Figure 2 which shows for the period of 1997–2006, much of the LEB had average rainfall while there were drier conditions in the Queensland reach of Cooper Creek and wetter than average conditions over the western catchments.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial A report detailing the application, development and trial of an Integrated Ecological Condition Assessment (IECA) for High Ecological Value Aquatic Ecosystems (HEVAE) in the Cooper Creek catchment. Relevance: Impacts of contemporary climate change is discussed.

Surface water – groundwater interaction

Reference	Region	Summary
Cendon et al. (2010)	Cooper Creek	Freshwater recharge into a shallow saline groundwater system, Cooper Creek floodplain, Queensland, Australia Describes the process of groundwater recharge in the Cooper floodplain during flood flows in waterholes, and interactions between surface and groundwater during no-flow periods. Recharge takes place through the base of scoured waterholes during flooding and ceases after flooding flows, as the waterhole base reseals with mud. Less recharge occurring around secondary, floodplain channels. They found that little recharge was occurring through the floodplain sediments. As a consequence, lenses of fresh groundwater occurred around the channels while the groundwater became progressively more saline away from channels. Indicators suggest there is no interaction between ground and surface water during periods of no flow.

Reference	Region	Summary
		The position of dunes did not seem to facilitate recharge as was observed in the Diamantina by Irvine et al. (2006). Relevance: Indicates the importance of flooding flows to groundwater recharge on the Cooper floodplain.
Costelloe et al. (2008)	Neales, Diamantina	Water use by arid zone riparian trees in highly saline environments Very saline, shallow groundwater typical of the western LEB catchments can restrict the distribution of riparian trees (particularly Coolabahs) despite the high salinity tolerance of these trees. 'The study identified three strategies used to cope with typically high groundwater and soil water salinities. Firstly, the trees preferentially grow in zones of most frequent flushing by infiltrating streamflow, such as the bank-tops of channels. Secondly, the trees limit water use by having low transpiration rates. Thirdly, the trees are able to extract water at very low osmotic potentials, with water uptake continuing at chloride concentrations of at least 20 000–30 000 mg L^{-1}.'
Costelloe et al. (2009)	Cooper Creek	Groundwater recharge and discharge dynamics in an arid zone, ephemeral lake system Coongie Lakes are zones of groundwater recharge during flood events, but the resulting shallow water tables result in the salinisation of the lake bed sediments due to capillary rise and evaporation during dry periods. The more ephemeral the lake, the higher the lake bed soil salinity. The more permanent lakes have mounds of relatively fresh, shallow groundwater, but are surrounded by higher salinity groundwater. These patterns are likely to influence the distribution of riparian and surrounding floodplain vegetation, in addition to algal seed-bank and zooplankton egg-bank that occurs in the lake bed sediments.
Costelloe et al. (2005b)	Neales	Spatial and temporal variability of water salinity in an ephemeral arid-zone river High stream salinity observed in the Neales River during recession flows and in waterholes during disconnected phases. The salinity of streamflow increases during the recession of flood events with larger floods generating more saline flow during the very low flow stages. This is considered to be caused by unconfined groundwater discharging back into the ephemeral channels following recharge during peak flood stages. The salinity of Algebuckina Waterhole was shown to be controlled by saline streamflow from upstream rather than direct groundwater discharge. Some of the processes in this paper have been somewhat superseded by later papers.
Costelloe et al. (2006b)	Neales	Recharge mechanisms in an arid zone river: effects of channelisation Piezometer and modelling indicate that most recharge to the unconfined groundwater during flow events occurs in channelised reaches and probably involves some bank recharge. Poorly channelised, 'floodplain' reaches in the middle reaches did not contain a saturated zone in the alluvial sediments, indicating that only limited infiltration and recharge occurs in these reaches.
Costelloe et al.	Neales	Development of hypersaline groundwater in alluvial aquifers of ephemeral rivers

Reference	Region	Summary
(2007b)		Field data and numerical modelling demonstrate that phreatic evaporation through bed sediments in ephemeral channels can lead to the development of hypersaline unconfined groundwater. This suggests that longer periods of no flow (e.g. through extraction or diversion) could increase the salinity of unconfined groundwater in reaches with deeper primary channels and relatively shallow unconfined groundwater. Increases in groundwater salinity would then have adverse effects following streamflow events when recharge increases groundwater levels and allows discharge of groundwater back into the channel once flow has ceased.
English (1998)	NT (GAB)	Cainozoic geology and hydrogeology of Uluru-Kata Tjuta National Park Recharge; local recharge Banded vegetation communities enhance penetration of water to depth, and therefore recharge.
Duguid (2013a)	Finke	Delineation and Description of Ecological Character of the Mid-Finke Waterholes: A Trial of Guidelines for HEVAEs Local groundwater discharge found to be evident, with complex contributions from local alluvial and regional groundwater. Hypersaline water found at some sites while other sites were found to have very low salinities, the differences are interpreted to be a result of complex groundwater interactions in the Mid-Finke.
Fulton et al. (2010)	Finke	Localised recharge in the arid zone: a case study of the Finke River, GAB Conference presentation describing hydrogeological study of recharge processes in the Finke River in response to the large flood of 2010. Tracer data (stable isotopes, ^{14}C) and bore data demonstrated that larger floods deliver significant recharge to the GAB unconfined aquifer in the lower Finke. The recharge rates during the large 2010 flood were found to be up to 900 mm/y (5600 ML/y). A small flood in 2008 was found to provide no significant recharge to the GAB aquifer (abstract by Brad Wolaver, Flinders University). This study demonstrates the importance of large flood events reaching the recharge areas of the western GAB.
Hamilton et al. (2005)	Cooper Creek	Persistence of aquatic refugia between flow pulses in a dryland river system (Cooper Creek, Australia) Assessed water loss by evaporation in Cooper Creek waterholes. Results suggest that water levels are controlled by evaporative loss during times of isolation/no flow, and that some waterholes are effectively isolated from underlying groundwater. Predicted persistence durations (months) were calculated and implications for flow management is discussed. Relevance: Highlights the importance of occasional, irregular flood pulses sustain these aquatic refugia, and that more waterholes would dry out with a reduction in frequency and intensity of flows.
Jolly (2005)	Finke	Report on Field Trip to Boggy Hole Waterhole on the Finke River, May 1990 Brief report on a field visit to a waterhole (Boggy Hole) in the mid Finke. Chemical samples taken from the waterhole showed moderate conductivities (1500–6300 EC)

Reference	Region	Summary
		and the report concluded that the chemical data was evidence for the discharge of regional groundwater into the river reach. The Read (2011) report has more comprehensive analysis and more data and suggests that the Finke alluvial groundwater is largely fed by fluvial recharge and that regional discharge is only a minor component, particularly when evaporation processes on the groundwater and river water are taken into consideration. However, the Jolly (2005) report provides some valuable data points and its findings of at least some regional discharge into the Finke are still consistent with the Read (2011) report.
Kellet et al. (2003)	Thomson	Groundwater Recharge in the GAB Intake Beds, Queensland Detailed report of recharge rates into the eastern intake beds of the GAB. The upper part of the Thomson catchment covers these intake beds. The Thomson stream network was found to be not one of the more prominent sources of fluvial recharge and the Thomson tributaries (e.g. Torrens Creek) showed alternating recharge and discharge behaviour.
Love et al. (2000)	Neales, Macumba	Sources of chloride and implications for 36Cl dating of old groundwater, south-western GAB This paper examined flow velocities and recharge rates for the western part of the GAB covered by the Neales and Macumba catchments. Of most interest to the bio-assessment is that the paper found that recharge rates to the unconfined GAB aquifer along the western margin were very low (0.16±0.08 mm/y). This is in contrast to higher, localised recharge rates identified for the Finke River by Fulton et al. (2010). Love et al. (2000) concluded that most of the recharge in the western margin of the GAB occurred during past, wetter climatic periods. Many of the exposed recharge beds occur to the west of the Stuart Highway and outside the catchment boundaries of the western rivers. These areas likely require diffuse recharge during very large rainfall events or wetter periods, in comparison to the fluvial recharge observed in the Finke River in response to the large flood event of 2010.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial A report detailing the application, development and trial an Integrated Ecological Condition Assessment (IECA) for High Ecological Value Aquatic Ecosystems (HEVAE) in the Cooper Creek catchment. Relevance: Changes in spring wetland was mapped and reported on.
Payne et al. (2006)	Neales, Diamantina	Riparian tree water use by *Eucalyptus coolabah* in the Lake Eyre Basin Conference paper that preceded Costelloe et al. (2008). Water sources used by *Eucalyptus coolabah* and dealt with in more detail in Costelloe et al. (2008).
Read (2011)	Finke	Hydrogeology of the Finke River Report that describes aspects of the groundwater–surface water connectivity in the middle reaches of the Finke River. Regional groundwater in the Amadeus Basin has a gradient towards the Finke River and is generally considerably more saline than

Reference	Region	Summary
		the alluvial groundwater around the Finke River. The report demonstrates that the alluvial groundwater has moderate salinity (400–9000 mg/L TDS) indicating that it is largely derived from fluvial recharge during flow events. Chemical sampling shows that the waterholes are often of similar or higher salinity than the alluvial groundwater and this indicates that the waterholes may be containing evapoconcentrated water derived from the alluvial groundwater (or possibly some mixing with the regional groundwater – particularly if waterholes form on or adjacent to outcropping Amadeus Basin bedrock). These findings indicate that the waterholes are at least partially sustained by groundwater inputs and not just surface flow.
Silcock (2009a)	Qld & SA (Cooper Creek, Georgina-Diamantina)	Identification of Permanent Refuge Waterbodies in the Cooper Creek & Georgina-Diamantina River Catchments for Queensland and South Australia Concludes that without the influence of groundwater in some form there would only be four truly permanent waterbodies across the entire Georgina catchment.
Tweed et al. (2011)	Diamantina	Arid zone groundwater recharge and salinisation processes; an example from the LEB Analysis of unconfined groundwater adjacent to the Diamantina floodplain found that no significant recharge was identified following a flood event in 2007 and that the groundwater signature was dominated by diffuse recharge following large rainfall events. The role of recharge in transporting solutes back into the unconfined groundwater was proposed to help explain the high salinity commonly observed in the groundwater.

3.3.2.4. Biological processes

General

Reference	Region	Summary
Brim Box et al. (2009)	Finke	Response and Resilience of Waterbodies in Central Australia: West MacDonnell Ranges and George Gill Range The objective of this project was to determine the response and resilience of aquatic communities in multiple waterbodies in central Australia, by comparing three separate inventories of macroinvertebrates over 20 years ago from these same sites. Surveys were one-off surveys and no discussion of short-term variation a possible explantion of variability between assemblages encountered, however, they infer that, as these are relictual ecosystems, all species should be present in refuges if they are not degraded. However, changes were correlated with changes in land management (e.g. reduced stock and pest animals). Consider the ecosystems to be resilient because, despite disturbance events, macrinvertebrate species abundance and diversity generally increased. Some water chemistry parameters also measured.
Costelloe et al. (2004)	LEB	ARIDFLO Various chapters: • Biology (algae, invertebrates, fish, waterbirds) • Specific observations for Neales catchment (Summary and Section 4.4)

Reference	Region	Summary
		• Bare microhabitats with high salinity, low richness but not necessarily low abundance with indicator species including the beetle Necterosoma, chironomid Tanytarsus, and Culicoides • Areas with fast discharge rates washing mosquito (Aedes) and three crustacean taxa (Branchinella, Triops and conchostrachans) into waterholes providing rich food sources for the few fish present. • Lower species richness but similar abundance of fish in Neales compared with Diamantina and Cooper. Suggests similar productivity levels but isolation from other rivers. • Important observation regarding the use of floodplain habitat by native fish species • Low incidence of fish disease in the Neales was associated with elevated salinities in the catchment.
Golder Associates (2009)	Cooper Creek	Cooper Creek Water Resource Plan: Environmental Discussion Paper Summarises existing knowledge regarding the ecological processes operating within the Cooper Creek Catchment. Highlights the strong linkage between processes and hydrological regime, and identifies the key processes as: • Sediment transport and nutrient cycling • Colonisation, recruitment and migration of species • Species population expansion and contraction • Reproduction and speciation. Relevance: Future monitoring should be catchment-wide and should contain a long-term perspective of flow history, due to flow variability.
Lake (2000)	National	Disturbance, patchiness, and diversity in streams Reviews patterns of disturbance and diversity in streams. Role of floods and drought in regulating species diversity: • Importance of refugia • Outlines the changes that floods can have on species composition and the lag effect that droughts can have on aquatic diversity. • Highlights the role of resistance and resilience in aquatic ecosystems. Describes the effects of drought on flowing water as a disturbance regime: • Role of drought and drying ecosystems • Importance of refugia for recovery • Describes drying patterns and the different effects on ecosystem processes. Outlines the recovery of ecosystems post drought.
Marsh et al. (2012b)	National	Synthesis of case studies quantifying ecological responses to low flows One case study (Balcombe & Sternberg 2012) from LEB, other case studies focussed on more temperate zones; primarily macroinvertebrates but some fish studies. Seven key findings: 1. There is a strong and consistent distinction between the macroinvertebrate community composition of perennial streams compared with ephemeral streams. 2. There is a predictable transition in macroinvertebrate community composition based on changes in flow. 3. Increasing durations of low flow are highly correlated with declining water

Reference	Region	Summary
		quality. 4. Poor water quality due to reduced flow is a primary driver of ecological response. 5. Reduced flows have a relatively more dramatic and consistent effect on community composition than elevated flows (note that changes to the timing and temperature of flows due to releases were not considered and these are likely to have negative ecological consequences). 6. Fish are relatively resilient to cease-to-flow conditions. 7. The community composition of streams that are usually perennial, but cease to flow for a short time (weeks) will mostly recover in the next season. However, community composition will decline when cease-to-flow conditions recur over consecutive years.
Morton et al. (2011)	Australia	A fresh framework for the ecology of arid Australia Gives an overview of vegetation differentiation among geographical zones of Australian deserts, detailing rainfall, soil type and fire regime. Discusses the development of desert soils and rainfall patterns and their influence on plant communities. Discusses the range of plant life-history strategies to survive wet and dry periods, but not in detail. Mentions the knowledge gaps of Australian desert plants. Briefly discusses plant leaf morphologies of desert plants and water sources. Notes the importance of fire to maintain plant diversity in arid Australia. Discusses the history of Aboriginal people's influence on desert vegetation communities.
Schmarr et al. 2013	Cooper	**Ecological** *Aquatic ecology assessment and analysis of the Cooper Creek, South Australia* Reports on results of assessments of aquatic ecology (mostly fish as well as turtles, large bodied invertebrates and water rats) following the 2010 floods at 25 sites from Cullyamurra to Kati Thanda-Lake Eyre. Found that the assemblages of the upper and lower reaches were quite different despite significant flooding connecting the entire length. The lower reaches were dominated by resilient species with a few resistant species. Less resistant species maintained their populations in the upper reaches. Freshwater Mussels, Water Rats and Turtles were also only found in the upper reaches, with Water Rats having the more restricted distribution (caught at 4 sites, Mussels at 5 while turtles were caught at 12 sites). Freshwater Crabs were found at one site only (Gidgealpa waterhole). Waterholes and floodplains on the northwest branch were found to be significant for fish recruitment while large permanent waterholes had some recruitment but were mainly dominated by large mature fish. Notes the importance of movement pathways on floodplains being maintained so that young fish can move back into permanent waterholes to replenish populations in these. Recommend that the Cooper in SA be treated as 3 units for management: permanent refugia in the upper reaches, semi-permanent main branch and north-

Reference	Region	Summary
		west branch refugia and ephemeral lower Cooper refugia. Knowledge gap: the contribution of recreational fishing to fish mortality.
Sheldon et al. (2010)	LEB	Early warning, compliance and diagnostic monitoring of ecological responses to low flows Ecological responses to low flows (mainly macroinvertebrates, some fish). Changes to flow regime have significant effects on the diversity and persistence of biota in these aquatic ecosystems. Under reduced flows the availability of habitat is a key driver to how the ecosystem responds. Limited habitat area and complexity would restrict the species able to inhabit the ecosystem. Three dispersal modes: 1. movers – not truly aquatic, connections among waterholes, even under drought conditions, maybe high through the riparian network 2. networkers – restricted to refugial waterholes when flows are low, but can rapidly disperse among waterholes in the channel network when waterholes are connected; includes many of the fish and crustaceans 3. permanent refugials – entirely restricted to refugial waterholes, showing very limited dispersal even under flow conditions. Of the taxa reviewed, only some of the molluscs fit this group.
Woods et al. (2012)	Northern MDB	Riverine and floodplain ecosystem response to flooding in the lower Balonne and Border Rivers Floods (and floodplain inundation) resulted in increases in native fish abundance, but this response was shortlived. Floodplain inundation allowed fish access to terrestrial plants which underpinned the food web during this period. Ongoing pulse flows during the study make extrapolation to disconnected waterholes in the LEB (particularly SA) unreliable. Continued unequal flood pulses benefited carp (cf Costello 2010).

Fish

Reference	Region	Summary
Arthington et al. (2005)	Qld (Cooper Creek)	Spatial and temporal variation in fish-assemblage structure in isolated waterholes during the 2001 dry season of an arid-zone floodplain river, Cooper Creek, Australia Investigated the effects of natural drought (i.e. stress/pressure) and the influence of water chemistry on fish assemblages in waterholes and river reaches over time. In early dry: fish assemblage structure was strongly influenced by the extent of prior floodplain inundation, interconnectedness of waterholes and waterhole habitat structure. In late dry: fish assemblage structure was strongly influenced by habitat loss, not water chemistry. Relevance: Flooding and drying interactions between flow and habitat across the spatial spectrum are crucial for fish persistence.

Reference	Region	Summary
Arthington et al. (2010)	Qld (Cooper Creek)	Multi-scale environmental factors explain fish losses and refuge quality in drying waterholes of Cooper Creek Change in fish assemblage over 6 months during no-flow. Low incidence of piscovores in assemblage; only 3 of 12 and once confined to waterhole they switch to invertebrates and zooplankton. 74% of change in fish assemblage over six months during no-flow was explained by: • Waterhole morphology (wetted perimeter, depth) • Habitat structure (bench development, off-take channels) • Waterhole quality (eroded banks and GPP) • Size of surrounding floodplain and relative isolation. Of the waterholes studied, none sustained all species over the drying phase. Surprising non-driving factors were: • Water loss per se but indirectly was though loss of habitats • Water quality except slight increase in pH drove slightly higher level of assemblage change.
Balcombe & Kerezy (2008)	Qld (LEB)	Preliminary Fish Sampling for the LEBRA: Testing of the Fish Trajectory Model in Qld Surveys of freshwater fish were undertaken in the Qld LEB in the Cooper, Diamantina and Georgina catchments in mid-November 2007 and March/April 2009 to provide some baseline fish data for testing the relevance of the Fish Trajectory Model (FTM). 'The results from the two sampling trips, demonstrate the problems with applying simplistic conceptual models to highly unpredictable riverine ecosystems, such as those of the LEB. However, the FTM serves as a useful guide for monitoring fish assemblages as indicators of ecosystem health. In many cases, departures from model predictions could be explained by complexities of the environmental background that are not currently covered under the six antecedent hydrology groupings of the FTM. We propose that the utility of the FTM will be enhanced by increasing the range of antecedent flow conditions, or adding qualifiers to account for the variability of environmental conditions within the current hydrological groups.'
Balcombe and Arthington (2009)	Cooper	Temporal changes in fish abundance in response to hydrological variability in a dryland floodplain river Fish sampled over 8 occasions between 2001 and 2004 in four waterholes in the Windorah reach of Cooper Creek. Found antecedent flows had a marked influence on fish species richness and assemblage structure, with rich and abundant fish fauna following high summer flows and fewer species and lower numbers following periods of zero channel flow. Inundation of backwater and floodplain habitats lead to enhanced recruitment of three of the four most common and abundant species. Low level recruitment continues to occur during periods of no to low flow ('bust') but opportunistic responses to rising channel flows and occasional large floods lead to 'booms' of fish production.
Balcombe	Qld	Fish responses to low flows in dryland rivers of western Queensland

Reference	Region	Summary
& Sternberg (2012)	(Cooper Creek)	Used data from the Dryland Refugia project for Cooper. Found that fish in the Cooper Creek were more responsive to low flows than fish in Moonie River; hypothesises that this may be because Moonie River is less ephemeral. Fish abundance and diversity responded predictably to flow phase, fish condition and population structure varied between species. Finds that in arid river systems fish abundance, species richness and condition indices (such as Fulton's K) are appropriate metrics to measure response to low flow.
Balcombe et al. (2005)	Qld (Cooper Creek)	Variability of fish diets between dry and flood periods in an arid zone floodplain river Described diets for nine native fish species, sampled over two dry periods and during one major flood event. Fish diets exhibited a narrow breadth during dry season when confined to waterholes and a wide breadth when utilising floodplain habitat. Diets were dominated by aquatic resources rather than terrestrial input, although fish were able to capitalise on more diverse food resources accompanying flood events. Implications for habitat conservation are discussed. Relevance: Flooding of the floodplain is important for a number of reasons, including the advantage of fish completing their lifecycle with flooding of the floodplain compared to those completing their cycle without flooding.
Balcombe et al. (2007)	Qld (Cooper Creek)	Fish larvae, growth and biomass relationships in an Australian arid zone river: links between floodplains and waterholes Investigated structure of fish assemblages on Cooper floodplain, how assemblages vary among floodplain locations, and the influence of connectivity on fish biomass. Eleven of 12 native fish species were collected on the floodplain, represented by at least two life stages; and site specific differences in larval assemblage were found among sites. The floodplain was identified as a key area of high fish production that supports waterhole productivity, spawning and recruitment of fish, and provides a conduit for fish movement/transfer. Relevance: Floodplains are important at many levels of fish biology and ecology.
Costelloe et al. (2010)		Are alien fish disadvantaged by extremely variable flow regimes in arid-zone rivers? Uses ARIDFLO and DRY/WET data to examine hypothesis. Results equivocal should be re-examined with more complete data. *Finding:* Native fish species had big recruitment in response to floods, but exotics no increase → Variable flow regime and abundance of native fish prevents proliferation of alien fish.
Huey et al. (2011)	Qld (LEB)	Evidence for multiple historical colonisations of an endoreic drainage basin by an Australian freshwater fish Utilises genetic analysis to suggest that Ambassis spp. are capable of recolonising extirpated waterholes of the LEB after disturbance events and/or extensive drought. This species is likely to have entered the LEB in two occasions, one each in the Cooper and the other in the Georgina. Relevance: Gene flow not observed between catchments, but is likely within catchment.

Reference	Region	Summary
Kerezsy et al. (2011)	Qld (LEB)	Continuous recruitment underpins fish persistence in the arid rivers of far-western Queensland, Australia. Describes the analysis of length frequencies of fish from a number of waterholes across a number of catchments, over varied seasons and hydrological conditions. Fish species are grouped into likely recruitment strategies, based on their dependence on flow regime and seasonality. Relevance: Details the likely recruitment strategy of LEB fish spp (flow related, seasonal etc.)
Kerezsy et al. (2013)	Georgina - Diamantina	Fish movement strategies in an ephemeral river in the Simpson Desert In the Eyre Creek catchment fish dispersed from refuges in the Georgina-Diamantina catchment into the Mulligan River up to 300km from the nearest permanent waterhole. Trait-based dispersal patterns were observed with some species dispersing earlier and further while others dispersed later and did not move past deeper waterholes in the middle reaches, or move into the catchment at all.
McNeil and Schmarr (2009)	SA (LEB)	Recovery of Lake Eyre Basin Fishes Following Drought: 2008/09 Fish Survey Report A study of ecological responses following drought and increased flows throughout the Lake Eyre Basin. Examines fish data collected during post drought flows in the Lake Eyre Basin. Discusses the ecological processes surrounding the recovery of fish species within intermittent flow rivers and enforces the importance of critical reguge areas. Highlights the use of Ark refuge during drought and the subsequent radiation of species back into recently inundated waterholes. Fish establish populations in progressively distant habitats following predictable patterns of species resilience, i.e. more resilient species establish first, followed by less resilient species and some species that did not establish populations away from Ark or Polo club refugia.
McNeil et al. (2008)	LEB (SA)	Preliminary Fish Surveys for the LEBRA: Testing the Fish Trajectory Model in SA Fish trajectory model less useful in the variable habitats that characterise the SA LEB. Larger, deeper waterholes contain the highest species diversity. Even the smallest habitats rarely have species richness less than 2.
McNeil et al. (2011a)	Western Rivers (Neales)	Climate variability, fish and the role of refuge waterholes in the Neales River catchment Salinity and hypoxia trials inform on persistence under drying regimes. Fish tolerance thresholds and response to flow.
Puckridge et al. (2010)	SA (Cooper Creek)	Ecological responses to variable water regimes in arid-zone wetlands: Coongie Lakes Fish movement during floods and dry phases. Increased retention time in waterbodies lead to: • fish diversity increased – more mobile fish species colonise recently inundated wetlands, less mobile species less likely to therefore higher total

Reference	Region	Summary
		diversity in more permanent sites • disease incidence increased – may be due to more substrates for fungi as well as high temperatures and low oxygen • fish species dominance decreased • macroinvertebrate abundance decreased – rapid emergence of micro-crustations following inundation of floodplains. Water resource usage that results in reductions in the frequency of inundation will decrease fish diversity, beginning with the least mobile species.
Schmarr et al. (2012)	SA (Cooper Creek)	Aquatic Ecology Assessment and Analysis of the Cooper Creek Catchment: Lake Eyre Basin, South Australia Assessment of critical refugia in Cooper Creek SA. Fish distribution, dispersal and recruitment dynamics in arid systems. Observed spatial divergence between fish communities in upstream permanent and semi-permanent habitats, and downstream ephemeral habitats.

Waterbirds

Reference	Region	Summary
Jaensch et al. (2005)	Qld (LEB)	Sightings and breeding of pied heron 'Ardea picata' in the Queensland channel country, 1999-2004 Presence and breeding of Pied Heron reported from wetlands of the Queensland Channel Country within the Lake Eyre Basin; esp. Diamantina River and Eyre Creek. Discussion of flow requirements for breeding events.
Jaensch (2003)	Qld (Diamantina)	Breeding by Australian Painted snipe in the Diamantina channel country, South-western Queensland Detailed record of nest, eggs, behaviour and habitat of vulnerable Painted snipe on inundated shrub swamp on Diamantina channel. Relevance: Highlights the limited knowledge of this species nesting within the LEB, and therefore the implications of management actions during their nesting or lack thereof.
Jaensch (2009)	Qld (LEB)	Further records of Painted snipe in the Lake Eyre Basin, Queensland, with evidence of breeding Detailed record of sightings of vulnerable Painted snipe on wetlands of Diamantina and Georgina floodplains. Relevance: Highlights the limited knowledge of this species nesting within the LEB, and therefore the implications of management actions relating to this species or lack thereof.
Kingsford and Porter (1994)	Qld (Western)	Waterbirds on an adjacent freshwater lake and salt lake in arid Australia Aerial surveys of waterbirds across Lake Wyara and Lake Numulla yielded >42k waterbirds, and 41 species. The salt lake supported larger densities of waterbirds,

Reference	Region	Summary
		likely due to greater food resources: invertebrates and macrophytes. Relevance: In this instance, the saline lake supported more biodiversity than the freshwater lake.
Kingsford et al. (2004)	Arid Australia	Imposed hydrological stability on lakes in Arid Australia and effects on waterbirds Differences between regulated and unregulated lakes for the survival of waterbirds. Explores the effect of altering natural flooding and drying on the densities of waterbirds. The distribution and abundance of aquatic biota in freshwater ecosystems are controlled by hydrology. Reducing hydrological variability with river regulation reduces biodiversity and has a negative effect on ecological process in these systems. A significantly higher number of species was present on unregulated lakes than regulated lakes, showing the importance of natural hydrology in ecosystems for waterbirds and their food supply (invertebrates and vegetation). Drying periods of floodplain lakes are important for the ecology of aquatic ecosystems and removal of these drying events could reduce biodiversity.
Kingsford et al. (2010)	National	Australian waterbirds – time and space travellers in dynamic desert landscapes Waterbirds use a mosaic of habitats in time and space, a bottleneck in resource availability is therefore the most serious threat to their conservation; this is more likely now with much of Australia's river systems regulated/drained. In Australia, patterns of resource availability for waterbirds are mostly pulsed with peaks of productivity, coinciding with flooding and differing in time and space, affecting individuals, species and functional groups of waterbirds. Waterbirds respond to changing patterns of resource distribution, with rapid movements at spatial and temporal scales commensurate with the dynamics of the resource.

