Sustainable Minerals Institute

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA
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# Lake Eyre Basin Synthesis Report

**Final**

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# Executive Summary

The Queensland Government is undertaking a review of the current protection of the rivers and floodplains of the Lake Eyre Basin in Queensland (referred to as LEB initiative). The basin includes the catchments of Cooper Creek, Georgina and Diamantina Rivers and is one of the world's last arid river systems where water can flow freely without any obstruction from major infrastructure, such as large dams. The hydrology specific to the region has led to complex and unique ecosystems, supporting aquatic organisms (fish, turtles), waterbird breeding colonies, large populations of waterbirds (several millions during major floods) and high numbers of migratory bird species. Floodplain swamps provide breeding grounds for at least one endangered species under the EPBC Act, the Australian Painted snipe. They are at least three native fish species under threat of extinction (the Cooper Creek catfish, the red-finned blue eye and the Edgbaston goby), who depend on springs or waterholes.

Environmental and cultural values need to be balanced against the potential cumulative threats arising from the grazing, tourism and resource sectors while maximising the economic return from those sectors. The LEB overlies geological basins which are targets for petroleum and gas exploration, development and extraction, with the Cooper geological basin identified as one of the geological basins with the greatest potential for additional delivery of conventional or unconventional gas to the East Coast gas market within the next five to ten years.

A range of studies were commissioned to assess the extent of environmental and cultural values, understand the potential risks from development of economic activities and the suitability of existing regulatory frameworks to manage or mitigate these risks. They included:

- A review by an independent scientific expert panel who completed a risk assessment of potential impacts from activities related to conventional and unconventional petroleum and gas extraction, mining, agriculture, tourism and infrastructure.
- An assessment of scientific knowledge related to the potential impacts of shale gas and shale oil extraction, compiling findings from national and international scientific literature.
- A geological and bioregional assessment for the Cooper geological basin, which occurred in three consecutive stages. The third one comprised a comprehensive body of technical work, with collection of large spatial data sets and scientific investigations on ecosystems' extent, condition and sensitivity to gas resource development, hydrological and flood modelling, relationships between flood water and vegetation communities, interactions between surface water and groundwater, and risks associated with hydraulic fracturing.

These studies and associated reports provide a large amount of information, but the level of details and the scope vary from study to study. The review by the independent scientific expert panel considered the whole extent of the LEB within Queensland, evaluated a range of economic activities and relied on a qualitative risk assessment methodology. The assessment of scientific knowledge related to impacts of shale gas and oil extraction had a Queensland-wide scope, with findings derived from a high-level qualitative assessment based primarily on literature from North America. Cumulative impacts were out of scope. The bioregional assessment was constrained to the Cooper geological basin, solely evaluated the extraction of unconventional gas and produced a fully quantitative assessment of risks. Many of the qualitative assessments provided by the expert panel were confirmed by the quantitative studies undertaken as part of the bioregional assessment.

All studies clearly establish that the Lake Eyre basin has unique environmental values of state, national and global significance. There is a shared understanding of the key biophysical processes and associated environmental values, their significance, and the need to protect them. The major difference is that the independent scientific expert panel evaluated the effectiveness of the current regulatory framework and concluded that it would not deliver adequate protection of environmental values; in contrast, the bioregional assessment assumed that the current regulatory framework was effective, without testing this assumption. There is a clear example for which this assumption is not valid: under the Water Act and associated water plans, an approved water extraction can still lead to impacts on environmental values, as water plans do not consider potential localised impacts on groundwater systems, groundwater-dependent ecosystems and cultural values, and do not include the impacts of climate change on water availability. This constitutes the most significant and easily identified gap in the regulatory framework.

Similarly, the assessment of scientific knowledge related to impacts of shale gas and oil extraction assumes that most impacts should be covered under the current regulatory framework, without assessing its effectiveness. However, the qualitative risk assessment undertaken as part of this review does identify several impacts that may require additional attention during the assessment and approval process, largely related to water.

There are knowledge gaps concerning the understanding of protected matters, with a lack of accurate records of the spatial distribution of threatened and migratory species, of accurate mapping of species habitat and no detailed knowledge of ecology, distribution and threats to individual threatened species. This is an area of concern given all studies highlight the unique ecological values of the region.

Finally, climate change is a significant threat with the potential for direct and indirect effects on water resources, riverine ecosystems, biodiversity and endemic species. The current regulatory framework is not designed to address this, as it is only concerned with assessing the impacts of proposed activities.

# 1. Introduction

The Queensland Government is undertaking a review of the current protection of the rivers and floodplains of the Lake Eyre Basin in Queensland (referred to as LEB). The basin includes the catchments of Cooper Creek, Georgina and Diamantina Rivers and is one of the world's last arid river systems where water can flow freely without any obstruction from major infrastructure, such as large dams.

Grazing of both sheep and cattle is the key industry in the LEB. It relies on the environmental features of the region, such as waterholes for stock watering, natural flow regimes, and vast areas of native grasslands on the floodplains. Grazing is worth $65 million per year with single large floods increasing this value by up to $150 million (Holland et al., 2021).

The LEB overlies geological basins which are targets for petroleum and gas exploration, development and extraction. In particular, the Cooper geological basin underlies a large proportion of the Cooper Creek surface water catchment. Figure 1 shows the location of the Lake Eyre Basin and the extent of the Lake Eyre catchment and of the Cooper geological basin in Queensland. The Cooper basin has been assessed as being one of the geological basins in Queensland with the most potential for additional delivery of conventional or unconventional gas to the East Coast gas market within the next five to ten years. Most of the Cooper basin is covered by exploration permits and production licences, with 3,000 existing petroleum wells. Activities related to exploration and development of conventional and unconventional gas resources are continuing (Holland et al., 2021).

There are also tourism activities, with recreational visitors travelling either by coaches with organised tours or with their own car (four-wheel drive) to experience the natural landscapes, towns, local culture and camping. The major town is Windorah (115 residents recorded by the 2016 Census). There are few permanent residents in the region, with most of the resource development workforce operating as "fly in – fly out" (Holland et al., 2021).

Ecological values include unobstructed flow of surface water and a wide range of groundwater-dependent ecosystems and the biodiversity they support. These values need to be balanced against the potential cumulative threats arising from the grazing, tourism and resource sectors while maximising the economic return from those sectors. In addition, the cultural values of the traditional owners need to be maintained. The LEB initiative is seeking to ensure that the adequate protection of the Lake Eyre Basin values is balanced with economic development. To support the initiative, a range of studies were commissioned to assess the extent of environmental and cultural values, understand the potential risks from development of economic activities and the suitability of existing regulatory frameworks to manage or mitigate these risks. The purpose of this synthesis report is to summarise findings from these studies, outlining the methodologies that were used to derive them, the differences that emerge, the limitations and knowledge gaps, and evaluation of whether the current regulatory frameworks can provide adequate protection of environmental values within the framework of ecologically sustainable development.

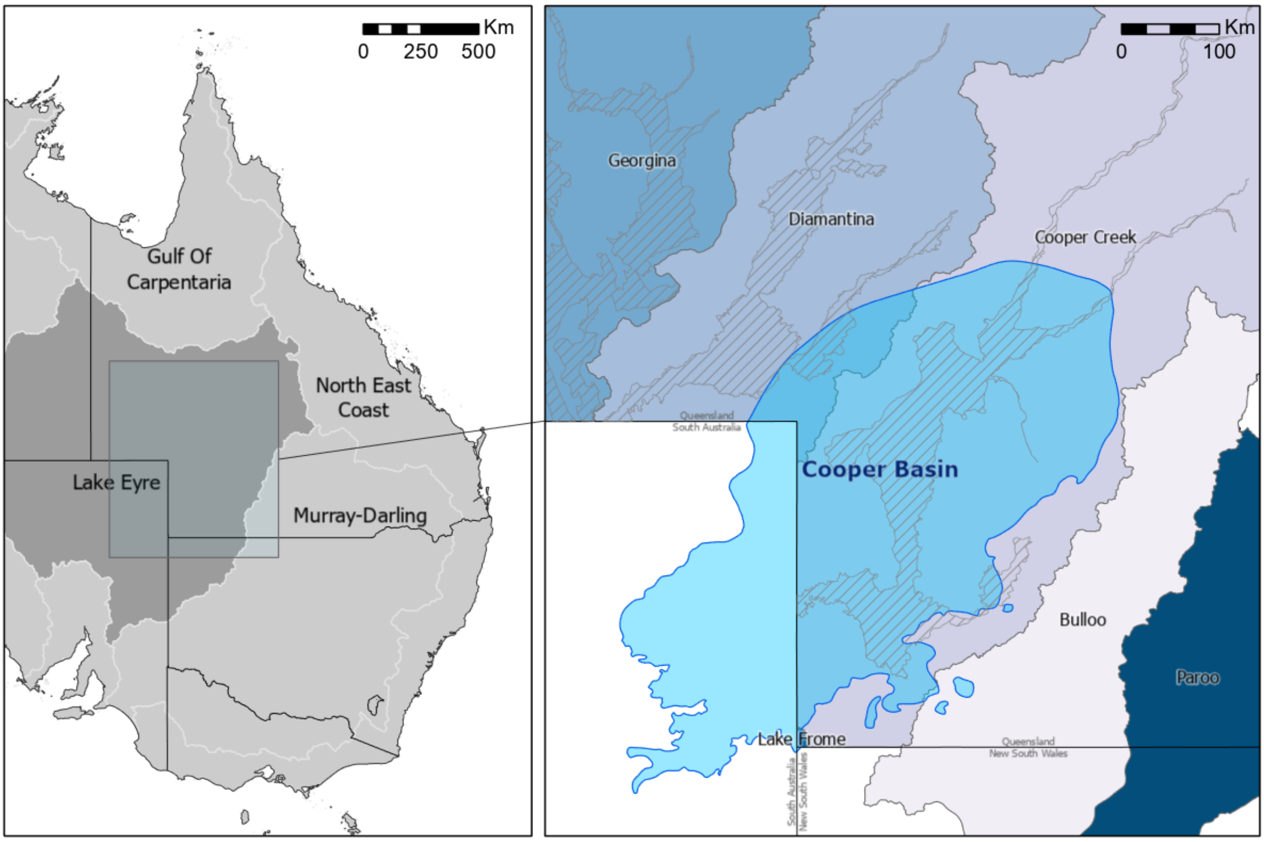


Figure 1: National catchment boundaries showing the extent of the Lake Eyre catchment (left), and the extent of the Lake Eyre Basin and of the Cooper geological basin in Queensland (right). The area denoted by hash lines shows the extent of the Strategic Environment Area and Designated Precinct (Section 4.2).

## 2. Objectives

The objectives of this report are to

a. Provide synthesis of the information and scientific findings from available studies, outlining their scope, methodologies, limitations and the knowledge gaps they establish.

b. Outline the differences that emerge and if appropriate, the reasons that can explain them (study scope, study spatial domain, methodology, status of available information).

c. Summarise the conclusions that can be drawn from the findings and their relevance to the LEB initiative.

d. Indicate whether the findings are sufficient to deliver the aims of the LEB initiative and if not, articulate the additional knowledge that is required to complement existing findings.

# 3. Methodology

The information that was reviewed included reports prepared as part of:

- A review by an independent scientific expert panel (SEP) who completed a risk assessment of potential impacts from activities related to conventional and unconventional petroleum and gas extraction, mining, agriculture, tourism and infrastructure, and provided recommendations to inform the review of the current protection of the rivers and floodplains of the Lake Eyre Basin (Fielder et al., 2019). This study is referred to as “SEP Review”.
- An assessment of scientific knowledge related to the potential impacts of shale gas and shale oil extraction (Huddlestone-Holmes et al., 2018). This report compiles findings from national and international scientific literature, particularly from North America, where shale gas and oil development are well-established industries and their impacts are well documented; and from existing activities in Queensland, such as coal seam gas extraction. This study is referred to as “Shale Gas and Oil Knowledge review”.
- A rapid regional prioritisation process (Hall et al. 2018), to identify the basins with the greatest potential for shale and tight gas development, in eastern and northern Australia, within the next five to ten years. This is referred to as Stage 1 of the Geological and Bioregional Assessments Program. It is this Stage 1 report which states that the Cooper basin has the greatest potential for delivery of conventional or unconventional gas. This study is referred to as “Stage 1 Bioregional Assessment”.
- A second stage of a geological and bioregional assessment, focused on the Cooper geological basin (Holland et al., 2020). It provides a baseline analysis of the environmental values in the Cooper basin and identifies potential impacts from all life-cycle stages of shale, tight and deep coal gas development. The study is supported by detailed technical appendices on the topics of hydrogeology (Evans et al., 2020), hydraulic fracturing and well integrity (Kear et al., 2020), hydraulic fracturing chemicals (Kirby et al., 2020), protected matters (O’Grady et al., 2020) and geology (Owens et al., 2020). This study is referred to as “Stage 2 Bioregional Assessment” with mention of the specific technical appendix when relevant.
- A third stage of the geological and bioregional assessment, focused on the Cooper geological basin (Holland et al., 2021), which analyses the potential impacts of gas resources development on water and the environment, and proposes mitigation and management measures. This study is referred to as “Stage 3 Bioregional Assessment”. It represents a large and comprehensive body of work, with additional scientific investigations on hydrology, flooding, ecosystems and risks associated with hydraulic fracturing. It also includes a methodology to assess the regional-scale risks of gas resource development on water and the environment. A synthesis report describes the methods and assessment results and will be referred to as “Stage 3 Bioregional Assessment”.

These studies and associated reports provide a large amount of information, but the level of details and the scope vary from study to study. This synthesis report aims at outlining where differences in scope and intent may impact on findings and recommendations.

## 3.1 Shale Gas and Oil Knowledge Review

The aim was to identify the potential environmental impacts of shale gas and shale oil (shale gas and oil) extraction in Queensland, the potential impacts on other industries, including agriculture and tourism, and how these impacts are managed under the current Queensland regulatory framework.

The report provides an assessment of the current scientific knowledge of the potential impacts of shale gas and oil activities for regulators, governments and the community to consider as they seek to manage, respond to and understand this emerging industry. The scope was confined to gather existing knowledge from a range of sources, with no analysis or modelling of development scenarios.

The potential impacts that were assessed were related to water (quantity of water consumed; surface spills that could cause contamination; requirement for storage, treatment and discharge of flowback and wastewater; flow of contaminants underground; long-term implication for abandoned wells), land disturbance and associated erosion resulting from surface infrastructure, land contamination, habitat loss, flora and fauna health.

The spatial scope of this study is wide as findings are applicable to any extraction project. However, while the report establishes that potential impacts are well documented, the likelihood of occurrence and consequences will be determined by the environment in which they occur, and by the mitigating controls that are in place. The findings are based on a high-level qualitative assessment based primarily on literature from North America. They focus only on direct impacts and do not assess indirect or cumulative impacts. Impacts on human health were not included. The report also clearly states that impacts specific to the Queensland context, and to arid environments similar to the Lake Eyre Basin, are not strongly represented in the literature.

## 3.2 SEP review

In 2019, an independent Scientific Expert Panel (SEP) was commissioned to deliberate on the Lake Eyre Basin and its river catchments in Queensland. Experts were invited from a broad cross section of academic, consulting, industry and government scientific organisations, including past and current members of the Independent Expert Scientific Committee on Coal Seam Gas (CSG) and large coal mining development and LEB Scientific Advisory Panel. The primary purpose for the SEP was to provide scientific advice, complete a risk assessment of potential impacts from the activities of conventional and unconventional petroleum, and gas, mining, agricultural practices, tourism and infrastructure, and to provide recommendations to inform the review of state policy, legislation and administrative frameworks to ensure the long-term ecological sustainability of Queensland's free flowing rivers.

The methodology was based entirely on gathering the knowledge held by the panel members, with reference to the literature. There was no process of data collection and no new investigation, and no access to the information generated by the bioregional assessment, as the SEP review preceded it. The spatial scope concerned the Queensland Lake Eyre basin, including the Cooper Creek, Georgina and Diamantina Rivers catchments. The panel members undertook a group activity during which they walked over a large fabric printed map of the catchments, facilitating discussion of ecological processes, ecological functions, connectivity and ecological values for each catchment. The panel evaluated a range of economic activities, not constrained to gas extraction. Two case examples (or scenarios) were provided to the SEP to allow for discussion and thought on the challenges to the LEB (Qld) on emerging and cumulative risk likelihoods. These scenarios were to be assessed under the current regulatory framework in Queensland:

- Development application for a petroleum activity with 250 production wells and ancillary infrastructure in the Diamantina River floodplain.
- Development application for a petroleum activity with 500 production wells and ancillary infrastructure in the Diamantina River floodplain, with proposed activities taking place over 50 years and assuming the LEB (Qld) was developed into a significant resource hub, with mining and petroleum activities, rail access, improved and unimproved roadways. In this scenario, there would be cumulative impacts from all the different development activities and the SEP were asked to assess them.

These scenarios are mentioned in the SEP review report but there is no specific detail describing how they were used to inform the findings. They are to be interpreted as triggers the panel members relied on to ensure all risks were considered and assessed, many of which are not related to petroleum and gas activities. The risk assessment was based on a standard methodology, using likelihood, consequence and risk ratings from existing risk assessments of conventional and unconventional petroleum and gas extraction activities, including the Shale Gas and Oil Knowledge Review. The outcomes from the risk assessment were then used to define the recommendations, with deliberations occurring over a two-day workshop and not an extended timeframe.

## 3.3 Stage 1 Bioregional Assessment

The objective was to identify and prioritise the geological basins with the greatest potential for shale and tight gas development, in eastern and northern Australia, within the next 5-10 years. The spatial extent covered a large proportion of Eastern and Central Australia, as it considered most geological basins. Details are shown in Figure 2 in Appendix A (originally Fig. 5.3 of Hall et al. (2018)). It was conducted as a "desktop study", meaning that it relied on the collation of existing data sets with no new physical investigation to collect additional information. Collated data sets included petroleum data, geology, shale and tight gas prospectivity (potential for these resources to be present and extractable).

The conclusions from this report that are most relevant to the LEB initiative are that:

- The Cooper basin is ranked highest in terms of both prospectivity and confidence, reflecting the extensive exploration data collected to date;
- While Queensland has no current exploration and development restrictions on shale oil and gas, within the Cooper basin there are protected areas, including national parks, wetlands of national importance, and Native Title areas. The report did not assess risks to these areas as its scope was only concerned with assessing the potential for extraction of these resources, and not with the impact of extraction.

Findings are based on existing data sets and are consistent with broader literature. Conclusions from Stage 1, led to Stage 2 Bioregional Assessment.

## 3.4 Stage 2 Bioregional Assessment

The spatial scope of the Stage 2 studies was limited to the Cooper geological basin, the extent of which is shown in Figure 1. The Cooper geological basin underlies about a third of the Queensland Lake Eyre basin, mostly the Cooper creek surface water catchment.

Stage 2 of the Geological and Bioregional Assessments Program produced a range of detailed technical findings, which are focused on extraction activities in the Cooper geological basin. They do not capture the remainder of the Queensland Lake Eyre basin and do not assess risks associated with the other economic activities (grazing and tourism).

The studies covered a range of technical aspects, organised in technical appendices, with the overall report summarising the findings. All were conducted as desktop studies, collating available data sets that supported the scope of each technical assessment. This has produced a baseline assessment with data gaps clearly identified and to be addressed as part of a Stage 3 assessment program (presented in the following section). The scope was confined to deriving the baseline assessment, with no analysis or modelling of development scenarios.

Since findings are based on existing data sets, they are consistent with broader literature and knowledge. The reference lists are comprehensive and capture the most notable work that has been undertaken in the area. Specific findings from the Stage 2 assessment are discussed in this report in the section related to each topic.

### 3.5 Stage 3 Bioregional Assessment

The spatial scope of the Stage 3 studies was also limited to the Cooper geological basin. The methodology aimed at addressing the knowledge gaps identified during Stage 2, and at developing a consistent way to guide the use of that knowledge in environmental impact assessment studies. Stage 3 studies encompass a comprehensive body of technical and innovative work, in line with the funding that supported them (the full Geological and Bioregional Assessment program is valued at $35.4 million). All findings are available online (https://gba-explorer.bioregionalassessments.gov.au), along with the outcomes of all risk assessments, captured in a “causal network”, and a series of short factsheets containing summary information about methods, field investigations and results. A synthesis report describes the methods and assessment results and is referred to as “Stage 3 Bioregional Assessment” (Holland et al., 2021). Stage 3 studies included:

- Collection of large spatial data sets compiling information on climate and fire regime; vegetation extent, condition and disturbance; biodiversity; and topography, through development of a digital elevation model.
- 11 scientific investigations on ecosystems’ extent and condition and their sensitivity to gas resource development, hydrological and flood modelling, relationships between flood water and vegetation communities, interactions between surface water and groundwater, and risks associated with hydraulic fracturing.
- Development of a two-dimensional hydrodynamic flood inundation model for the Cooper Creek floodplain, calibrated using stream gauge and satellite monitoring data for historical floods and aligned with current best practice (Jarihani et al., 2013; 2015).
- Analysis of risks through any chain of events that links the driver (resource development) to activities (e.g., civil engineering, transport), stressors (e.g., dust generation, vehicle movement), processes (e.g., air pollution, habitat degradation) and endpoints (e.g., floodplain vegetation extent, aquifer condition). This is presented in a “causal network”, a graphical tool that captures all potential impacts and shows the links (“causal pathways”) that lead to these impacts, via the activities, stressors and processes. The causal network was built by compiling all information from the Stage 2 Bioregional assessment and considered inputs from multiple disciplines and wide stakeholder engagement.
- Application of the causal network to potential impacts on 8 valued assets (aquifers, ecosystems and protected species), showing which activities and causal pathways are of potential concern to the valued assets, and where residual risk (i.e., risk remaining after all feasible mitigations have been implemented) is greatest. Maps were produced to reveal the “risk hotspots” where there should be more focus on detailed local-scale assessments and monitoring. Risk assessments were undertaken for two scenarios both covering 50 years: a fast development scenario (92 petajoules per year, 1,180 wells) and a slow development scenario, equivalent to one quarter of the production of the fast scenario (see Fact Sheet 28 of State 3 Bioregional Assessment).

Specific findings from the Stage 3 assessment are discussed in this report in the section related to each topic.

## 4. Background

### 4.1 Lake Eyre Basin

The SEP review report provides an overview of the LEB (Qld): the Cooper Creek, Georgina and Diamantina rivers traverse an arid region and support complex wetland ecosystems on densely channelised floodplains. There has been relatively low anthropogenic disturbance and a key feature is that there is no major infrastructure to regulate flow. These rivers are characterised by extreme flow variability, with most flow events resulting from variable monsoonal rainfall in the northern zones of the catchments. Rather than being a permanently flowing, discrete river channel, these rivers are composed of a series of anastomosing[1] channels and anabranches situated in a broad floodplain, filling every few years after long dry periods with flood waters from upstream rainfall. During the wet periods, habitat complexity and availability in the catchments is vast with extensive flooding producing a complex system of swamps, channels, lakes, billabongs and waterholes on the floodplains. In dry periods these rivers usually are reduced to a series of waterholes in the channels and isolated wetlands on the floodplain. These habitats serve as refuges for aquatic species but many dry up completely in prolonged drought.

The area is internationally recognised as an outstanding example of an unregulated, low-gradient, dryland river system. The Lake Eyre basin and its distributary systems were recognised in the Lake Eyre Basin Intergovernmental Agreement 2001 as one of the last arid-zone water catchments around the globe to flow intermittently without interruption, and therefore of high conservation significance on a world scale.

The Stage 3 Bioregional Assessment confirms that this characterisation applies to the Cooper basin, which is a biodiverse region. The boom-and-bust ecology is a driver of regional biodiversity, which comprises more than 2,000 known species. The Cooper basin has a relatively intact landscape, and the vegetation communities support high biodiversity (Holland et al., 2021).

## 4.2 Regulatory framework

There are numerous pieces of Commonwealth and Queensland legislation, regulation, guidelines and policies that apply to the approval, exploration, development and operation of resource projects. The Shale Gas and Oil Knowledge Review (Huddlestone-Holmes et al., 2018) provides a thorough overview of the regulatory framework in Queensland and their summary is reproduced in Table 1.

[1] The term ‘anastomosing’ refers to a type of river with multiple, interconnected, coexisting channel belts on alluvial plains.

*Table 1 – Overview of Queensland Regulatory Framework from Shale Gas and Oil Knowledge Review (Huddlestone-Holmes et al., 2018).*

| Legislation | Description | Administering department |
|---|---|---|
| *Petroleum Act 1923* | Regulates certain petroleum and natural gas activities. The *Petroleum and Gas (Production and Safety) Act 2004* supersedes this act, but an amended version of the *Petroleum Act 1923* was retained so that existing permit holders' existing rights were not lost | Queensland Department of Natural Resources, Mines and Energy |
| *Petroleum and Gas (Production and Safety) Act 2004* (P&G Act) | Regulates petroleum and gas exploration tenure, safety, production and pipelines | Queensland Department of Natural Resources, Mines and Energy |
| *Mineral and Energy Resources (Common Provisions) Act 2014* (MERCP Act) | Regulates land access for mineral and energy resource authority holders. Commenced on 27 September 2016 | Queensland Department of Natural Resources, Mines and Energy |
| *Environmental Protection Act 1994* (EP Act) | Regulates activities to avoid, minimise or mitigate impacts on the environment, and to protect Queensland's heritage places | Queensland Department of Environment and Science |
| *State Development and Public Works Organisation Act 1971* (SDPWO Act) | Facilitates timely, coordinated and environmentally responsible development. Provides ability for Queensland's Coordinator-General to declare a project a 'coordinated project'. Coordinated projects require an environmental impact statement and a high level of public input | Queensland Department of State Development, Manufacturing, Infrastructure and Planning |
| Queensland – other relevant legislation | | |
| *Environmental Offsets Act 2014* (EO Act) | Regulates the requirements and management of environmental offsets in response to activities that cause a significant residual impact on prescribed environmental matters | Queensland Department of Environment and Science |
| *Water Act 2000* (Water Act) | Regulates the sustainable management of Queensland's water resources and water supply, and the impacts on groundwater caused by the extraction of groundwater by the resources sector | Queensland Department of Natural Resources, Mines and Energy; Queensland Department of Environment and Science |
| *Water Supply (Safety and Reliability) Act 2008* (WS Act) | Regulates interactions and direct impacts associated with drinking water supply | Queensland Department of Natural Resources, Mines and Energy; Queensland Department of Health |
| *Waste Reduction and Recycling Act 2011* (Waste Act) | Regulates the production, reuse and disposal of waste materials | Queensland Department of Environment and Science |
| *Regional Planning Interests Act 2014* (RPI Act) | Identifies and protects areas of Queensland that are of regional interest, and resolves potential land use conflicts. The Act protects living areas in regional communities, protects high-quality agricultural areas from dislocation, protects strategic cropping land, and protects regionally important environmental areas | Queensland Department of State Development, Manufacturing, Infrastructure and Planning |

In broad terms, regulations aim at (1) managing the direct impact of activities, administered by relevant government departments; (2) guarantee the sustainable management of water resources; and (3) providing options for offsetting impacts.

The key piece of Queensland legislation that aims to regulate resource activities in a way which avoids, minimises or mitigates its environmental impacts is the Environment Protection Act 1994 (EP Act). The Water Act regulates the sustainable management of Queensland's water resources, with water plans establishing the volumes of water available for use. In addition, the Regional Planning Interests Act 2014 (RPI Act) aims to manage the impact of resource activities on areas of regional interest, including the Channel Country Strategic Environmental Area, and applies despite the EP Act.

Note that since this synthesis report is largely focused on the potential impacts of resource activities on environmental values, the protections afforded by the Aboriginal Cultural Heritage Act, or the rights provided under the Native Title Act have not been included and were not mentioned in any of the reports that were reviewed.

## 4.3 Environmental Protection Act 1994 (EP Act)

The objective of the Environmental Protection Act 1994 (EP Act) is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains ecological processes. The EP Act and its subordinate legislation provide a range of tools to ensure this objective is met, such as the licensing system for environmentally relevant activities (ERAs), called an environmental authority. Under the EP Act, all petroleum and gas production activities require a site-specific Environmental Authority (EA) to be granted and applications for an EA are subject to a strict assessment and approvals process supported by an environmental impact statement (EIS). The purpose of an EIS is to:

- assess the potential adverse and beneficial environmental, economic and social impacts of a project.
- assess the management, monitoring, planning and other measures that are proposed to minimise any adverse environmental impacts.
- consider feasible alternative ways to carry out the project.
- provide information to the public about the project.
- give information to other Commonwealth and state authorities to help them make informed decisions.
- allow the Queensland Government to meet its obligations for a single environmental assessment process under a bilateral agreement with the Australian Government.