Invertebrates

Reference	Region	Summary
Carini and Hughes (2006)	Qld (LEB)	Subdivided population structure and phylogeography of an endangered freshwater snail, Notopala sublineata, in Western Queensland, Australia Investigated the genetic structure and dispersal patterns of *N. sublineata* in the LEB. Results indicate the species has inefficient mechanisms of dispersal, making populations vulnerable to further decline as a result of habitat and flow modification. Relevance: This species is venerable to detrimental environmental changes, as it has limited dispersal mechanisms.
Davis et al. (1993)	Central Australia	Invertebrate communities of relict streams in the arid zone: the George Gill Range, Central Australia Conclude that:

Reference	Region	Summary
		• Almost complete absence of shredders may reflect low allochthonous inputs, because riparian vegetation in the arid zone is generally sparse. • A small proportion of the fauna of the Range appears to be a relictual stream fauna • The occurrence of new species at the Range suggests that it is a site of allopatric speciation within some groups.
Hughes et al. (2004)	Qld (LEB)	Past and present patterns of connectivity among populations if four cryptic species of freshwater mussels Velesunio spp. (Hyriidae) in central Australia. Investigated the contemporary and historical patterns of dispersal for freshwater mussels; specifically examined the influence of flood-flows and connectivity on dispersal success. Analysis of genetic structures revealed restricted gene flow among waterholes within drainages, discusses implications for management. Relevance: These species have restricted dispersal capabilities as suggested by their limited gene flow.
Marshall et al. (2006b)	Qld (Cooper Creek)	The macroinvertebrate fauna of an Australian dryland river: spatial and temporal patterns and environmental relationships Variations in macroinvertebrate fauna were examined in Cooper waterholes, across different spatial and temporal scales, and the impact of environmental variables (water quality, geomorphology, hydrology) was assessed. A 'differentiation by distance' pattern was observed for fauna across the floodplain landscape; while temporal assemblage patterns were influenced by the connectivity potential of waterholes. Outcomes for species ecology, conservation and management are discussed. Relevance: Distribution patterns were best explained by the position of waterholes within the floodplain and longer-term connectivity as opposed to time since last period of connection.
Sheil et al. (2006)	LEB	Zooplankton diversity and assemblages in arid zone rivers of the Lake Eyre Basin, Australia Uses ARIDFLO data to create a more concise set of results: • Zooplankton boomed in the season following large flood • Salinity was an independant driver of assembalge structure • Annual cycles overlay other trends • Zooplankton are a cornerstone for higher organism success and any models generated should account for the effects of salinity, flow and season.
Sheldon & Thoms (2006)	Qld (LEB)	Relationships between flow variability and macroinvertebrate assemblage composition: data from four Australian dryland rivers Sites with a high level of hydrological connectivity (permanent water in the lower Murray) had highly similar assemblages, distinct from extremely disconnected sites, however the latter were also similar to each other. Similar level of diversity across all rivers. Sampled once only so expect had missed temporal diversity which would be higher in unregulated rivers.

Metabolic processes and primary production

Reference	Region	Summary
Bunn et al.. (2003)	Qld (Cooper Creek)	Sources of organic carbon supporting the food web of an arid zone floodplain river Tested the dependence of a riverine food web on terrestrial carbon sources, by measuring rates of benthic primary production and respiration, and analysing sources and consumers of organic carbon. Results suggested that littoral filamentous algae were the major source of energy for aquatic consumers, and zooplankton were the other major source. Relevance: Contrary to other models, results indicate terrestrial carbon sources are of a minor importance in the aquatic food web in the LEB and that algae is the primary source.
Burford et al. (2008)	Qld (Cooper Creek)	Sources of carbon fuelling production in an arid floodplain river Examined the contribution of floodplain carbon sources to the productivity of a disconnected waterhole, after a major flood event. By developing a waterhole carbon budget, results showed that fish mortality (post-flood event) was responsible for creating high rates of heterotrophic production. Floodplain inputs are important for fuelling short-term production in waterholes; therefore, changes to episodic flooding may have significant impacts on river productivity. Relevance: Episodic flooding is highly important to the productivity of the Cooper.
Fellows et al. (2009)	Qld (Cooper Creek)	Benthic metabolism in two turbid dryland rivers Quantifies rates of benthic metabolism and identifies factors influencing the rates in the Cooper and Warrego Rivers; and identifies a positive relationship between fish abundance and gross primary production on a catchment scale. Specifically, the Cooper had higher rates of GPP and a more autotrophic benthic zone; light was the major control in benthic GPP. Discusses the role of benthic biofilms for ecosystems during differing hydrological phases, and the importance of maintaining littoral biofilms. Relevance: Benthic GPP is influenced by regional scale processes in flow and in low and no flow periods by local processes.

Vegetation

Reference	Region	Summary
Costelloe et al. (2008)	Australia (LEB)	Water sources accessed by arid zone riparian trees in highly saline environments Considers the relationship between the spatial distribution of riparian trees and the hydrology of surface water and groundwater. The two sites studied were the Diamantina River and the Neales River in the LEB. Discusses the influence of changes in flow regime on tree health because of their distribution and use of water sources.

Reference	Region	Summary
		Riparian trees mainly use ground water and soil water and respond with strategies to cope with higher salinities. Changes in ground and soil water, including highly saline soil water, restricts the water sources that can be utilized by riparian trees ultimately affecting their health and reproduction.
Gillen & Reid (2013)	Cooper	*Vegetation and soil assessment of selected waterholes of the Main and Northwest channels of the Cooper Creek, SA* Fieldwork undertaken in Autumn 2012 following extended wet season and vegetation of the region generally in very healthy state. Surveyed at 14 waterholes, three 100 * 4m transects parallel to the direction of flow. Soil samples in 10cm increments to 50cm depth collected from mid point of each transect for pH and salinity, with additional 15 samples to 5cm collected and tested for total nitrogen and carbon. Appendix 4 includes data for each site including species and photographs Total of 148 plant species recorded, 9% of which are introduced. Results support earlier observations of Gillen (2010) of a gradual shift in vegetation along the hydrological gradient. Diversity decreases downstream (*although the trend would be clearer if functional groupings were used to exclude non-wetland/riparian species*). Hydrology is the main influence, however as move downstream the frequency of flooding reduces and pH and salinity exert a stronger influence. Soil pH tended to increase downstream with decreasing biomass production and organic content. However, sites that showed signs of current or recent high grazing pressure had the highest soil carbon due to their importation of nutrients by cattle. Distribution of *E. camaldulensis* was correlated with soils with significantly lower salinity and pH than sites without *E. camaldulensis*. Significant recruitment of all large and small tree species was observed. Grazing impacts were observed, with heavily grazed sites lacking palatable species and in some cases being dominated by introduced species.

Algae

Reference	Region	Summary
Costelloe et al. 2005	SA (LEB)	Algal Diversity and assemblages in arid zone rivers of the Lake Eyre Basin, Australia. Summarises and highlights microalgal findings from ARIDFLO. Moderate microalgal diversity. Composition is driven by: • Transport from refuge habitats during flow events • Regeneration from resting stages during rewetting of sediments • Also possibly through sediment transport (either aerial or on the feet of waterbirds).

Reference	Region	Summary
		How these mechanisms relate to genus is unknown due to little work on this taxa. Salinity also plays a role favouring some species over others, however multivariate analysis must be fine enough not to group halophillic and halophobic species (otherwise this trend will be lost).
McGregor et al. (2006)	Qld (Cooper Creek)	Spatial and temporal variation in algal-assemblage structure in isolated dryland river waterholes, Cooper Creek and Warrego River, Australia Compared algal assemblages and their relationship to environmental aspects of waterholes across two dryland rivers. A relatively high abundance of species was recorded. Algal communities showed significant differences between catchments and over time; however, were poorly correlated with environmental variables. Relevance: algal communities need longer-term large scale investigations (than herein) to determine if any significant differences are present.

Hydro-ecology

Reference	Region	Summary
Cockayne et al. (2012)	LEB	Summary of data from spring 2010 and autumn 2011 LEBRA sampling Thresholds of potential concern in the LEB outlined. Hydrology And Water Quality findings summarised. No analysis of data at the present time.
Cockayne et al. (2013)	LEB	Summary of data from spring 2011 and autumn 2012 LEBRA sampling Thresholds of potential concern in the LEB outlined. Hydrology And Water Quality findings summarised. No analysis of data at the present time
Costelloe (2008)	SA (LEB)	Updating and analysis of the ARIDFLO water level data in the Lake Eyre Basin Hydrological attributes – for some catchments (e.g. Neales) more up to date reports exist.
Costelloe et al. (2003)	LEB	Environmental flow requirements in arid zone rivers Analyses the ecological significance of unregulated rivers, especially for fish and waterbirds. Tests biotic responses to hydrological influences within regulated and unregulated rivers. More work needs to be done before models can predict future changes in response to hydrological variability. The rivers in the LEB contain high levels of ecological health due to their highly variable flow regimes as they remain unregulated. Regulation of these arid rivers could impact negatively on the health and diversity of these systems.
Costelloe	LEB	ARIDFLO

Reference	Region	Summary
et al. (2004)		Various chapters: Hydrology (hydro-chemistry, flow regime, waterhole morphology). A variable flow regime and an undisturbed system are important in maintaining algal diversity. There is a variation in salinity levels of waterbodies in the LEB.
Morton et al. (1995)	SA (LEB)	Natural Heritage Values of the Lake Eyre Basin in South Australia: World Heritage Assessment Literature review documenting natural heritage values for possible (but ultimately unsuccessful) World Heritage listing. Section 4.2 covers hydrology.
Puckridge et al. (1998)	Worldwide	Flow variability and the ecology of large rivers Emphasises the variability of Australian dryland rivers compared to dryland rivers in the rest of the world and that flow variability is often correlated with climate. Discusses the major influence of flow variability on ecology of dryland Rivers, including the negatives effects of reduced natural flows. Water resource agencies need to collaborate with ecologists. Importance of habitat restoration to allow natural hydrological variability, focussing on ecosystems rather that particular species groups. Highlights the importance to conserve unregulated rivers to maintain high biodiversity and ecological function.
Puckridge et al. (2000)	Cooper Creek (SA)	Hydrological persistence and the ecology of dryland rivers Examines effects of floods in reference to fish recruitment, population dynamics and evolutionary changes. Discusses fish adaptations to live in a highly variable environment. Suggests the importance of high flows and persistence for management of rivers in reference to water resources of the arid regions. Timing and duration of floods are also ecologically important for species of plants, fish and waterbirds in dryland rivers. The unpredictability of flooding and drying is a fundamental attribute to maintaining high biodiversity.
Sheldon et al. (2000)	MDB	The impacts of flow changes in large dryland rivers. Estimating flow related ecological change. Defines characteristics that affect a river's response to hydrological changes. Suggests that a river's ecological response to the development of water resources is predictable, but modelling should not replace long-term studies.
Sheldon et al. (2002)	SA (Cooper Creek)	Conservation value of connectivity Discusses the importance of hydrological connectivity for gene flow and flow of nutrients.

Reference	Region	Summary
		Outlines the complexity of biological response to hydrology. Expansions in water resource development in the arid zone could threaten natural variation in hydrology, irregular water flows and intermittent connectivity. Preservation of the variable flow regime of these dryland rivers is important for conservation of these aquatic ecosystems.
Tyler et al. (1990)	SA (LEB)	Natural History of the North East Deserts Comprehensive literature review for entire NE corner of SA with some overlap with Arckaringa and Pedirka Basins. Covers: • Geology • Hydrology • Soils • Limnology.

Floodplain and Dryland

Reference	Region	Summary
Brandle et al. (1999)	SA LEB	*The distribution, habitat requirements and conservation status of the plains rat,* Pseudomys australis Propose that minor drainage lines are primary habitat ('source') and gilgais secondary ('sink') as per source/sink habitat model (Pulliam 1988) further explored in a subsequent article in the same issue (Brandle & Moseby 1999: not reviewed as it was not conclusive).
Brandle et al. (1999)	SA LEB	*The distribution, habitat requirements and conservation status of the plains rat* Species only found in gibber desert from NT SA border NW of Kati Thanda-Lake Eyre to south of Kati Thanda-Lake Eyre south and near Lake Torrens. Propose that minor drainage lines are primary habitat ('source') and gilgais secondary ('sink') as per source/sink habitat model (Pulliam 1988) further explored in a subsequent article in the same issue (Brandle & Moseby 1999: not reviewed as it was not conclusive). Suggest that they prefer cracking clays because they are more productive and seed and other plant material is trapped in the cracks and less likely to be harvested by other species.
Capon (2003)	Qld Cooper	Plant community responses to wetting and drying in a large arid floodplain Explored flow-related responses in plant communities of Cooper floodplain, utilising a conceptual framework for floodplain vegetation dynamics. Plant communities were found to be strongly structured by flow regimes; both wet and dry phases provided crucial triggers for ecological processes (germination, colonisation, growth). Potential impacts of water extraction on floodplain plant communities are discussed. The results indicate that alterations to flow may produce a shift in community structure and an eventual loss of biodiversity. Relevance: Floodplain plant communities need inclusion in assessments/management actions for waterways due to their reliance on flooding.

Reference	Region	Summary
Capon (2007)	Qld (Cooper Creek)	Effects of flooding on seedling emergence from the soil seed bank of a large desert floodplain Compared the seedling emergence rates of soil seed banks taken from different flood frequency zones, when subjected to different flooding regimes in a greenhouse. Results showed differences in seed bank composition between flood frequency zones, and opportunistic germination strategies in dominant species. Detailed effects of hydrological attributes (duration, drawdown etc.) on emergence patterns are discussed, along with implications for management and anthropogenic alterations. Relevance: Reductions in flood pulse magnitude and frequency could result in a decline in the abundance of plants germinating in response to summer flooding and a loss of hydrophytic species in rarely flooded areas.
Gillen (2010)	Cooper Creek	*An ecological study of the landscape, perennial plants and soils of the Cooper Creek floodplain, SA* Identified soil factors influencing floodplain species: pH, salinity, texture, total organic carbon, cation exchange capacity, pottasium and calcium carbonate (with the first 3 most influential). Hydrology (*cf* Tunn & Cameron 2008 and Wainwright et al. 2006, these are not referenced), topography and disturbance were not investigated directly, although these will influence soil characteristics. Found a longitudinal gradation in vegetation in relation to increasing salinity and alkalinity downstream. Laterally there is a less clear gradation on floodplains due to the micro-topographical variation across the floodplain, but around lakes it is very clear. Vegetation is therefore related to the lateral and longitudinal position in relation to the watercourse Propose that the distribution of *E. coolabah* may be related to recharge zones on the floodplain, with *E. coolabah* growing well at the base of dunes because of increased rainfall recharge through dunes and flushing of salts.
Greenville et al. (2013)	Simpson Desert	*Extreme rainfall events predict irruptions of rat plagues in central Australia* Long-haired rat populations 'erupt' into plagues following high rainfall years (>750mm) but are otherwise only found in low numbers. Rat numbers were found to be highest close to drainage lines suggesting these areas are refuge sites for the rats during dry periods.
Pavey & Nano (2009)	Finke	*Bird assemblages of arid Australia: vegetation patterns have a greater effect than disturbance and resource pulses* Found resource availability (i.e. flowering and fruiting) and grazing disturbance were not major drivers of bird assemblages, with foraging behaviour, breeding requirements and vegetation identified as the main factors. Five distinct assemblages of birds were determined, four of which could be related to habitat types; mulga tall open shrubland, chenopod (on floodplains/floodouts) and riverine woodland supported distinct associations. The results support the theory that bird assemblages in the arid zone are constrained by fixed habitat availability.

Reference	Region	Summary
		Majority of birds were resident species, despite there being a resource pulse at time of survey. Note that the good season may have masked potential effects of low water availability and grazing and re-sampling during resource limiting periods is recommended.
Read (1992)	Olympic Dam	*Influence of habitats, climate, grazing and mining on terrestrial vertebrates at Olympic Dam, South Australia* Used results of monitoring over 5 years. Found the frog *Neobatrachus centralis* was the most abundant vertebrate in the region but was only recorded after heavy rains. Reptiles were most species diverse and abundant in the mine site, generally only in swales and not dunes. Mammal numbers and distribution were variable and were driven by climatic fluctuations. The one aquatic ecosystem site, a Canegrass swamp, had the highest species diversity and capture for mammals and was the only site where some species were caught. Many of the reptile species caught feed on termites or ants that harvest plant food and they are therefore buffered from seasonal and climatic variation. Property is destocked and conclude that the lack of difference between the minesite and pastoral land is that the grazing impacts are long term and the mine site has not yet fully recovered.
Read et al. (1999)	SA LEB	*The distribution, ecology and current status of Pseudomys desertor in SA* Propose that desert mouse spinifex populations are maintained by populations in wetter sites.
Reid & Gillen (2013)	Cooper	*Riparian bird assemblages of Cooper Creek, SA* Surveyed riparian and floodplain bird assemblages along the Cooper from Cullyamurra downstream. Nomadic and transient species complicated the data and trends could not be determined with these species included in the dataset. Bird abundance and diversity highest in the upper reaches and declined downstream. Species richness and community abundances was higher in riparian sites than non-riparian. The cover abundance of Coolabahs explained most of this variance. Found a shift in community composition as went downstream, with species that were more characteristic of the open floodplain environments of the upper catchment became increasingly prominent in downstream sites. The cover of small trees corresponded to the change from upstream to downstream riparian communities. Overall Coolabah found to be most significant in influencing bird assemblages, however the confined River Red Gum distribution was also significant for 6 species. Produced a conceptual diagram showing the relationship between longitudinal position, hydrology, vegetation and bird assemblages. Need to improve understanding of Coolabah regeneration.

3.4. Values

<table>
<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td>LEBCAC (2012)</td><td>LEB</td><td>LEBRA SAM Workshop
Draft LEB Objectives, highest priority LEB assets and threats, highest priority partners
LEBCAC identified and ranked in priority order assets of the LEB:
<table>
<tr><td>LEB Assets – summary heading</td><td>LEB Assets – workshop outputs</td></tr>
<tr><td>Naturally variable flow in rivers, floodplains, waterholes</td><td>Rivers, floodplains and waterholes; integrity of LEB rivers (flows, connectedness, quality, minimum change to natural state); landscape and watercourses; aquatic refuges; last major desert rivers still intact (internationally); clean-green, wilderness, intactness (marketing advantage); naturally variable flow regimes and water quality.</td></tr>
<tr><td>Cultural strength, culturally significant sites</td><td>Cultural strength, culturally significant sites and storylines e.g. rockholes, local and aboriginal knowledge.</td></tr>
<tr><td>Biodiversity values; unique flora and fauna</td><td>Biodiversity values; unique flora and fauna</td></tr>
<tr><td>Local and scientific knowledge and experience</td><td>Local knowledge; local knowledge and experience; scientific information; best available scientific and technical information.</td></tr>
<tr><td>Resources and associated industries: pastoral, mineral, petroleum and tourism</td><td>Agricultural and mineral resources; resources, agricultural and mineral; industry: pastoral, mining, petroleum, tourism, govt/community.</td></tr>
<tr><td>People, culture, lifestyle and thriving communities</td><td>Communities, towns, people, culture, lifestyle, sustainable economies to support functioning communities.</td></tr>
<tr><td>Springs</td><td>Springs</td></tr>
<tr><td>LEB process</td><td>LEB process</td></tr>
<tr><td>Unique location</td><td>Location: unique, organic?</td></tr>
</table></td></tr>
</table>

3.4.1. Ecological and Conservation Values

3.4.1.1. Ecological values

Reference	Region	Summary

Reference	Region	Summary
AETG (2012b)	National	Guidelines for identifying HEVAE Describes the criteria and workflow for identifying HEVAEs. HEVAE criteria: 1. Diversity 2. Distinctiveness 3. Vital habitat 4. Naturalness 5. Representativeness. The HEVAE has been trialled in Northern Australia (Kennard REF) and the LEB (AETG 2012e).
Costelloe et al. (2003)	LEB	Environmental flow requirements in arid zone rivers Discusses the ecological significance of unregulated rivers in the LEB, especially for fish and waterbirds.
Davis et al. (2013a)	National	Evolutionary refugia and ecological refuges: key concepts for conserving Australian arid zone freshwaterbiodiversity under climate change Reviews the potential role of aquatic refuges under climate change in the arid region, which has been subject to a long-term climatic drying trend. Both evolutionary and ecological refuges are of critical value under climate change: 'Evolutionary refugia are likely future refugia because their water source (groundwater) is decoupled from local precipitation but their biota is extremely vulnerable to changes in local conditions… Ecological refuges are vulnerable to changes in regional climate because they have little thermal or hydrological buffering. Accordingly, conservation planning must focus on maintaining meta-population processes, especially through dynamic connectivity between aquatic habitats at a landscape scale.'
Duguid (2006)	NT	Jewels on a necklace of sand: the Finke River of central Australia A qualitative and descriptive overview of the Finke River, describing its physical, climatic, hydrological and ecological features. There is a short description of the different aquatic ecosystems that are found in the area, including waterholes and springs. There is also a short paragraph about social and cultural values from a historic perspective. It includes many photographs of the Finke River environment.
Duguid (2013a)	NT	Delineation and Description of Ecological Character of the Mid-Finke Waterholes: A Trial of Guidelines for High Ecological Value Aquatic Ecosystems – INTERNAL DSEWPaC DRAFT for AETG review: not for distributionThis report describes ecologically significant waterholes in the middle section of the Finke River in the Northern Territory, in order to test draft guidelines for delineating and describing the ecological character of High Ecological Value Aquatic Ecosystems (HEVAE). 'As a result of this study it has been confirmed that three of the waterholes have never dried out in living memory and are therefore regarded as permanent. Landholder knowledge was essential to this determination but field observations and satellite imagery were also used. This information underpins the importance of the mid-Finke Waterholes as an HEVAE.'

Reference	Region	Summary
Golder Associates (2009)	Cooper Creek	Cooper Creek Water Resource Plan: Environmental Discussion Paper Lists the eight ecologically significant areas of the Cooper Creek Catchment, as identified by RAMSAR, DIWA, JAMBA and CAMBA, and world heritage criteria.
AETG (2012e)	LEB	Lake Eyre Basin High Conservation Value Aquatic Ecosystem Pilot Project Trial of the draft HCVAE (now HEVAE as per AETG 2012b) framework with recommendations for determining HCVAE. Based on criteria of diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness and based on data available, the criteria were applied to LEB AEs but note that this is a trial of the method and further work should be undertaken to identify HCVAE in the LEB. Two assessment units scored very high in three categories (containing Kati Thanda-Lake Eyre and Dalhousie Springs), 7 very high in 2 categories (containing Cullyamurra waterhole, Goyders Lagoon, Coongie Lakes, Edgbaston Springs and Lake Mueller, Dalhousie Springs, Lake Eyre Mound Springs and Palm Valley Area Springs) and 49 scored very high in one criteria (see Table 6, pp. 51–52).
Kingsford et al. (2010)	LEB	From 'Table 1: Major River Basins [only LEB shown] and key wetlands for waterbirds (maximum estimates available)' p. 877 Coongie Lakes — Lakes — 250 000 Lake Galilee — Saline lake — 105 400 Lake Mipia — Saline lake — 8800 Lake Koolivoo — Lake — 4800 Lake Torquinnie — Saline lake — 72 700 Lake Mumbleberry — Saline lake — 54 700 Lake Eyre — Saline lake — 325 000 Lower Cooper Creek — Saline lake — 134 200 Lake Blanche — Saline lake — 147 800 Lake Callabonna — Saline lake — 100 000 Lake Torrens — Saline lake — 100 000 Lake Killamperpunna — Lake — 73 100
Macdonald and McNeil (2012)	SA (arid zone)	Environmental and cultural values of South Australia's outback water resources Includes documenting knowledge on GDEs and surface WDEs, identifying attributes for each value and current and perceived threats to these attributes. The report explores groundwater, surface water, the interactions between them and the dependence of particular aquatic and terrestrial ecosystems and livelihoods upon them. It then focusses more specifically on GDEs, both subsurface (e.g. cave and aquifer ecosystems) and surface (e.g. spring-fed ecosystems), providing definitions and information on the distribution, values and threats to these values through case studies. Physical, biological, ecological values: Connectivity, refugia, unique environments, significant sites, climatic variability, ancient landscape, geology/geomorphology features, natural state, hydrological variability, paleoclimatic significance, new species potential, mesocosm for studying unimpacted ecosystems.

Reference	Region	Summary
Mancini (2013)	Cooper	*Ecological condition assessment of Cooper Creek wetlands, SA* Used similar method as Scholz & Deane (2011) to assess ecological condition of twelve sites on Cooper Creek in SA. Most sites rated as having 'good' ecological condition, with Cullyamurra found to have 'near reference' condition with high ecological value due to being a permanent deep waterhole. Prolific regeneration of Coolabah and seed production of annual fords and native grasses occurred due to preceding flooding and high rainfall conditions. Found main pressures are from: increasing tourism and recreational activity, total grazing pressure and infrastructure development for mining and exploration. Rabbits and Buffel Grass both pose serious future threats that are on the increase. Important to improve the understanding of Coolabah and River red Gum recruitment.
Negus et al. (2012)	Cooper Creek	Developing and Integrated Ecological Condition Assessment (IECA) framework for High Ecological Value Aquatic Ecosystems in an arid landscape: the Cooper Creek catchment trial A report detailing the application, development and trial an Integrated Ecological Condition Assessment (IECA) for High Ecological Value Aquatic Ecosystems (HEVAE) in the Cooper Creek catchment. Relevance: Ecological values are discussed and PSR conceptual models are presented for sites within the study.
Robson et al. (2008)	National	Identification and management of refuges for aquatic organisms Refuges provide habitats for wholly aquatic organisms such as well as for riparian and wetland vegetation, invertebrates, amphibians, reptiles (including lizards and turtles), mammals and birds.
Schmarr et al. (2012)	SA (Cooper Creek)	Aquatic Ecology Assessment and Analysis of the Cooper Creek Catchment: Lake Eyre Basin, South Australia Biotic assessment of Cooper Creek (SA). Primarily fish focussed with a brief examination of threatening processes in the region.
Scholz & Deane (2011)	Western Rivers (Neales)	Prioritising waterholes of ecological significance in the Neales and Peake Catchments Summarises the results of field surveys of six waterhole and floodplain environments, intended to help place overall project findings within a landscape context. Qualitative field assessments used to establish a synthetic reference condition for the aquatic ecosystem type under investigation. Target sites then assessed against this functional reference condition using a standardised methodology based on the Riverine Vegetation Indicator Protocol for river health (Roberts and Hale, 2009). Grades permanent aquatic refuges throughout the Neales River Catchment in order of management priority and ecological significance. Identifies and assesses risks

Reference	Region	Summary
		from invasive species and grazing activities on permanent aquatic refuge habitats within the Neales River catchment. The sites were found to have varying impact levels depending largely on grazing and tourism history. Grazing was observed to impact on the vegetation structure as well as having an influence on the density of species diversity, selecting out palatable species and allowing less-palatable species to dominate. Visitation to the sites had a greater impact on the landscape through compaction and soil erosion from vehicular and traffic access, while the overstorey species *Eucalyptus coolabah* were impacted from being selectively cut for fire wood.