This EIS documentation must provide a baseline assessment of fauna and flora, groundwater and surface water, and any other relevant biophysical aspect, capturing the current state of the area prior to establishment of the operation; quantify the impacts of the proposed operation; and prepare an environmental management plan to document the measures implemented to avoid, minimise, mitigate and/or offset impacts. Given these assessment requirements, EIS must be supported by extensive data sets to support baseline and management assessment. The regional-scale studies undertaken as part of the Stage 2 and Stage 3 Bioregional Assessment provide significant support to any EIS being undertaken in the Cooper region.

Under section 172 of the EP Act, when deciding a site-specific application, the administering authority must decide that the application be approved subject to conditions or be refused. When making this decision the administering authority must have regard to the criteria stated in section 176 of the EP Act which includes regulatory requirements, the application, standard conditions, responses to information requests and the standard criteria. The standard criteria are listed in Schedule 4 of the EP Act. Among the list of 11 standard criteria, the following ones are of interest to the LEB initiative:

- principles of environmental policy as set out in the Intergovernmental Agreement on the Environment including the precautionary principle, intergenerational equity, and conservation of biological diversity and ecological integrity;
- the character, resilience and values of the receiving environment;
- the financial implications of the requirements under an instrument, or proposed instrument (…) as they would relate to the type of activity or industry carried out, or proposed to be carried out, under the instrument; and
- the public interest.

Each petroleum or gas lease that has an application for an EA approved is subject to environmental conditions that are tailored to the individual project under Chapter 5, Division 6 of the EP Act.

## 4.4 Water Act 2000 (Water Act)

The Water Act 2000 (Qld) regulates water extraction in Queensland by requiring any take or interference with water to be authorised by that Act or another Act. A general statutory authorisation permits the taking or interference with underground water for any purpose across the state, subject to the provisions of the relevant water plan for the area or the regulation. Water plans for different catchment areas of the state are prepared by the regulator, who is currently the Department of Regional Development, Manufacturing and Water (DRDMW). The plans allocate the quantum of water provided for consumptive and environmental purposes and are created following a planning and consultation process for each catchment. The plans are implemented through water management protocols for the relevant catchment which set out, for example, water dealing, trading and sharing rules and reservations of unallocated water (Robertson, 2020).

Water allocations are either:

- Supplemented: the water supplied is delivered from infrastructure (e.g., dams and weirs) and is obtained from a Resource Operations Licence Holder; or
- Un-supplemented: the water supplied is not reliant on any infrastructure to store or distribute it and is supplied by DRDMW.

There are three water plan areas that intersect the Lake Eyre basin: the Georgina and Diamantina plan, the Cooper Creek plan and the Great Artesian Basin and Other Regional Aquifers (GABORA) plan. The Georgina and Diamantina plan has very low volumes of available water: 13,500 ML of unallocated surface water and 108 ML of un-supplemented surface water. Of all the water plans, this is the smallest volume of un-supplemented surface water. The Cooper Creek plan lists 2,200 ML of unallocated surface water, 14,550 ML of un-supplemented surface water and 394 ML of un-supplemented groundwater.

The GABORA plan lists 90,000 ML of un-supplemented groundwater. Domestic use and stock use (in some areas) is only generally authorised where the bore is controlled by a watertight delivery system and the extraction would not affect groundwater dependent ecosystems or other groundwater users by certain drawdown[2] levels (Robertson, 2020). If there are high-priority groundwater-dependent ecosystems and culturally significant sites, a "make-good" agreement will be required if drawdowns exceed 0.2 m. A make-good agreement is a legally binding agreement that includes measures to offset the impacts of water extraction. In many instances, make-good agreements are focused on offsetting the impacts of extraction on existing bore owners, rather than addressing the impacts on the water resource itself.

[2] "drawdown" denotes the reduction in hydraulic head observed at a well in an aquifer, typically due to water extraction.

Technical assessments underpin the development of water plans and include environmental, hydrologic, social, economic and cultural assessments. As such, water plan allocations are based on extensive quantitative analysis that calculates the volumes of water that can be extracted without impacting on environmental values. However, the scope of the information required to inform such impact assessment has evolved. It is now recognised that current methods lack consideration of groundwater systems, groundwater-dependent ecosystems, impacts of climate change and cultural connections. Current water plans do not capture the risks associated with these aspects, and to address these gaps, additional science themes have been developed and included in the Water Planning Science Plan 2020-2030, published in 2020 by the Department of Regional Development, Manufacturing and Water and the Department of Environment and Science[3].

Themes that are relevant to the LEB are:

**Theme 3 - Groundwater-dependent ecosystems (GDE)**

This theme highlights GDEs as a class of ecological asset which remain poorly characterised in terms of their location and the nature of their water dependency. They are potentially vulnerable to the management and allocation of both groundwater and surface water, particularly in those areas where surface and groundwaters closely interact.

The objectives of the research will be to identify and map GDEs for each water plan area; establish environmental water requirements for key GDEs across a range of aquifer types and dependencies; improve the understanding of surface water - groundwater interactions and how these may alter the provision of critical water requirements for GDE assets.

**Theme 5 - Hydrology**

Opportunities exist for further enhancement of hydrological modelling to support operational decision-making within the life cycle of the Water Plans. Assessment of unallocated water releases and changes to scheme operations have very localised impacts on entitlements and environmental flows that may not be reflected due to the scale of the models used for Water Plan development and review. Climate change projections need to be included in hydrological simulations, along with uncertainty analysis. There is the requirement to develop the ability to inform short-term management decisions (e g. water permits, announced entitlements, seasonal restrictions) as well as longer-term security objectives.

**Theme 6 - Cultural Values**

Aboriginal people and Torres Strait Islanders have valuable insights and perspectives on water management however, the science and planning frameworks have not fully incorporated this traditional knowledge. Cultural values and use of natural resources including riparian areas, plants and animals, springs, lakes, rivers, creeks are potentially represented by environmental assets and functions already understood through environmental and risk assessments that underpin water planning. This provides a foundation from which cultural knowledge can be incorporated into water plans. There is a requirement to develop an inventory of water-related cultural values that are supported by flow regimes, and potentially responsive to identified hydrological threats, and to improve understanding of the interactions between the flow regime and cultural values.

Water requirements for gas development are approximately 15 - 20 ML per well during the exploration, appraisal and development stages, and 10 ML per well to refracture wells during the production stage (Stage 2 Bioregional Assessment). The Stage 3 Bioregional Assessment states the same assumptions for

[3] The Water Planning Science Plan can be accessed online via several websites: https://www.business.qld.gov.au/industries/mining-energy-water/water/catchments-planning/planning/implementing or https://wetlandinfo.des.qld.gov.au/resources/static/pdf/assessment-toolbox/water-planning-science-plan-2020-2030.pdf

calculating the required water extraction for the fast development scenario (1,180 wells over 50 years). This suggests that over a 50-year period, water extraction would be between 17,700 and 23,600 ML for the exploration, appraisal and development stages, and 11,800 ML for the production stage, yielding a total volume of 29,500 – 35,400 ML over 50 years, equivalent to 590 – 710 ML per year. However, the Stage 3 Bioregional Assessment used a figure of 19,680 ML of water extracted over 50 years, equivalent to approximately 400 ML per year. Despite using the same assumptions, a different extraction volume was selected, with no information justifying this selection. Nevertheless, there is sufficient water available in the Great Artesian Basin and Other Regional Aquifers plan to supply a volume between 400 and 700 ML per year, but the local and cumulative impacts will need to be assessed. As aforementioned, due to the scale of the models used for Water Plan development and review, water availability does not currently account for the risks of localised impacts on entitlements and environmental flows. The local impacts of water extraction have not been evaluated.

The SEP review and the Stage 2 Bioregional assessment both highlight "water extraction" as a key risk, supporting the view that catchment-level assessment of water availability is not sufficient to ensure that water supply to economic activities will not impact on environmental values, as reflected in the research priorities of the Water Science Plan 2020-2030.

In conclusion, there is a comprehensive water planning framework in Queensland to regulate water extraction but there are knowledge gaps and associated risks related to localised impacts, groundwater-dependent ecosystems and cultural values.

## 4.5 Regional Planning Interests Act 2014 (RPI Act)

Of interest to this synthesis are strategic environmental areas (SEA), which are areas of regional interest under the Regional Planning Interests Act 2014 (RPI Act). Each SEA is identified in the Regional Planning Interests Regulation 2014 (RPI Regulation) or a regional plan. The extent of the Lake Eyre basin SEA is displayed with hash lines in Figure 1.

The RPI Act restricts the carrying out of resource and regulated activities in SEAs where the activity is not exempt under the provisions of the Act, or a regional interests development approval (RIDA) has not been granted.

To be able to carry out a resource activity that impacts an area of regional interest, an application for a regional interest development approval must be applied for and granted (usually with regional interest conditions) under section 48 of the RPI Act. The chief executive can also refuse an application under this same section of the Act by using the criteria for decision in section 49 of the RPI Act. This criteria for the chief executive to consider includes the extent of the expected impact of the resource's activity on the area of regional interest and any other matter the chief executive considers relevant.

The RPI Act also prescribes broadacre cropping and water storage dams as regulated activities in strategic environmental areas. A water storage dam includes any barrier that may impound water; the water storage area created by the barrier; any embankment or other structure that is associated with the barrier and controls the flow of water. This is relevant to the synthesis as most, if not all, gas extraction activities will require some form of water storage. Whilst the RPI Act specifically refers to water storage dams as regulated activities, the statutory guidelines that have been published to assist in understanding when and how to apply for a regional interests development approval (Department of Infrastructure, Local Government and Planning, 2017) clearly state that activities should not alter the natural flow of water in the SEA catchments. Applications for a regional interests development approval should provide details of any proposed impoundment, extraction, discharge, injection, use or loss of water (surface or groundwater) or diversion or interception of overland flow. The guidelines stipulate that all types of flow interception will be assessed, not just those created by permanent infrastructure such as water storage dams.

The Stage 2 Bioregional Assessment (Holland et al., 2020) also states that the regulatory pathway that all petroleum resource projects must follow is consistent, although additional requirements may be required in areas of regional interest. It discusses the Lake Eyre Basin Intergovernmental Agreement, which was signed by the Australian, Queensland and SA governments in 2000 and by the NT Government in 2004, for the sustainable management of water and related natural resources in the Lake Eyre Basin Agreement Area. The second review of the Lake Eyre Basin Intergovernmental Agreement specifically identified the potential impacts on water resources associated with gas development and climate change. This review signalled the need for integrated surface water and groundwater management and improved governance of both these resources. Six policies have been prepared to support the agreement:

- River Flows Policy
- Water Quality Policy
- Water and Related Natural Resources Policy
- Existing Entitlements and Water Resource Development Policy
- Research and Monitoring Policy
- Whole-of-Basin Approach Policy.

Under the agreement, the condition of all watercourses and catchments within the Lake Eyre Basin Agreement Area is reviewed and reported on at least once every ten years. The first assessment took place in 2008, with a second assessment commissioned in 2016 and finalised in 2017. This latest State of the Basin Condition Assessment documents the current status of the hydrology, water quality, and fish and waterbird populations of the Lake Eyre Basin and on the current and emerging threats to the basin. It reveals an internationally significant river catchment in good condition, which is a rarity around the globe.

### 4.6 Assessment of the effectiveness of the Queensland regulatory framework

The Shale Gas and Oil Knowledge Review (Huddlestone-Holmes et al., 2018) states that a critique of the effectiveness of the current Queensland regulatory framework in managing the impacts of existing petroleum operations or the potential impacts of future operations was outside its scope. It assumes that most impacts should be covered under the current regulatory framework, without assessing its effectiveness.

However, the qualitative risk assessment undertaken as part of this review does identify several impacts that may require additional attention during the assessment and approval process. An aspect that will require a high degree of regulatory focus is related to water take. Other aspects that will require a moderate degree of regulatory focus concern hydraulic fracturing, management and disposal of flowback water (hydraulic fracturing fluid that flows back out of the well after hydraulic fracturing is complete), spills and leaks, greenhouse gas emissions, land access and disturbance.

## 5. Environmental Values of Queensland Lake Eyre Basin

### 5.1 Surface water

The SEP Review scope included the entire LEB (Qld), and it provides an overview of the three main catchments: Copper Creek, Diamantina River and Georgian River.

Cooper Creek is fed by the Thompson River and Barcoo River and flows southwest to the South Australian border and onwards to Lake Eyre. In the headwaters of the Thompson River, there are two large groundwater-fed lakes: Lake Buchanan (saline) and Lake Galilee (fresh to saline), which support a wide variety of freshwater and salt tolerant wetland species. They are also essential to many migratory bird species, with Lake Galilee at times supporting breeding and foraging of up to 100,000 water birds. Lake Galilee and Lake Buchanan are not currently included in the Channel Country SEA. There are petroleum exploration permits (ATP) covering Lake Galilee as well as coal and petroleum exploration permits (EPC and ATP) surrounding Lake Buchanan.

The Diamantina River catchment provides water most frequently to Lake Eyre as there are very few large lakes to intercept flood water and most of the lower reach has a distinct single channel. Floodplain swamps nevertheless occur providing breeding grounds for endangered species under the EPBC Act (Australian Painted snipe). The largest-known breeding colony of mixed waterbird species in the LEB is located on the Diamantina floodplain. It is essential that the flow paths of the Diamantina River are not disturbed, as they provide most of the water to Lake Eyre.

The Georgina River and its ecological values have been the least studied. The catchment covers a large area, with headwaters in the Northern Territory. It has three main tributaries (Hamilton River, King Creek, Mulligan River) and flows through Western Queensland before joining Eyre Creek and eventually Lake Eyre.

There are at least three native fish species under threat of extinction in the LEB: the Cooper Creek Catfish (*Neosiluroides cooperensis*), who is dependent on permanent waterholes and is becoming critically endangered; the red-finned blue eye (*Scaturiginichthys vermeilipinnis*) and the Edgbaston goby (*Chlamydogobius squamigenus*), who both depend on springs and are listed as endangered and vulnerable under the EPBC Act, respectively.