3.4.1.2. Conservation values

Reference	Region	Summary
Carini et al. (2006)	Qld (LEB)	The role of waterholes as 'refugia' in sustaining genetic diversity and variation of two freshwater species in dryland river systems (Western Queensland, Australia) Investigated genetic diversity and patterns of connectivity among waterholes for two species: *M. australiense* and *N.sublineata*. Discusses the conservation values of main and satellite waterholes as refugia for sustaining genetic diversity. Relevance: Highlights the requirement of maintaining connectivity, to ensure the conservation of genetic diversity, and that equal conservation/protection priority should be applied to satellite waterholes as to main channel waterholes.
Costelloe & Russell (2014)	Neales	*Identifying conservation priorities for aquatic refugia in an arid zone, ephemeral catchment: a hydrological approach* As arid zone rivers are generally populated by generalist species with high dispersal capabilities and overall low species diversity, they tend not to have high rates of endemism. Therefore conservation prioritisation based on traditional conservation priorities of endemism and diversity tend to overlook such arid river ecosystems, overlooking their vulnerability to anthropogenic impacts. Identifies Algebuckina waterhole as having the highest conservation value for fish in the Neales because it is the only habitat capable of sustaining all species under extended drought. GAB springs are also noted for conservation value but that their shallowness limits their suitability to a subset of the total catchment diversity.
Davis et al. (1993)	Central Australia	Invertebrate communities of relict streams in the arid zone: the George Gill Range, Central Australia Study of invertebrate communities within isolated streams of southern NT. Evaluates the conservation value of the area, determining it to be of extremely high importance due to the high species richness, low levels of disturbance and isolation of the waterbodies.
Davis et al. (2013b)	National	Building the climate resilience of arid zone freshwater biota Describes the research undertaken to develop national guidelines for climate adaptation planning for arid zone aquatic ecosystems and freshwater biodiversity.

Reference	Region	Summary
		The guidelines focus on the protection of habitats and processes that support the persistence of freshwater biota under a changing climate. "Strategies to increase resistance represent a major adaptation goal for arid zone evolutionary refugia where resistance implies the ability to withstand change, despite changing water availability… Strategies to increase resilience are essential for the conservation of ecological refuges… Maintaining high quality habitats spanning the distributional ranges of priority taxa, and restoring degraded ecological refuges that are not well represented across the landscape, are also important climate adaptation actions."
DEH & SAALNRMB	SA (LEB)	SA Arid Lands Biodiversity Strategy Describes the conservation priorities and threats to them. Includes information about high priority species such as the Grey Grasswren that are dependent on riparian and wetland habitats but generally not included in aquatic ecosystem work.
DERM (2010c)	Qld (LEB)	Desert Channels Back on Track Actions for Biodiversity Lists 50 priority species for conservation within the Desert Channels NRM region, including aquatic species; details threats to species persistence; and details and prioritises actions, plans and strategies for management of species and associated threats.
DERM (2013)	Qld (LEB)	Lake Eyre Basin and Bulloo Catchments: Aquatic Conservation Assessments Draft Expert Panel Report The results of this process for the LEB and Bulloo have not been made available to date. Documents the process, findings and recommendations from an expert panel, for prioritising areas of aquatic conservation importance using the AquaBAMM approach. The process involves using a range of ranked and weighted criteria to evaluate and prioritise species, ecosystems and special features. A hierarchical method is used to achieve an overall conservation value: • Measure score (Level 1): an individual conservation score/rating (e.g. 3/4) is assigned to specific measures/ indicators/criteria (e.g. waterbird habitat areas) based on their identified values (e.g. >8 ha, supports >100k breeding ducks) • Indicator score (Level 2): arithmetically combined measure scores • Criterion rating (Level 3): arithmetically combined indicator scores AquaBAMM Conservation Value or AquaScore (Level 4): each criterion rating for a spatial unit is combined using a 'decision filter table' to form the overall score (e.g. Very Low, Low, Medium, High and Very High). Relevance: Selection of monitoring parameters (on a larger scale, e.g. naturalness, diversity, connectivity).
Duguid (2011)	NT (GAB)	Wetlands of the GAB Water Control District (Northern Territory) An assessment of conservation significance of wetlands was undertaken based on the following criteria:

Reference	Region	Summary
		• Relatively large areas and/or long lasting water with an associated benefit for wetland dependent plants or animals • Presence of plant species that are rare in central Australia • Presence of plant species that are locally rare • High diversity of wetland plant species • High diversity of water birds • Unusual or rare wetland type. In addition to eight wetlands previously identified in Duguid et al. (2005) as being regionally, nationally or internationally significant, one wetland is identified as having national/regional significance and another eight wetlands are considered possibly significant.
Duguid et al. (2005)	NT	Wetlands in the arid Northern Territory This report describes the wetland values of the arid southern-part of the Northern Territory based on information collected as part of a two year survey. The Inventory uses ground and aerial surveys with remote sensing and GIS to define and describe the types of wetlands that exist, assess their general biological attributes, and to improve mapping of their distribution. The overall value of arid NT wetlands has been assessed for three key biotic groups: birds, plants and fishes, whilst Individual wetlands have been assessed against the criteria for inclusion in *A Directory of Important Wetlands in Australia* and a subset have been assessed against the Ramsar criteria for internationally significant wetlands. A preliminary list of wetland plants has been produced for the study area, as well as a summary of major groups of wetland plants. Waterbirds were surveyed from the ground and air, and fish and aquatic invertebrates were sampled opportunistically. Examples of the field survey sheets are included as appendices.
Fensham et al. (2011)	Cooper Creek, Georgina-Diamantina	Four desert waters: Setting arid zone wetland conservation priorities through understanding patterns of endemism Provides a framework for determining the conservation priorities for four different wetland types (riverine waterholes, rockholes, discharge springs, outcrop springs) based on the endemism of species found in these refugia. They emphasise the importance of persistence and connectivity in determining endemism, with extremely persistent and isolated discharge springs (e.g. GAB springs) having the highest endemism. The paper deals with refugia in the eastern LEB (e.g. Cooper and Georgina-Diamantina) but the principles of setting conservation priorities can be extended to the western LEB.
AETG (2012e)	LEB	Lake Eyre Basin High Conservation Value Aquatic Ecosystem Pilot Project Trial of the draft HCVAE (now HEVAE as per AETG 2012b) framework with recommendations for determining HCVAE. Based on criteria of diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness and based on data available, the criteria were applied to LEB AEs but note that this is a trial of the method and further work should be undertaken to identify HCVAE in the LEB. Two assessment units scored very high in 3 categories (containing Kati Thanda-

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<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td></td><td></td><td>Lake Eyre and Dalhousie Springs), 7 very high in 2 categories (containing Cullyamurra waterhole, Goyders Lagoon, Coongie Lakes, Edgbaston Springs and Lake Mueller, Dalhousie Springs, Lake Eyre Mound Springs and Palm Valley Area Springs) and 49 scored very high in one criteria (see Table 6, pp.51–52).</td></tr>
<tr><td>Harrison et al. (2009)</td><td>NT</td><td>An inventory of sites of international and national significance for biodiversity values in the Northern Territory

This report provides information about the 67 sites of conservation significance that were identified in Ward and Harrison (2009).

Each site has an information paper that describes:
location and site boundaries,
data supporting significance ratings for five conservation values (threatened species, endemic species, wildlife aggregations, wetlands and flora)
information on other environmental values, management issues and management information.
There is also information on the sources of data used in producing the maps, a full list of references for all the site information papers and a glossary.</td></tr>
<tr><td>Kingsford & Porter (2008)</td><td>LEB</td><td>Scientific Validity of Using Waterbird Measures to Assess River Condition in the LEB

Sites of conservation significance to waterbirds.

<table>
<tr><th>Wetland site</th><th colspan="2">Conservation Status</th><th colspan="2">Significance for waterbirds</th></tr>
<tr><td>Coongie Lakes</td><td>DIWA</td><td>Ramsar</td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Diamantina River Wetland System</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Strzelecki Creek Wetland System</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Inland Saline Lakes</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Lake Eyre</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Birdsville - Durrie Waterholes Aggregation</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Cooper Creek Overflow Swamps - Windorah</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Cooper Creek Swamps - Nappa Merrie</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Cooper Creek - Wilson River Junction</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Diamantina Lakes Area</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Diamantina Overflow Swamp - Durrie Station</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Georgina River - King Creek Floodout</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Lake Constance</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Lake Cuddapan</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Lake Mipia</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Lake Koolivoo</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Lake Phillipi</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Lake Torquinie</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Lake Mumbleberry</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Lake Yamma Yamma</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Moonda Lake - Shallow Lake Aggregation</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Mulligan River - Wheeler Creek Junction</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Muncoonie Lakes</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
<tr><td>Lake Galilee</td><td>DIWA</td><td></td><td>Abundance</td><td>Breeding</td></tr>
<tr><td>Lake Machattie</td><td>DIWA</td><td></td><td>Abundance</td><td></td></tr>
</table>
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Reference	Region	Summary
Reid et al. (2010)	LEB	Waterbird surveys in the Channel Country floodplain wetlands, autumn 2009 Documents results of waterbird surveys in Cooper and Georgina-Diamantina catchments in 2009 following flooding. Results included: • 1% thresholds exceeded for 4 migratory species: Little Curlew, Sharptailed Sandpiper, Australian Pratincole and White-winged Black Tern • 6 sites with over 100,000 waterbirds (exceeding Ramsar threshold of 20,000).
Kingsford et al. (1999)	Cooper Creek	Water flows on Cooper Creek in arid Australia determine boom and bust periods for waterbirds. Cooper Creek wetlands are recognised for their conservation value at an international scale. Wetland function relies on a guaranteed water supply from upstream. Importance of natural water flows for waterbird populations and breeding.
Macdonald and McNeil (2012)	SA (Arid zone)	Environmental and cultural values of South Australia's outback water resources Conservation values: Diversity, endemism, evolutionary significance, unique environments, rare species, natural state, hydrological variability, paleoclimatic significance, archaeological uniqueness, anthropological significance.
Moller (1999)	Qld (LEB)	State of the Rivers Cooper Creek and Major Tributaries An assessment of the physical and environmental condition was conducted for 273 sites on the Thomson River, Barcoo River, Cooper Creek and their tributaries. Parameters were assessed against presumed natural condition by comparison to remanent sites. Conservational value was assessed [other parameters also]. Higher ratings were attributed to the presence of good remnant aquatic habitat, 'reasonable' wildlife corridors and good representative riparian vegetation. Relevance: Presents a method for fast environmental condition assessment; describes the state of rivers in the Cooper catchment; and discusses method for monitoring and potential for identification of temporal changes if monitoring the same parameters occurs.
Morton et al. (1995)	SA (LEB)	Natural Heritage Values of the Lake Eyre Basin in South Australia:World Heritage Assessment Literature review documenting natural heritage values for possible (but ultimately unsuccessful) World Heritage listing.
Neave et al. (2004)	NT	A Resource Assessment Towards a Conservation Strategy for the Finke Bioregion This report covers the Northern Territory portion of the Finke Bioregion. and provides a set of conservation options and recommendations, which will ensure that the species, ecosystems and ecological processes in the Finke Bioregion are conserved, whilst also considering the social and economic needs of the bioregion's residents. Specifically the report aims to: • determine (using existing and new data) what plant and animal species

Reference	Region	Summary
		are present in the Finke Bioregion • identify significant species and ecological communities in the Finke Bioregion (e.g. those that are rare, threatened, endangered or endemic) • determine patterns in the distribution of wildlife assemblages in the Finke Bioregion; identify threatening processes in the Finke Bioregion which impact on significant species and ecological communities • identify other values in the bioregion (in addition to significant biodiversity values), including cultural heritage and aesthetic/recreational values (i.e. social values) • determine which of the values in the Finke Bioregion require conservation management • apply assessment criteria to determine priorities for off-reserve conservation management of identified values, or should the opportunity arise, for the establishment of conservation reserves which would contribute to the comprehensive, adequate and representative reserve system in the Northern Territory. • prepare a report for the Finke Bioregion in consultation with stakeholders, which includes recommendations and options for the conservation management of identified biodiversity and social values. Several key habitats identified which are in need of conservation action, including the Todd River floodplain, stony lowlands, sandy southern plains, dunefields and sandplain, and salt lakes. There are also a number of other habitats of conservation value in the Finke Bioregion such as important wetlands. Vegetation assemblages of conservation value are those that are species rich and/or are limited to, or are a feature of, the Finke Bioregion: including wooded (Coolabah) claypans, Samphire or Inland Teatree saltpan margins and wooded (Ironwood)/shrubby sandy floodplains. The assessment also identified a number of threatened and near threatened species that could benefit from innovative offreserve conservation management including Australian Bustard.
NRMMC (2010)	National	Australia's Biodiversity Conservation Strategy 2010-2030 'The Priorities for action section identifies three national priorities for action to help stop the decline in Australia's biodiversity. These priorities for action are: 1. Engaging all Australians in biodiversity conservation through: • mainstreaming biodiversity • increasing Indigenous engagement • enhancing strategic investments and partnerships. 2. Building ecosystem resilience in a changing climate by: • protecting diversity • maintaining and re-establishing ecosystem functions • reducing threats to biodiversity. 3. Getting measurable results through: • improving and sharing knowledge • delivering conservation initiatives efficiently • implementing robust national monitoring, reporting and evaluation.'
Puckridge et	International	Flow variability and the ecology of large rivers

Reference	Region	Summary
al. (1998)		Emphasizes the variability of Australian dryland rivers compared to dryland rivers in the rest of the world. Importance of conservation of unregulated rivers. Importance of habitat restoration to allow natural hydrological variability focusing on ecosystems rather that particular species groups.
Rolfe et al. (2000)	Qld (Upper Thomson)	Valuing the preservation of rangelands: tree clearing in the desert uplands region of Queensland Presents results of a choice modelling study, to determine the values which the community associated with retaining remnant vegetation in the desert uplands region. Specifically, the community placed highest value on endangered species and unique ecosystems. Discusses the values of the public on environmental preservation, some discussion of method and references to document with detailed method.
Schmarr et al. (2012)	SA (Cooper Creek)	Aquatic Ecology Assessment and Analysis of the Cooper Creek Catchment: Lake Eyre Basin, South Australia Assessment of critical refugia in Cooper Creek SA. Identifies key refugia in the system.
Sheldon et al. (2002)	SA (Cooper Creek)	Conservation value of connectivity Efforts to conserve and manage rivers are hampered by limited scientific data on ecology in response to variable flow regimes. Discusses the importance of connectivity for gene flow and flow of nutrients. Outlines the complexity of biological response to hydrology. Water resource development in the arid zone could threaten natural variation in hydrology.
Ward and Harrison (2009)	NT	Recognising sites of conservation significance for biodiversity values in the Northern Territory The overall assessment identifies 67 sites of significance for biodiversity conservation in the NT, restricted to terrestrial (and aquatic) sites and values (does not consider strictly marine values or sites). Only biodiversity values were considered in this report, not cultural or social ones. This report describes the methodology used to compile the inventory of sites, undertake community consultation and prioritise sites. There is also a discussion section which describes project limitations, site management issues, and future priorities for research and conservation. The relevant inland aquatic ecosystem classes included in the assessment are: • River • Floodplain/permanent swamp • Ephemeral lake/swamp/floodout • Saline lake • Permanent water • Groundwater-dependent ecosystem

Reference	Region	Summary
		• Other freshwater wetlands. There is a companion document: An inventory of sites of international and national significance for biodiversity conservation in the Northern Territory (Harrison et al. 2009), which contains an information paper for each identified site summarising the conservation values identified, and the resulting conservation significance ratings.
Zeidler and Ponder (1989)	SA (Dalhousie Springs)	Natural History of Dalhousie Springs Multidisciplinary survey of the Dalhousie Springs Complex. One of the few surveys in this spring complex which includes four endemic fish species.
Kerle et al. (1992)	NT & SA desert	*The decline of the Brushtail Possum … in arid Australia* Brushtail Possum was once widespread in arid Australia and noted in Aboriginal culture. Were particularly abundant in, but not restricted to watercourses, being also found in rocky gorges and outcrops. The species is believed to have declined dramatically in the 1920's -1930's and now only found in NT. Presents a model of the factors leading to their decline which include changes in Aboriginal people's activities, habitat decline and introduced species along with a period of below average rainfall.
Pavey et al. (2010)		*Foraging ecology and habitat use of Slater's skink (Egernia slateri): an endangered Australian desert lizard* Slater's skink is nationally endangered and now only found in desert river floodplains of southern NT. They depend on the mounds that form at the base of shrubs to burrow. Species vulnerable to impacts from introduced herbivores grazing shrubs and destroying mounds, as well as from weeds.
Fenner et al. (2012)	Central Australia	"The endangered Slater's skink (*Liopholis slateri*) is restricted to the river floodplain habitat of central Australia. It is an obligate burrower and creates complex, multi-entrance burrow systems in the mound of soil that builds up around the base of some shrubs and small trees. We provide detailed information about the behaviour and use of the burrow systems by Slater's skink." Burrow systems can be destroyed during heavy rainfall (and presumably during high flood events).
Neagle (2003)	LEB SA	*An inventory of the biological resources of the rangelands of South Australia* Threatened ecological communities: Mound springs only nationally threatened ecological community. SA threatened ecological communities associated with watercourses and floodplains (report identifies which bioregion these are associated with): • *E. coolabah ssp arida* woodland on levees and channel banks of regularly inundated flooplains (of concern) • *E. camaldulensis* woodland on levees and channel banks of regularly inundated floodplains (of concern) and on levees and banks of drainage lines in semi-arid areas (vulnerable) • Acacia salicina, E coolabah ssp arida +/_ Lysiphyllum gilvum woodland of drainage lines and floodplains • *Atriplex nummularia* open shrubland with occasional emergent *E.*

Reference	Region	Summary
		camaldulensis or *E. coolabah ssp arida* on low sandy rises of floodplains (of concern) • *Chenopodium auricomum* shrubland on cracking clay depressions subject to periodic waterlogging (swamps) (of concern) • *Alectryon oleifolius ssp. canescens* tall shrubland on alluvial soils of plains (vulnerable) • Freshwater wetlands including herblands/sedgelands (endangered) Threats associated with these communities relate to heavier grazing pressure and other impacts from introduced herbivores (soil disturbance, weeds, lack of recruitment), as well as tourism impacts (soil disturbance, weeds, firewood collection) for vegetation associated with more permanent water; freshwater wetlands also threatened by additional threats: sedimentation, nutrient redistribution, flow threats. Also includes threatened plant species (predominantly dryland), and threatened fauna, many of which are associated with aquatic ecosystems. Notes on the ecology of nationally threatened fauna are included: • Dusky Hopping Mouse (*Notomys fuscus,* Aus: V, SA: V) is recorded in dune habitats in the vicinity of major drainage systems. • Plains Rat (*Pseudomys australis,* Aus: V, SA: V) associated with cracking clay with minor drainage features and small depressions of gibber plains (gilgais), association due to these areas being more productive and plant material collecting in cracks being less accessible to other species • Flinders Ranges Purple-spotted Gudgeon (*Mogurnda clivicola*, Aus: V, SA: R) in groundwater fed pools of northern Flinders Ranges • Bronzeback Legless Lizard (*Ophidiocephalus taeniatus*, Aus: V, SA V) found in deep litter overlying well-drained deep cracking clays along drainage lines (see McDonald et al. 2012), threats include floods that change the soil surface habitats and stock trampling Threats to biodiversity include from introduced herbivores impacting waterholes and surrounding vegetation, and weeds are more of a threat on floodplains and watercourses than surrounding terrestrial areas.
Reid & Gillen (2013)	Cooper	*Riparian bird assemblages of Cooper Creek, SA* Nationally threatened Barking Owl found to have a restricted distribution in the upper reaches where River Red Gums are present.
Gillam & Urban (2013)		Regional Species Conservation Assessment Project, Phase 1 Report: Regional Species Status Assessments A regional species conservation assessment was undertaken for most of the region comprising the SA LEB using The assessment process was completed, using quantitative data obtained from the DEWNR Biological Database of SA, and qualitative data and information gathered from panels of experts during workshops. (note did not include Aridflo of SARDI data) "Across the Outback Region, 11% (11% fauna, 11% flora) of all species were considered threatened (that is, Vulnerable, Endangered or Critically Endangered). If species classed as "Rare" and "Near Threatened" are included in the analysis, then the percentage of "species at risk" rises to 56.5% (45% fauna, 68% flora). In addition, up to 6.5% of all species (6% fauna, 7% flora) were believed to be in a

Reference	Region	Summary
		state of decline."

3.4.2. Cultural values

3.4.2.1. Overview

Reference	Region	Summary
Australia ICOMOS (1999)	National	The Burra Charter: the Australian ICOMOC Charter for Places of Cultural Significance Australia ICOMOS Inc. http://australia.icomos.org/wp-content/uploads/BURRA_CHARTER.pdf The Burra Charter encompasses assessment of all types of places of cultural significance including natural, indigenous and historic places with cultural values. Places of cultural significance are historical records that provide a tangible, deep and inspirational sense of identity and connection to community and landscape, to the past and to lived experiences that may be irreplaceable. The Burra Charter advocates cultural significance is retained through changing as little as possible. It recommends the co-existence of cultural values (Article 13) including in places where such values may conflict with policy development and management decisions. 'The term cultural values refers to those beliefs which are important to a cultural group, including but not limited to political, religious, spiritual and moral beliefs. This is broader than values associated with cultural significance.' Articles 1.1 to 1.7 defines values, cultural group, national estate, conflict and acknowledges the values of all associated cultural groups. It specifically defines cultural significance to means 'aesthetic, historic, scientific or social value for past, present or future generations' (1.4) Article 5 includes the understanding that cultural values may evolve over time and that acceptance of new issues and associated cultural groups towards a balanced approach to competing cultural and natural values is necessary in assessment of significance. The physical location of a place and the maintenance of visual settings and landscape relationships contribute to the cultural significance of places (Articles 8, 9 & 13). 'New construction, demolition, intrusions or other changes which would adversely affect the setting or relationships are not appropriate. Other relationships, such as historical connections, may contribute to interpretation, appreciation, enjoyment or experience of the place'. The Charter also confirms the necessity to provide interpretation to enhance understanding and enjoyment of culturally significant places, and be culturally appropriate (Article 25).
Australian Heritage Council (2009)	National	Guidelines for the Assessment of Places for the National Heritage List Under the process of listing places, sites and areas for inclusion on the National Heritage List definitions of National Heritage values are central to understanding significance against criteria. The place is seen to have outstanding heritage value due to criteria including its: 1. importance in the course, or pattern, of Australia's natural or cultural history: 2. possession of uncommon, rare or endangered aspects of Australia's natural or cultural history

Reference	Region	Summary
		3. potential to yield information that will contribute to an understanding of Australia's natural or cultural history 4. importance in demonstrating the principal characteristics of a class of Australia's natural or cultural places or environments 5. importance in exhibiting particular aesthetic characteristics valued by a community or cultural group 6. importance in demonstrating a high degree of creative or technical achievement at a particular period 7. strong or special association with a particular community or cultural group for social, cultural or spiritual reasons 8. association with the life or works of a person, or group of persons, of importance in Australia's natural or cultural history 9. importance as part of Indigenous tradition. These multiple criteria establish a position on the critical relationship between natural and cultural conditions and acknowledge that cultural aspects mean Indigenous and/or non-Indigenous values.
Australian Heritage Council (2004)	National	Australian Natural Heritage Charter: for the conservation of places of natural heritage significance 2nd Edition, Australian Heritage Commission in Association with the ACIUCN, Canberra, pp. 2–25 http://www.environment.gov.au/heritage/ahc/publications/commission/books/pubs/australian-natural-heritage-charter.pdf The Charter incorporates a range of values, from existence value to socially based values with respect to a wide interpretation and respect for natural heritage differentiated from cultural heritage through determination of ecological, earth and evolutionary processes. It states that places may have intrinsic, related natural and cultural heritage values which many Indigenous and non-Indigenous people regard as inseparable. Acknowledging the principles of intergenerational equity, existence value, uncertainty and precaution, in particular existence value is the concept that affirms living organisms, earth processes and ecosystems holding value beyond the social, economic or cultural values held by humans. From a management perspective the Charter's 'precautionary principle means that where there are threats or potential threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation'. Cultural values are noted in Articles 2 and 7 of the Conservation Principles. Where statements of significance present assessment of the natural qualities and importance of a place, cultural values should also be considered and referenced in the statement of significance including Indigenous or historic cultural heritage.
Bird Rose (1996)	National	Nourishing Terrains, Australian Aboriginal Views of Landscape and Wilderness, Australian Heritage Commission Canberra ACT www.environment.gov.au/heritage/ahc/.../nourishing-terrains.pdf A general introduction to cultural values written by a non-Indigenous researcher, this commissioned essay reviews concepts of landscape and wilderness across Australia including Aboriginal people's own words through stories, songs and poems around concepts of their significant relationships to the own country. Through questioning

Reference	Region	Summary
		whether Aboriginal peoples could be considered through the contemporary term as conservationists, issues such as land management and related sustainable practices based upon concern and philosophies around the continuing wellbeing of Country. 'Country is not a generalised or undifferentiated place…rather country is a living entity with a yesterday, today and tomorrow, with a consciousness, and a will towards life. Because of this richness, country is home, and peace; nourishment for body, mind and spirit…' p. 7 Since European settlement the impact on water sources and competition for water as sustenance has resulted in both Aboriginal and ecosystem destruction, including water systems and salinity, and Rose provides a generalised history concluding with a commentary on Human and Ecological rights expanded through quotes offered by Aboriginal people.
Cathcart (2009)	National	The Water Dreamers: The Remarkable History of Our Dry Continent, Text Publishing, Melbourne. A foundational study on the connection between water presence and absence in the Australian landscape that links the spatial dimensions of water assets to the patterns of settlement, exploration and resource and infrastructure development. The major narratives include water scarcity, use and misuse towards environmental degradation, grand schemes and epic failures and the expansion of viable settlement into the inner arid lands of central Australia by the groups Cathcart describes as Waterdreamers. His proposition is that we will not know ourselves, or the land in which we live, until we understand its water, because it is water that will determine the future of Australia. 'As settlers and explorers moved inland, dreaming of an inland river system, they found instead dry riverbeds, dry lakebeds, desert, and 'howling silence'. But the dream of abundant water continued to inspire politicians, pastoralists and farmers, poets and novelists, to become a patriotic truth. Hopes were invested in great water schemes: irrigation and dams would transform the dead heart of Australia. When in the 1920s the geographer Griffith Taylor declared that rainfall determined the viable limits of settlement, he was demonised. More than two centuries later, anxiety about water still lies at the heart of national environmental debates.'
Common-wealth Environ-mental Water Office (2013)	National	What is Commonwealth Environmental Water? Commonwealth water holdings are the direct result of government purchases of entitlements and a substantial investment in more efficient water infrastructure in the Murray Darling Basin. The Commonwealth Environmental Water Holder is responsible for government policies and programs that seek to protect and restore environmental assets – rivers, floodplains and wetlands – that contain a wide diversity of life and provide habitat for native animals and plants. The Water Holder, supported by the Commonwealth Environmental Water Office, manages the Commonwealth's environmental water portfolio, research projects that inform approaches to aquatic ecosystems and environmental watering policy, and major projects to improve water quality and the ecological health of iconic wetland assets in the Murray Darling Basin. The Office is also the administrative authority within Australia for the Ramsar Convention on Wetlands of International Importance."

Reference	Region	Summary
Corner, J., (1997)	Inter - national	Ecology and Landscape as Agents of Creativity, In *Ecological Design and Planning* Thompson, G.F. et al. (eds.) New York pp. 80–180 Cross-disciplinary and emerging views of ecology confirm that scientific accounts of natural processes and their interrelationships are also social constructions. The conservationist/resourcist paradigm suggests further ecological knowledge will enable progressive management and control of ecosystems through regarding landscapes as composed of various resources that have particular value to people. Strategies for landscape conservation are developed as balances between human needs and natural life. Rational and conceptually value-neutral criteria are developed for evaluating fit between proposed land uses and environmental systems. Conversely the restorative – ecological paradigm has scientific, planning and landscape design knowledge used to heal and reconstruct natural systems through linking landscape practices to ecological and social values.
Fry et al. (2009)	Inter - national	The ecology of visual landscapes: exploring the conceptual common ground of visual and ecological landscape indicators, Ecological Indicators 9: pp. 933–47. http://www.sciencedirect.com/science/article/pii/S1470160X08001581 To recognise and understand the relationship between ecology and aesthetics on a conceptual level is of importance to landscape planning and management and landscape ecology has always included humans as central to landscape change and its impact. A cultural perspective in landscape ecology takes account of what is important for people. The area of cross-over conceptual development is between landscape aesthetics and landscape ecology in trying to quantify the spatial structure of landscapes where there is common ground even though the terminology is often different. The development of landscape ecological indicators has resulted in a wide range of landscape metrics and composite indices with a strong conceptual base in landscape ecological principles, although visual indicators are still underdeveloped. Landscape indicators inform policy agendas and are increasingly used in the assessment of different landscape values and this review has uncovered considerable overlap between currently used indicators of landscape aesthetics and landscape ecology resulting also in the development of new tools for landscape planning and management. Gobster et al. (2007) outlines a model for human-environmental interactions in the landscape focusing on the perceptible realm where ''aesthetic experiences occur and where intentional actions towards landscapes can directly or indirectly affect ecological functions'. Key concepts include; stewardship, coherence, disturbance, historicity, visual scale, imageability, complexity, naturalness and ephemera and each concept includes a definition relating to the visual perception, scale, patterns and diversity of features from both natural and cultural perspectives. This approach focusses on the identification key assets and their ecosystems by means of landscape theory and assessment relevant to specific landscape contexts.
Gibbs (2006)	LEB	Valuing Water: variability and the Lake Eyre Basin, central Australia, Australian Geographer, March 2006, Vol. 37, No. 1, pp. 77–85 http://ro.uow.edu.au/cgi/viewcontent.cgi?article=7575&context=scipapers

Reference	Region	Summary
		Gibbs proposes valuing variability as a new framework for valuing water in the arid and semi-arid Lake Eyre Basin, central Australia in order to embrace diversity, change and complexity, and emphasises interconnections between water, humans and the non-human world. 'Environmental values' form an increasingly important component of natural resource economic management, but use of the term 'value' is confined to analysis of ecological and natural systems. Commenting on the separation of themes in the LEB Biennial Conference in 2002; water for making a living', 'water for wildlife and nature conservation' and 'water for society and culture' Gibbs suggests these separation of values limits understanding of complex value systems.
Hopkins, J. (2005)	Inter - national	'Music –makers and the dreamer of dreams' in eds Harvey, S. & Fieldhouse, K., *The Cultured Landscape Designing the environment in the 21st century,* Routledge, Oxon and New York, pp. 25–54 Explores extended definitions of landscape including D.W Meinig in *The Beholding Eye* in relation to complex human relationships in viewing landscape. Summaries of these relationships under the themes of: nature, nabitat, artifact, system, problem, wealth, ideology, history, place, and aesthetic. Landscape has powerful physical, environmental, economic, cultural, psychological and aesthetic components. It discusses the emergence of an environmental ethics response to global issues of water and ecology and economics through the concept of natural capitalism where the environment is an 'envelope containing, provisioning and sustaining the entire economy' p41.
HREOC (2008)	National	Indigenous Peoples and Water, Chapter 6, Native Title Report 2008 http://humanrights.gov.au/social_justice/nt_report/ntreport08/pdf/chap6.pdf The concept the cultural value of water goes to the essence of values in central Australia confirming that 'Water is the life for us all. It's the main part. If we are gonna lose that I don't know where we gonna stand. If that water go away, everything will die. That's the power of water. He connect with the land. *Pukarrikarra* (the dreaming) put 'em all together. One life.' John 'Dudu' Nangkiriyn p. 171 Indigenous values are regionally diverse and complex, with commonalities and distinctions from non-Indigenous laws that are important to recognise and understand. Indigenous relationships with water are holistic; combining land, water, culture, society and economy. Consequently water and land rights, the management of resources and native title are inseparable. The Productivity Commission non-Indigenous perspective on water values and water rights is defined as 'A legal authority to take water from a water body and to retain the benefits of its use'. Water rights can come in the form of: licences, concessions, permits, access and allocations. As well as the right to take water, other related rights include: access, exclusion, alienation, and management of the resource' p. 170.
Lee, G., (2010)	LEB	Cultural landscape assessment and analysis of the Neales Catchment and Algebuckina Waterhole, SAAL NRM http://www.saalnrm.sa.gov.au/PublicationsResources/ProjectReports.aspx The cultural landscape assessment into the physical features and human influences of the Neales Catchment uses a landscape design based methodology, fieldwork and

Reference	Region	Summary
		cross-disciplinary approach to documenting the landscapes of waterholes and their environs for the Neales River system. This approach utilises a stakeholder-driven assessment matrix, where natural as well as cultural systems are regarded as stakeholders, to identify the environmental, economic, cultural and social values associated with water landscape features. The report seeks to attribute values based upon the structural and visual conditions of waterholes and the relationship between the natural and cultural dynamics of these systems over time.
Lee (2013)	Cooper	*Landscape assessment and analysis of the Cooper Creek Catchment* Documents the range of landscape values associated with the Cooper Creek in SA; Identifies that the cultural landscape is made up of overlying industrial, conservation, productive and storied landscapes. Provides detailed landscape assessment of individual sites
Lennon, J., (2009)	Qld	*Cultural Landscapes in South East Queensland*. A discussion paper for Queensland Department of Infrastructure and Planning (unpublished report) Establishes the concepts of the components that contribute to understanding what a cultural landscape is including the landscape features of areas and places, co-interactions between humans and landscapes leading to considerations of their conservation. The discussion paper nominates the range of disparate components that contribute to assessments of cultural landscapes, the key to which is gaining negotiated understanding of values through community involvement aligned to on the ground assessment and historical and contemporary policy and management research. World Heritage criteria are explained to include intentionally designed, organically evolving or continuing use and associative landscapes such as Aboriginal sites. Heritage values can be considered through definitions including aesthetic, historic, scientific, social values. Lennon recommends methods for identifying and assessing cultural landscapes leading to developing conservation policy and implementation of conservation strategies. Identification of components in the landscape might include; structures, complexes, sites, features and linear networks.
Macdonald JI and McNeil DG (2012)	SA (LEB)	Environmental and cultural values of South Australia's outback water resources. Goyder Institute for Water Research Technical Report Series No. 12/7. Provides definitions of values from first principles and links the fundamental need for water for human survival with universally held values for sustenance yet acknowledging the complexities of such values related to cultural perspectives in specific landscapes. The context for the review is located in arid South Australia and reports upon a multidisciplinary and multicultural Forum and Workshop, May 2012. The project methodology includes defining values and attributes and undertaking social/cultural values baseline studies. The report's conclusions towards gaining understanding of the role and meaning of water in the arid landscape concede that achieving a definition of water's value that is acceptable to all appears extremely complex especially in the light of climate change towards drier conditions and diminishing water resources and therefore economic and community sustainability, in the light of increasing competition for water from industries such as large scale mining.

Reference	Region	Summary
Ndubisi, F. (2002)	International	Ecological Planning: A Historical and Comparative Synthesis, The Johns Hopkins University Press, Baltimore The book reviews environmental planning history, theory and practice and makes distinctions between ecological design, ecological planning beyond environmental design and planning as 'ecology is concerned with relationships and interrelationships within a living landscape' (p. ix). The review of Ian McHarg's human-ecological-planning method confirms the influence of integrating human processes in planning and design towards healthy environments. A key process is to synthesise cultural analysis outcomes with biophysical assessment through the use of overlay techniques and GIS mapping and interpretation. Other approaches reviewed include the applied-landscape ecology approach utilising ecotope assemblages and habitat networks and the assessment of landscape values and landscape perception in relation to the sources of contemporary landscape aesthetic and social values linked to public policy.
Office of the United Nations High Commissioner for Human Rights (no date)	International	*Right to Water*, Office of the United Nations High Commissioner for Human Rights http://www.ohchr.org/Documents/Publications/FactSheet35en.pdf Analyses the international context for the right to water and the provision of safe drinking water to specific groups, the obligations and responsibilities of states and monitoring such rights. It specifically has no reference to values beyond confirming the essential need for safe water to sustain life linked to environmental and social challenges such as climate change, pollution and depletion of water resources.
RAMSAR (1999)	International	Guidelines for establishing and strengthening local communities' and indigenous people's participation in the management of wetlands, adopted as an annex to Resolution VII.8 (1999). http://www.ramsar.org/pdf/participation-guidelines.pdf The Ramsar Convention's wise use of wetlands objectives are concerned with 'their sustainable utilization for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem.' (COP3 (1987)). Ramsar guidelines recommend 'community involvement and participation in management decision-making for sites included in the List of Wetlands of International Importance (Ramsar sites) and other wetlands. Local and Indigenous people's involvement includes from consultation to devolution of management authority and recognises the consistent factor in establishing such participatory management is based upon beliefs and values that sustain healthy wetlands from environmental, social and economic perspectives.##
Shanks, M., & Pearson, M. (2001)	Inter-national	*Theatre/Archaeology,* Routledge, London, pp. 64–65 Deep mapping as a recording practice stems from a range of writing, archaeological, art and landscape design practices that attempts to record the multiple layers of places through surveys and representations which include 'the historical and the contemporary, the political and the poetic, the discursive and the sensual; the conflation of oral testimony, anthology, memoir, biography, natural history and everything you might ever want to say about a place…' Clifford McLucas was one practitioner who proposed ten elements for deep mapping including that the produced maps should be:

Reference	Region	Summary
		1 - big enough to support different scale and detail resolutions 2 - include aspects of geomorphology and weather systems 3 and 4 – be multilayered and utilise a range of media in their recording and preparation according to practical necessity 5 – include graphics, time-based media and a database or archive that remains open to future recording 6 and 7 – include a range of people both familiar with and new to the place, art and science, amateur and professional, national and local 8 – potentially the site of new creative outputs 9 – beyond traditional cartography will require negotiation as to what is included to give rise to debate about the documentation and portrayal of people and places 10 – be open to conversation beyond a statement of facts. Abridged from: http://documents.stanford.edu/michaelshanks/51
Swaffield S (2005)	International	'Landscape as a way of knowing the world', in eds Harvey, S. & Fieldhouse, K., The Cultured Landscape Designing the environment in the 21st Century, Routledge, Oxon and New York, 2005 pp. 3–23 Aims to review the different ways in which landscape embodies knowledge through discussing the relationship between personal narrative forms in relation to observation and experience of landscape. These narrative forms include the science of landscape and process and pattern, of landscape design and management interventions, the social and political relationships that underlie landscape and of cultural readings of landscape. Themes developed in landscape as a way of knowing include landscapes of the mind, landscapes of the body, landscape of the hand made through everyday practices and landscape architecture.
Taylor, JG, Zube, EH, Sell, JL (1987)	International	'Landscape assessment and perception research methods,' *Environmental And Behavioural Research*, Van Nostrand Reinhold Company, pp. 361–393, 1987. www.ideal.forestry.ubc.ca/frst524/02_TaylorZubeSell.pdf An historical account of the development of landscape assessment methods relative to standardising landscape values against economic or technical measures. A human - landscape interaction process is the basis for gaining understanding of the mutual influences that affect the character and quality of landscapes. Four research paradigms are posited for landscape perception leading to evaluations of various qualities. The use of scenic evaluations towards preferences is critiqued through the use of value ratings for scenes, predicated on geomorphology, ecology and human use and interest. US Forest Service visual landscape manuals are based upon expert landscape architectural design principles including landscape character, visual variety and deviations from characteristic landscapes. The aesthetic preferences of the general public are tested as passive observers in the psychophysical paradigm through response to visual imagery. The issue is that the bias of the selection and quality of imagery may promote generic values in atypical environments such as central Australia.

Reference	Region	Summary
		Why landscapes are valued rather than what landscapes contribute to the cognitive paradigm in relation to perception space – the visual condition, and action space in relation to human involvement in landscape situations. Cognitive research is verbal and communicative whereas visual methods rely on observation and potential detachment. Value judgements are linked to landscape description, which promotes values in relation to preference. The experiential paradigm relates to expanding judgements beyond aesthetics to include knowledge of history, ecology, economics, cultures and developing an eye for the complex subtleties, which underpin cultural landscapes. The authors advocate a combination of paradigms commencing with exploration of landscape experience through literature review to provide direction, identification of representative landscapes and related human values. Landscape features for specific environments are prepared prior to research to final development of detailed maps of landscape values, which can only be drawn from operations in the field.
UNESCO, (2003)	International	*Operational Guidelines 2003* Annex3, World Heritage Convention http://whc.unesco.org/archive/opguide08-en.pdf Under the definition of World Heritage and the concept Outstanding Universal Value, cultural and natural heritage are defined in Articles 1 and 2 of the World Heritage Convention. Article 1 defines cultural heritage from the point of view of history, art or science as monuments: architecture, sculpture and painting, archaeological remains, inscriptions, cave dwellings and combinations of features, groups of structures in relation to their homogeneity or their place in the landscape. Sites are defined as the combined works of nature and of man, including archaeological sites, valued from aesthetic, ethnological or anthropological points of view. Article 2 defines natural heritage as natural features from aesthetic, science or conservation points of view valued as physical and biological formations or groups, geological and physiographical formations and areas which constitute the habitat of threatened species of animals and plants, and natural sites or precisely delineated areas of natural beauty. Values and authenticity are associated in the Nara Document on Authenticity where 'Conservation of cultural heritage in all its forms and historical periods is rooted in the values attributed to the heritage. Our ability to understand these values depends, in part, on the degree to which information sources about these values may be understood as credible or truthful'. (9) Authenticity is considered as 'the essential qualifying factor concerning values…and …the understanding of authenticity plays a fundamental role in all scientific studies of the cultural heritage and other cultural heritage inventories'. (10) 'Judgements about values…may differ from culture to culture, and even within the same culture. It is thus not possible to base judgements of values and authenticity within fixed criteria. (11) so that within each culture, recognition be accorded to the specific nature of its heritage values and the credibility and truthfulness of related information sources. (12)

Reference	Region	Summary
United Nations (2008)	International	United Nations Declaration on the Rights of Indigenous Peoples, United Nations http://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf Article 8 1. Indigenous peoples and individuals have the right not to be subjected to forced assimilation or destruction of their culture. 2. States shall provide effective mechanisms for prevention of, and redress for: (a) Any action which has the aim or effect of depriving them of their integrity as distinct peoples, or of their cultural values or ethnic identities;

3.4.2.2. Indigenous cultural and landscape values and methods

Reference	Region	Summary
Ah Chee, D (2002)	SA (GAB)	'Indigenous people's connections with *Kwayte* (water) in the Great Artesian Basin' http://www.gabcc.org.au/tools/getFile.aspx?tbl=tblContentItem&id=26 Ah Chee writes from the perspective of the responsibility to care for this country belongs to his people, the Indigenous Southern Arrente people and the Irrwanyere Aboriginal Corporation. He traces Aboriginal connections to water and holistic approaches to the land in contrast to western priorities for water to support economic development through pastoralism and mining. Tracing early European settlement in the now Witjira National Park and the Dalhousie Springs complex to present times, he describes the dramatic changes to the mound springs within the Great Artesian Basin (GAB) and their accompanying eco-systems, water sources and plant materials including the destruction of archaeological sites by stock and associated infrastructure alongside the inability to access sites for ceremony and traditional practices. Recognition of Indigenous skills, knowledge and traditional land management practices to care for and conserve mound springs as a valuable resource is regarded as the way forward in combining western scientific methods and Indigenous skills and knowledge is a better way to effectively manage the valuable resource of water within the GAB and the dependent ecosystems.
Altman et al. (2009)	NT (GAB)	*Chapter 7 Indigenous Interests in land and water* in Northern Australia Land and Water Science Review Full Report Oct 2009. http://nalwt.gov.au/files/Chapter_07-Indigenous_interests_in_land_and_water.pdf In the context of research in Northern Australia, many shared values across Indigenous communities appear relevant for central Australia. Altman et al. summarise seven key points regarding cultural values and water. Indigenous groups conceptualise water as part of the living cultural landscape and inseparable from land, people, ancestors and social relations. Relationships to water are expressed through story, social etiquette, ceremony and daily practices, and are highly significant in Indigenous economies, identities and ways of life. Traditional Indigenous perspectives on water are summarised in Section 3.3.1 to include practices on country and kinship relationships.

Reference	Region	Summary
		Indigenous perspectives on sustainability may incorporate the customary relationships between people and place, opportunities for economic development on country and the exercise of rights in water management and planning. Economic models that overlook Indigenous productive activity, contested rights to water including access to, and ownership of require greater clarity in order to improve Indigenous people's customary and commercial opportunities. Water is important for both customary and commercial economic activities. Water planning needs to recognise and accommodate the diversity of Indigenous economic activities and interests in water resources. The hybrid economy is heavily reliant on natural resources. This poses distinct risks for Indigenous people whose livelihoods may be adversely affected by the development or expansion of water-dependent industries that impact on flows, generate pollution or accelerate the spread of invasive species. The *Indigenous values and river flows* research project is described as seeking to: improve understanding of the social and economic significance of water, rivers and wild resources to Indigenous people in the Daly (NT) and Fitzroy (WA) catchments; provide systematic and comprehensive assessment of Indigenous values related to flow and impacts of change in flow regimes; test methods to assess, incorporate and monitor Indigenous values in water planning; ensure Indigenous participation in a trial monitoring program for flow regime change and wild resources use; and ensure collaborations enhance the capacity of researchers, Indigenous communities and managers in water allocation decisions and planning that incorporate Indigenous values. p. 46 This project may offer useful methods for similar approaches in arid regions.
Australian Heritage Commission (2002)	National	Ask First: A guide to respecting Indigenous heritage places and values Australian Heritage Commission, National Capital Printing, Canberra http://www.environment.gov.au/heritage/ahc/publications/commission/books/pubs/ask-first.pdf These published guidelines and protocols for working with Aboriginal people on their country include general definitions with a precis reproduced below: *Indigenous heritage* is dynamic and includes tangible and intangible expressions of culture that link generations of Indigenous people over time. Indigenous people express their cultural heritage through 'the person', their relationships with country, people, beliefs, knowledge, law, language, symbols, ways of living, sea, land and objects all of which arise from Indigenous spirituality. *Indigenous heritage places* are landscapes, sites and areas that are particularly important to Indigenous people as part of their customary law, developing traditions, history and current practices. All Indigenous heritage places have associated Indigenous heritage values. *Indigenous heritage values* include spirituality, law, knowledge, practices, traditional resources or other beliefs and attachments. *The precautionary approach* is taken where an activity involves a risk of significant irreversible damage to a place. Uncertainty about heritage values at the place should not be used as justification for proceeding with that activity.

Reference	Region	Summary
		Traditional Owners are those people who, through membership in a descent group or clan, have responsibility for caring for particular country and are authorised to speak for country and its heritage. *Other Indigenous people with interests* are those people who through their personal or family history of involvement with a particular place have an interest in its heritage values. Such places could include, but are not limited to, mission stations, places of Indigenous protest, and areas of land where people worked.
Australian Human Rights Commission (2008)	National	'Indigenous Peoples and Water' (Ch. 6) and 'The Protection of Indigenous knowledge's (Ch. 7) in *Native Title Report 2008* pp. 169–210 http://humanrights.gov.au/social_justice/nt_report/ntreport08/pdf/chap6.pdf http://humanrights.gov.au/social_justice/nt_report/ntreport08/chapter7.html Chapter 6 reports on a cumulative body of knowledge, knowhow, practices and representations maintained and developed by peoples with extended histories of interaction with the natural environment. These sophisticated sets of understandings, interpretations and means are part and parcel of a cultural complex that encompasses language, naming and classification systems, resource use practices, ritual, spirituality and world-view. Indigenous traditional knowledge generally means traditional practices and culture and the knowledge of plants and animals and of their methods of propagation. It includes: expressions of cultural values, beliefs, rituals and community laws and knowledge regarding land and ecosystem management. National principles for protection of water assets include the need to seek free, prior and informed consent for access Indigenous lands and waters for any purposes, including collection. Under the heading Water Rights, chapter 7 includes discussion on The Cultural Value of Water and issues of co-existence and exchange where Indigenous peoples are connected to and responsible for our lands and waters and in turn, Indigenous peoples obtain and maintain our spiritual and cultural identity, life and livelihoods from our lands, waters and resources. These cultural and customary rights and responsibilities include: a spiritual connection to lands, waters and natural resources associated with water places management of significant sites located along river banks, on and in the river beds, and sites and stories associated with the water and natural resources located in the rivers and their tributaries, and the protection of Indigenous cultural heritage and knowledge associated with water and water places access to cultural activities such as hunting and fishing, and ceremony.
Badman (2000)	SA (GAB)	Aboriginal occupation of mound springs in the Lake Eyre South area, *Proceedings of the 3rd Mound Spring Researchers Forum 2000*. pp. 3– 13 http://www.gabcc.org.au/tools/getFile.aspx?tbl=tblContentItem&id=46 This paper summarises knowledge of the occupation of mound springs by indigenous people. Including plant and animal foods and water resources of the mound springs. The fresh waterholes along the upper reaches of Stuart Creek were the focus of Aboriginal occupation of this area the importance of mound springs for water and food, during dry periods. The availability of fresh surface water following

Reference	Region	Summary
		rainfall is ephemeral, including freshwater springs and soaks, while mound springs are the only permanent water source allowing permanent occupation of the region allowed occupation of this area, with its abundant plant food resources, during all but the driest years. Some waterholes are almost permanent, going dry only about once in each decade. Stuart (1865) considered them to be permanent and described the larger ones as '...long reaches of permanent water, divided here and there by only a few yards of rocks, and bordered by reeds and rushes'. He also reported seeing numerous Aborigines and their tracks along the watercourses, and to a lesser extent in the nearby sandhills. The importance of the springs is demonstrated by the numerous artefacts and stone flakes that remain in their vicinity. A keen botanical knowledge would have been essential for the survival of Aboriginal people in the Australian arid zone. Food and emergency water supplies are available from at least 13 species of plants found within the area allowed movement between more permanent water sources in dry times. Phragmites may have provided the staple food during times of prolonged drought. Mound springs allowed Aboriginal people to remain in the area during even the worst droughts, rather than having to temporarily move away as was the case in some other areas. The mound springs are close enough to each other to allow easy travel between them at all times. They may also have been important as watering points along trade routes, when food would have been collected between the springs.
Bandler, H (2007).	National	Expertise in water resources exploitation in Australian prehistory, *Australian Journal of Water Resources*, Vol 11 No. 1 http://search.informit.com.au/documentSummary;dn=659625222724703;res=IELENG Due to the fairly low precipitation rate particularly in the dry desert areas, it was necessary to search for, find and protect all natural sources of water. The water resources of naturally occurring rock pools were extensively used and carefully guarded. Important sources of water, particularly in the arid inland, were the so-called native wells. Native wells are diggings in soil or sand to hold often only limited water and are often hidden under vegetation and can be easily overlooked. Bandler traces and maps the structure and material culture of nine native wells in the Simpson Desert through following accounts from various explorations over time, Bonython (1973), Lindsay (1870s), Giles (1889), Leichhardt (1844–5). The Simpson Desert wells, with depths ranging from 3 to nearly 7 metres had all been at one time centres of habitation for groups of the Wangkangurru Aborigines, but now abandoned, indicating that these people at another time had the remarkable ability to locate and treasure water available below ground level in difficult surroundings.
Birckhead et al. (2011)	SA & Vic	Economic and Cultural Values of Water to the Ngarrindjeri People of the Lower Lakes, Coorong and Murray Mouth. *River Consulting*, Townsville http://www.riverconsulting.com.au/reports/Ngarrindjeri_Aug2011.pdf This project develops a 'negotiated methodology' approach to redress the lack of emphasis on Indigenous values of (and corresponding rights to) water and natural resource management. Engagement of the Ngarrindjeri of South Australia to articulate the essential role of water as the foundation for Indigenous wellbeing in

Reference	Region	Summary
		the community's present and future economic and social development. Methods include: a workshop-based focus group approach to combine social and cultural issues with the more formal economics methodology based on the 'wellbeing' approach, engage local people as partners in research, collaboration and owners of the knowledge developed. Recommendations in establishing and delivering research programs include: benchmark research agreements, protection of the interests of Indigenous people, research design to minimise stress on Indigenous leadership, collaborative projects should always begin with discussions involving potential Indigenous nation partners, possible long-term, community-based researchers should be incorporated into project teams, funding directed towards Indigenous capacity building, allocations of cultural water to Indigenous Nations in the Murray-Darling Basin be supported and understood as critical in the rehabilitation of the lands and waters and how Indigenous allocations are used, actively Indigenous engagement in the long-term sustainable management of their lands and waters The overarching principles identified in the recently ratified UN Declaration on Indigenous peoples provide the basis for collaborative projects that aim for best practice in Indigenous research, NRM and water policy development, linking such research to projects occurring in other Pacific Rim countries.
Bird Rose, D (1996)	National	Nourishing Terrains, Australian Aboriginal Views of Landscape and Wilderness, Australian Heritage Commission Canberra ACT Australia www.environment.gov.au/heritage/ahc/.../nourishing-terrains.pdf 'Water throughout the year' is both a description and a name of a place'. The essay discusses the lexicon of Aboriginal concepts and words that describe the qualities of landscapes physically and spiritually. Water places and names are linked to living practices across Australia described through themes including dreaming ecologies, sacred sites, knowledge and maintenance of water resources in dry landscapes including the wells of the Simpson Desert (p. 51) Bird Rose notes the Arrernte peoples countries linked to major rivers systems, where people tracked the ephemeral rivers during times of flood and drought guided by the Dreamings that travel the same routes. Dreaming centres for meetings include rockholes, soaks, wells, rovers, claypans, springs and the rare waterholes, which may have a totemic focus. These sites link the tracks that follow surface and artesian water which coincide with areas rich in plant and animal life (p. 52).
Clarke P (2003)	National	Where the Ancestors Walked, Australia as an Aboriginal Landscape, Allen & Unwin, Crows Nest. Traces the origins of Aboriginal Australia including customary practices, material culture and the way in which regional difference resulted in different patterns and pathways across the landscape. The book concludes with the changes that occurred upon the arrival of Europeans and how the cultural landscape has changed and is continuing to. A chapter on the Central Deserts discusses the landscape as one of deep religious meaning and creation stories connected by a network of alliances

Reference	Region	Summary
		brought about my mobility of groups moving according to water needs and climatic conditions and transformations during the wet and the dry. Clarke distinguishes the eight types of landscape features that produce drinking water; soak, rockhole, spring, creek or river, billabong, swamp, claypan and salt lake and discusses seasonal variation and the impact on traditional uses, and the strategies and practices employed to contain and/or harvest water. Seasonal variations are recognised from three to five conditions depending upon location. One reading from the Uluru region notes the hot time, green time, cold time and dry time in sequence with the four European seasons summer, autumn, winter and spring. Aboriginal movement patterns followed the seasons and the climate to minimise impact on the landscape through population dispersal.
Dept of Aboriginal & Torres Strait Islander and Multicultural Affairs Qld Govt	Qld (GAB)	Indigenous Cultural Heritage website, Queensland Government Cultural Heritage Unit, Brisbane. http://www.datsima.qld.gov.au/atsis/aboriginal-torres-strait-islander-peoples/indigenous-cultural-heritage The Queensland Government Cultural Heritage Unit website defines what Indigenous Cultural Heritage is and contains information on Indigenous Cultural Heritage including databases, legislation and guidelines, locating significant places, fact sheets reports and publications and Aboriginal cultural heritage duty of care. The Indigenous Cultural Heritage map for Queensland identifies specific artefacts in the study area including hearths, stone artefact scatters, dwellings and potentially wells. The Aboriginal heritage map brochure identifies the types of artefacts and sites that people need to be aware of when travelling in remote inland Queensland. The range of grants programs, legislation and guidelines are also located here.
Donovan V & Wall C (eds),	National (LEB)	Making Connections: A journey along Central Australian Aboriginal trading routes, Arts Queensland, Brisbane Qld. Written for tourists, this book reveals the Aboriginal customs, trade routes and tracks across central Australia prior to European settlement, which formed trade, social and ceremonial networks and form the storylines, economic and social structure of Aboriginal society. Understanding the concept of country and the naming of places is critical to understanding where water places have been over time. Beginnings or endings of Aboriginal words (appa, nappa, anna, ninna, etc) refer to places where water can be found. Chapters dealing specifically with the Aboriginal histories in the LEB research area include; *Landscape of Exchange* (McBryde, I), *The Channel Country*, *The Red Centre* (Rose, D), *In the Simpson Desert* (Hercus, L), *Lake Eyre, Kwayte (water) in the Great Artesian Basin* (Ah Chee, D). A brief section on guidelines and protocols on ways to approach seeking experience of Aboriginal culture include: identifying the custodians of knowledge, ask for assistance, seek approval before visiting traditional sites, research information and collections from regional galleries and historical societies, be sensitive to issues that can't be told, photographing sites and people and leaving all cultural material where it is found.
Duff, N 2011	National	'Introduction to Cultural Flows in Australia Primer on Cultural Flows part 1 of 3', *Knowledge Note,* Synexe for the First Peoples Water Engagement Council and the National Water Commission in Australia

Reference	Region	Summary
		http://www.synexe.com/assets/Uploads/201101+Cultural+Flows+pt1.pdf To engage with government systems of water planning and management the broad and flexible concept of cultural flows has recently been developed as a perspective on 'water entitlements…legally and beneficially owned…of sufficient quality to improve the spiritual, cultural, environmental, social and economic conditions of Indigenous Nations'. Benefits of cultural flows can include: periodic flooding, recognise primacy and agency of the river, respecting connectivity between water, country, life, culture and history – not a separate space for nature, allowing natural growth and breeding grounds, caring for places, making resources available for cultural business, fishing is linked to water level, speed, variability, riparian vegetation, bank condition and access – and is an important cultural and healthy practice, places for teaching, storytelling, camping, recreation and ceremony. Cultural flows need Indigenous input into conception, determination and delivery and respect custodianship over country. Whether economically productive uses of water should be included in the definition of cultural flows is still open to discussion.
Eds, Mulvaney, J, Morphy, H & Petch, A (1997)	SA (GAB)	*My Dear Spencer: The letters of F.J. Gillen to Baldwin Spencer*, Hyland House, South Melbourne http://trove.nla.gov.au/work/23087357 The collection of letters sheds light on race relations, social conditions and Aboriginal culture in central Australia, and documents a crucial and poorly understood period in the history of anthropology. The book makes an invaluable contribution to the understanding of central Australian Aboriginal society, and to current debates concerning land rights.
Glover and Sim (1978a)	Central Australia	A survey of central Australian ichthyology Historical account of ichthyological surveys from the 1840s to 1970s. Mentions early explorer records on the importance of fish in traditional diets. This approach tends to deal with water and aquatic ecosystems as a resource or asset, but ignores the spriritual and identity issues connected with these areas.
Harris, C. (2001)	SA (GAB)	'Culture and geography: South Australia's mound springs as trade and communication routes', *Historic Environment* 16.2, pp. 8–11. http://www.aicomos.com/wp-content/uploads/Culture-and-geography-South-Australia%E2%80%99s-mound-springs-as-trade-and-communication-routes1.pdf The scope and scale of mound springs in Australia as the natural outlets of the GAB noting flow decline since European settlement. Focusses on the Dalhousie Springs and their flow. Discusses the need for Aboriginal people to move around from spring to spring due to water quality, with reference to the quantity of artefacts found around them indicating their centrality to traditional Aboriginal life and sustenance. Trade routes and communication systems aligned with the springs over hundreds of kilometres. Noting the Palthiri Pithi grinding stone quarry on northern Kati Thanda-Lake Eyre as one of the major exchange centres throughout the LEB. In Kuyani, Arabana and Wangkangurru traditions the springs are closely identified with simple watering to important ceremonial and major dreaming cycles. All indigenous sites are protected under the provisions of the *South Australian Heritage Act 1998*.