The Stage 2 Bioregional Assessment focused on Cooper Creek geological basin and provides information about its hydrology, based on collected data sets for precipitation, evapotranspiration, flow and water quality. The Cooper basin intersects three surface water catchments (Diamantina River, Cooper Creek and Bulloo River) but the Diamantina and Bulloo rivers only overlie a small portion of the Cooper Basin. All three rivers follow a similar pattern, with most of the runoff generated in the higher rainfall headwater areas before flowing down into extensive floodplains and ending up in terminal lake systems.

Cooper Creek supports the Ramsar-listed Coongie Lakes (located in South Australia) and many waterholes and terminal lakes, with many located in Queensland. When flooded, the floodplain becomes a huge inland 'sea' that contracts in the dry season to channels, lagoons and claypans. Surface water quality is variable in space and over time, with floodwaters in the upper reaches having low salinity and the terminal lakes tending to be saline. Median salinity recorded at three stream gauges on the Cooper, Barcoo and Thomson rivers is approximately 100 mg/L total dissolved solids (TDS), which is suitable for drinking water and for stock watering. There are no definitive trends of significantly increased TDS, nitrogen and phosphorus concentrations over time, suggesting that current levels of development have not deteriorated the water quality for aquatic biota. However, it does highlight the importance of developing water quality guideline values tailored to the local environment.

Both the SEP Review and the Stage 2 Bioregional Assessment articulate that it is the variability in the flows that drives the ecological boom and bust nature of the catchments. The Stage 3 Bioregional Assessment confirms that Cooper Creek has one of the most variable flow regimes of all rivers worldwide. When flooded, the floodplain becomes a huge inland sea broken only by a few ridges and stunted trees. It contracts in the dry season to channels, lagoons and claypans.

The Cooper Creek floodplain is more than 60 km wide at its broadest point and is characterised by a hydrologic gradient from the wetter riparian vegetation - including channels, waterholes and fringing vegetation - to the less frequently flooded wetland and floodplain vegetation. The surrounding dryland environment is characterised by gibber plains, low hills, and mesas and high sand dunes with swale wetlands (Holland et al., 2021).

Water assets such as the permanent waterholes and non-riverine wetlands of the region are identified as significant refugia for aquatic organisms during dry years or dry seasons. Apart from the major flooding events that cover vast floodplains, the riverine ecosystems exist for much of the time as discrete waterholes. Most waterholes are filled by surface flows with little evidence of groundwater contributions.

Numerous scientific studies have been conducted on waterholes in the region, but the focus has centred on their geomorphology, surface water hydrology and ecological diversity. Only 3 studies have investigated the connectivity of waterholes with groundwater, and each were conducted at a local scale (on individual waterholes). One of the scientific investigations of the Stage 3 Bioregional Assessment sought to characterise the connectivity of a subset of permanent waterholes with groundwater. It concluded that these permanent waterholes were indeed fed by surface water and provided conduits for ephemeral groundwater recharge, confirming the statements from the SEP review (see Fact Sheet 7 of Stage 3 Bioregional Assessment).

However, the SEP review states that there are exceptions to this with some waterholes in the upper streams of the Cooper Creek and Georgina catchments where groundwater discharge contributes to their persistence. For the waterholes reliant on surface flows, their permanence is largely determined by waterhole morphology and evaporative loss. The interconnections between sand-dunes and waterholes and sand-dune outflow contribution also influence the permanence of water holes. It is estimated that most Cooper Creek waterholes would dry up within 22 months if not replenished by channel flows or flooding; after 24 months of no flow, only four of the named waterholes along Cooper Creek would remain. Few waterholes can persist for more than two years without surface flow connection.

These refugial waterholes represent the only permanent aquatic habitat during extended periods of low or no flow and are critical components of a functioning ‘source and sink’ system for aquatic organisms (fish, turtles) in arid and semi-arid landscapes. During dry periods, species maintain their populations in isolated permanent waterholes and then disperse to less favourable habitats during extensive flooding. They experience variable patterns of connection and disconnection which are a fundamental driver of ecological processes that are essential for dispersal and survival of diverse populations in these riverine environments. Many breeding colonies of cormorants and other fish-eating waterbirds, generally of moderate size, occur at waterholes either during flood events or following floods, when certain fish species may be more abundant or accessible to the birds (Fielder et al., 2019).

Conclusions from these assessments are that the Lake Eyre basin has unique hydrological features which support diverse aquatic habitats and aquatic species that disperse and survive according to flow patterns. Any disruption to flow patterns can impact on the ecological processes that characterise the region. The understanding of surface flow patterns is based on expert knowledge that includes reference to literature (SEP Review), and is supported by extensive quantitative analysis: firstly, the data collected for the Stage 2 Bioregional assessment (observations from space, climate data, flow gauges, water quality sampling) and secondly the hydrodynamic flood inundation model developed for the Cooper Creek floodplain as part of Stage 3 Bioregional Assessment (see Fact Sheet 16 of State 3 Bioregional Assessment).

## 5.2 Hydrogeology and Groundwater

The SEP Review does not provide specific information or description of the hydrogeological setting in the LEB (Qld). However, the panel included members with extensive experience in this field and was well equipped to assess potential risks to groundwater.

The Stage 2 Bioregional Assessment contains a technical appendix describing the hydrogeological system in detail for the Cooper Basin (Evans et al., 2020), with a concise summary in Section 3.1 of Holland et al. (2020). Since gas extraction raises concerns related to the impact of hydraulic fracturing on groundwater resources, during Stage 2, the hydrogeological assessment was much more thorough than the hydrological one. It provided regional hydrogeological analysis and conceptualisation of the Cooper basin in the context of shale, tight and deep coal gas developments. The regional groundwater conceptualisation is based on hydrostratigraphy, hydrodynamics, hydrochemistry, analysis of potential basin inter-connectivity and groundwater-surface water interactions and represents all current hydrogeological knowledge.

Hydrogeology is difficult to summarise as it relies on the analysis of complex data sets and three-dimensional representation of geological and hydro-geological features. The 3D sketch of the conceptualisation of the Cooper and Eromanga basin in Figure 4 in Appendix A (originally Fig. 4 of Evans et al. (2020)) will assist with understanding the key features described in the Stage 2 Bioregional Assessment and reproduced below.

There are three geological basins in the Cooper region: the Cooper Basin, the Eromanga Basin and Lake Eyre Basin. The Cooper Basin is comprised of the Gidgealpa Group and the overlying Nappamerri Group. Where shale, tight, and deep coal gas accumulations occur in the Gidgealpa Group, the rocks are likely to be relatively dry as the contained gas displaces the groundwater. However, at shallower levels (less than about 2800 m), the Gidgealpa Group becomes increasingly water saturated and the hydrocarbon accumulations become more discrete. Whilst the Nappamerri Group can also contain hydrocarbon reservoirs and groundwater, regionally it acts as the seal (aquitard) to the underlying Gidgealpa Group.

The Eromanga Basin sequence is up to 2800 m thick and covers the entirety of the Cooper Basin. It includes a sequence of aquifers and aquitards that comprise a part of the Great Artesian Basin (GAB). From bottom to top, these include the artesian[4] GAB aquifers (e.g., Hutton Sandstone and Cadna-owie–Hooray aquifer), the Rolling Downs aquitard and the Winton–Mackunda partial aquifer. Regionally, groundwater flow in artesian GAB aquifers occur in a south-westerly or southerly direction. Groundwater flow rates and hydraulic gradients in more deeply buried parts of these aquifers approach near-stagnant conditions, particularly in western parts of the region. Greater groundwater flow tends to occur preferentially at shallower levels in areas of higher porosity and permeability, around the margins of the Cooper region.

The Rolling Downs aquitard is the regional aquitard that separates artesian GAB aquifers from shallower aquifers. Groundwater flow in the sub-artesian Winton-Mackunda partial aquifer is topographically controlled. Local flow directions are towards major drainage lines, whilst more regional flow is to the southwest, out of the Cooper region and towards Lake Blanche. Hydrochemistry suggests that hydrodynamics of the Winton-Mackunda partial aquifer may be more complex and compartmentalised than what is currently conceptualised.

The Lake Eyre Basin is up to 300 m thick and encompasses several locally important aquifer systems. Groundwater flow patterns are similar to the Winton-Mackunda partial aquifer, which suggests potential connectivity between the two systems.

Sparse salinity data suggests that there are two aquifer systems, a shallow system, approximately 60 - 80 m thick with highly variable salinity and a deeper system with more consistent salinity down to about 300 m.

Most bores in the region target the Lake Eyre basin aquifers (shown in yellow in Figure 4 (Fig. 4 of Evans et al. (2020)) or the Winton-Mackunda partial aquifer (shown in light blue). Much fewer bores target the artesian GAB aquifers (shown in dark blue), even though these aquifers generally provide more consistent

[4] An artesian aquifer is a confined aquifer containing groundwater under positive pressure. If a bore is drilled into an artesian aquifer, water will rise to a height corresponding to the point where hydrostatic equilibrium is reached and can often rise to the ground surface.

and higher quality groundwater, as well as higher yield and more sustainable flow rates. This is because the Winton-Mackunda partial aquifer is much deeper (as clearly shown in the figure) and would require much greater drilling depth.

The conceptualisation of hydrogeological context in the Cooper region is well advanced. Groundwater is extracted from aquifers near the surface (up to 300m), although there are other groundwater resources further down. The gas resources are located much deeper than the water that is extracted (about 3 km down). Groundwater extraction is a likely source of water for resource operations in the Cooper basin. As costs increase with depth, it is likely groundwater will be sourced from the shallower aquifers in the region, in preference to the deeper confined aquifers.

Such detailed hydrogeological assessment is only available for the Cooper basin region and cannot be extrapolated to the remainder of the Queensland Lake Eyre basin.

## 5.3 Protected matters

The SEP review provided an overview of the biodiversity values of the LEB (Qld) throughout the document, with no specific section grouping all considerations related to protected matters and endangered species. The common thread is that the hydrology specific to the region has led to complex and unique ecosystems, supporting aquatic organisms (fish, turtles), waterbird breeding colonies, large populations of waterbirds (several millions during major floods) and high numbers of migratory bird species. Lake Eyre and several large ephemeral terminal or sub-terminal lakes (Lake Yamma Yamma, Lake Mipia, Lake Machattie, Lake Galilee, Lake Buchanan, Bilpa Morea Claypan) are significant for their unique geological features, water regimes and assemblage of fauna.

Several native fish species are under threat of extinction in the LEB (Qld). There are major waterbird breeding colonies, large populations of waterbirds (several million during major floods) and high numbers of some migratory bird species. There are National Parks on the Diamantina River that protect several endemic endangered species Astrebla Reserve is one of the last natural refuges for the Greater Bilby in Queensland.

The SEP review also outlines the significance of Great Artesian Basin (GAB) springs, which contain unique flora and fauna and have experienced considerable habitat loss and extinction due to the unrestricted extraction of water and physical modification. The mapped groundwater dependent artesian springs contain numerous endemics and threatened flora and fauna species. There are about 98 taxa of plant, fish, amphipods and isopods that are only found in these springs. Of these taxa, 33 are undescribed species and nearly half (44%) are narrow endemics, whereby a taxon is found in only one spring complex. The vulnerability of these spring communities is extreme due to their variable size, isolated locations and reliance on permanent groundwater supplies from the GAB aquifers. The SEP review states that these water assets are of high priority for maintaining Australia’s unique aquatic biota and for terrestrial species as a permanent source of water during dry periods in the largely terrestrial environments of Lake Eyre basin. However, it does not provide specific information about these springs (such as maps providing their locations) and the magnitude of stresses they have experienced (such as volumes of uncontrolled water extraction).

Throughout the Diamantina Basin, groundwater systems in the alluvia support vegetation communities. Impacts to groundwater levels could be catastrophic, not just to these ecosystems, but also to the organic beef industry that uses the basin for extensive grazing of beef cattle.

Panel members highlighted the possible need to exclude livestock and tourists from the banks of permanent waterholes, but not restricting access to the entire riparian and floodplain system.

The Stage 2 Bioregional Assessment contains a technical appendix compiling all available information related to protected matters (O'Grady et al., 2020, summarised in Holland et al., 2020). Matters of National Environmental Significance (MNES) are Australia's national environmental assets as defined in the Environment Protection and Biodiversity Conservation Act (1999, EPBC Act). In the Cooper basin, MNES are:

- Coongie Lakes, a Ramsar-listed wetland located in South Australia
- 26 taxa (plants, reptiles, birds and mammals) listed as threatened

This assessment of MNES was limited to the Cooper basin but did outline that there is a threatened ecological community that is dependent on the springs at Lake Blanche, located in South Australia and in all probability, hydrologically connected to groundwater from the Cooper basin. This highlights that many environmental values are connected beyond the boundaries of specific study areas, and beyond State borders.

In Queensland, Matters of State Environmental Significance (MSES) include protected areas (e.g., national parks), strategic environmental areas, regional ecosystems listed as "of concern" or "endangered", threatened species, wetlands with high ecological significance and waters with high ecological values. In the Cooper basin there are 28 species listed as endangered, near threatened, vulnerable or special least concern. The region also contains areas of significant environmental value, including protected areas, High Ecological Value Aquatic Ecosystems (HEVAE) and regional ecosystems listed as 'of concern'. There are seven nationally important wetlands:

(i) Bulloo Lake
(ii) Cooper Creek – Wilson River Junction
(iii) Cooper Creek Overflow swamps - Nappa Merrie
(iv) Cooper Creek Overflow swamps - Windorah
(v) Lake Cuddapan
(vi) Lake Yamma Yamma
(vii) the Strzelecki Creek Wetland system

The Stage 2 Bioregional Assessment outlines that there are large knowledge gaps associated with the assessment of protected matters: lack of accurate records of the spatial distribution of individual species, particularly for threatened and migratory species; lack of accurate mapping of species habitat; no detailed knowledge of ecology, distribution and threats to individual threatened species. Currently, there are species listed as 'likely to occur' or 'may occur' rather than 'known to occur'. Research is needed to identify whether an individual species is present and define the groundwater and surface water requirements for these species and habitats.

The Stage 2 Bioregional Assessment proposes a landscape classification (floodplain and alluvium, known as 'Channel Country'; inland dune fields and undulating country on fine grained sedimentary rocks; loamy and sandy plains; tablelands and duricrusts; clay plains) that should be used to provide a basis for systematic assessment of potential impact of activities on landscape function and protected matters nested in each landscape class. This represents significant progress towards a comprehensive framework for impact assessment.

In the Stage 3 Bioregional Assessment, this complex information is summarised, stating that the Cooper basin provides potential habitat for 68 species protected under state or national legislation and that many species are culturally significant. For example, the iconic river red gum stabilises rivers banks, provides habitat for birds and animals and has long provided food, timber and medicines for Indigenous peoples. Stage 3 assessment prioritised 12 species (4 birds, 3 mammals and 5 plants) based on the importance of the region to the preservation of each species. However, collection of new ecological data was not a priority of the Stage 3 investigations and the knowledge gaps outlined as part of Stage 2 would still be valid.

### 5.4 Cultural heritage

The SEP review states that the LEB holds continuing significance for Traditional Owners who speak of their obligations to look after rivers and water places according to ancestral lore and custom. The healthy flows and water quality of rivers are particularly important in the maintenance of tradition and the wellbeing of Traditional Owners. It specifically mentions that there are significant cultural values to be preserved such as the Pituri sacred areas, the Bilpa Morea Claypan European heritage area and the Camooweal Caves, which are a popular tourist destination.

The Stage 2 Bioregional Assessment technical appendix on protected matters (O'Grady et al., 2020, summarised in Holland et al., 2020) compiled the information related to sites with historical and cultural significance. The Burke, Wills, King and Yandruwandha National Heritage Place located along the course of Cooper Creek is a national heritage place listed as a protected matter. The Register of the National Estate also lists nine Indigenous sites, twelve heritage sites and two recreational areas. Cooper Creek and associated waterholes have a long and enduring cultural significance as part of traditional trade routes. The Stage 3 Bioregional Assessment states that more than 60% of the Cooper basin is covered by Indigenous Land Use Agreements.

## 6. Potential Threats to the Environmental Values of the Lake Eyre Basin

The Shale Gas and Oil Knowledge Review, the SEP Review and the Stage 2 and Stage 3 Bioregional Assessments all provide some form of risk assessment for analysing threats to environmental values but due to their different scope and methodologies, their findings are not easily assimilable:

- The SEP review considered potential impacts from all activities, based on qualitative assessments, including those presented in the Shale Gas and Oil Knowledge Review. Their list of impacts is comprehensive and influenced by the consideration of two development scenarios (application for petroleum activity and ancillary infrastructure in the Diamantina River floodplain, with or without consideration of cumulative impacts from additional development).
- The Stage 2 Bioregional Assessment and supporting detailed technical appendices only considered potential impacts of shale gas and shale oil extraction, including hydraulic fracturing and use of chemicals. Some impact assessments are really detailed, particularly those related to hydraulic fracturing and chemical screening. There is extensive information and analysis provided for these two specific threats, compiled in the relevant technical appendix. The assessment of other threats remains essentially qualitative.
- The Stage 3 Bioregional Assessment provides quantitative analysis of risks at regional scale, through application of the causal network, use of extensive spatial datasets, modelling and accounting approaches. Risk analysis is undertaken for all threats and is comprehensive. As such, it largely supersedes the risk analysis undertaken during Stage 2.

### 6.1 Potential impacts from activities

The SEP Review states that the literature identifies several impacts to natural ecosystems from petroleum and gas activities and mining. Not all these impacts are fully understood nor their magnitude quantifiable. Several of these impacts could be very difficult or impossible to reverse in the short and medium time frames. When the SEP review was undertaken, participants stated that within the LEB, uncertainty remained about the full extent of unconventional and conventional gas production and mining activities planned for the foreseeable future.

The SEP review states that currently there are extractive activities in the LEB; that the number of existing production wells (gas and petroleum) is low compared to the expected 30,000 to 40,000 coal seam gas wells throughout the Surat and Bowen Basins; that there is no available data for the predicted number of wells in the LEB; and that it cannot be predicted what plans companies have for developing these resources in this region. It also states that there are few existing mines in production in LEB but that there are extensive areas of mineral and coal exploration areas located across the LEB. The SEP review compiled a comprehensive list of potential impacts from all economic activities in the LEB, including mining and coal seam gas extraction. The Stage 2 and 3 Bioregional Assessments only assessed risks associated with shale gas, as it is the resource that is targeted in the Cooper basin. As such, many of the impacts that are discussed in the SEP review are not relevant to the Cooper basin and many are well understood and controlled by existing mechanisms. They will not be discussed in this synthesis report but for completeness, they are provided in Appendix B. Risks identified by the SEP review that are relevant to this synthesis report are impacts from infrastructure; altering the hydrological regime; water extraction; consequences of establishing aquifer connectivity; well integrity; and use of chemicals in wells.

The following sections discuss these impacts according to this grouping, with the altering of the hydrological regime expanded to the broader consideration of altering the landscape.

## 6.2 Water extraction

As discussed in Section 4.2, whilst the overall volume of available groundwater could be sufficient to meet the requirements of a range of activities, the local impacts of such extraction has not been evaluated.

As the SEP review considered all activities, it is worth providing general comments comparing water requirements. Grazing relies largely on natural flow regimes and waterholes for stock watering. Mining activities can mostly rely on the runoff they collect. If a mine intersects the groundwater table, impacts will be assessed as part of the approval process. Water requirements of CSG, shale gas and oil production are described in the SEP Review report.

CSG production involves extracting quantities of groundwater from coal formations to reduce the water pressure in the coal seams. This dewatering operation releases the gas that is attached to the coal. The CSG dewatering process produces significantly more water than conventional petroleum and gas production. It will require storage and/or disposal. This is not a risk in the Cooper basin as there will be no extraction of CSG. Shale gas extraction does not produce large volumes of associated water.

The main differences for shale/tight gas and oil compared with CSG is the prevalence of hydraulic fracturing. Shales and tight sands will always require hydraulic fracturing to yield gas. CSG only requires hydraulic fracturing in some wells. On a per well basis:

- Shale/tight gas and oil will require more water up-front for drilling and hydraulic fracturing than CSG activities
- Shale/tight gas and oil will have more flowback water (hydraulic fracturing fluid that flows back out of the well after hydraulic fracturing is complete) than CSG activities
- Shale/tight gas and oil will have less produced water (water that comes from the resource during production) than CSG activities since CSG wells need to be dewatered to allow gas production
- Shale/tight gas and oil resources are also deeper than CSG resources, so different drilling rigs will be used that can reach deeper and drill long horizontal sections once they reach the resource. This will

also allow multiple wells to be drilled from a single well pad and there might be greater separation from artesian aquifers. The well pads will be bigger for shale/tight gas and oil than for CSG wells, although the drilling of multiple wells from a single pad will mean a decreased footprint overall (this is also discussed in the Shale Gas and Oil Knowledge Review).

The Stage 3 Bioregional Assessment quantified the potential risks associated with surface water extraction and groundwater extraction.

## 6.3 Surface water

The Stage 3 Bioregional Assessment first states that surface water is not considered a reliable water source for unconventional gas resource development (page 27 of Holland et al., 2021) but it then proceeds to evaluate the impact of surface water extraction. There are inconsistencies in the reporting of Stage 3 investigations that will need to be addressed.

As part of the Cooper Plan, surface water can be extracted under licence from river channels, the floodplain and permanent waterholes. The Stage 3 hydrological model was used to evaluate how the required water extraction (selected as 400 ML per year under the fast development scenario) would impact on Cooper Creek if it was sourced from surface water. The water requirements represent about 2% of annual flows and the model showed extraction of that magnitude would not impact flows or alter flooding regimes in Cooper Creek. However, it is recommended to investigate potential impacts on agricultural productivity, protected wetlands, as well as protected fauna and flora on the floodplain. This aligns with the knowledge gaps identified in the Water Planning Science Plan.

Despite this, the Stage 3 Bioregional Assessment states that there is high confidence that state regulations, as well as industry mitigation strategies, can mitigate potential impacts in sensitive areas, including permanent waterholes. This is not aligned with the status of water planning: it is recognised that the water plans do not necessarily capture all localised impacts, particularly in regions with complex networks of environmental values. As such, the state regulation (Water Act 2000), represented by the volume of surface water available for extraction, might not be a sufficient control. With current regulatory processes, an application for a water license can be made and is likely to be granted given the plan has provision for un-supplemented surface water.

## 6.4 Groundwater

Groundwater can be sourced from the GABORA plan. As costs increase with depth, the Stage 3 Bioregional Assessment assumed groundwater would be sourced from the shallower aquifers, in preference to deeper confined aquifers. Using calculation of groundwater drawdown resulting from extraction, it was determined that potential impacts on groundwater-dependent ecosystems due to groundwater extraction were generally of low concern (Geological and Bioregional Assessment Program (2021), Groundwater extraction: Stressor node description for the Cooper GBA region, accessed 11 November 2021)

Exceptions are ecosystems dependent on the Cenozoic aquifer in the west of the Cooper basin and near existing groundwater bores accessing the Cadna-owie - Hooray aquifer, where it is less than 150 m thick, in the south-west of the region. Sourcing groundwater from deeper aquifers could avoid potential impacts on groundwater-dependent ecosystems in these areas.

## 6.5 Aquifer connectivity

The SEP review established that in the Cooper Creek catchment, groundwater connectivity is vital to the health of the basin and regional towns. There are numerous artesian springs with most falling outside of the existing Channel Country SEA. The SEP recommended that all known springs should be included in the

SEA as interference with groundwater sources, pressures and levels within the vicinity of springs of the LEB could have a catastrophic impact on their conservation values. There was support within the SEP for increased restrictions under the RPI Act to ensure activities are not carried out in sensitive areas (such as near springs) or in an inappropriate fashion (over-extraction) throughout the entire LEB (Qld).

In the upper channels of the Georgina catchment, groundwater dependent ecosystems (GDEs) and subsurface groundwater dependent ecosystems (SGDEs) are common. The ecological values of these ecosystems are not well understood and are often overlooked. Their connectivity to other ecosystems and aquifer permeability means there are unknown risks from water extraction. The SEP identified imposing restrictions on groundwater extraction and drilling methods in the Georgina catchment.

Throughout the Diamantina Basin, groundwater systems in the alluvia support vegetation communities. Impacts to groundwater levels could be catastrophic, not just to these ecosystems, but also to the organic beef industry that uses the basin for extensive grazing of beef cattle. The SEP highlighted the possible need to exclude livestock and tourists from the banks of permanent waterholes, without restricting access to the entire riparian and floodplain system.

The Stage 2 Bioregional Assessment produced an extensive assessment of hydrogeology in the Cooper basin but clearly outlined that there were knowledge gaps, particularly concerning connectivity between surface water and groundwater and between the various aquifers. The report recommends that connectivity must be evaluated as it will determine how prolonged groundwater pumping from a multi-layered aquifer system can affect aquifers other than the one being pumped. Similarly, connectivity between surface water and groundwater will determine if pumping groundwater from aquifer can impact on availability of surface water. Potential impacts beyond the pumped aquifer can include:

- enhanced leakage of water from overlying and underlying aquifers and aquitards;
- mobilisation of natural salts from overlying and underlying aquifers and aquitards and deterioration of water quality in the pumped aquifer;
- mobilisation of anthropogenic contaminants from overlying and underlying aquifers and aquitards;
- changes in the nature and fluxes between surface water and groundwater systems near the ground surface;
- declining water levels in shallow aquifers, leading to changes in the recharge and/or discharge rates.

The assessment also states that there is evidence to suggest that connectivity between numerous permanent waterholes and the floodplain or bedrock aquifers is more diverse and complex than what is indicated by the current knowledge. Hydrological connectivity between the Cooper and Eromanga basins is likely and the hydrogeological assessment describes where and how it might occur. The assessment highlights that considerable data and knowledge gaps exist, and outlines hypotheses that can be tested in future studies to better understand the likelihood of potential hydrological connections between stressors and assets. Additional knowledge is required to finalise assessment of threats to groundwater and surface water values.

The Shale Gas and Oil Knowledge review has also identified that potential impacts related to the taking of surface water or groundwater would require additional attention during the assessment and approval process.

The Stage 3 Bioregional Assessment sought to address these concerns and included calculation of the groundwater drawdown that would result from the extraction of the water associated with the two development scenarios. As explained in Section 4.2, under the Water Act, prevention or mitigation options are likely to be required where predicted drawdown is greater than 0.2 m. The Cenozoic and Winton-Mackunda aquifers were selected as the primary targets for water extraction because they are relatively shallow with suitable water quality. However, extraction from the deeper Cadna-owie – Hooray system could be considered if required. Groundwater drawdown calculations considered three mechanisms: (i) drawdown from groundwater extraction in the same aquifer, (ii) drawdown from groundwater extraction in an over- or underlying aquifer, and (iii) drawdown from depressurisation of an underlying gas reservoir. They rely on information on layer thicknesses and the presence of faults, and conservative estimates of hydraulic properties based on regional measurements because local measurements are not available for the entire spatial extent. Results of groundwater drawdown calculations show that:

- Drawdown is not expected to impact on the baseflow to streams in the Cooper region.
- Within the Cenozoic aquifer, there are areas where drawdown is predicted to be greater than 0.2 m and there is presence of GDEs. As such, water extraction is of potential concern. These areas only represent 0.9% of the total aquifer area. Potential impacts can be mitigated by extracting groundwater from the deeper aquifers (Winton-Mackunda or Cadna-owie - Hooray).
- Groundwater drawdown is of low concern in the Cenozoic and Winton-Mackunda aquifers where the saturated aquifer thickness is greater than 20 m, except within 1 km of existing bores where drawdown greater than 0.2 m cannot be ruled out.

The Stage 3 Bioregional Assessment does note that the calculation method is a simplification as there is no detailed information on yield and salinity for the aquifers. Moreover, the evaluation implies that if water is extracted in accordance with existing water plans, associated risks are by default mitigated. This is not necessarily the case, as discussed in Section 4.2.

The drawdown calculations provide a solid basis to start the evaluation of potential impacts of water extraction, and clearly outline the areas with the greatest potential risks. They will need to be complemented by studies of localised ecological and hydrological impacts.

## 6.6 Impact of infrastructure

The SEP review states that due to the flat topography of the basin, disturbance to natural ground level will impact aquatic ecosystems downstream of disturbance by either cutting off, redirecting and/or concentrating existing flow paths, as well as potentially impacting water quality (turbidity, dissolved oxygen, algal blooms). In the view of the SEP, any development with the ability to significantly impact the natural floodplain and channel flow paths and/or downstream water quality of waterholes must be restricted. Existing oil and gas extraction on the Cooper floodplain in Queensland has illustrated the impacts to overland flow of minor structures such as graded roads and cleared seismic lines, with grader spoil forming barriers to minor flows.