Reference	Region	Summary
		Harris recommends a national approach from the Northern Territory, South Australia and the Commonwealth working with the indigenous people of the region to celebrate the trade and communication routes, which were based, on the mounds springs as features of the landscape.
Hercus, L Hodges, F & Simpson, J (2002)	National	The Land is a Map Placenames of Indigenous Origin in Australia, Pandanus Books, ANU ePress, Canberra http://epress.anu.edu.au/titles/the-land-is-a-map/pdf-download Networks of Indigenous place names evoke important information about features of the environment and their place in Indigenous systems of knowledge. In areas where Indigenous societies remain relatively intact, thousands of Indigenous place names are used, but have no official recognition. While many Indigenous place names have been taken into the official place name system, they are often given to different features from those to which they originally applied. In the process, they have been cut off from any understanding of their original meanings. Chapters pertinent to the LEB include: Indigenous Placenames: An Introduction (Hercus, L & Simpson, J) on the superimposition of Indigenous and non-Indigenous networks of place names, The Concept of Place Among the Arrernte (Wilkins, D) where the idea of place (Pmere) is more complex than in English language and is usually discussed as camp, country or totem for place, that all topographical places are important sites created by ancestors and are connected to other places through Dreaming tracks, Naming the Dead heart: *Hillier's Map* and *Reuther's Gazetteer of 2,468 Places names of North Eastern South Australia* (Jones, P) regarding the 1904 map drawn by the schoolteacher Hillier around the east and north of Kati Thanda-Lake Eyre and the density of names and therefore meanings of places in relation to the ongoing sparseness of European and contemporary mapping, *Guidelines for the Recording and Use of Aboriginal and Torres Strait Islander Place Names* regarding the recognition of names as part of Australian heritage to be preserved and methods for achieving this, *Index of Places and Placenames* and *Index of Languages and Language Groups*.
Hercus, L.A. (1980)	GAB	*'How we danced at Mudlunga:* memories of 1901 and 1902', *Aboriginal History,* Central Printery, Canberra http://epress.anu.edu.au/wpcontent/uploads/2011/05/whole24.pdf An account and map of the Mudlunga ceremonies and story lines of travel from north-western LEB Peake station across Kati Thanda-Lake Eyre north the Diamantina and across to Clifton Hills Station to Killalpannina to Clifton Hills. Presented in language with translation by Hercus, the stories are told of the places where main performances took place and then where the story travelled consequently from Clifton Hills.
Hercus, LA (1990)	SA (GAB)	'Aboriginal people' In Tyler, M.J., Twidale, C.R., Davies, M. and Wells, C.B. (eds) *Natural History of the North-East Deserts*. Royal Society of South Australia, Adelaide. Hercus discusses in detail the traditional lives and post-European occupation of the Aboriginal groups of the Kati Thanda-Lake Eyre region including tribal boundaries

Reference	Region	Summary
		and territorial ownership; the relationships between seasonal movement and occupation of places and water supply including strategies for water gathering and extraction such as native well. Networks and tracks across country are described through myth and Dreaming narratives including the local Mosquito Dreaming. The history and subsequent dispossession of Wangkangurru and Yawarawarrka peoples of northern South Australia is traced in relation to sites and places.
Kimber, RG (1992)	NT (GAB)	*Finke River Survey: Historical Analysis and Site Documentation*, Unpublished report to National Trust of Australia (Northern Territory), National Estate Grants Program (Australia), Canberra Kimber's extensive survey of the Finke River area covers Aboriginal and non-Aboriginal histories, customs, societies and cultures across the region including contemporary issues regarding ongoing use and occupation of sites on the Finke system. Written in nine parts, the pertinent themes are: 1. Aboriginal use of the Finke River valley 2. Exploration 3. The O.T. Line 4. Pastoral properties, 1870s–1890s 5. Stock routes 6. Missionaries of the Finke River country 7. Police 8. Early scientific studies and expeditions 9. Tourism.
Kimber, RG (2011)	NT	*Cultural Values associated with Alice Springs Water,* commissioned by the Alice Springs Water Management Branch of the Northern Territory Department of Natural Resources, Environment, the Arts and Sport lrm.nt.gov.au/__.../Cultural-Values-of-Alice-Water-Kimber-2011.pdf This historical account discusses the Alice Springs Water District and its many contemporary cultures that live within an ancient Arrernte template, including analysis of Indigenous (Arrente) and European water values. As a very detailed account of the history, culture and ecology of an area subject to development and ongoing needs for negotiation around the use and management of water, the paper contains pertinent knowledge on the time scale and changing conditions of the environments and people intrinsically linked to water. Seasonal change and use of country and landscape, associations with place, linking water sites, place names ancestral and contemporary occupation, water over time and the impacts of explorers, settlers and developers on country and water quality and availability are told through both Arrernte and Kimber's detailed knowledge of the water assets, river and creek systems and their links.
Macfarlane, I (2005)	SA (GAB)	A water history of the western Simpson Desert, Australia, Published in 23 Degrees South: Archaeology and Environmental History of Southern Deserts, edited by M.A. Smith and P. Hesse, National Museum of Australia, Canberra, 2005 http://acih.anu.edu.au/sites/default/files/documents/23_deg_chap_22.pdf This review covers the area north of Oodnadatta to south-east of Alice Springs, through documenting the range of traditional and new water places in the arid

Reference	Region	Summary
		landscape. Cultural water concepts move beyond its use as a resource to embrace water places as sites for memory and renewal, stories, connections and identity. Mcfarlane sets down a number of themes: *water as a social actor* over time tracing how water places affect people and in turn are affected by them, *water is meaningful* regarding distinguishing water character from place to place, *using water for practical uses* through documenting and knowing the variety of Indigenous and non-Indigenous people's practices, the *temporality of desert water* and its *forms* including typologies of the Lower Finke and Simpson Desert areas. Aboriginal water systems are designated as *mikiri* meaning reliable soakages and networks of wells, paths and places which allow for semi-permanent for residency. Individual habitation sites and ritual centres are associated with artefacts and signs of occupation and water places from Pandi Pandi to the Finke River and Dalhousie Springs are noted.
Maclean K et al. (2012)	MDB	Ngemba Water Values and Interests Ngemba Old Mission Billabong and Brewarrina Aboriginal Fish Traps (Baiame's Ngunnhu) https://publications.csiro.au/rpr/download?pid=csiro:EP127320&dsid=DS2 This research provides insight into the water values, knowledge and management interests of one Murray-Darling Basin Aboriginal community, the Ngemba, although its principles can be considered in arid and more remote regions. Australia's premier water policy, the National Water Initiative (NWI) (Australian Government 2004), explicitly recognises Indigenous interests in water, although the rights acknowledged are limited (McFarlane 2004). The NWI requires jurisdictions to include Indigenous customary, social and spiritual objectives in water plans. Native title interests in water are to be taken into account and Indigenous water use assessed and addressed in plans which involve Indigenous communities in their development. The Indigenous access and representation provisions of the NWI are 'arguably the most underdeveloped of any area covered by the NWI' (Tan 2009), having received relatively little attention from policy makers, water managers and researchers. Challenges relate to: the neglect by the western water governance paradigm to recognise the spirit of the river and to consider the water needs of the river aside from human requirements; leadership capacity building within the community to engage better with water planners; and capacity to co-ordinate leadership for project and program co-ordination within the community. Aboriginal people articulated the desire for water allocations to both ensure the spiritual and environmental health of the river systems and artefacts of Aboriginal occupation to enable the development of local sustainable livelihood opportunities.
McBryde, IF (1997)	Kati Thanda-Lake Eyre & Methods	The Cultural landscapes of Aboriginal long distance exchange systems: can they be confined within our heritage registers? *Historic Environment*, Vol. 13. Nos 3–4, 1997: pp. 6–14 http://search.informit.com.au.ezp.lib.unimelb.edu.au/fullText;dn=980606323;res=APAFT Macbryde maps the traditional tracks across central Australia and specifically in the

Reference	Region	Summary
		Oodnadatta Track and Simpson Desert area as exchange centres for the movement of hatchets, ochre and other goods. Aboriginal cultural knowledge of trading routes, social and ritual practices and economic systems are analysed alongside issues for contemporary heritage management. She discusses the concept of two cultural landscapes – the Aboriginal landscape as a world mapped by stories and the archaeological landscape of sites relating to material goods that are economic/technological and symbolic, that are linked by mental maps beyond any physical markers. The exchange system is comprised of the places (most usually associated with water) and the lines of travel between them. Management of what McBryde calls the Kati Thanda-Lake Eyre/Cooper exchange system involves cross-cultural programs and multidisciplinary field work, consultation and archiving in partnership with local Aboriginal people.
Mulvaney, J (2002)	SA (GAB)	.....these Aboriginal lines of travel, *Historic Environment V*ol. 16. No. 2, 2002: pp. 4–7. http://www.aicomos.com/wp-content/uploads/these-Aboriginal-lines-of-travel.pdf This paper focusses upon Aboriginal ceremonial exchange routes during recent centuries and also on the Overland Telegraph Line during the period from 1860 to 1890. It emphasises the social and economic role of Dreaming Tracks and their environmental relevance, and the environmental and cultural consequences of the Line's construction. Certain places are selected to illustrate the differing perceptions and roles of those places when viewed by indigenous people and European colonists. These places include Alitera on the Finke River.
Piddocke (2009)	Cooper	Historical Collation of Waterbody Information in the LEB Catchments for Qld and SA Collates information from explorers' journals on waterbodies over 150 years, including their interactions with Aboriginal people. Presents observation on Aboriginal culture at the time of first contact with Europeans for future analysis.
Rea, N and Anmatyerr Water Project Team (2008)	NT	Provision for Cultural Values in Water Management: The Anmatyerr Story, Land & Water Australia Final Report 18, Canberra. http://www.aiatsis.gov.au/research/publications/Land&Water/pn30117.pdf A senior Anmatyerr elder of the Ti Tree region 200 km north of Alice Springs is the custodian of the law and ceremonies of the Kwaty (Rain) Dreaming that passes through Anmatyerr country. He is known as the rain maker. Anmatyerr voice: *'Our cultural values of water are part of our law, our skinship responsibilities, our history and our everyday lives. Everyone and everything is related.'* Five categories of cultural values are outlined: law, responsibilities and protocols, economies, environment and education, recreation and well-being and history of people and place.
Silcock (2009a)	Cooper Creek & G-D	Identification of Permanent Refuge Waterbodies in the Cooper Creek & Georgina-Diamantina River Catchments for Qld & SA Sections reviewing permanent water in cultural context (e.g. Section 4.5)
Tyler et al.	SA (LEB)	Natural History of the North East Deserts

Reference	Region	Summary
(1990)		Comprehensive literature review for entire north-east corner of SA with some overlap with Arckaringa and Pedirka Basins. Chapter 12 covers Aboriginal people, language, history and the impacts of European contact. A brief mention of traditional fisheries in Chapter 16.
Yu, S (1999)		Ngapa Kunangkul: (Living Water): Report on the Aboriginal Cultural Values of groundwater in the LA Grange Sub-basin, The Centre for Anthropological Research, UWA for the Water and Rovers Commission of Western Australia http://www.water.wa.gov.au/PublicationStore/first/11504.PDF The study aims to assess whether the use of groundwater will have a negative impact on the culturally-constituted values attaching to traditional water sources. A number of issues were investigated with the traditional owners (TOs). Aboriginal heritage aspects for the area includes Karajarri concepts of country including Dreamtime, country, totems, seasonal cycles, water sources and their significance described, named and mapped on country with TOs, the concept of living waters and seasonal cycles and movements and cultural relationships with water sources. This research reveals the detailed study over time required to accurately map and describe local water sources and cultural concepts. 'Water is the basis for our songs and our culture. We have been looking after our waterholes and rivers for thousands of years. We have respect because we know that if you don't treat it right many things can happen. This is the lesson that we need to make other people learn. People see water just as a thing that can be drunk or used. They don't see it as a part of everything. They think they can control it. They think that they can own it. We know better. Many things fail because people don't understand this. (Langton, 1999: 14)'
Zeidler and Ponder (1989)	SA (Dalhousie Springs)	Natural History of Dalhousie Springs Multidisciplinary survey of the Dalhousie Springs Complex. Chapter 2 details one of the stories associated with Dalhousie Springs and highlights this area as 'an extraordinarily dense concentration of sites of considerable mythological significance'.

3.4.2.3. Non-indigenous values

Reference	Region	Summary
Ah Chee (2002)	SA (GAB)	Indigenous people's connections with Kwayte (water) in the Great Artesian Basin In relation to the mound springs of the GAB Ah Chee notes the western priority for water as an essential and valuable economic base for pastoral and other industries, yet these interests interrupted and often destroyed the Indigenous holistic and integrated perspective of this resource. Tracing combined histories of non-Indigenous and Indigenous people working and living in the GAB uncovers narratives concerning historical pastoral use, changing lifestyles and ecosystems and the combined need to

Reference	Region	Summary
		travel between reliable water sources. Over time both Aboriginial people and pastoralists have recorded the effects of free-flowing bores on springs, impacts of drought and pastoral stock levels on waters, slower flows and lower water levels, and the localised impacts on waters and their surrounding ecosystems and landscapes due to increased tourist use for recreation and swimming. http://www.gabcc.org.au/tools/getFile.aspx?tbl=tblContentItem&id=26
Angas (2004)	SA GAB	Outback Heritage – Heritage and Tourism along the Birdsville and Strzelecki Tracks www.history.sa.gov.au/history/conference/Hamish_Angas.pdf Report on the South Australian Heritage Branch's Regional Heritage Survey Program (1983 to 2003) that undertook a systematic program of heritage surveys in South Australia to identify and record all the non-Aboriginal heritage of the State. Surveys of remote area (Region 13) local heritage places and local heritage areas have resulted in a non-conventional approach to recording along transport corridors such as the Oodnadatta Track (2001), the Birdsville & Strzelecki Tracks (2001), the former Ghan Railway Line from Marree to the SA–NT border. Ranging approximately 50 km either side of each track the heritage of each area is recorded under themes such as Aboriginal contact, exploration, pastoralism, transport and communications, social life and organisations (hotels, settlements, outback general stores) and the geology and natural history of the region. In addition to assessing and documenting the heritage resources of the Birdsville and Strzelecki Tracks, the documentation for this heritage survey included recommendations for developing heritage tourism and interpretation products.
Arthur (2003)	National	The Default Country: A Lexical Cartography of Twentieth-Century Australia. University of New South Wales Press Ltd, Sydney A lexical account of the development of Australia in the 20th century including an account of water and water values specifically in the arid outback. Non-Indigenous concepts of water commence with colonists visions, including the descriptions of inland rivers as water lost or flowing to the dead end of Kati Thanda-Lake Eyre. Arthur makes the point that river and lake descriptions don't apply to inland waters that operate in boom and bust flood and drought conditions. She traces the lexicology of terms such as salina, chain of ponds, billabong, waterhole, soak, damplands, dam, tank, etc. Water distribution is seen as out of control, wasteful and a problem to be solved.
Austral Archae-ology Historical Research (2001)	SA (GAB)	Oodnadatta Track heritage survey: part of the Far North & Far West Region (Region 13), Dept. for Environment and Heritage, Adelaide. A general history of the landscapes along the Oodnadatta Track including explorers and graziers, the early pastoral history, droughts, making the Overland Telegraph Line, the coming of the railways including a useful map showing stations and principal waterways (1940, 1075 rev), mining and the advent of the 20th century. The survey also documents the Finniss Springs Mission. A detailed survey including location maps and Heritage Assessment Reports of the non-Aboriginal heritage of the Oodnadatta Track identifying a range of sites through their primarily architectural and social heritage values including description, statement of heritage value, history and references including photographic imagery. Places on the State Register associated

Reference	Region	Summary
		with water assets include Algebuckina Bridge, Coward Springs Railway siding and Plantation, Curdimurka Railway Siding (and Stuart Creek Bridge), Peake Historic Site and Strangways Springs Overland Telegraph Station. Other heritage places not listed are documented, some in association with water assets.
Bayley, IAE (1999)	National (GAB)	Review of how Indigenous people managed for water in desert regions of Australia *Journal of the Royal Society of Western Australia,* 82:17-25 Bayley traces the Indigenous and non-Indigenous use of water through documenting the accounts from explorer, naturalist and anthropologist journals such as Giles (1889), Tindale (1974), Grey and Eyre. Specific sources of water are described as both ecological and cultural concepts and formations including: rock-holes (gnammas) - water lying in hollows on hard, impermeable rock, soaks (native wells) – water that seeps into hollows dug in freely permeable sediments, impoundments (dams constructed from clay with wooden shovels), claypans – water lying in a depression in soft sediments with low permeability, riverine waterholes – water in holes scoured out of river beds by water movement, mound springs – systems fed by carbonated water under hydrostatic pressure, tree-trunk hollows – water accumulated in pockets of decay in trees above ground level, tree roots – water that flows from cut tree roots after excavation, dew – water collected from vegetation in the form of dew droplets and frog – water contained within the body of frogs. The concept of existence based upon drought evasion is posited.
Burmill, S Daniel, T Hetherington, J (1999)	International	Human values and perceptions of water in arid landscapes http://www.colorado.edu/geography/class_homepages/geog_4501_s12/readings/Burmil.et.al1999.pdf A wide-ranging discussion on the cultural, spiritual and religious values related to water in arid landscapes. Changes in water regimes and associated changes in landforms, vegetation and wildlife can have significant effects on many different types of human perception and values. The link between water management and technical and legal standards do not usually adress the relevant human values beyond basic consumption. Bio-physical perspectives discuss water as a primary landscape element and its secondary landscape effects and water in arid ecosystems. Philosophical and spiritual perspectives include water images and symbols and images of water in arid areas. Water and environmental meanings in arid landscapes and water and the sense of place, landscape aesthetics, landscape perception of water in arid landscapes, water based recreation and finally legal and technical perspectives including water and arid landscape management policy through control of the resource and/or preservation and protection.
Donovan, V & Wall, C (eds),		Making Connections: A journey along Central Australian Aboriginal trading routes, Arts Queensland, Brisbane Qld. Written for tourists, this book reveals the Aboriginal customs, trade routes and tracks across central Australia prior to European settlement. It concludes with histories of early explorer routes and narratives, which enable the settler experience to be reviewed alongside traditional Aboriginal cultures. Chapters dealing specifically with European histories in the LEB research area include The Explorers (Bell, P) and Three Tracks Across the Desert (Bell, P)

Reference	Region	Summary
Gibbs, L M (2009a)	LEB	Just add water: colonisation, water governance, and the Australian inland*, Environment and Planning A*, 41 (12). pp. 2964–2983 (doi:10.1068/a41214) Water has played a key role in the development of the Australian inland and the nation. For European colonists, the dry and variable landscape challenged ideas about nature imported from northern temperate regions. Colonists brought with them ideas for ordering nature and tools for transforming landscapes that led to inappropriate and destructive water management and the silencing of local voices and knowledge systems. Secondly, colonial patterns of ordering and transforming landscapes are ongoing, in particular the methods of irrigation, river diversion, and bore drilling. These two ways of governing water as existing in tension; a tension between engineering-based and knowledge-based approaches to water governance.
Gibbs, L (2009b)	SA (GAB)	Water Places: Cultural, Social and More – Than – Human Geographies of Nature, *Scottish Geographical Journal* Vol. 125, Nos 3–4, 361–369 Exploring the watering places of the Birdsville Track, this account investigates artesian bores, boredrains and boredrain wetlands and the layers of interaction that have formed these water places, including their insertion into the landscape through drilling. Their various roles include: opening the country for stock, as a means for developing the inland and the nation, as tools for displacing Aboriginal peoples from their country, as a focus for life in the desert and as key to mining and petroleum exploration.
Gill, NJ (1997)	SA (GAB)	The contested domain of Pastoralism: Landscape, Work and Outsiders in Central Australia in Rose, DB and Clarke, A (eds), *Tracking Knowledge - North Australian Landscapes: Studies in Indigenous and Settler Knowledge Systems,* North Australian Research Unit, Darwin, 1997, pp. 50–67 This paper charts the past and current issues of identity, occupation and the social nature and values of pastoralism in relation to external influences such as conservationism. Pastoralists construct identities for themselves and others, such as conservationists, according to how one is embedded in nature through work and in time. Knowledge gained through work on the station is one means by which pastoralists construct a sense of place, a sense of self and a sense of others. Today, however, the pastoral landscape is increasingly fractured and contested by indigenous and environmentalist claims on land. Pastoralists in central Australia are responding to environmentalist claims by reasserting territory constructed with reference to particular forms of social nature and social space. Identities of insider and outsider have developed that commonly correspond to pastoralists and others, such as conservationists and government, but the place-specific nature of pastoralists' environmental knowledge has the potential to render pastoralists as outsiders as well.
Harris, C, Lewis, S and Angas, H	SA (LEB)	South Australia's Mound Springs: Maintenance and Improvement of their environment and heritage values, paper presented at GABfest, Toowoomba

Reference	Region	Summary
(2002)		www.gabcc.org.au/public/content/ViewItem.aspx?id=24 Since European settlement reduced aquifer pressure in the wake of bore-sinking has resulted in the widespread decline of mound springs within Australia's Great Artesian Basin. The importance of the natural and cultural heritage associated with the springs has been well documented in South Australia and some important conservation and management measures have been put in place over the past two decades. This paper reports on the biodiversity conservation programs to protect the natural heritage values of selected springs, heritage conservation work at key cultural sites and a current heritage survey of the transportation corridor along the route of the old Overland Telegraph and Ghan Railway from Maree to Oodnadatta. It maps and describes the landscape context and interconnectivity of the springs and posits a number of historical themes including exploration, pastoralism, communications, transport and notes sites or heritage legacy and their conservation. A biodiversity protection program for the mound springs of the Witjira National Park and along the Oodnadatta Track includes future management challenges from tourism and pastoralism to achieve a diversity of outcomes.
Harris, C (2001)	SA (GAB)	'Culture and geography: South Australia's mound springs as trade and communication routes', *Historic Environment* 16.2, pp. 8–11. http://www.aicomos.com/wp-content/uploads/Culture-and-geography-South-Australia%E2%80%99s-mound-springs-as-trade-and-communication-routes1.pdf The scope and scale of mound springs in Australia as the natural outlets of the GAB noting flow decline since European settlement. Focusses on the Dalhousie Springs and their flow. Non-indigenous occupation of the springs upon the arrival of European interests was strategically important to exploration and opening up the country to pastoralism. Subsequently the springs were given a range of English names. The springs were a line of permanent waters through dry country. The route of the Overland Telegraph and the Ghan railway largely followed the mound springs. Conservation and management funding followed a number of heritage and biological surveys, including fencing, interpretive signage and stabilisation of buildings and infrastructure on ruins such as Old Peake and Strangways. The importance of the natural and cultural heritage associated with the springs has been well-documented in South Australia and some important conservation and management measures have been put in place over the past two decades.
Jaensch, R (2009)	Qld & SA (GAB)	*Floodplain Wetlands and Waterbirds of the Channel Country*. South Australian Arid Lands Natural Resources Management Board, Adelaide http://www.saalnrm.sa.gov.au/Portals/8/Publications_Resources/Project_Reports/SAAL_Report_Water_Floodplain_Wetlands_And_Waterbirds_Of_The_Channel_Country-022009.pdf Investigating the human use of Channel Country wetlands, Jaensch presents how the natural resources of the Channel Country wetlands support human communities, despite the region's harsh climate. Following aboriginal people's pattern of survival around the deeper waterholes in drought and in floodplain wetlands after floods. The failure of explorers to exist in similar conditions is documented through the accounts

Reference	Region	Summary
		of Burke and Wills who tried, unsuccessfully, to live on *Nardoo* when their supplies ran out. Europeans have operated productive pastoral enterprises on the floodplains since the 1860s, fattening cattle on natural pasture after floods and using the numerous waterholes, bore water and upland grassland during the dry times. The impacts of land use on floodplain wetlands are discussed while also acknowledging the importance of local heritage values for local human communities in the support of grazing, tourism and oil and gas mining.
Kimber, RG (1992)	NT GAB	*Finke River Survey: Historical Analysis and Site Documentation*, Unpublished report to National Trust of Australia (Northern Territory), National Estate Grants Program (Australia), Canberra Kimber's extensive survey of the Finke River area covers Aboriginal and Non-Aboriginal histories, customs, societies and cultures across the region including contemporary issues regarding ongoing use and occupation of sites on the Finke system. Written in 9 parts, the pertinent themes are: pt. 1. Aboriginal use of the Finke River valley, pt. 2. Exploration, pt. 3. The O.T. Line, pt. 4. Pastoral properties, 1870s-1890s, pt. 5. Stock routes, pt. 6. Missionaries of the Finke River country, pt. 7. Police, pt. 8. Early scientific studies and expeditions, pt. 9. Tourism.
Kimber, RG (2011)	NT	*Cultural Values associated with Alice Springs Water,* commissioned by the Alice Springs Water Management Branch of the Northern Territory Department of Natural Resources, Environment, the Arts and Sport lrm.nt.gov.au/__.../Cultural-Values-of-Alice-Water-Kimber-2011.pdf This historical account discusses the Alice Springs Water District and its many contemporary cultures that live within an ancient Arrernte template, including analysis of Indigenous and European water values. As a very detailed account of the history, culture and ecology of an area subject to development and ongoing needs for negotiation around the use and management of water, the paper contains pertinent knowledge on the time scale and changing conditions of the environments and people intrinsically linked to water. European history of the Alice Springs Water District encompasses the earliest excursions of John McDouall Stuart (1860), the Overland telegraph survey and construction (1870-712), the beginnings of the Pastoral industry in the area (1872-1893) and their increasing need for water during the 20th century leading to extraction from numerous bores and including damming natural systems, mining for gold (1886-1889) and the impact of exploration and rapid change on the Arrernte People (1886-1911). Water pressures from 1911-2011 linked to development and the development of infrastructure including water piped from other places to sustain the city.
Lee (2011)	Western Rivers (Neales)	Cultural landscape assessment and analysis of the Neales Catchment and Algebuckina Waterhole AE site values
Litchfield, L. (1983)	Qld & SA (GAB)	Maree and the tracks beyond in black and white: A History of the Birdsville Track Lois Litchfield, Marree, Self-published. Lois Litchfield's personal history and collected stories and articles by various people from northern South Australia grew from the collection of photographs that she had

Reference	Region	Summary
		collected or were handed down was published to celebrate the town's Centenary in 1983. The book covers stories about the early explorers, the aboriginal people, the geology of the region, the local townships and their development, with lists of local birds, animals, flora and vegetation. Themes developed include the Birdsville Track, the centenary of Marree, the Kujani People and accounts of outback explorers and travellers such as Hans Mincham, Edward J Eyre and A C Gregory, the Overland Telegraph Line, Geology of the Marree District, Missionary Endeavours and Lutheran Mission, the pastoral leases Umberatna Station, Mundowdna Station, Wilpoorinna Station, Hergott Springs and Nappa Merrie.
Macdonald and McNeil (2012)	SA (Arid zone)	Environmental and cultural values of South Australia's outback water resources. Goyder Institute for Water Research Technical Report Series No. 12/7. http://www.pir.sa.gov.au/__data/assets/pdf_file/0007/178117/Environmental_and_cultural_values_of_South_Australias_outback_water_resources.pdf This review of the results of a research project and forum of the same name presents a range of non-Indigenous and Indigenous and ecological values of outback water resources. Including perspectives gained from people working and living in the GAB and arid areas of South Australia, the research seeks to define the value of arid lands waters. Themes established from these report are summarised as follows (in alphabetical order): *Aesthetic value* (i.e. artistic, personal, less tangible); *Amenity/Consumptive value* (i.e. domestic supply); *Cultural value* (i.e. historic, heritage, social, spiritual); *Economic value* (i.e. agriculture, mining, commercial fishing, science, tourism), *Ecosystem value* (i.e. physical, biological, ecological, conservation) *Educational value*, *Knowledge value*, *Political value*, *Legal value*, *Ownership value*, *Recreational value* (i.e. tourism, local use) (p. vi) Non-Indigenous areas for further investigation of arid water assets based upon historical and contemporary accounts include: Mining resourcing, critical agricultural supply, social infrastructure provision, drinking water and amenity for tourism, commercial fisheries, employment opportunities, filming, art and photography, observation of landscape alteration over time allows interaction with nature, fosters relationships between cultures, power to protect water, traditional and historic knowledge, multiple values of some sites, fishing hotspots and recreational opportunities.
Macfarlane, I (2005)	SA GAB	A water history of the western Simpson Desert, Australia, *23 Degrees South: Archaeology and Environmental History of Southern Deserts,* edited by M.A. Smith and P. Hesse, National Museum of Australia, Canberra, 2005 http://acih.anu.edu.au/sites/default/files/documents/23_deg_chap_22.pdf This water history of the western Simpson Desert covers the area north of Oodnadatta to south-east Alice Springs. Settlers across the area inserted new water places into an existing cultural landscape including also reconfiguring of the old Aboriginal water places. In non-Indigenous contexts, water is a cultural idea beyond the use simply as a resource; water places act as locations for memory and renewal, telling stories, making connections, establishing identities, and the sites for past and future possibilities. Macfarlane suggests the following themes: water as a social actor – through the history of peoples involvement in how a water place affects and is affected by them,

Reference	Region	Summary
		water is meaningful – where local histories distinguish water from place to place, using water for practical uses – which records accumulated histories and meanings linked through people's practices, the temporality of desert water and forms of water – described through typologies of the Lower Finke and Simpson Desert water places. Co-occupation is a feature of the use of water places. Dalhousie Springs is a site of both non-Aboriginal and Aboriginal settlement, Anniversary Bore is an Irrwanyere homeland established next to European Well and Ewillina Waterhole was a pre-colonial occupation material camp. Dalhousie Homestead was settled based upon the Springs potential, which were a regular watering place on late 19th century stock routes. With pastoralism came commercial sourcing of water from aquifers through wells and bores which untapped the potential of the desert. Mapping water point development traces the boom and bust conditions over time as water became a resource to be traded. The importance of knowing the desert through water, such as mappings made by geographer Madigan in 1929, enables improved knowledge as to how processes are lived out at the local level. What is the difference between organising life around a technologically derived water point or around a long-term waterhole or well? New points may have no reference to Aboriginal ancestor stories, but new wells have associative significance for non-Aboriginal people.
MacMillen, R & MacMillen, B (2009)	Qld & SA (GAB)	Meanderings in the Bush - Natural History Explorations in Outback Australia (ed. 2) CSIRO Publishing The extreme aridity of the Channel Country is disrupted unpredictably by summer monsoonal rains and massive flooding, followed by prodigious growth of plants and reproduction of animals, before returning to daunting conditions of drought. It is also a region favoured by hardy pastoralists and their livestock, who have learned to coexist with this harsh climate. These studies are cast in the light of both the prehistoric and historic records of the Lake Eyre Basin, including the probable impacts of changing and/or stable climates, Aboriginal occupation, later European pastoral development and the influences of introduced exotic mammals.
McLaren (1986)	SA (GAB)	Assessment of exploration and Post-European settlement significance of the Mound Springs of South Australia, Dept. of Environment and Planning, Adelaide http://trove.nla.gov.au/work/13469064?selectedversion=NBD5613145 Included within the report is a biological assessment of the South Australian mound springs alongside an assessment of Aboriginal archaeological and cultural significance of the springs. An assessment of exploration and post-European settlement significance of the mound springs of South Australia includes historical and locational details of a range of springs.
Morton SR, Doherty MD & Berker RD (1995)	SA (GAB)	Natural Heritage Values of the Lake Eyre Basin in South Australia: World Heritage Assessment http://www.lebmf.gov.au/publications/pubs/leb-world-heritage-values-1995.pdf This assessment of the natural heritage values of the Lake Eyre Basin in South Australia was carried out by surveying scientific literature concerned with geomorphology, hydrology, palaeontology, limnology, biology, ecology and environmental management. The research aimed to identify features of the Lake Eyre Basin in South

Reference	Region	Summary
		Australia that appear to be unique or unusual compared to other parts of Australia and then to assess these against World Heritage Criteria. Section 4.13 Aesthetics and Natural Beauty acknowledges 'the Australian outback is a cultural icon for many Australian people of non-Aboriginal origin. This outback emblem includes many components of the Lake Eyre Basin, such as the explorations of successful and not-so-successful explorers such as Burke and Wills, the early adventurers, the sheep and cattle industries established with physical courage and still represented by ringers, stockmen and station owners, the laying of the Overland Telegraph Line and the Ghan railway through the desert, the flying doctor, and miners of opal and other precious metals and stones. The environment of the Lake Eyre Basin is essential to this outback history and its legends, and includes such striking natural phenomena as the harsh aridity, its episodic flooding, its vital and beautiful waterholes and springs, and its deserts, in particular, the Simpson Desert. There are often elements of a love-hate relationship contrasting the beauty of the landscape with the solitude, harshness and 'unforgiving nature' of the arid environment. These cultural notions are notoriously difficult to quantify, but the subsequent paragraphs mention some of the writings which contain elements of these reactions to the Basin.' The entry names the range of authors of definitive histories including discussion on the beauty of the landscapes, its artistic recreational and spiritual significance, aesthetic reaction to water in the desert, scale, floods and the sense of security brought about by bores and water infrastructure. Increasing tourism pursuits by vehicle or canoe. It notes that 'National Estate listings of a portion of the Cooper Creek floodplain in South Australia (see Fig. 4, Section 4.9.2.4), and of the Coongie Lakes suggest recognition of the aesthetic qualities of parts of the region. In addition, the National Wilderness Inventory (Australian Heritage Commission 1995) indicates that substantial sections of the Lake Eyre Basin in South Australia possess the highest ranking for wilderness quality.' The report confirms there is a growing appreciation among our people of the aesthetic values of the arid heart of the continent.
Mulvaney (2002)	SA (GAB)	.....these Aboriginal lines of travel, *Historic Environment* vol 16. No 2, 2002: pp. 4-7. http://www.aicomos.com/wp-content/uploads/these-Aboriginal-lines-of-travel.pdf This paper focusses upon Aboriginal ceremonial exchange routes during recent centuries and also on the Overland Telegraph Line during the period from 1860 to 1890. It emphasises the social and economic role of Dreaming Tracks and their environmental relevance, and the environmental and cultural consequences of the Line's construction. Certain places are selected to illustrate the differing perceptions and roles of those places when viewed by indigenous people and European colonists. These places include Alitera on the Finke River.
Piddocke, T (2009)	Qld & SA (GAB)	Historical collation of waterbody information in the Lake Eyre Basin Catchments for Qld and SA, SAAL NRM http://www.saalnrm.sa.gov.au/Portals/8/Publications_Resources/Project_Reports/SAAL-Report_Water_Historical_Collation_Of_Waterbody_Information_June_2009-122009.pdf This project used an historical perspective to build a picture of dynamism in waterbodies of the Lake Eyre Basin over the past 150 years since first European contact with the area. The journals of three nineteenth century explorers and one

Reference	Region	Summary
		early twentieth century traveller (Landsborough, McKinlay, Sturt and Basedow and Grenfell Thomas) were examined, and references to waterbodies and other environmental phenomena extracted and geo-referenced. 'The search for potable water was a constant preoccupation of explorers in inland Australia. Indeed, the search for water was generally the main determinant of their daily path and their selection of campsite' (p. 39). Descriptions of eight case study locations from the explorer record were compared with current assessments of waterhole permanence derived from a recent broad-scale study. Using anecdotal and empirical evidence strongly suggests that overgrazing in the late nineteenth century has resulted in localised reductions in waterbody permanence. Waterholes studied include: O'Halloran Creek, Strzelecki Creek, Ooga-Boogina Watehole (visits by Sturt and McKinlay), Lake Lady Blanche, the Mulligan River (Sturt's Description), Cooper Creek waterholes (Cullymurra, Mulkonbar, Nappaoonie, Nappa Merrie, Nappapethera and Maapoo) and Quartier Creek, Durham Downs Qld.
Powell, OC (2012)	Qld (GAB)	Song of the Artesian Water: aridity, drought, and disputation along Queensland's pastoral frontier in Australia, CSIRO Publications http://www.publish.csiro.au/paper/RJ12014.htm Unpacks Patterson's *Song of the Artesian Water* by exploring interactions between water, scientific knowledge, drought and environmental transformations along the pastoral frontier of Queensland. The poem is used as a framework to provide historical interpretation of European exploitation of GAB as well as a framework for current economic and environmental threats.
Reid & Gillen (1988)	Coongie	The Coongie Lakes Study. Two year biological survey of the region. Broad focus: birds, terrestrial vertebrates (mammals, reptiles, frogs), vegetation, aquatic biota (fish and zooplankton). Consideration given to the importance of tourism in the region and its effects on the local biota.
Reid, J & Gillen, J (1988)	Coongie	*The Coongie Lakes Study*, South Australian Department of Environment and Planning, Adelaide. Undertaken 25 years ago, this biological survey undertook a survey of the natural history of the Coongie Lakes system in part seeking to 'identify and document the impact on the natural environment of human activities such as mining, tourism, grazing, feral animals and hunting'. A range of management strategies were recommended.
Ridgway, N (2008)	SA	'Early water pumping technology in Australia', *Australian Journal of Multi – disciplinary Engineering*, Vol. 6, No. 1, 2008 pp. 119–128 The supply of water for mining and pastoral stations was vital to the development of the Australian economy. Settler health was often affected by contaminated water while the exploration and development of new pastoral lands were inhibited by the availability of water. Natural water supply in Australia pastoral areas is unreliable because landscape features may not include natural catchments while rainfall in some areas is erratic or insufficient. Driven by the rising price of copper and wool, mining and pastoral production required water supplies of ever increasing capacity. Stock

Reference	Region	Summary
		routes between stations or to ports required regular watering points and, from the 1880s, Governments employed well sinkers and cable tool drillers to exploit groundwater (pp. 1–2). This paper traces the archaeology from remote pastoral stations and wells to establish the significance of the engineering heritage and record this technology, although the locations of these wells and their relationship to permanent surface water assets is not recorded.
Robin, l et al. (eds.) (2011)	Qld (GAB)	Desert Channels – The impulse to conserve, CSIRO Publishing *Desert Channels* is a book that combines art, science and history to explore the 'impulse to conserve' in the distinctive Desert Channels country of south-western Queensland. The region is the source of Australia's major inland-flowing desert rivers. Under sections including themes such as place, landscape, biodiversity and livelihood, the connections between natural and cultural values are intertwined. Detailed descriptions of Channel Country rivers and artesian springs and their floodplains and riparian zones are located and described through seasonal variation. Some of Australia's most interesting new conservation initiatives are in this region, including partnerships between private landholders, non-government conservation organisations that buy and manage land (including Bush Heritage Australia and the Australian Wildlife Conservancy) and community-based natural resource management groups such as Desert Channels Queensland.
Ryan, S (1996)	National	The Cartographic Eye: How Explorers Saw Australia. Cambridge University Press, Melbourne. This book is about the mythologies of land exploration, and about space and the colonial enterprise in particular. An investigation of the presumptions, aesthetics and politics of Australian explorers' texts that shows that they uncover the quest for knowledge of the early explorers and establish ongoing relationships with the arid lands of Australia as empty and uninhabited. Settler aspirations and relationships to landscape, water, ecologies and human occupation by Aboriginal people are discussed through the understanding of explorer diaries, the language and detail of their recordings as cartographies and narratives.
Schmarr et al. (2012)	SA (Cooper Creek)	Aquatic Ecology Assessment and Analysis of the Cooper Creek Catchment: Lake Eyre Basin, South Australia Preliminary recreational fishing survey (p. 43) considers the importance of fishing to tourism in the region. Further comprehensive surveys required to determine recreational fishing impact in LEB.
Schmiechen, J (2004)	SA (GAB)	Lake Eyre Basin Heritage Tourism Future Directions, Lake Eyre Basin Coordinating Group www.lakeeyrebasin.org.au/archive/media/future_directions.pdf Schmeichen's LEB tourism strategy survey links natural and cultural heritage values and assets to economic benefits from tourism in the same way as mining and pastoralism contribute to arid lands economies. The heritage tourism project firstly identifies the characteristics of the major river and wetland systems along with the main towns and communities and major land uses and industries. It advocates for a

Reference	Region	Summary
		continuing process for inventorying heritage assets in the region alongside a series of priority projects including the Oodnadatta Track/Finke Track, Simpson Desert and travelling tracks thematic approaches to telling the heritage stories of the LEB. Important heritage assets are noted throughout the report with imagery including tourism sites at waterholes, creeks and springs. Water as a heritage asset is discussed in 'Future Direction 4 Protect water quality to maintain and conserve water dependent eco-systems and preserve heritage values' and 'Ensure that outback communities have adequate systems to provide water for increasing tourist use,' and confirm the attraction that tourists have to water locations, wetlands, river and bore drains and their ecosystems (p. 10).
Silcock, J L (2009b)	Qld & SA (GAB)	Experiencing Waterholes in an Arid Environment with Particular Reference to the Lake Eyre Basin, Australia: A Review, *Geographical Research*, Institute of Australian Geographers http://onlinelibrary.wiley.com/doi/10.1111/j.1745-5871.2010.00642.x/abstract The intangible qualities of 'waterhole experience' in arid landscapes are mapped through the interaction of humans with water primarily from a settler perspective. A large body of literature pertaining to waterholes including: Aboriginal histories, explorer journals, accounts of early settlers, and numerous fictional and factual accounts of life in inland Australia are the basis of the research. Human appreciation of arid-zone waterholes runs deeper than the survival imperative, and can be enriched by considering landscape aesthetics and psychology. This attraction has spawned a rich mythology centred on permanent waterholes. The paper is an overview of the intangible values of LEB water assets dealing with themes such as aesthetic appreciation of waterholes, the beautiful, sublime and picturesque, the oasis, the sensory experience and water holes as wellsprings of thought and creativity. Silcock discusses factors affecting the waterhole experience in relation to the surrounding landscape, cultural context and the importance of knowledge of the water place to enhance aesthetic experiences.
Silcock, JL (2009a)	Qld & SA (GAB)	Identification of permanent refuge waterbodies in the Cooper Creek, and Georgina-Diamantina River Catchments for Queensland and South Australia Permanent waterbodies support a distinctive biotic assemblage and act as important refuges for aquatic and some terrestrial fauna during dry times. Their tiny surface area relative to the immensity of the surrounding landscape belies their immense ecological, cultural, economic and social significance as they dictate settlement and travel patterns and inspire mythology across the predominantly arid region. Silcock has researched the patterns of human interaction with waterholes, lakes, rockholes and springs across the two catchments, finding that since European settlement, the distribution and permanence of water has changed dramatically. Some water sources have declined in abundance and/or permanence, primarily through silting of waterholes and loss of springs, alongside a massive increase in the distribution and abundance of permanent water. Today, human impacts are evident at many waterholes, primarily as a result of increased total grazing pressure, introduced species and some localised recreational impacts. The section on human significance records and analyses impacts and associations with water bodies through; naming, the concept of living water, Indigenous people and waterholes, exploration and

Reference	Region	Summary
		waterholes, early settlement and waterholes, waterholes and recreation and the diminishing of current knowledge on water asset location and persistence due to changing management regimes.
Tolcher, HM (1986)	Qld & SA (GAB)	Drought or Deluge: Man in the Cooper's Creek Region. Melbourne University Press, Carlton A detailed history of human exploration and settlement in the Cooper's Creek region. Discusses Aboriginal prehistory, and the interaction between Aboriginals and European settlers, explorers and travellers. Examines the harsh environmental conditions faced by the inhabitants of the region, and how they coped with them. The section on the great floods examines changing perceptions of the Cooper and Coongie Lakes in regard to settlement histories. It concludes with a prescient discussion entitled pastoral present, oil future relating the relationship with drought and flood and ultimately the ravages of water on occupation of the arid lands.
Yelland, L (2002)	SA (GAB)	Pads, tracks and waters South Australian pastoral stock routes, Outback Areas Community Development Trust This book outlines the pastoral routes across the SA GAB It includes historical maps, stories and water types essential for the operation of these routes waters, wells bores and tanks including a reproduction of stock routes mapped in 1905 and a drover's map of the Birdsville Cattle Track marking all the water sources, bores, wells and waterholes from Birdsville to Marree. The chapter on waters, wells, bores and tanks documents the variety of water sources and their use by stock and drovers while tracking through the country. The construction and failure of many settler and Government water systems is described alongside the policy and methods for protection and access to water for conservation purposes.
Zeidler and Ponder (1989)	SA (Dalhousie Springs)	Natural History of Dalhousie Springs Multidisciplinary survey of the Dalhousie Springs Complex. Chapters 3 and 4 describe Archaeology and European History of the area

Explorer journals and historical reports / papers

Reference	Region	Summary
Babbage (1858)	SA (GAB)	Northern explorations. Reports from Messrs. Babbage and Warburton and Police trouper Burtt, on exploration into the north and north-western interior of South Australia.
Gregory (1906)	SA (GAB)	The Dead Heart of Australia: A journey around Lake Eyre in the summer of 1901-1902 with some account of Lake Eyre and the flowing wells of central Australia, John Murray, London.
Mitchell (1847)	Qld & NSW (GAB)	Journal of an Expedition into Tropical Australia in Search of a Route from Sydney to the Gulf of Carpentaria, University of Adelaide Library Electronic Texts Collection, Adelaide.

Reference	Region	Summary
Mulvaney et al. (2000)	SA (GAB)	*From the frontier: letters from the outback to Baldwin Spencer,* Letters from Ernest Cowle and Paddy Byrne to Baldwin Spencer written between 1894 and 1925.
Simpson (1990)	SA (GAB)	*Horrie Simpsons Oodnadatta,* edited by John Dallwitz, Oodnadatta Progress Association, Oodnadatta
Spencer (1928)		Wanderings in Wild Australia, Macmillan, London
Stuart (1865, 1984)	SA (GAB)	Explorations in Australia : the journals of John McDouall Stuart during the years 1858, 1859, 1860, 1861, & 1862 ... / edited by William Hardman. Hesperian Press, Carlisle, W.A.
Sturt (1849)	GAB	Narrative of an Expedition into Central Australia Performed under the Authority of Her Majesty's Government, During the Years 1844, 5, and 6, Corkwood Press (2001 edition) North Adelaide
SA Parliament & others	GAB	Northern explorations, 1857 South Australian Parliament & Babbage BH, 1815 1878 1889 (1856) & Warburton PE, 1813

3.4.2.4. Community values in the Lake Eyre Basin

Community engagement and management regimes

Reference	Region	Summary
Davies, J & Holcombe, S (2009)	National and International	Desert Knowledge: integrating knowledge and development in arid and semi-arid drylands*, GeoJournal*, Vol. 74, pp. 363–375. http://www.springerlink.com/content/l69gw86346lv8439/fulltext.pdf The value of the knowledge that local traditions and science have generated about living sustainably in deserts is being promoted and extended through the 'desert knowledge' movement in Australia. Research in partnership with desert Aboriginal groups is contributing to their engagement with new livelihood opportunities. The local knowledge of livestock graziers is also being engaged to support sustainable management of desert water sources and landscapes for multiple values. In doing so it contributes to a 'neo-ideographic approach' wherein desert people might better harness their locality, knowledge and diversity in adaptations that shape their encounters with globalisation.
Desert Channels Qld Inc (2004)	Qld (GAB, Galilee Basin)	Our Country: Our Community: A community information paper for the Queensland Section of the LEB, Desert Channels Qld Inc. http://www.dcq.org.au/sites/default/files/Community%20Information%20Paper.pdf A community discussion paper in two parts with the first part setting the scene regarding planning processes and how they inform and fit within the immense scale

Reference	Region	Summary
		and complexity of the LEB and how the communities understand their identities, their origins and their aspirations and achievements. The second part is an overview of the region's features, dynamics and its unique communities. The overview presents information on how the landscape evolved and how people have interacted with the natural resources of the catchments. The history of community planning processes and key issues are defined and have implications for water asset research on the ground and with communities. The Desert Uplands Build-up and Development Strategy Committee and the Lake Eyre Basin Coordinating Group have developed plans and strategies for their areas and through extensive community consultation identified a number of thematic areas of concern that impact on the natural resources of the region, many of which are implicitly aspects of both water values and water asset management. These include: Biodiversity Conservation / Endangered Species, Chemical Contamination / Waste Management / Pollution, Climate Risk and Drought, Diversification, Education / Awareness, Grazing Pressure / Pasture Management / Safe Carrying Capacity, Great Artesian Basin, Indigenous Land Management, Lack of data, Land Degradation, Mining and Petroleum, Property Management Practices / Planning, Salinity, Security of Tenure, Streamline Ecology, Surface Water Management, Tourism, Vegetation Management, Viability / Economics, Weeds / Feral Animals and Wildlife use / Harvesting.
Leek, D (2001)	SA (GAB)	Management of the Great Artesian Basin in South Australia – looking forward, looking back, Arid Areas Catchment Water Management Board, South Australia. http://www.gabcc.org.au/tools/getFile.aspx?tbl=tblContentItem&id=23 The use of water sourced from the Great Artesian Basin in South Australia has long been the subject to management and as the demand for water has intensified with mining and tourism expanding rapidly in the region, the need for a more formalised and restrictive management regime to control the taking of water has become apparent. This paper explores the history of the management of the GAB SA in order to provide a context for a discussion of the framework and challenges that face resource managers.
Measham, TG & Brake, L (eds.) (2009)	SA (GAB)	*People, communities and economies of the Lake Eyre Basin*, DKCRC Research Report 45, Desert Knowledge Cooperative Research Centre, Alice Springs. www.desertknowledgecrc.com.au/.../DKCRC-Report-45-People-communities-and-economies-of-the-Lake-Eyre-Basin.pdf This publication is an overview of the main findings of the 'People, communities and economies of the Lake Eyre Basin' project. The research finds that successfully caring for the country and the communities of the Lake Eyre Basin (LEB) depends on four principles; to better understand the social and economic landscape of the LEB and its resources, effective management of the LEB is underpinned by building effective engagement processes between residents, management agencies and policy makers, to identify and explore the key human dimensions specific to remote regions and to develop a mechanism to underpin long-term social learning to support the effective governance of the LEB in the form of a monitoring process. Contents of the report include chapters on the regional profile of the LEB Catchments, overview of the natural

Reference	Region	Summary
		resources management arrangements in the LEB, achieving, sustaining and monitoring effective stakeholder engagement in the light of demographic changes, the need to assess local, regional and LEB-wide institutional arrangements for Aboriginal governance of desert environments.

Tourism

Reference	Region	Summary
Barker, J (ed.) (2011)	SA (GAB)	Bursting with life or loved to death? Lake Eyre Basin and outback tourism Across the Outback April 2011 Number 54 www.saalnrm.sa.gov.au/.../SAAL-Across_The_Outback_Issue_54-042011.pdf This community reports on the impact of national and international tourism on the LEB over three years of flooding and the challenges and impacts that come with the boom in tourism that such events provoke. The Lake Eyre Basin Community Advisory Committee is progressing developing a regulatory framework to manage tourism impacts. The pressure on limited outback infrastructure and fragile environments from increased visitation has seen estimates of more than 2 million visitors in 2011 and subsequent impacts on key places, which are most usually situated at water assets and their infrastructure and heritage assets and in wider riparian areas and downstream. Impacts include soil erosion or compaction from driving off-road and along channels and waterholes, poor waste disposal, over-use of limited water supplies, wood collection for fires, transport of weeds, and direct effects on biodiversity (fishing, hunting, and disturbance).
Earthcheck Pty Ltd, EC3 Global (2010)	SA (GAB)	Review of the 2004 Lake Eyre Basin Heritage Tourism Report – Final Report May 2010, Department of the Environment, Water, Heritage and the Arts Under Issue 2: Environmental Impacts and management this review and update of the Schmiechen Report and in particular Future Direction 4 regarding protection and maintenance of water quality and dependent ecosystems documents what has been achieved over 6 years. Under Plans and Strategies a LEBIA Water Quality Policy and a Knowledge strategy have been developed: 'Strategy 3: Coordinate water quality monitoring and data management frameworks across jurisdictions to enable data collation, analysis, comparison and reporting at regional, catchment and whole-of-basin scales' and LEB Knowledge Strategy (p2): Identifies priority knowledge needs in relation to water and related natural resources, including knowledge priorities and opportunities. Under Projects and Programs LEBIA's cross border partnership has adopted a range of strategies including Policy 6: 'water and related natural resources in the LEB Agreement Area will be managed through a 'whole-of-basin' approach'. The various State of the Environment Reports contain recommendations for managing water quality and supply. Most set targets for achieving sustainable water supplies. And the Stakeholder Recommendation advises that 'The story of water from the overland flow to the Artesian Basin and the ancient inland sea need to be developed and better communicated to key agencies and travellers'

Reference	Region	Summary
		(p. 10).
Gibber Plain Solutions and Pitstop Marketing (2012)	SA (GAB)	How can the outback benefit from and promote tourism in the region when Lake Eyre is Dry? For the Flinders Ranges and Outback Tourism SA Outback working party This Issues and Opportunities Paper commissioned following three consecutive wet Kati Thanda-Lake Eyre events bringing new markets and tour operators to the region for the Flinders Ranges and Outback SA Tourism Association (FROSAT) Outback Working Party (OWP). Key research findings include; 'experiences', 'infrastructure' and 'marketing'. Water places and water assets are not specifically mentioned beyond water sports, but the recommendations include increasing infrastructure and services in places are tourist interest, this impacting upon the ability of water resources to satisfy demand. The attraction to the area is summarised as lying in 'the un-spoilt nature, sense of isolation, challenge of 'conquering the tracks'' (p. 6).
Leader-Elliott, L (2002)	SA (GAB)	Indigenous cultural tourism as part of the Birdsville/Strzelecki Experience, *Australian Aboriginal Studies*, Issue 2, pp. 35–44 In the context of a review of the heritage tourism study undertaken for the region, the paper examines issues relating to inclusion of Aboriginal cultural heritage along the Birdsville and Strzelecki Tracks. The perception of 'Aboriginality' linked to the outback is linked to a lack of information available – an issue that is improving in the 10 years since this was written. Importantly, the 'report recommended that the Aboriginal story be told where appropriate, and that this be based on consultation with Aboriginal communities to identify places suitable for interpretation, so that a layered understanding of people and place can be developed.' Within the brief for the survey 'cultural heritage' only meant historic heritage and the term contact history used for connection to Indigenous cultural heritage. Relevant themes were identified as Aboriginal contact, exploration, pastoralism, transport and communications, social life and organisations (hotels, settlements and outback general stores) and the geology and natural history of the region. Places of significant interest were defined to 'include a building, an industrial site, a monument, a ruin, a vacant area which may be of archaeological significance, a burial place, a garden, a plantation, a geological site or a variety of other places'. It is clear that the connection of historic places to water assets was not made implicit in relation to heritage landscapes and sites.
Moller (1999)	Qld (LEB)	State of the Rivers Cooper Creek and Major Tributaries, Department of Natural Resources http://www.nrm.qld.gov.au/science/state_of_rivers/pdf/cooper_summary.pdf An assessment of the physical and environmental condition was conducted for 273 sites on the Thomson River, Barcoo River, Cooper Creek and their tributaries. Parameters were assessed against presumed natural condition by comparison to remnent sites. Scenic, recreation and conservation value was assessed and related predominantly good in relation to inherent natural beauty of stream settings, scenic rural settings and the artistic merit of the landscape.