This is especially important on floodplains as drainage lines are used by fish returning to permanent waterholes in times of flood recession. Most fish species in the LEB use the floodplains to feed and grow during flood events. It is critical that interference with natural flow paths does not occur on the floodplains. The significance of the Cooper Creek floodplain was raised continuously by SEP members who agreed that if the health of the LEB (Qld) ecosystems is to be preserved, all floodplains in the Cooper Basin and greater LEB must be included in the Channel Country SEA, and development in floodplains must be restricted.

The Stage 2 Bioregional Assessment describes the surface infrastructure associated specifically with gas development: pipelines, storage tanks, transport vehicles, machinery (civil construction equipment, drilling and hydraulic fracturing equipment) and operating plant.

Fluids that may be released include produced hydrocarbon gas and liquids, produced water, flowback water, hydraulic fracturing fluids, fuels and lubricants in machinery and plant, and process chemicals that are used in some infrastructure. Release of fluids may result from a failure in the integrity of the fluid storage/delivery system (storage vessels and tanks, tankers and pipelines) or operating equipment (pumps and other plant);

human error or accidents during transport or operation of equipment; and overflow of open storage tanks or ponds due to heavy rainfall and/or flooding. This gives additional details for the type of impacts that will require mitigation.

In the Stage 2 Bioregional Assessment, the volume of flowback water is estimated as being between 25% and 75% of the initial injected water volume, which is itself estimated as 10 ML per well (Holland et al. 2020). There are potentially large volumes of water, and associated compounds, which are not returned to the surface. The fate of that water and compounds, and potential impacts on groundwater resources, are not understood. Additionally, there is the potential for the requirement to store up to 8 ML of flowback water per well. This is beyond the capacity of most tanks and would require construction of storage ponds. In the flat topography of the landscape, such infrastructure is at risk of flooding, of creating flow obstructions and changes to hydrodynamic patterns, potentially increasing erosion risks.

The Stage 3 Bioregional Assessment quantified the level of disturbance that would be created by the two development scenarios and calculated that the spatial extent of the development area (roads, well pads, seismic lines, as well as the areas between well pads and seismic lines, which are not “disturbed”) would be between 586 and 7,350 $km^2$ (or 0.5 to 5.6% of the Cooper region). The disturbed area itself was calculated as less than 27 $km^2$, and as such, does not pause a high risk of flow obstructions. Activities that would block or obstruct flows are of potential concern in about 6% (1,613 $km^2$) of the floodplain, excluding the riparian and wetland areas.

The Stage 3 Bioregional Assessment has delivered a regional scale hydrological model that can be used to assess the impact of overland flow obstruction on floodplain inundation at local scale (See Fact Sheet 13). Project proponents will be able to simulate the impact of a change in land surface and constructions of water impoundments. The Stage 3 Bioregional Assessment does note that little is known about how material changes to floodplain inundation and scouring will affect environmental values and that ongoing site-based assessment and investigation of changes to agricultural productivity, protected wetlands, and protected fauna and flora on the floodplain will be warranted.

There were two large knowledge gaps regarding the impact of infrastructure in the landscape, associated with assessing the interactions between infrastructure and surface flows:

1. Lack of understanding of flood risks to outline high risk areas for infrastructure (regional scale hydrology)
2. Requirement to develop conceptual understanding of the potential impacts of infrastructure on local surface hydrology and flows, such as increased risk of erosion (local scale hydrology, hydraulics, erosion)

The first gap has been addressed by the Stage 3 Bioregional Assessment, which has delivered a highly sophisticated regional hydrological model, in line with leading practice. It can be used by projects' proponents to assess whether the proposed infrastructure (roads, pipelines, well pads) will have an impact on flood levels, whether it will impact on ecologically important permanent waterholes and whether it will lead to local disruptions to hydrodynamic processes.

## 6.7 Hydraulic fracturing and well integrity

The Shale Gas and Oil Knowledge Review and the Stage 2 Bioregional Assessment compile the scientific understanding of the risks of shale gas and oil development (Huddlestone-Holmes et al., 2020; Kear and Kasperczyk, 2020). They demonstrate that the risks related to hydraulic fracturing are low but do acknowledge there is some uncertainty. They make recommendations for changes to the Queensland regulatory frameworks to reduce the likelihood of adverse impacts, particularly in relation to water extraction (page 177 of Huddlestone-Holmes et al., 2020). The Northern Territory and Western Australian inquiries found that shale gas and oil development and hydraulic fracturing could proceed with minimal risk if appropriate regulations and industry practices were in place.

All the inquiries note community concerns about the risks of hydraulic fracturing or shale gas and oil activities. Although the South Australian fracking inquiry found that the risks of hydraulic fracturing were low, they recommended a moratorium on hydraulic fracturing in south-east South Australia until the industry could gain a “social licence to operate”. The parliamentary committee conducting the Victorian inquiry could not reach a majority view on the future of unconventional gas development.

Where these inquiries conducted community consultations or invited submissions from the public, the most consistently raised concern was the potential impact of hydraulic fracture stimulation on groundwater. Risks associated with hydraulic fracturing have been assessed in detail for the Cooper basin (Kear and Kasperczyk, 2020) with a description of three impact modes, which are theoretical situations where hydraulic fracture propagation extends beyond the designed area and creates a subsurface flow path between geological layers in a way which was not intended. The impact modes are fracture growth into aquifer, fracture growth into well, and fracture growth into fault. Mitigating controls are proposed for each impact mode.

Wells should be constructed such that fluids cannot pass from outside the well to the inside or to travel along the outside of the well between different geological layers or to the surface. The practice of designing, constructing, operating and decommissioning wells in such a way to prevent unintended fluid movement is known as maintaining well integrity (Kear and Kasperczyk, 2020). Compromised well integrity can conceptually result in the unintended underground flow of fluids and gases into overlying stratigraphic units which could lead to an environmental impact. There has been significant work to understand the likelihood of those impacts occurring and they are generally considered manageable to a suitably low level given appropriate regulatory controls, sufficient understanding of the baseline geological and environmental systems, and implementation of best industry practices (Huddlestone-Holmes et al., 2017).

Community concerns about the risks of hydraulic fracturing and lack of well integrity led to numerous studies and inquiries, which concluded that risks were low, provided suitable controls are in place. There is no information indicating that risks would be any higher in the Lake Eyre basin. To confirm this, The Stage 3 Bioregional Assessment undertook more detailed analysis of the risks associated with hydraulic fracturing (See Fact Sheet 2). It considered two mechanisms:

1. Compromised aquitard integrity, which describes changes in the integrity of low permeability rock layers between gas reservoirs and aquifers. This is important where there is concern for groundwater contamination resulting from hydraulic fracturing.
2. Compromised well integrity, which refers to breaches of a well system that allow the unintended movement of fluids, including contaminants, outside of the well. Standards require two independent well barriers that form a protective leak-tight seal between the well and surrounding rock.

Aquifer contamination due to compromised well integrity is of very low concern based on findings from the domestic and international inquiries, as well as historical compliance reports for Cooper Basin petroleum wells. Regarding aquitard integrity, the assessment identified that in the Cooper region, a pathway for aquifer contamination due to hydraulic fracturing of the Toolachee Formation (where the shallowest unconventional gas resource is located) is only possible if a fracture propagates through the Nappamerri Group aquitard into the overlying Cadna-owie - Hooray aquifer. It thus investigated whether there were locations where hydraulic fracture propagation through the Nappamerri Group aquitard could occur, using modelling of hydraulic fracturing (See Fact Sheet 2), by undertaking hydraulic fracture modelling which showed that.

- For more than 90% of the prospective development area, there is a very low to low risk of hydraulic fractures propagating. This is where the thickness of the Nappamerri Group aquitard is greater than the maximum hydraulic fracture extent of 151 m. Hydraulic fracture growth into an aquifer, well or fault has a low likelihood of occurring and natural barriers, such as the Nappamerri aquitard, protect overlying aquifers from contamination.
- For less than 10% of the prospective development area, there is a medium to high risk of hydraulic fractures propagating. Compromised aquitard integrity is of potential concern. Careful design and monitoring of hydraulic fracturing treatments will be required, including site-specific hydraulic fracture risk assessments using more advanced hydraulic fracture modelling, analysis and monitoring techniques.

It is worth noting that the information provided in Fact Sheet 2 and the Stage 3 Bioregional Assessment synthesis report does not state whether a hydraulic fracture propagating through the areas that have been assigned a medium to high risk could eventually affect the areas assigned a very low to low risk. The map included in Fact Sheet 2 shows that these areas are adjacent. As the assessment is essentially based on the thickness of the aquitard within these areas, it can be inferred that if a fracture were to propagate from a high risk area to a low risk area, the aquitard thickness in the low risk area would prevent any intersection with the overlying aquifer.

The assessment also concluded that while fracture growth is an important aspect of understanding the risk of aquifer contamination, other aspects such as dilution, pore pressures and permeability of different strata provide greater understanding of the overall risks.

Whilst numerous high-level studies and inquiries concluded that risks from hydraulic fracturing were low, there are areas where they are material and must be controlled. As part of the Stage 3 assessment, a methodology has been developed to identify and quantify these risks and was applied to the Cooper region, clearly showing where additional controls of hydraulic fracturing will be required. Areas at risk represent less than 10% of the prospective area.

## 6.8 Chemicals

Industrial chemicals are required in gas operations for activities such as drilling, cementing, well construction and completion, well clean-up, hydraulic fracturing and waste treatment. The composition and concentration of chemicals will depend on site-specific conditions such as the geology and mineralogy of formations, environmental conditions such as temperature and pressure, and requirements to maintain well integrity and production. The managed use or accidental release of chemicals can have negative impacts on local and regional water quality and water- dependent ecosystems if not adequately controlled or managed.

Impacts from chemicals are assessed in the Stage 2 Bioregional Assessment, with a qualitative assessment of chemicals associated with drilling and hydraulic fracturing for the Cooper basin (Kirby et al., 2020). It concluded that 42 chemicals were of ‘low concern’ and considered to pose minimal risk to aquatic ecosystems; 33 chemicals were of ‘potentially high concern’; and 41 were of ‘potential concern’. These chemicals would require further site-specific assessments to quantify risks to aquatic ecosystems.

Natural rock formations contain elements and compounds (geogenic chemicals) that could be mobilised into flowback and produced waters during hydraulic fracturing. Laboratory-based leachate tests were designed to provide an upper-bound estimates of geogenic chemical mobilisation from target formations in the Cooper basin, which will guide future field-based monitoring, management and treatment options. The tests identified several elements that could be substantially mobilised into solutions by hydraulic fracturing fluids: aluminium, arsenic, barium, cadmium, cobalt, chromium, copper, iron, lead, lithium, nickel and zinc.

Priority organic chemicals such as phenols, polycyclic aromatic hydrocarbons (PAHs) and total recoverable hydrocarbons (TRHs) were also detected in extracts of powdered rock samples (Kirby et al., 2020). The storage of flowback water will thus pose risks to regional water quality, as it is likely to contain several contaminants of concern. As discussed in Section 6.4, there has been no study of the interactions between water storage infrastructure and regional water levels, although there is now a regional hydrological model that can be used to support this type of study.

The Stage 3 Bioregional Assessment states that if an accidental spill occurs, there are limited options to avoid or remediate surface water contamination due to more rapid spreading of chemicals through surface water and accumulation in sediments. As such, it highlights the importance of compliance with existing regulations and approval conditions (captured in Environmental Authorities) that are designed to avoid spills and leaks.

It also provides a quantitative assessment of migration of chemicals through deep unsaturated zones, using chemical transport modelling that accounts for key landscape parameters that determine natural attenuation, such as soil type, depth to groundwater and groundwater velocity, and relies on best-available hydraulic properties from a digital soil database. This modelling estimates the time it takes for concentrations of chemicals in hydraulic fracturing fluids or flowback water that are accidentally released into the environment to decrease to levels that are no longer considered harmful to the environment. It shows that:

- Contamination in the Cenozoic and Winton-Mackunda aquifers due to spills and leaks is of potential concern where depth to groundwater is less than 9 m, and of low concern when groundwater is less than 14 m from the surface.
- Potentially affected areas are predominantly along waterways in the central and western parts of the region and represent 0.2% of the Cenozoic aquifer and less than 0.01% of the Winton-Mackunda and Cadna-owie - Hooray aquifers.

Risks of contamination cannot be completely ruled out but areas where they might occur are well identified. The Stage 3 assessment states that there is high confidence in existing mitigation strategies, materiality thresholds and cause-and-effect relationships associated with groundwater contamination due to accidental release.

## 6.9 Altering landscape

Altering landscape includes altering cultural heritage, altering natural and agricultural productivity, altering natural habitat and species distributions, altering surface hydrology, and introducing invasive species (Holland et al., 2020).

## 6.10 Altering surface hydrology

The Stage 3 Bioregional Assessment states that surface water hydrology is not likely to be affected by requirements for water supply (noting that the assessment is not clear about whether surface water extraction will be sought by industry). However, it may be affected by bank instability and erosion.

Surface disturbance occurs during all stages of development and can potentially increase sediment load in surface waters. Siltation of streams and waterholes, as well as a decline in surface water quality associated with changed water regimes, can negatively impact aquatic flora and fauna by decreasing fitness and survival of aquatic plants, invertebrates and fish. Activities that can create surface disturbance include construction of access roads and well pads that could affect the magnitude, duration, timing and frequency of surface water flows. Beyond the development of gas resources, other activities can also impact on erosion, bank stability and water quality. Grazing has long been identified as a key contributor to hillslope and gully erosion (McCloskey et al., 2021).

Construction activities for roads and development facilities can obstruct the flow of water across the floodplain but the Stage 3 Bioregional Assessment demonstrated that for the two development scenarios that were considered, this is only a potential concern for about 6% (1,613 km$^2$) of the Cooper Creek floodplain.

To assess potential impacts to surface hydrology from activities, hydrological modelling will be required. To that end, the regional hydrological model delivered by the Stage 3 assessment can be used to assess whether any proposed infrastructure will have an impact on flood levels, whether it will impact on ecologically important permanent waterholes and whether it will lead to local disruptions to hydrodynamic processes.

## 6.11 Altering cultural heritage

The Stage 2 Bioregional Assessment discussed this aspect.

Cultural heritage sites can be physically, socially and spiritually linked to ecologically significant areas and archaeological or historic sites across the region. Traditional Owners value their country and have good knowledge of ecosystem function and the physicochemical and biological processes that drive an ecosystem and sustain life, particularly the links between water, vegetation and wildlife in arid landscapes. Damage or loss of cultural heritage values may permanently diminish cultural values for a community or group. Waterholes, lakes and rivers have spiritual values, with many sites attached to creation stories. Traditional Owners are concerned about damage to sacred sites that may restrict or inhibit use as a cultural or ceremonial site. This includes waterholes associated with customary rituals, such as women's business and historic burial sites.

Risks to cultural heritage are related to site vegetation removal, transport of seeds and pest species, damage to scared sites, and impacts on waterholes, lakes and rivers. Construction activities may facilitate the introduction and establishment of invasive species that can diminish cultural heritage values. Vegetation removal for the development of roads and surface infrastructure could remove food and medicinal plants and may also affect cultural values associated with natural habitat and species distributions.

These risks are associated with stressors that are evaluated in the GBA Explorer. There is now a tool that can assist with analysing the potential impacts of activities by consulting the causal network and applying it to the area and stressor of interest. However, it is worth noting that the causal network does not articulate any specific chain of events that links the driver (resource development) to an endpoint that is clearly defined as cultural heritage. Processes and endpoints are essentially concerned with environmental values per se and do not clearly articulate the relationships with cultural values.

The region also contains historic heritage sites associated with the early explorers, Burke and Wills and increased visitation to the sites may also increase vehicle traffic, which may lead to erosion and damage to the site. These are not captured in the causal network.

Mitigating controls include cultural heritage consultation and clearances, along with training and education to promote awareness of cultural heritage values and to improve recognition of culturally sensitive areas.

## 6.12 Altering natural and agricultural productivity

The Stage 2 Bioregional Assessment discussed this aspect.

Risks to natural and agricultural productivity include increased soil erosion and reduced soil productivity. Increased soil erosion is caused by disturbance to the soil structure by a range of activities, including grazing, and as far as gas resource development is concerned, from inappropriate design and construction of access roads, borrow pits, pipelines, seismic surveys, surface infrastructure and well pads.

Changes to surface elevations, site vegetation removal, poor topsoil management and ground compaction from earthmoving equipment can reduce soil productivity in nutrient-poor environments, and this may reduce regrowth and recovery during the re-establishment of native flora as part of site rehabilitation.

Changes to surface water flows, spring and waterhole depth and extent, and water quality from unconventional gas resource development operations can also affect natural and agricultural productivity through change in soil moisture (too much or too little) and loss of waterhole connectivity. Removal of nutrients from soil erosion and facilitation or introduction of invasive species can also affect the productivity of natural ecosystems. Changes to soil structure can alter agricultural productivity.

As with risks to cultural values, these aspects are too site-specific to be assessed at regional level. The GBA Explorer can assist with ensuring all stressors and endpoints are suitably identified and evaluated. The Stage 3 Bioregional Assessment provides a comprehensive overview of the level of concern for activities, stressors, processes and endpoints, and includes consideration of natural and agricultural productivity. This overview is provided in table format in Figure 7 on pp. 29 of the Stage 3 Bioregional Assessment synthesis report.

For these risks, mitigating controls are minimising construction footprints and avoiding fragile areas, including slopes, water bodies and sensitive vegetation communities.

## 6.13 Altering natural habitat and species distributions

The Stage 2 Bioregional Assessment discussed this aspect.

The region contains important wetlands and groundwater-dependent ecosystems of unique environmental value. Natural habitat and species distribution may be affected by habitat fragmentation and loss, increased mortality of native species, changed air quality, contamination of soil, groundwater and/or surface water, changed groundwater levels or pressures and changed surface water flows. Vegetation removal can potentially affect both terrestrial and aquatic environments, as well as removing ground cover that provides habitat. Holland et al. (2020) outline these threats:

- Disturbance can lead to invasive species being introduced and out-competing native vegetation, reducing suitable habitat for threatened species. Once weeds and pests become established, eradication becomes very difficult. Introduced plant species, such as invasive grasses, can also increase the severity and likelihood fire. Invasive species (plants, herbivores and predators) are included as stressors in the GBA Explorer.
- Infrastructure used to store water, such as small dams or ponds, create artificial watering points that can create imbalance within the ecosystem by allowing some native species populations to increase, facilitating new species to establish within the area, potentially impacting on threatened species. Entrapment of native fauna in quarries, dams and trenches can increase mortality of native species. Artificial water sources are included in the GBA Explorer.
- Any change to flooding regimes can impact on species distributions and natural habitat, as native species have evolved and adapted to the current flow variability. Impacts on flooding regimes have been assessed by the Stage 3 Bioregional Assessment.
- Dust, emissions of particulate matter and compounds (nitrogen oxides, sulphur dioxide, carbon monoxide and volatile organic compounds), noise and light pollution can affect habitat quality and species distribution. Terrestrial mammals, birds and reptiles can also be at risk due to collisions with

increased vehicle traffic. Atmospheric emissions, dust generation and vehicle movements are included in the GBA Explorer.

- Construction and maintenance of roads, pipelines and seismic survey lines can lead to habitat fragmentation and loss through removal of vegetation. Vegetation removal is included in the GBA Explorer.
- Other threats include alteration of natural fire regime during construction of fire breaks; artificial lighting during drilling and well construction; night-time flaring from gas processing plants. These threats can be analysed by consideration of the activities included in the GBA Explorer, and the associated causal pathways, which include ecosystem burning and habitat degradation.

Mitigating controls are reducing the development footprint and ensuring earthworks are conducted with minimal damage and rehabilitated as soon as possible.

Training is provided for fauna identification and habitat restoration to ensure fauna entrapment does not occur, including leaving measures for fauna to escape during construction or assisting with relocation of trapped fauna. Site-based protocols to mitigate impacts of dust and emissions, including noise and light, involve monitoring of air quality and ensuring that noise and light emissions are minimised in space and time.

With respect to ecosystem health and species distribution, the Stage 3 Bioregional Assessment gathered baseline data for ecosystem extent and condition (see Fact Sheet 26) and showed that ecosystems are relatively intact in the Cooper region, despite 50 years of conventional oil and gas industry activity. This is because the disturbance footprint is relatively small, representing less than 0.01% of the region extent.

Nevertheless, the assessment also states that reduced floodplain inundation is of potential concern for 2 endangered bird species, the Australian painted snipe and the grey grasswren. The hydrological modelling showed that gas development activities could reduce floodplain inundation in about 6% of the floodplain habitat that support these species. Where knowledge of plant biology and water requirements was limited, the assessment applied the precautionary principle and concluded that changes to floodplain inundation were also of potential concern for braided sea heath, *Indigofera oxyrachis* and *Xerothamnella parvifolia*.

Key knowledge gaps relate to the distribution and abundance of the Australian painted snipe and the grey grasswren and the water regimes required to support critical habitat for these species. The current data and knowledge base are also insufficient to establish robust materiality thresholds for a decrease in persistence of native fauna due to stressors such as soil and surface water contamination.

All these aspects are captured in the GBA Explorer, although a key conclusion is that knowledge gaps remain with respect to understanding the links between development activities and impact on threatened species and ecological assets, as they have not been studied in arid environments, in Australia and globally. These are likely to vary both spatially and temporally or may act in additive, multiplicative and nonlinear ways, further complicating the interpretation of the cumulative impacts associated with resource development.

Beyond gas resource development, the SEP Review raised concerns for park management methods currently being practised in these national parks, such as extensive grazing of livestock within the national park boundaries.

## 6.14 Climate change

All available studies stated that the consideration of climate change was out of scope, as it is not an issue specific to the LEB area. However, most environmental values rely on the surface flow regime and climate change is highly likely to impact on it.

The SEP review acknowledges climate change as an emerging threat, quoting a 30% decrease in water levels and increased spread of invasive species.

The Stage 2 Bioregional Assessment estimates potential changes to rainfall, evapotranspiration and number of hot days (temperature greater than 35$^{o}$c) based on a worst-case emissions scenario (referred to as RCP8.5 in the current IPCC report). Mean annual rainfall is predicted to decrease, mean annual evapotranspiration is predicted to increase, and the number of hot days is predicted to increase. The assessment does not provide comments or analysis about the impact of these potential changes on environmental values.

The Stage 3 Bioregional Assessment lists in its assumptions that climate change is not assessed, as it will not change processes and predicted responses to such a degree that impacts on endpoints would be materially altered. However, its analysis of ecosystem burning contradicts this assumption. The assessment states that changes to ecosystem burning regimes are of potential concern in 30% of the Cooper region for all protected species. Increased average temperatures, increase in number of hot days and shifting rainfall patterns will combine to increase risks to biodiversity associated with fire. These are all related to climate change, so it is incorrect to state that it will not materially alter the impacts on endpoints. In addition, flood modelling scenarios did not include consideration of climate change scenarios: this is a gap in the analysis and any further studies should address it.

Indirect and cumulative impacts from climate change have not been considered in the available studies. These impacts are highly complex and describing all the potential contributing factors and their interactions under a range of possible scenarios would require a large study. Nevertheless, this should be considered as it is almost certain future events such as extreme rainfall or prolonged dry periods will impact on environmental values.

Given the reliance of environmental values on flow regime and water availability, and impact of changes to fire regimes on biodiversity, climate change constitutes a key threat to the LEB. None of the reports that were reviewed provide comments or recommendations about mitigating these threats.

# 7. Protection of Environmental Values

As outlined in Section 4.2, there are numerous pieces of Commonwealth and Queensland legislation, regulation, guidelines and policies that apply to the approval, exploration, development and operation of resource projects. The key piece of Queensland legislation that aims to regulate resource activities in a way which avoids, minimises or mitigates its environmental impacts is the EP Act, supported by environmental impact statement that compiles, among other things, all potential adverse and beneficial environmental, economic and social impacts of a project.

The SEP deliberated on the suitability of regulatory frameworks, with a strong focus on the spatial extent of the SEA as it is currently presented in the RPI Act. In the SEP review report, there is no discussion about the suitability of the EP Act for avoiding, minimising or mitigating environmental impacts. It is solely concerned with the status of the SEA and communicates strong support from the SEP to expand the current spatial extent to include the key ecosystems, ecosystem processes and functioning across the broader LEB (Qld) landscape. Some of the deficiencies the SEP identified with the existing map extent were that:

- It did not currently protect the critically endangered artesian springs or their endemic species from potential impacts from unconventional and conventional petroleum and gas activities or from mining.
- It did not include all the relevant floodplain areas within the LEB (Qld).

- It did not include significant wetlands important for waterbird breeding events and other aquatic fauna and flora communities (e.g., Lake Galilee, Lake Buchanan) The consensus amongst panel members was that these two lakes should be included as part of the SEA for additional protection from future development in the SEA area.
- There was not any buffer around the significant floodplain and riverine ecosystems to account for indirect impacts or cumulative impacts from potential activities.
- It did not consider the whole of the LEB (Qld) catchment across the broader landscape where international and nationally significant ecological values are present.

Several proposed expansions for the SEA were considered. Although consensus was not reached, most of the SEP members supported expansion of the SEA to incorporate the entire LEB (Qld) basin boundary. Some panel members expressed concern regarding the economic and social burden on towns and agriculture to expand the SEA to the LEB (Qld).

The causal network provided as part of the Stage 3 Bioregional Assessment includes the Channel Country SEA as an endpoint, and identified 104 pathways between resource development and its condition, of which:

- 0 are possible, material, unavoidable and cannot be mitigated and therefore of potentially high concern
- 19 are possible, material and unavoidable but can be mitigated and therefore of potential concern
- 20 are possible, material but avoidable or possible but not material and therefore of low concern
- 65 are not possible and therefore of very low concern

## 7.1 Pathways of potential concern

The aspects that are of potential concern should be a priority for more detailed local-scale assessment. They include accidental release of chemicals, overland flow obstruction, soil compaction, vegetation removal, vehicle movement. The total area where aspects can be of potential concern within the Cooper region is 10,418 $km^2$.

## 7.2 Pathways of low concern

The aspects that are of low concern are controlled release of wastewater, invasive herbivores, surface water extraction and waste disposal.

The deficiencies that the SEP identified with the existing extent of the SEA are not captured by the quantitative assessment of risks that was conducted for the part of the SEA that overlies the Cooper region. Where the SEP was concerned about protection of artesian springs or their endemic species, significant wetlands, aquatic fauna and flora communities, the quantitative assessment for the part of the SEA that overlies the Cooper region identified that concerns are related to accidental release of chemicals, overland flow obstruction, soil compaction, vegetation removal, vehicle movement, with no direct link to the protection level outlined by the SEP.

The RPI Act statutory guidelines provide examples of how a project proposal might meet the prescribed solution in relation to different environmental attributes of the SEA. There are several that are relevant to the stressors identified above for the part of the SEA that overlies the Cooper region:

- The activity will be carried out with an appropriate buffer area around all watercourses, lakes, wetlands or springs and defined riparian vegetation zones.
- The activity will not have any direct or indirect release of contaminants to waters including groundwater from the operation of the activity.

- The activity will not result in any potential or actual adverse effect on a wetland, lake, watercourse or spring.
- Water storage dams are located off stream or not in major watercourses.
- Construction activities are undertaken in times when there is no water present.
- The activity will not inhibit the overflow or flow of surface water in or out of a wetland or watercourse. Operation of the activity will not result in actual or potential adverse effects on groundwater.
- The activity will not result in the clearing of native vegetation within or adjoining watercourses, lakes, wetlands or springs; cause disruption to soil profiles through earthworks or excavation; result in disturbance to land which cannot be rehabilitated immediately after the activity is completed.
- The activity is separated from wildlife corridors by an appropriate buffer and will not result in actual or potential adverse effects onto the integrity or functioning of the corridor.

Complying with the statutory guidelines within the SEA would largely control the pathways of potential and low concern. For the part of the SEA that overlies the Cooper region, most risks from gas resource development can be mitigated by complying with the RPI Act statutory guidelines.

Regarding potential extension of the SEA within the Cooper region, the Stage 3 Bioregional Assessment identified risks that must be mitigated and determined the specific areas where these risks would occur. However, these risk areas were not compared with the current extent of the SEA. As such, the outcomes from the Stage 3 assessment cannot be used to determine if the current SEA extent provides an additional level of protection to the identified risk areas within the Cooper region.