Reference	Region	Summary
		Recreation opportunity rated some streams as having semi-natural or pristine natural opportunity. Activities include shore fishing, fishing from small boats, camping, nature appreciation and swimming (p. ii).
SA Government, SA Tourism and BHP Billiton	SA (GAB)	The Oodnadatta Track – String of Springs Tourist Brochure – Water and Plants www.southaustralia.com/.../oodnadatta-track-string-of-springs.pdf A very informative pamphlet for tourists documenting the GAB and its watercourses and springs, providing maps, histories, natural systems interpretations and an extensive section on water and the key sites:Hergott Spring, Finniss Springs, Hermit Hill, Wibma-Malkara, Curdimurka, Wabma Kadarbu Mound Springs Conservation Park, Coward Springs, Beresford, Strangways Springs, Anna Creek, Old Peake Paddock, Algebuckina Waterhole, Oodnadatta and Dalhousie Springs.
SA Tourism	SA (GAB, Arkaringa)	Australia's Explorer's Way: From Adelaide to Darwin Itinerary Tourist Brochure http://www.trade.southaustralia.com/__data/assets/pdf_file/0016/6901/SA_SelfDriveItinerary_ExplorersWay.pdf A joint production from SA Tourism and Northern Territory tourism, this brochure provides itineraries for travel between Adelaide and Darwin. It follows the major inland tracks in the Arckaringa and Pedirka Basins area and includes the Oodnadatta track, Coober Pedy, Mount Dare and Witjira National Park, including Aboriginal communities and the Old Ghan Heritage Trail.
Schmiechen, J (2004)	SA (GAB)	Lake Eyre Basin Heritage Tourism Future Directions, Lake Eyre Basin Coordinating Group, Longreach www.lakeeyrebasin.org.au/archive/media/future_directions.pdf Schmiechen's LEB tourism strategy survey proposes a series of policy, program and management strategies for LEB tourism. With regard to water assets, he recommends 'Future Direction 4 – Protect water quality to maintain and conserve water-dependent ecosystems and preserve heritage values. Ensure that outback communities have adequate systems to provide water for increasing tourist use'. Specific recommendations for the management of these places and resources include that 'Water catchment committees and boards, along with the relevant government agencies, need to work together to plan, implement and manage the prime water dependent ecosystems and ensure adequate and safe supplies of water for outback communities.' And 'A major education campaign and appropriate interpretive information should be provided. This signage needs to tell the water story to travelers at strategic locations throughout the Basin'.
Urban & Regional Planning Solutions, Econsearch, Ecological	SA (GAB)	Flinders Ranges and Outback SA Integrated Strategic Tourism Plan 2008 – 2014 http://www.portaugusta.sa.gov.au/webdata/resources/files/Strat_Plan_Exec_Summary__Action_Plan_Framework_FINAL.pdf The FROSAT Strategic Tourism Plan seeks to bring more money into the region through increasing visitor numbers by 'addressing current gaps in transport, products and service...'. In promoting increased tourism the Plan also sees 'the

Reference	Region	Summary
Associates (2009)		need to protect and enhance the natural environment and landscapes that provide the source of the region's appeal to visitors. It is also critical to ensure that rural communities are adequately resourced and supported to manage the impacts of tourism and provide satisfying experiences for visitors'. The primary theme is journeys, tracks and trails to support visitors' journeys of exploration without borders or boundaries. Under 'Infrastructure and Services that Support Positive Visitor Experiences' the areas for detailed development to facilitate visitor experience may include physical items such as roads, toilets, signage, boat ramps, picnic facilities, shelters, boardwalks, cycle paths and jetties usually provided by public authorities for the free use of residents and visitors – facilities which may impact upon the riparian and surrounding water assets ecologies. The Plan also states that water quality and quantity is essential to support industry development including tourism and mining.

Landscape, water and management

Reference	Region	Summary
Bellamy J, Head, B & Ross, H (2012)	LEB	*Blurring boundaries and building bridges: Challenges of managing across borders in the Lake Eyre Basin* in Grove, J.R and Rutherford, I.D (eds.) Proceedings of the 6th Australian Stream Management Conference, Managing for Extremes, 2012, Canberra, Australia, published by the River Basin Management Society, pp. 1–11. http://www.asm6.org.au/assets/6ASM/Abstracts/022.pdf The environmental, social, economic and institutional context of the LEB provides distinct challenges in the management the boom and bust cycles of flood and drought ecology of dryland river systems. Bellamy et al. state that 'Catchment and river management policy is a wicked problem concerned with the interaction between complex multi-level institutional landscapes and the dynamics of ongoing change in inter-linked social and natural systems'. The paper investigates five political jurisdictions overlaying the LEB to uncover the challenges experienced in bridging the boundaries associated with multi-scalar and multi-actor cross border river management. This is critical to protect the diverse values of large river systems. Collaboration is seen as essential to 'develop and evolve feedback loops to support an adaptive approach to governance systems'.
DERM (2011f)	Qld (LEB)	Cooper Creek Water Resource Plan 2011**,** Consultation Report http://www.nrm.qld.gov.au/wrp/pdf/cooper/cooperck-consreport-nov11.pdf Queensland government report on community consultation into the preparation of water resource plans for the Cooper Creek system. The basin is confirmed as being of national and international environmental significance, and includes areas of high economic, social and cultural heritage value. The report links to other planning initiatives such as the LEB Intergovernmental Agreement, the Cooper Creek Wild Rivers Declaration 2011 and the National Water Initiative. Noting widespread support for a holistic approach, ecological sustainability and cross-border river management the range of key community issues include:

Reference	Region	Summary
		Unallocated water, Indigenous water reserves, irrigation licences and storage conditions, protected waterholes and lakes, interference with water in a watercourse, lake or spring for stock and domestic use, management of overland flow water, water trading and relocation of water licences, monitoring and reporting, ongoing consultation process and hydrologic assessment.
Duguid, A (2011)	NT (GAB)	Wetlands of the Great Artesian Basin Water Control District (Northern *Territory)*. Technical Report No. 13/2011A. Northern Territory Government Department of Natural Resources, Environment, the Arts and Sport. Alice Springs. http://lrm.nt.gov.au/__data/assets/pdf_file/0016/120553/GABWCD_Wetlands_Report_FINAL-.pdf While this report is principally concerned with wetland typology and mapping in the Northern Territory, it includes important information to inform cultural mapping approaches to wetland mapping. It includes descriptions of selected wetlands and wetland aggregations collated from various sources, and it highlights the diversity of wetlands that occur. It also highlights knowledge gaps that could be filled with further survey and mapping of wetlands through remote sensing and aerial survey methods during timers of inundations. Currently many wetlands are not mapped and for those that are mapped, the type of wetland is not known. The report confirms that boundaries of individual wetlands need to be mapped on a case-by-case basis using field observations and remotely sensed imagery such as aerial photography and very high resolution satellite as judgments about the extent of a wetland can be difficult to make and satellite imagery. Angus recommends that further systematic collation of existing data and information for wetlands combined with field survey of biological values in the NT-GAB would assist in future assessments of conservation significance. A parallel cultural mapping of significance would enable communication with land managers and communities regarding the relationship of human practices to wetland condition over climatic time scales.
Lee, G (2010)	SA (GAB)	Cultural landscape assessment and analysis of the Neales Catchment and Algebuckina Waterhole, SAAL NRM http://www.saalnrm.sa.gov.au/PublicationsResources/ProjectReports.aspx A detailed cultural landscape assessment into the physical features and human influences of the Neales Catchment uses a landscape design based methodology and cross-disciplinary approach. A landscape design approach Identifies the environmental, economic, cultural and social values associated with landscape features (e.g. waterholes, rivers, creeks and dams). It provides practical solutions, such as, identifying impacts from tourism pressure, and designing visitor management options through consultation with stakeholders and reference to scientific knowledge. It identifies the Aboriginal cultural importance of waterbodies and options for a combined management approach. A landscape assessment has been carried out for the well-visited waterholes along and associated with the Oodnadatta Track and the Neales Catchment.

Reference	Region	Summary
Ludwig et al. (1996)	National	*Landscape Ecology Function and Management –Principles from Australian Rangelands* CSIRO Publishing http://www.publish.csiro.au/pid/180.htm Although published 17 years ago, this book pertinently encapsulates the extensive knowledge developed by CSIRO's National Rangelands Program on how rangeland landscapes function and the implications for management. It looks at the ecology of rangeland landscape processes and deals with when a landscape becomes dysfunctional and loses its ability to efficiently capture and store water and nutrients. Ways of managing rangelands in response to understanding landscape function are also considered. The concluding section looks to the future, providing some scenarios for the way rangeland landscapes may be used in 2020. The book includes the following relevant sections in relation to water assets. Section I - Landscape Function, The Landscape Approach, Conserving Nutrients and Water, Production Pulses and Linkages, Consumers, Feedbacks and Off-take, Section II - Landscape Dysfunction, Nature, Causes and Consequences of Dysfunction and Section III - Landscape Management Implications, The Management Framework, Managing for Production and Conservation Goals, Rehabilitation of Landscape Function. It concludes with Towards a Sustainable Future under the broad context of Rangeland Landscapes.
Morton et al. (1995)	SA (GAB)	*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 Environment, Sport and Territories, Canberra http://docs.exdat.com/docs/index-158799.html See review in non-Indigenous landscape and cultural values.
Neave et al. (2004)	NT (GAB)	*A Resource Assessment Towards a Conservation Strategy for the Finke Bioregion,* Department of Infrastructure, Planning and Environment, Northern Territory Government. http://lrm.nt.gov.au/__data/assets/pdf_file/0008/17279/app2.pdf The Finke Bioregion is recognised by the former Australian Government Department of the Environment and Heritage (formerly EA - Environment Australia), and in the National Land and Water Resources Audit as a national priority bioregion for conservation planning. It is regarded as one of the most poorly documented bioregions in the Northern Territory in terms of its biodiversity and social values. This report presents important issues and recommendations arising from a Natural Heritage Trust (NHT) and Northern Territory Government funded project titled 'A Conservation Strategy for the Finke Bioregion, NT'. Priorities are to 'broaden understanding of the biodiversity and other values of the Finke Bioregion and ensure that existing and new knowledge is made available to land managers in the bioregion, and is integrated with sustainable land management practices across the bioregion and with any future development that may occur in the region'.
Phipps, L (2008)	SA (GAB)	Assessment of the social amenity and physical characteristics of Great Artesian Basin bore-fed wetlands in South Australia, Phase 1. South Australia Arid Lands

Reference	Region	Summary
		Natural Resources Management Board. http://www.saalnrm.sa.gov.au/Portals/8/Publications_Resources/Project_Reports/SAAL-Social_Amenity_And_Physical_Characteristics_Of_GAB_June_2008-062008.pdf Bore-fed wetlands have significant social, economic and environmental value for the local community, regional visitors and tourists and these wetlands could not persist without the supply of GAB water. This report documents the social and amenity values as ascribed by landholders and users, and the physical characteristics of 17 bore-fed wetlands in the GAB in South Australia. Landholder values include social and environmental benefits with the belief that wetlands contribute to the conservation of wildlife and wetland vegetation as a drought refuge for wildlife. They don't necessarily regard bore-fed wetlands as contributing to problems with feral animals or the spread of weeds. Wetlands are common sites for recreation and relaxation with interaction depending on factors such as the size of the wetland, its proximity to homesteads and whether or not the public accessed the site. Social values included adding to the feeling of belonging, reducing tension, providing a site for entertaining family and visitors and also education opportunities.
Read, J (2003)	SA (Roxby Downs)	Red Sand, Green Heart: Ecological Adventures in the Outback. Lothian Books, Melbourne. In the context of the arid landscapes of central Australia and its harsh climate, where he has been working as an ecologist for mining companies and as a private consultant, Read nominates Indigenous groups having been recently joined by pastoralists, conservationists, miners, tourists and military, communications and transport users as key stakeholders in the outback. The roles of different industries, organisations and the public in outback conservation, which is vital to prevent extinctions, are also explored. He advocates challenging conventional approaches to pastoralism, mining, tourism and environmental management.
Silcock, JL (2009b)	Qld & SA (GAB)	Experiencing Waterholes in an Arid Environment with Particular Reference to the Lake Eyre Basin, Australia: A Review See non-Indigenous landscape and cultural values.

Indigenous perspectives and methods

Reference	Region	Summary
Australian Human Rights Commission (2008)	National	'Indigenous Peoples and Water' (Ch. 6) and 'The protection of Indigenous knowledge's (Ch. 7) in *Native Title Report 2008* pp. 169–210 http://humanrights.gov.au/social_justice/nt_report/ntreport08/pdf/chap6.pdf Water is regarded as particularly important in light of the expected impacts from climate change as well as ongoing drought. Issues such as access to cultural water, rights to fulfil cultural responsibilities, including environmental

Reference	Region	Summary
		conservation, as well as the lack of protection of these rights to water under the current legislative framework that governs water resources are discussed. The protection of Indigenous peoples' knowledge's has been identified as a vital component to responding to issues such as climate change and biodiversity conservation. There are a number of national water programs to fund Indigenous engagements and participation in water management including: water centred GAB, Lake Eyre Basin and inland water initiatives and Caring for our Country natural resource management programs. The Indigenous Water Policy Group (IWPG) aims to improve indigenous peoples awareness of water reform and to direct research relating to Indigenous rights, Indigenous water allocation, community consultative process and best practice community engagement, legal rights and water resource management in terms of interests, issues, access and economic opportunities. Chapter 7 considers the lack of protection afforded under current intellectual property laws and considers the need for a mechanism, which provides protocols around the use, access, and ownership of Indigenous knowledge's and a protection regime. However these provisions would be in accordance with the traditional law and customs that govern this use and appropriation, and provide for the unique communal nature of this knowledge.
Bark et al. (2012).	International and National	Adaptive basin governance and the prospects for meeting Indigenous water claims. Environmental Science & Policy 19–20: pp. 169–177. http://www.sciencedirect.com/science/article/pii/S1462901112000421 'The United States and Australia confront the challenge of meeting multi-faceted Indigenous water requirements within the wider context of intensified competition for freshwater supplies and expiation of historic inequality of access. Fulfilment of Indigenous water claims requires acceptance of currently unrecognised uses that may be in conflict with water planning in irrigation-dominated (read also mining) basins. Adaptive governance regimes have been applied to deal with uncertainly and change in water planning and allocation decisions, including changes related to the recognition of Indigenous water claims, values, and knowledge. This paper examines the prospects of adaptive governance regimes to combine: (a) insights into decision-making and policy learning in contexts of high levels of uncertainty over the information base and legal and policy arrangements; with (b) institutional arrangements to coordinate decision-making and accountability across multiple decision-making units, values and jurisdictions, to accommodate Indigenous water claims. In both countries, efforts have involved (re)allocation of water entitlements and greater participation in multi-stakeholder basin planning. A mix of these adaptive governance mechanisms shows greatest promise for overcoming resistance to the recognition of Indigenous water claims'.
Collings, N & Falk, V (2008)	National	'Water, Aboriginal peoples in Australia and their spiritual relationship with waterscapes',in E Johnston, M Hinton and D Rigney, (eds) *Indigenous Australians and the Law* (2008) 131, p 132 http://humanrights.gov.au/social_justice/nt_report/ntreport08/pdf/chap6.pdf

Reference	Region	Summary
		The main objective of this report is to provide advice and input by the First Peoples' Water Engagement Council to the National Water Commission's 2011 Biennial Assessment of progress in implementation of the National Water Initiative (NWI). A summary of Recommendations include: '• Aboriginal people must be given the opportunity to be part of decision-making and water planning processes. • To effectively participate in these processes Aboriginal people need to further develop relevant expertise, and this requires sufficient time to provide input and make decisions within each catchment. • Culturally appropriate resources are also needed to build the capacity of Aboriginal people to participate effectively, including the provision in culturally appropriate ways of information about water resource management and planning, water infrastructure, water sharing plans, and market trading. Where appropriate, this should include the provision of information to communities by trained Aboriginal liaisons. • Government agencies should promote and facilitate effective and collaborative partnerships with Aboriginal people, enabling information sharing and capacity building. Supporting partnerships between regional and national-level Aboriginal groups is also an important means of strengthening capacity across the board. • The time allowed for comment on draft water plans needs to be long enough for community consultation and decision. • The National Cultural Flows Planning and Research Committee should be supported in its work of generating guidance and materials which will assist water agencies to understand and protect Aboriginal cultural values in water.'
Durette, M (2008)	International	*Indigenous Legal Rights to Freshwater: Australia in the International Context*, Centre for Aboriginal Economic Policy Research Working Paper No. 42/2008, College of Arts and Social Sciences, The Australian National University, Canberra http://caepr.anu.edu.au/sites/default/files/Publications/WP/CAEPRWP42.pdf A comparative study of Indigenous freshwater rights in ten USA states, Canada, New Zealand and Australia promoting four key themes; water ownership, water rights, commercial rights and management rights. Ownership and control of water is vested in the government although Aboriginal people may have customary rights. Agreements over title and natural resources in Canada and New Zealand should be seen as models for Australia. The promotion of water rights towards economic self-sufficiency in the other three jurisdictions has seen improvement in the range of water rights for Indigenous peoples beyond Australia. Emerging water markets and water pricing in water allocation will significantly impact upon Indigenous water rights. Rights to participate in the management of freshwater and development of conservation programs are well developed in the USA. Canada has strong partnerships on resource management with Indigenous governments under federal legislation.

Reference	Region	Summary
		Indigenous communities can set their own environmental standards and New Zealand may be moving towards vesting ownership of waterways in Maori. Australia's common law agreements are the least formal legal representation of the right for participation.
Jackson et al. (2012)	National	Principles and guidelines for good practice in Indigenous engagement in water planning, Journal of Hydrology: doi:10.1016/j.jhydrol.2011.12.015. http://www.sciencedirect.com/science/article/pii/S0022169411008882 'Indigenous rights, values and interests relating to water have been identified by Australia's National Water Commission as a national priority area, requiring greater understanding, research attention and government action. Yet Indigenous water values are rarely addressed in water planning, despite objectives in national policy requiring Indigenous participation and the identification of Indigenous social, spiritual and customary values in water plans. Water planners are presently equipped with a very limited number of engagement tools tailored to the water resource management context to redress the historical neglect of Indigenous interests. In an Australian research project focused on water planning, seven participatory planning tools were employed in three Australian case studies with different social and hydrological characteristics to improve the way in which Indigenous values are elicited and incorporated and to enhance the status of Indigenous knowledge in water planning'.
Lee, G & Morris, D (2005)	Central Australia	Best practice models for effective consultation: towards improving built environment outcomes for remote Indigenous Communities. http://www.ahuri.edu.au/publications/p40184/ Using fieldwork in remote Indigenous communities and interviews with built environment practitioners (e.g. architects, builders) the research identifies cross-cultural and cross-disciplinary consultation methods that engage remote Indigenous communities and service providers in developing appropriate and sustainable improvements to housing environments. Principles include: *Engagement* – gaining negotiated and mutual under-standing of the aspirations of clients, consultants, managers and providers, and the adoption of agreed protocols for communication between all parties, at the inception of projects, *Communication* – developing appropriate communication based upon local conditions and experience, influenced by the negotiation of appropriate and coordinated project specifications, and the documentation and timely implementation of expected outcomes arising from consultation. *Reciprocation* – enabling inclusive, reciprocal relationship building based upon increasing knowledge and awareness of physical, cultural and environmental conditions and available expertise, *Feedback* – including use of post occupancy evaluations and extending information gathering beyond physical and technical issues to embrace social, cultural and environmental factors, with the direct involvement of Indigenous clients and *Continuity* - in building cross-cultural and cross-disciplinary relationships, through effective and ongoing communication systems to influence good practice models for project management.

Reference	Region	Summary
RAMSAR (1999)	National	Guidelines for establishing and strengthening local communities' and indigenous people's participation in the management of wetlands, adopted as an annex to Resolution VII.8 (1999). People and Wetlands: The Vital Link, 7th Meeting of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar, 1971), Costa Rica http://www.ramsar.org/pdf/participation-guidelines.pdf 'Community involvement and participation in management decision-making for sites included in the List of Wetlands of International Importance (Ramsar sites) and other wetlands have been recognised as essential throughout the history of the Ramsar Convention. These guidelines were conceived with the premise that local and indigenous people's involvement in wetland management can substantially contribute to effective management practices that further Ramsar's wise use objectives. The case for local and indigenous people's involvement is even stronger when: • local stakeholders have historically enjoyed customary/legal rights over the wetland • local interests are strongly affected by the way in which the wetland is managed • decisions to be taken are complex or controversial (e.g., different values need to be harmonised or there is disagreement on the ownership status of the land or natural resources) • the existing management regime has failed to produce wise use • stakeholders are ready to collaborate and request to do so • there is sufficient time to negotiate among stakeholders in advance of management decisions being made. The concept of Participatory Management for local and indigenous people is central to the Ramsar Guidelines through the maintenance of sustainable livelihoods, including activities such as: fishing and hunting, farming and haying, reed harvesting and collection of forest products, salt extraction, recreational uses and ecotourism, and water for domestic consumption. Other benefits include: maintaining spiritual and cultural values associated with a wetland, more equitable access to wetland resources, increased local capacity and empowerment, reduced conflicts among stakeholders and maintaining ecosystem functions (e.g., flood control, improved water quality, etc.). Additionally it is seen that Government agencies benefit from participatory management arrangements through: improved ecosystem viability, reduced management costs, assistance with monitoring and surveillance, fewer infringements and enhanced social sustainability and quality of life for communities dependent on wetlands and riverine systems.
Rea, N & Anmatyerr Water Project Team, 2008.	NT	Provision for Cultural Values in Water Management: The Anmatyerr Story, Land & Water Australia Final Report 18, Canberra. http://www.aiatsis.gov.au/research/publications/Land&Water/pn30117.pdf Focussing on the Ti Tree region 200 km north of Alice Springs, the Anmatyerr Water Project Team have developed ways to identify, convey and provide for Aboriginal values in water plans. Cultural water provisions are a mechanism to

Reference	Region	Summary
		protect cultural values of water, similar to water allocations for other users. Recommendations include that Anmatyerr tyerrty and the Northern Territory Government develop an *Anmatyerr Water Agreement* to deliver the three major categories of cultural water provisions which are: 1. arrangements for non-volumetric provisions (language, protocols, access and co-existence, livelihoods, equity between Australian and Anmatyerr water Law and governance 2. a non-licensed volumetric water allocation to sustain water places and associated cultural and environmental assets or values 3. a licensed volumetric water allocation for current and future economic and cultural enterprises.
SAAL NRM (2013)	SA (GAB)	Everybody's land: A strategy for Aboriginal partnerships in the South Australian Arid Lands Natural Resources Management region Draft report for the SA Arid Lands NRM Board http://www.saalnrm.sa.gov.au/Portals/8/Our%20Community/Aboriginal%20partnerships%20strategy/20130313_Aboriginal_Partnerships_Draft_Strategy.pdf Establishes the guiding principles for SAAL Regional NRM commitment to incorporate traditional knowledge and culture to provide for effective partnerships with Aboriginal people: 1. Aboriginal people have rights and responsibilities for traditional lands and waters 2. Aboriginal cultural diversity, knowledge and obligation to country is acknowledged, respected and incorporated into decision making, 3. Information and knowledge regarding natural resources management will be shared and communicated in a culturally appropriate way, 4. Adequate time will be allowed for genuine and meaningful participation, 5. Adequate support will be provided for Aboriginal people to participate, 6. The partnership is based on fairness, equity and mutual respect, 7. The partnership is a learning process for all parties, and involves a long-term commitment, 8. Partnership initiatives and practices will be accountable within an overall integrated approach to natural resources management consistent with the SAAL Regional NRM Plan. The four key strategies to achieving partnerships with Aboriginal people include: 1. Building relationships 2. Partnership and capacity building 3. Delivery and resourcing 4. Governance and accountability.
Santos 2007	National, SA, NT & Qld	Procedure for the management of Indigenous Cultural Heritage Sites: A Handbook for personnel and contractors http://www.santos.com/library/Santos_cultural_heritage_handbook.pdf The mining company Santos has prepared a detailed and illustrated handbook of procedures to guide on-the-ground mining practices for their operations. The list of areas to be managed including the need for cultural clearance of sites and areas. It includes a section on Indigenous Australians' history and culture

Reference	Region	Summary
		including evidence through understanding stone artefacts and their significance, protecting indigenous cultural heritage sites, gaining understanding of site types and the range of evidence of occupation including mythological stories, scarred trees, stone arrangements, rock art, burials, campsites, shell middens, hearths (campfires), dwellings, raw materials sources (including quarries) and tool-making workshops. Broader understanding of landscape systems in order to avoid sensitive areas include sections on; inland sand dunes, lakes, rivers and claypans, floodplains and rockholes, wells, soaks and dams. Management aspects and project planning include a checklist on what do if a site is found and what to record and report.
United Nations (2008)	International	United Nations Declaration on the Rights of Indigenous Peoples, United Nations Article 25 http://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf Indigenous peoples have the right to maintain and strengthen their distinctive spiritual relationship with their traditionally owned or otherwise occupied and used lands, territories, waters and coastal seas and other resources and to uphold their responsibilities to future generations in this regard. Article 32 1. Indigenous peoples have the right to determine and develop priorities and strategies for the development or use of their lands or territories and other resources. 2. States shall consult and cooperate in good faith with the indigenous peoples concerned through their own representative institutions in order to obtain their free and informed consent prior to the approval of any project affecting their lands or territories and other resources, particularly in connection with the development, utilization or exploitation of mineral, water or other resources.
Wilderness Society & Qld Conservation Council (2004)	Qld	Caring for Queensland's wild rivers – Indigenous rights and interests in the proposed *Wild Rivers Act* *http://www.indigenviro.asn.au/Indigenous%20interests%20in%20Wild%20Rivers.pdf* Prepared for the original development of the *Wild Rivers Act 2004* this report establishes Indigenous rights and interests in Wild Rivers in order to set down the rights and responsibilities of traditional owners for their rivers. 'A new Wild Rivers Act offers a decisive opportunity for consideration of Indigenous peoples' interests in the conservation of land and waters in Queensland. It is a chance to remove the impacts that have so devastated the hydro-ecology of many parts of the continent, while reflecting the inter-relationship between indigenous environmental, spiritual and cultural values.' Discussion includes Indigenous rights and customary tenure, river conservation, conservation economy, Aboriginal land rights and native title and Indigenous interest in the Wild Rivers Act including legislating protection.

Mining exploration, production and cultural heritage values

This review of information produced by both mining companies and the various organisations who are involved and impacted upon by mining exploration and production also include references to a number of websites which produce a range of information on CSG and other mining operations in the study area and from a national perspective. The reports and information sheets are in some instances reviewed and alternatively the website links to their entire reports are included without review. The intent has been to identify the range of operators and companies in the study area to date.

Reference	Region	Summary
AGL (2013)	Qld	The Galilee Gas Project and Gas Exploration Fact Sheet http://agk.com.au/galilee/index.php/the-project/ http://agk.com.au/galilee/assets/pdf/Galilee-Gas-Exploration-Fact-Sheet.pdf The Project encompasses ATP 529P, which covers approximately 3953 km^2 in the Galilee Basin near Longreach in Queensland Maps locations, explains processes for public information. Covers seismic exploration methods and hydraulic fracturing. Exploration processes explained leading to future full scale production – suggests continuing to work with landowners, local suppliers and community – operations to be sympathetic to regions farming and other land uses. No mention of tourism and Aboriginal interests.
BHP Billiton (2009)	SA (GAB)	Olympic Dam Expansion Draft Environmental Impact Statement: Appendix P Cultural Heritage http://www.bhpbilliton.com/home/aboutus/regulatory/Documents/odxEisAppendixPCulturalHeritage.pdf The cultural and social aspects of the Olympic Dam study area are defined under a series of headings: Aboriginal Cultural Heritage, Non-Aboriginal Cultural Heritage and Defining Cultural Heritage. Additionally, detailed descriptions of the project area, chronology of events, previous assessments, places identified in field assessments and management recommendations are included. The structure and content of the range of EIS statements informs the basis of both literature and fieldwork research required by companies required to prepare such submissions.
Department of State Development	SA (LEB)	Department of State Development Coal Seam Gas website http://www.petroleum.dmitre.sa.gov.au/prospectivity/basin_and_province_information/unconventional_gas/coal_seam_gas The website focusses on the Arckaringa and Pedirka Basins in South Australia to explain to the general public the operational aspects and companies engaged in CSG feasibility programs. 'The sub-bituminous coals in the Arckaringa Basin have features (coal thickness, continuity and suitable depth) which make them appealing for CSG feasibility projects.' It lists the number of exploration sites, who and what arrangements are in place in conjunction with the South Australian government

Reference	Region	Summary
		oversight including access agreements with native title holders over the land. Linc Energy owns and operates seven PELs in the basin and is exploring for conventional hydrocarbons, shale oil and CSG in the basin. Department of State Development notes that most of the coal in the eastern Pedirka Basin appears to be too deep for CSG extraction using current technologies and in the western Purni Formation sub-bituminous coals are well developed at suitable depths. The Pedirka Basin is now fully under application for conventional oil and gas as well as CSG by Merlin Energy Pty Ltd, Stuart Petroleum Limited and Tri-Star Energy Company.
Epov, P 2011	NSW	Inquiry into Coal Seam Gas Submission 345 Manning Valley Alliance http://parliament.nsw.gov.au/Prod/parlment/committee.nsf/0/3e9ee06cfe880ffcca25790d00261f19/$FILE/Submission%200345.pdf Under a series of themes, this submission documents the concerns of an organised community group of locals and experts known as the Manning Valley Alliance in northern New South Wales. Their submission includes; consultation between government, industry and community, landholder rights, The CSG Myth, health concerns, food security, Council Infrastructure Levy, questionable technologies, advertising campaign by CSG industry, perceived political and bureaucratic corruption resulting in the following conclusion: 'It is the Manning Alliance Inc's opinion that based on the above environment, health and safety, and social implications of CSG mining which has been undertaken to date-considering that CSG mining has been banned and/or restricted in overseas countries, has been closed down by the EPA in the Margaret River Area of WA and operations have been closed down on health and safety aspects in Queensland, local councils within NSW have voiced their opinions that they do not want CSG mining in their area – it is our opinion that it is not realistic to ask that a total moratorium on CSG mining be placed within NSW whilst the true impacts of CSG mining operations are exhaustively and independently assessed.'
Galilee Basin Operators Forum	Qld (GAB, Galilee Basin)	Website for all mining and energy operators in the Galilee Basin that includes links to water reports and articles regarding groundwater mapping by CSG companies. http://www.gbof.com.au/
Hancock Galilee Pty LTD (2011)	Qld (GAB, Galilee Basin)	Kevin's Corner Project Environmental Impact Statement volume 1 2011 http://www.dlg.qld.gov.au/resources/project/kevins-corner-project/kevins-corner-executive-summary.pdf
Hancock Prospecting Pty Ltd (2010)	Qld (GAB, Galilee Basin)	Alpha coal Project Environmental Impact Statement http://www.dlg.qld.gov.au/resources/project/alpha-coal-project/alpha-coal-executive-summmary.pdf
Linc Energy	SA (GAB, Arckaringa)	Linc Energy corporate presentation 2013 http://www.lincenergy.com/data/asxpdf/ASX-LNC-465.pdf
Lloyd, D,	National	Community perspectives of natural resource extraction: coal seam gas mining and

Reference	Region	Summary
Luke, H & Boyd, W.E 2013		social amenity in Eastern Australia Coolabah, No.10, 2013, ISSN 1988-5946 Observatori: Centre d'Estudis Australians, Australian Studies Centre, University of Barcelona http://epubs.scu.edu.au/cgi/viewcontent.cgi?article=2476 "Using a recent case study of community reaction to proposed coal seam gas mining in eastern Australia, we illustrate the role of community views in issues of natural resource use. Drawing on interviews, observations and workshops, the paper explores the anti-coal-seam gas social movement from its stages of infancy through to being a national debate linking community groups across and beyond Australia. Primary community concerns of inadequate community consultation translate into fears regarding potential impacts on farmland and cumulative impacts on aquifers and future water supply, and questions regarding economic, social and environmental benefits. Many of the community activists had not previously been involved in such social action. A recurring message from affected communities is concern around perceived insufficient research and legislation for such rapid industrial expansion. A common citizen demand is the cessation of the industry until there is better understanding of underground water system interconnectivity and the methane extraction and processing life cycle. Improved scientific knowledge of the industry and its potential impacts will, in the popular view, enable better comparison of power generation efficiency with coal and renewable energy sources and better comprehension of the industry as a transition energy industry. It will also enable elected representatives and policy makers to make more informed decisions while developing appropriate legislation to ensure a sustainable future."
Rickson, K (2012)	Qld	Coming apart at the seams? Social Impact Assessment and the coal seam gas controversy in Queensland, Australia www98.griffith.edu.au/dspace/bitstream/handle/10072/.../82432_1.pdf *A review of* CSG 'mega-projects' and development, mining exploration permits covering most of the region on the Darling Downs area of the Surat Basin. 'Debates about whether the scale and pace of coal seam gas mining are booming ahead of scientific understanding and legislative protections and putting communities and environments irreversibly at risk have, however, become highly charged.' The safety of cumulative and longer-term impacts on aquifers and agriculture, including on the nation's food security, but also about the very future of Australia's rural and regional communities, environment and economy are under question. 'This paper examines these issues in relation to current and proposed provisions for social and environmental impact assessment including debates about the nature and role of social impact assessment in development decisions, and tensions over the legitimacy and science of assessment.'
RPS Ecos (2007)	SA (GAB, Arckaringa)	Arckaringa Basin Exploration Drilling Activities Environmental Impact Report http://www.pir.sa.gov.au/__data/assets/pdf_file/0020/57224/740-Arckaringa_Basin_Drilling_EIR-Rev2.pdf This Environmental Impact reports broadly on the Arckaringa Basin on the physical condition, scale and natural and cultural aspects of the region in the context of

Reference	Region	Summary
		exploration activities. Cultural aspects include heritage; Indigenous, historical and natural and nomination of sites, land use and potentially affected pastoral leases and conservation parks, socio economic aspects such as settlements, infrastructure and Aboriginal native title areas. Environmental hazards and consequences are discussed. Proposed activities include exploration drilling for conventional oil and gas and coal seam gas involving different types of drilling, using different rigs that are suitable for: Drilling wells for oil and gas, drilling coreholes (and encapsulating the core to capture gas within it) to evaluate coal seam gas potential and drilling wells for coal seam gas. It specifies guidelines for activities on land systems including wetlands and springs, drainage lines and floodplains and salt lakes.
Storey, K (2010)	International (USA/AUS)	Fly-in/Fly-out: Implications for Community Sustainability Sustainability 2010, 2, 1161-1181:doi:10.3390/su2051161 www.mdpi.com/2071-1050/2/5/1161 'Fly-in/fly-out' is a form of work organisation that has become the standard model for new mining, petroleum and other types of resource development in remote areas. In many places this no town model has replaced that of the new town. The work system has both beneficial and adverse implications for the sustainability of both existing communities near new resource developments and for the more distant communities from which workers are drawn. This paper explores these outcomes drawing upon examples from Canada and Australia, including the Surat Basin.
Williams J., Stubbs T. & Milligan A. (2012)	National	*An analysis of coal seam gas production and natural resource management in Australia* A report prepared for the Australian Council of Environmental Deans and Directors by John Williams Scientific Services Pty Ltd, Canberra, Australia. http://www.wentworthgroup.org/uploads/An%20analysis%20of%20CSG%20production%20and%20NRM%20in%20Australia%20Oct%202012%20FULL.pdf Section 4 of the report includes the economic and social considerations involved in CSG production. It discusses the legislative frameworks in operation in NSW and Queensland but not in the Northern Territory or South Australia. Section 7 reviews CSG production and the protection of water resources and aquatic ecosystems including the protection of biodiversity and landscape function via vegetation and habitat management, the issue of fugitive leaks of methane in CSG production and its place in climate-change mitigation policy and considerations the of economic and social impacts of CSG production.

Media and social commentary CSG mining

The range of commentary on CSG and other mining operations is substantial from international to local opinions and information sharing. While not formally referred or reviewed for accuracy, these social networking sites often provide the most up to date information and community opinion, support and/or concerns regarding the industrialisation of the landscape and its benefits and impacts. For the purposes of this review, only one of the numerous sites has been selected here to demonstrate the types of networks and commentary posted.

Reference	Region	Summary
Western Downs Alliance (2012)	Qld	Western Downs Alliance Website http://westerndowns.group-action.com/2012/06/18/which-companies-are-drilling-for-coal-seam-gas-in-australia/ Links to reports, blogs and news items regarding coal seam gas operations and fraccing internationally and nationally. 'Our Philosophy: The right to have clean air, The right to have clean water, The right to lead our lifestyle free from interference, Recognition of freehold [fee simple] land to its full interpretation, To raise awareness about the dangers of hydraulic fracturing to our environment and human health, To expose gas and oil companies who use unsafe and exploitive methods in their operations, To hold our democratically elected representatives accountable for their actions in dealing with gas and oil companies.'

Government policy and management

Reference	Region	Summary
Australian Government	National	*Indigenous Australians Caring for Country*. At: http://www.environment.gov.au/indigenous/index.html This site lists and presents all the objectives funding and projects associated with the Caring for Country initiative (does not specifically cover GAB arid lands).
DERM (2011g)	Qld (LEB)	***Cooper Creek Basin Wild River Declaration Consultation Report*, Department of Environment and Resource Management, Queensland.** www.ehp.qld.gov.au/wildrivers/georgina.../pdf/consultation-**report**.pdf 'Under the Wild Rivers Act, the Minister (in the previous Bligh Government of Queensland) can propose any part of Queensland for consideration as a wild river area. A wild river area includes the wild river or rivers and their catchments. A wild river area is declared through approval of a wild river declaration which is a statutory instrument that describes: • the wild river area • any wild river requirements • in which circumstances parts of the Wild Rivers Code or other development assessment codes apply. The Wild Rivers Code is a development planning document that specifies the outcomes that a development must meet for approval. These required outcomes aim to minimise impacts on the natural values that could otherwise result from development activities in the catchment. The Wild Rivers Act is currently under community consultation in order to repeal sections of or the Act in its entirety. The result may allow greater provision for water use and extraction from Queensland Wild Rivers, including those in the Galilee Basin and with impact upon the Cooper Creek and Diamantina River systems.'
LEB Ministerial	LEB	Lake Eyre Basin 2012 Minister's Report to the Community: Australia's unique natural

Reference	Region	Summary
Forum (2002)		desert river system-healthy environments, sustainable industries, vibrant communities, adaptive cultures. http://www.lebmf.gov.au/publications/pubs/leb-ministers-report-2012.pdf The 2012 LEB Minister's Report Includes an overview of the five year plan – rivers assessment, the Strategic Adaptive Management (SAM) framework, an update on Tourism and the LEB and the LEB Aboriginal Map and Booklet. The LEB Minister's Report over the years provides a history of the LEB, its condition and management since the inception of the LEB organisational authority.
National Water Commission (2012)	National	Indigenous access to water resources: Position statement http://nwc.gov.au/__data/assets/pdf_file/0009/22869/Indigenous-Position-Statement-June-2012.pdf Access to water resources for cultural and economic purposes can make a significant contribution to the aspirations and wellbeing of Indigenous Australians. Until recently this has been largely overlooked in our water planning and management decisions. The National Water Initiative (NWI) recognises Indigenous people as legitimate stakeholders in water planning and management, and acknowledges the need to identify Indigenous water values and water requirements in water plans Priorities: water for culture, water for economic development including access, leadership and governance recognising leadership bodies such as the First People' Water Engagement Council. Water Planning to build capacity and knowledge and remote community drinking water security.
RPS (2011)	National	Onshore co-produced water: extent and management http://nwc.gov.au/__data/assets/pdf_file/0007/18619/Onshore-co-produced-water-extent-and-management_final-for-web.pdf This report is designed to raise and discuss issues regarding the current and future extent of co-produced water and the management options for water produced during the oil and gas extraction process. It is acknowledged that some regulators, industry and stakeholders have been addressing CSG co-produced water issues for some time. The National Water Commission's interest is in the sustainable management of all water resources, including coproduced water. The scope of the paper includes only the volume and management of coproduced water associated with onshore (land-based) oil and gas reserves. There are two types of reserves: conventional (natural gas and oil) and unconventional (gas from coal seams). While it is recognised that there are broader impacts on other water users—including the environment—associated with CSG development, the focus of this paper is on the practical management of co-produced water at the surface.
SAAL NRM	SA (GAB)	SAAL NRM Biodiversity Strategy *http://www.environment.sa.gov.au/Conservation/Ecosystem_conservation/Biodiversity_strategy_-_SA_Arid_Lands* The Strategy provides an overarching framework to halt, and where possible reverse, the decline in the region's terrestrial and aquatic biodiversity over the next ten years. The Strategy consists of six documents. Volume one identifies the region-wide goal

Reference	Region	Summary
		for biodiversity conservation and sets resource condition targets, management action targets and regional strategies to achieve this goal. Volumes two to six are separate documents, each identifying conservation priorities for each of the bioregions in the South Australian Arid Lands. The areas of interest to this study and its occupants and communities are the sandy deserts, stony plains and channel country bioregions which provide the context for landscape assessment and land management processes and programs.
Wakelin-King & White (in prep.)	Channel Country	The National Heritage potential in Australian desert landscapes Within the Australian arid zone, this paper delineates a number of places that pass National Heritage criteria, including Cooper Creek (Windorah to Nappamerry reach), Cooper Creek (Innamincka Dome), Strzelecki Desert, and the Neales River. The criteria which these areas achieve the threshold values include events and processes, research, principle characteristics, aesthetic, and social. The social criteria, in this case, relates to the importance on a national and global scale of the information uncovered by research in the LEB: 1. In geology modern environments are studied to understand the depositional environments found in the geological record. The Cooper Creek (especially the Windorah to Nappamerry reach) is almost the only modern analogue for a very important lithotype; it is significant on a world scale. 2. The Cooper in the Strzelecki Desert is significant on a national scale for its capacity to reveal Australian palaeoclimatic information.

3.5. Gaps

Reference	Region	Summary
Barma & Lowe (2012)	National	Low-flow hydrological monitoring and modelling gaps Comprehensive review of monitoring and modelling low flows and gaps in our capacity to model and manage these flows. The report is more focussed on gauged rivers and streams in eastern Australia but does touch upon waterhole hydrological processes. It identifies that the understanding of processes driving low flows is poorly understood and this is particularly so in the LEB. The report has a useful summary of modelling methods and hydrological variables describing low flow conditions that have ecological relevance.
Clifford et al. (2010)	Qld (LEB)	Stream and Estuary Assessment Program, Lake Eyre and Bulloo Province Stressor Prioritisation Workshop Report Stressor models with low levels of confidence were: • Sediments • Climate change • In-stream pest species (flora).
Duguid (2011)	NT (GAB)	Wetlands of the Great Artesian Basin Water Control District (Northern Territory) Many wetlands in the area are not mapped, of those that are, the type is not known; knowledge of their conservation significance would be improved through systematic

Reference	Region	Summary
		mapping combined with field survey of biological values. Lack of information about hydrology.
GA & Habermehl (2010)	Qld	Summary of advice in relation to the potential impacts of CSG extraction in the Surat & Bowen Basins Highlight uncertainty in assessing cumulative, regional scale risks from multiple assessments. Need for regional groundwater models. Although improved groundwater models may be developed, these will have high inherent uncertainties due to lack of CSG production data.
LEBSAP (2009b)	LEB	LEB Knowledge Strategy Identifies key knowledge gaps for the LEB with the over-arching question: • What knowledge is required to improve our understanding of, and support informed decision making about the water and related natural resources of the Basin? Knowledge gaps relevant to LEBRM are: A: What limitations on our understanding of surface and groundwater constrain our ability to manage the surface and groundwater resource of the Basin? • A1: How might climate change affect of rainfall variability and temperature, and hence flow patterns and persistence of waterbodies? • A2: Where and how are groundwater and surface water systems connected? To what degree is the persistence of water holes dependent on surface flows? • A3: How should we manage waterholes – grazing, abstractions, groundwater linkages B: What are the impacts of present and future land use (e.g. land clearing, pastoral activities, mining) on quantity and quality of surface and groundwater? • B1: What are the changes in catchment and river health that are not yet evident but are likely to occur over the next 30 years from decisions already taken? • B2: What are the impacts of levees, road/rail links on water flow and the health of floodplains? • B3: What are the impacts of present and likely future land use on run-off within the catchment? C: How do we measure the health of rivers, waterholes, terminal lakes/wetlands? Can trends be detected? • C1: Where are the key aquatic refugia, what are the processes that sustain them & what are the threatening processes? • C2: What threatened (aquatic) species and communities exist, where are they, & what are the threatening processes? • C3: What are the risks (to aquatic systems) from non-endemic species – present and potential? Where are they? • C4: What are the likely impacts of water use on aquatic biodiversity and river health? D: What is the current catchment health (baseline assessment)? • D1: Where are salinity hazards and impacts of vegetation management on shallow groundwater?

Reference	Region	Summary
		F: What are the values and aspirations of key stakeholders across the LEB? • F2: What are the values associated with water – particularly from an Indigenous perspective? • F3: What are the creation/dreamtime stories that are attached to Basin springs, water bodies and other waterways?
LEBSAP 2008	LEB	State of the Basin 2008: Rivers Assessment Information limitations affecting river and landscape management: • Potential impacts of future climate change • Lack of baseline data • Lack of long-term studies to monitor change • Insufficient whole-of-basin scale planning • Lack of comprehensive understanding of the location, function and management requirements of refugia • Relationships between surface and groundwater.
McNeil & Schmarr (2009)	SA (LEB)	Recovery of Lake Eyre Basin Fishes Following Drought: 2008/09 Fish Survey Report Future research recommendations.
Miles & Risby (in prep.)	SA (LEB)	LEB Strategy Scientific Report Seventeen key knowledge gaps for determining EWRS of SA LEB rivers are listed and catchments to which they apply are identified with recommendations for investigations or modelling options provided. Knowledge gaps: • Identification of assets, threats and assessment of risks • Potential climate change impacts on flows and other environmental drivers and the tolerance thresholds of biota to those changes • Classification of flow regime components and importance for each catchment and reach • Distribution of vegetation associations/ flora species/ functional groups at an appropriate scale • Distribution of fish • Water requirements of vegetation functional groups • Water requirements of fish species/ functional groups • Location of aquatic refugia • Classification of aquatic refugia (cease-to-flow level, depth, salinity, connectivity with groundwater) • Importance of littoral algae and rate of draw-down to maintain littoral algae • Method for determining condition of fish populations • Method for determining condition of vegetation • Long term and current daily flow • Hydrological models • Metrics/statistics for flow regime components • Current extractions and diversions • Infrastructure impacting flows.
Moran & Vink (2010)	National	Assessment of impacts of proposed CSG operations on S&GW systems in the MDB Impacts of subsidence at land surface and potential to fracture aquitards
Silcock et al.	Qld (LEB)	Assessing rarity and threat in an arid-zone flora

Reference	Region	Summary
(2011)		With the exception of spring-dependent species, plant conservation in western Qld is currently constrained by lack of basic data on distribution, abundance, population dynamics and realistic threat syndromes for nearly all species. Separating the influence of genuine rarity, temporal rarity and low collection effort, as well as a more detailed understanding of threatening processes are needed to address plant conservation in the arid zone Relevance: All flora in WQld is presented: Rarity is discussed including a 'definition' and forms. The need to understand threatening processes is discussed.
Takahashi et al. (2011)	Qld (MDB)	Stream ecosystem health response to CSG water release: decision support system Gaps: • Cumulative impacts • Baseline monitoring • Sensitivities of biological components.
Wakelin-King (2010)	Neales	Geomorphological assessment and analysis of the Neales Catchment An analysis of the fluvial function of the Neales River catchment identified the following topics for further research: 1. The nature and speed of gullying in the floodplain, especially with respect to different types of land use 2. The nature and development of the extremely large arroyos leading down to the Neales Delta, with respect to tectonic setting and historical documentation 3. Identification of old roads in the Algebuckina Crossing 4. Detailed assessment of the floodplain shadow bars, ideally including dated palynology of sediments 5. The palaeoflood record of the rivers, and its relationship to channel relocation and waterhole abandonment 6. Landscape evolution of the Tardetekarrina Waterhole, especially its post-European loss, and a general geomorphology of the Neales-Peake confluence 7. Landscape processes at the Blythe-Peake confluence, especially with respect to a possible failed waterhole 8. Observed flow hydrology allowing derivation of roughness values (i.e. Manning's n) for vegetated channels and floodplains. Also, the Neales study was a short time and a broad scale. More detailed investigations of fluvial processes and landscape history will undoubtedly deliver further new information.
Williams et al. (2012)	National	An analysis of CSG production and NRM in Australia Water resource related gaps: • Whole of system approaches to manage crossovers and feedbacks between energy production, biodiversity, climate change, water resources, agricultural production. • Interactions between CSG production, climate change and water resources through whole-of-life energy analysis • Tools for cumulative risk analysis and impact assessment • Capacity to determine volumes of water that will be extracted during CSG operations

<table>
<tr><th>Reference</th><th>Region</th><th>Summary</th></tr>
<tr><td></td><td></td><td>
Information on toxicity of extracted water for release into watercourses
Review of the references shows general lack of meaty/scientific research, generally all based on predictions.
</td></tr>
<tr><td>AETG (2012e)</td><td>LEB</td><td>
LEB HCVAE Pilot Project

Knowledge gaps for the identification of HCVAEs (p. 76):
Table 11: Summary and prioritisation of knowledge gaps.
<table>
<tr><th>Location / scale</th><th>Knowledge gap</th><th>Priority</th></tr>
<tr><td>National</td><td>Development of aquatic bioregionalisation – DEM-derived and catchment bound</td><td>Medium</td></tr>
<tr><td rowspan="5">South Australia</td><td>Macumba catchment – nothing known. Requires species sampling, improvements to mapping and classification (high priority)</td><td>High</td></tr>
<tr><td>Improvements in SA LEB mapping – GA 250k mapping with remote sensing information requires simplification of line work and alignment with other jurisdictions</td><td>High</td></tr>
<tr><td>Improvements in SA LEB AE classification through desktop analysis and remote sensing – to enable modelling of ecosystem function and habitat in a data poor area and to ID permanent aquatic ecosystems in the western catchments</td><td>High</td></tr>
<tr><td>Incorporation of data into State databases:
Flinders springs (med priority)
GAB springs mapping, water levels, species and classification (high priority)
AridFlo data (low priority)
Jenny Silcock's permanent waterbodies mapping (high priority)
Updates to species data (low priority)</td><td>High to Low</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="5">Northern Territory</td><td>Continued improvement in existing mapping with a priority to those areas of high relief that prove difficult to map from Landsat imagery.</td><td>High</td></tr>
<tr><td>Further validation of existing remotely sensed water body mapping from aerial surveys, ground truthing, landholder feedback and expert knowledge</td><td>High</td></tr>
<tr><td>Research of Landsat band ratio capabilities in detecting wetland extent</td><td>Medium</td></tr>
<tr><td>Development of Web based Northern Territory Wetland Information System</td><td>High</td></tr>
<tr><td>Development and application of HCVAE methodology to NT significance</td><td>Medium</td></tr>
</table>
</td></tr>
</table>

4. References Spreadsheet and Document Library

An associated product of the Literature Review is a References Spreadsheet and electronic Document Library. The references spreadsheet contains full references for each document reviewed and:

- Links to the document website if it is available on-line (in the case of journal articles the link is to the abstract)
- Links to the document in the document library, if an electronic copy of the document was obtained
- A one sentence summary of the findings or conclusions relevant to the LEBRM project
- Coverage: the geographic area to which the document applies
- Links to project data: project data are presented in a worksheet (discussed below), to link to the project data use Ctrl+Shift+F
- The major topics of the literature review that the document provides information about.

Using filters, the spreadsheet can be searched by coverage and topics.

The data worksheet lists the research project datasets that have been collected in the LEB, the majority of which are not stored in government data-bases. The LEBRM project has not obtained copies of the data, but has identified the data that exists that may be used to inform baseline assessments, modelling and other requirements of the bioregional assessment.

The References Spreadsheet and Document Library will be provided along with the Literature review to the LEB bioregional assessment. The products may be incorporated into existing database for the LEB such as WISE (Water Information System for the Environment, http://www.wise.unsw.edu.au/wise_v5.html), LEBRRIS (Lake Eyre Basin Regional Resource Information System) or a new database if one is to be developed for bioregional assessments.

5. Data deliverables

Four data deliverables have been produced for the LEBRM project:

1. Data stack
2. Data register
3. Interactive GIS
4. Maps

5.1. Data Stack

All data found to be relevant to the LEBRM project stored in windows operating system folders. This includes spatial and non spatial data in the following formats:

- ESRI Shapefiles
- ESRI raster Grids
- ECW images
- ESRI Personal and File Geodatabases
- Microsoft Access 2003 and 2007 datbases
- Excel spreadsheets
- Associated documentation and metadata files.

5.2. Data Register

An excel spreadsheet which lists all of the data included in the data stack. Data has been broadly categorised by national/state coverage and further categorised in pivot tables through the use of types and sub-types. In this format the data can be filtered and searched. The data register also contains links to available metadata, links to the stored data location, and general information about each dataset. In addition the data register contains links to internet resources which may include datasets available for download /viewing.

5.3. Interactive GIS

All spatially enabled data collected in the data stack and referenced in the data register has been added to a single ArcMap 9.3.1 mxd file. Data has been sorted into group layers which replicate the structured categorisation used in the data stack and the data register. The mxd file has also been used to generate an ArcReader package which can be viewed using free viewing software included with the data stack.

All three of the above products have been designed to work as a cohesive framework for the capture and viewing of data for the remaining phases of the project. A guide has been produced which outlines the data capture methodology and the relationships between these three deliverables.

5.4. Maps

A series of contextual maps produced using data included in the data stack. These show the location of the project area, key assets and areas of interest as well as water and topographic features.

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