The Stage 3 Bioregional Assessment states that in general, links from activities to stressors can be mitigated by existing regulatory and industry management frameworks. The validity of this assumption needs to be discussed. In addition, the assessment states that links from processes to endpoints associated with changes to natural processes are often difficult, if not impossible, to mitigate and it will be critical to ensure that these do not occur.

## 7.3 Surface Water and Groundwater extraction

The Stage 3 Bioregional Assessment states that there is high confidence that state regulations, as well as industry mitigation strategies, can mitigate potential impacts in sensitive areas, including permanent waterholes. This is not aligned with the status of water planning: it is recognised that the water plans do not necessarily capture all localised impacts, particularly in regions with complex networks of environmental values. As such, the state regulation (Water Act 2000), represented by the volume of surface water and groundwater available for extraction, might not be a sufficient control. As the EIS must assess the potential adverse environmental impacts of a project, it should include impacts from water extraction but at this stage, it is not clear whether there is sufficient information to undertake a comprehensive assessment, as it largely depends on progress with the Water Planning Science Plan, at least for surface water. For groundwater, the drawdown calculations provide a solid basis to start the evaluation of potential impacts of extraction, and clearly outline the areas with the greatest potential risks. They will need to be complemented by studies of localised ecological and hydrological impacts, as part of the EIS. Nevertheless, with current regulatory processes, an application for a water license can be made and is likely to be granted given the water plans has provision for un-supplemented water.

## 7.4 Impact of Infrastructure

The Stage 3 Bioregional Assessment delivered a regional scale hydrological model that can be used to assess the impact of overland flow obstruction on floodplain inundation and quantified the level of disturbance that would be created by the two development scenarios. Flow obstructions are of potential concern in about 6% of the floodplain. It is not clear whether the RPI Act statutory guidelines provide control to mitigate this risk as the risk area has not been mapped over the SEA extent.

With access to the hydrological model, project proponents will be able to simulate the impact of a change in land surface and construction of water impoundments but will also be required to undertake site-based assessment of changes to agricultural productivity, protected wetlands, and protected fauna and flora. As there is little information about how material changes to floodplain inundation and scouring will affect environmental values, it is not clear whether the EIS process will be able to capture this aspect. However, this is only of concern for about 6% of the floodplain and there is scope to exclude activities from this specific area. The RPI Act might already control activities in this area, but this could not be assessed as the risk area has not been mapped over the SEA extent.

## 7.5 Hydraulic fracturing

Community concerns about the risks of hydraulic fracturing and lack of well integrity led to numerous studies and inquiries, which concluded that risks were low, provided suitable controls are in place. There has been significant work to understand the likelihood of those impacts occurring and they are generally considered manageable to a suitably low level given appropriate regulatory controls, sufficient understanding of the baseline geological and environmental systems, and implementation of best industry practices. However, the Stage 3 Bioregional Assessment identified that for about 10% of the prospective development area, there is a medium to high risk of hydraulic fractures propagating. Careful design and monitoring of hydraulic fracturing treatments will be required, including site-specific hydraulic fracture risk assessments using more advanced hydraulic fracture modelling, analysis and monitoring techniques. It is not clear whether current regulation capture these requirements. In any case, there is scope to exclude activities from the specific area that present a medium to high risk of fractures propagating. As with impacts from infrastructure, the RPI Act might already control activities in this area, but this could not be assessed as the risk area has not been mapped over the SEA extent.

## 7.6 Disruption to natural habitat

Reduced floodplain inundation is of potential concern for 2 endangered bird species and for three plant species. Knowledge gaps remain with respect to understanding the links between development activities and impact on threatened species and ecological assets, as they have not been studied in arid environments. These are likely to vary both spatially and temporally or may act in additive, multiplicative and nonlinear ways, further complicating the interpretation of the cumulative impacts associated with resource development. There is scope to exclude activities from the specific area where reduced inundation is predicted (about 6% of the floodplain) but it is not clear if cumulative impacts on endangered species can be predicted and controlled.

## 7.7 Climate change

All available studies stated that the consideration of climate change was out of scope, as it is not an issue specific to the LEB area. However, given the reliance of environmental values on flow regime and water availability, and impact of changes to fire regimes on biodiversity, climate change constitutes a key threat to the LEB in general, and particularly the Cooper region. The impacts of climate change should be included in all further studies, as it is almost certain future events such as extreme rainfall or prolonged dry periods will impact on the risk assessment results with associated requirements to modify mitigation controls.

### 7.8 Cultural values

Risks to cultural heritage have not been quantified and this constitutes a major gap in the Stage 3 assessment. EIS studies will need to include them.

## 8. Conclusions

All studies that were reviewed for this synthesis clearly establish that the Lake Eyre basin has unique environmental values of state, national and global significance. There is a shared understanding of the key biophysical processes and associated environmental values, their significance, and the need to protect them. Differences between the studies relate to:

- Spatial extent: the SEP review considered the whole LEB (Qld) whereas the bioregional assessment was only concerned with the Cooper basin and the Shale Gas and Oil Knowledge Review had a Queensland-wide scope.
- Methodology: the SEP review was a qualitative assessment, entirely based on gathering the knowledge held by participants. The Shale Gas and Oil Knowledge Review was also a qualitative assessment, based primarily on literature from North America. The bioregional assessment progressed from largely qualitative at Stage 2 to fully quantitative at Stage 3. It is worth noting that many of the qualitative assessments provided by the SEP review were later confirmed by the Stage 3 quantitative studies (one example relates to waterhole hydrological processes, discussed in Section 5.1).
- The type of activities that were considered in the risk assessment: the SEP review evaluated a range of economic activities and was not constrained to gas extraction; the Shale Gas and Oil Knowledge Review focused on shale gas and shale oil extraction; and the bioregional assessment was solely concerned with potential risks associated with gas resource development.

The recommendation from the SEP review of most interest to the LEB initiative is that expansion of the SEA is required to ensure ecosystems are protected from future economic activities. Quantitative results from the Stage 3 assessment shows that this is not necessarily required as many risks will be controlled by existing regulatory processes, at least as far as gas development activities are concerned.

Under the EP Act, gas production activities require a site-specific Environmental Authority (EA) to be granted and applications for an EA are subject to an approvals process supported by an environmental impact statement (EIS). The Stage 3 Bioregional Assessment has delivered regional-scale datasets, methodologies and modelling tools ("Cooper GBA Explorer") that will provide strong support to any EIS study undertaken in the Cooper region, including an innovative causal network that will ensure all potential impacts are captured. It also provides a template for conducting similar bioregional assessments for the LEB region not covered by the Cooper basin. There are some limitations to the Cooper GBA Explorer:

- It is very difficult to navigate and find the information that will support EIS studies. Data, methodology descriptions, results, evaluation, supporting maps and conclusions are spread over a range of sources. Datasets are available on a public website (data.gov.au) but specific links to the datasets are not provided, making it challenging to locate the datasets of interest. Elements of the methodologies are described in three different sources (the fact sheets, the synthesis report and the text embedded in the GBA Explorer online tool) with no document providing a complete description. Users would need to compile information from the various sources to gather a complete method description, which is not a robust process. In its present form, the GBA Explorer is not suitable for supporting EIS studies, as it does not provide access to a comprehensive traditional report, with contents covering all aspects of standard scientific investigations for each biophysical aspect (data, methods, results, evaluation and discussion). Given the level of funding allocated to the assessment, it is reasonable to expect that a comprehensive report be made available to assist future users.

- The assessment contains inconsistencies: for instance, it states that surface water is not considered a reliable water source for unconventional gas resource development but proceeds to evaluate the impact of surface water extraction; it states that climate change is not assessed as it will not materially alter impacts but concludes that changes to ecosystem burning regimes from climate change are of potential concern in 30% of the Cooper region for all protected species. These inconsistencies will need to be addressed and it is highly likely that this will be achieved by producing a comprehensive report. Inconsistencies tend to occur when information is spread across several documents, which reduces the ability to analyse links between various topics.
- It assumes that if an aspect is covered by existing regulation (EP Act or Water Act), potential impacts can be mitigated by existing regulatory and industry management frameworks. The validity of this assumption will need to be validated. For water extraction, this assumption is not valid. Under the Water Act and associated water plans, a water allocation can be granted even if localised impacts have not been assessed. The GBA Explorer has not delivered an assessment of the effectiveness of the current regulatory framework, it has assumed it was effective. As stated above, the SEP review, based on experts' opinion, concluded that the current regulatory framework would not deliver adequate protection.
- The assessment does not compare the extent of the part of the SEA that lies within the Cooper region with the areas that are exposed to risks from water extraction, hydraulic fracturing and changes to floodplain inundation. As such, it does not evaluate whether the identified risk areas are currently granted an additional level of protection through the RPI Act.
- It does not include assessment of climate change scenarios to evaluate the impacts of climate change on the risk areas related to infrastructure, flood plain inundation, hydraulic fracturing, species distribution and fire regimes.
- It does not include a thorough assessment of cultural values.

Assuming these limitations can be addressed, the Cooper GBA Explorer will provide strong support to EIS studies. The regional analysis shows that there are differing levels of risks within the region and risk areas are well identified. There is scope to adapt the level of protection to the level of risk, either through specific EA conditions or through statutory guidelines in the RPI Act, depending on the location and extent of the risk areas. There is also the option to exclude specific activities from the risk areas, given they only represent a small proportion of the region.

The most significant gap in the regulatory framework relates to water plans, which do not consider potential localised impacts on groundwater systems, groundwater-dependent ecosystems and cultural values, and do not include the impacts of climate change on water availability. This must be addressed before water allocations are granted.

More generally, the effectiveness of the current regulatory framework has not been tested, which constitutes a key limitation to the risk assessment results, as it was assumed that if an aspect was covered by existing regulation, potential impacts would be mitigated.

There are knowledge gaps concerning the understanding of some values, particularly in relation to protected matters: lack of accurate records of the spatial distribution of threatened and migratory species; lack of accurate mapping of species habitat; no detailed knowledge of ecology, distribution and threats to individual threatened species; and difficulties with predicting and controlling cumulative impacts on endangered species. This is an area of concern given all studies highlight the unique ecological values of the region. EIS will require a strong focus on ecological processes.

Finally, climate change is a significant threat with the potential for direct and indirect effects on water resources, riverine ecosystems, biodiversity and endemic species. The current regulatory framework is not designed to address this, as it is only concerned with assessing the impacts of proposed activities.

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# Appendices

Additional information from scientific reports

Potential Impacts from activities in the LEB

# Appendix A

## Additional information from scientific reports

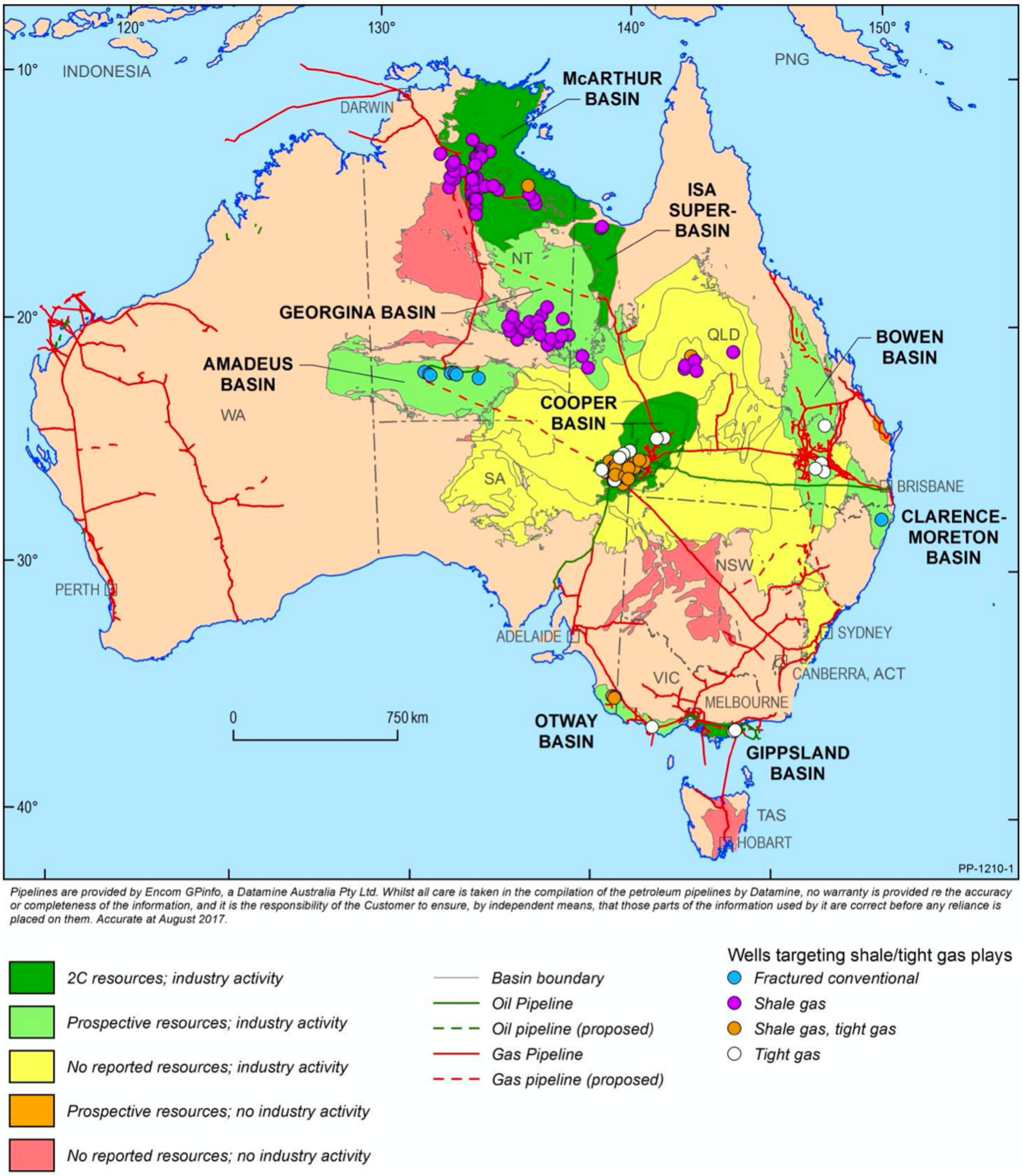


Figure 2 (Fig. 5.3 of Hall et al. (2018))

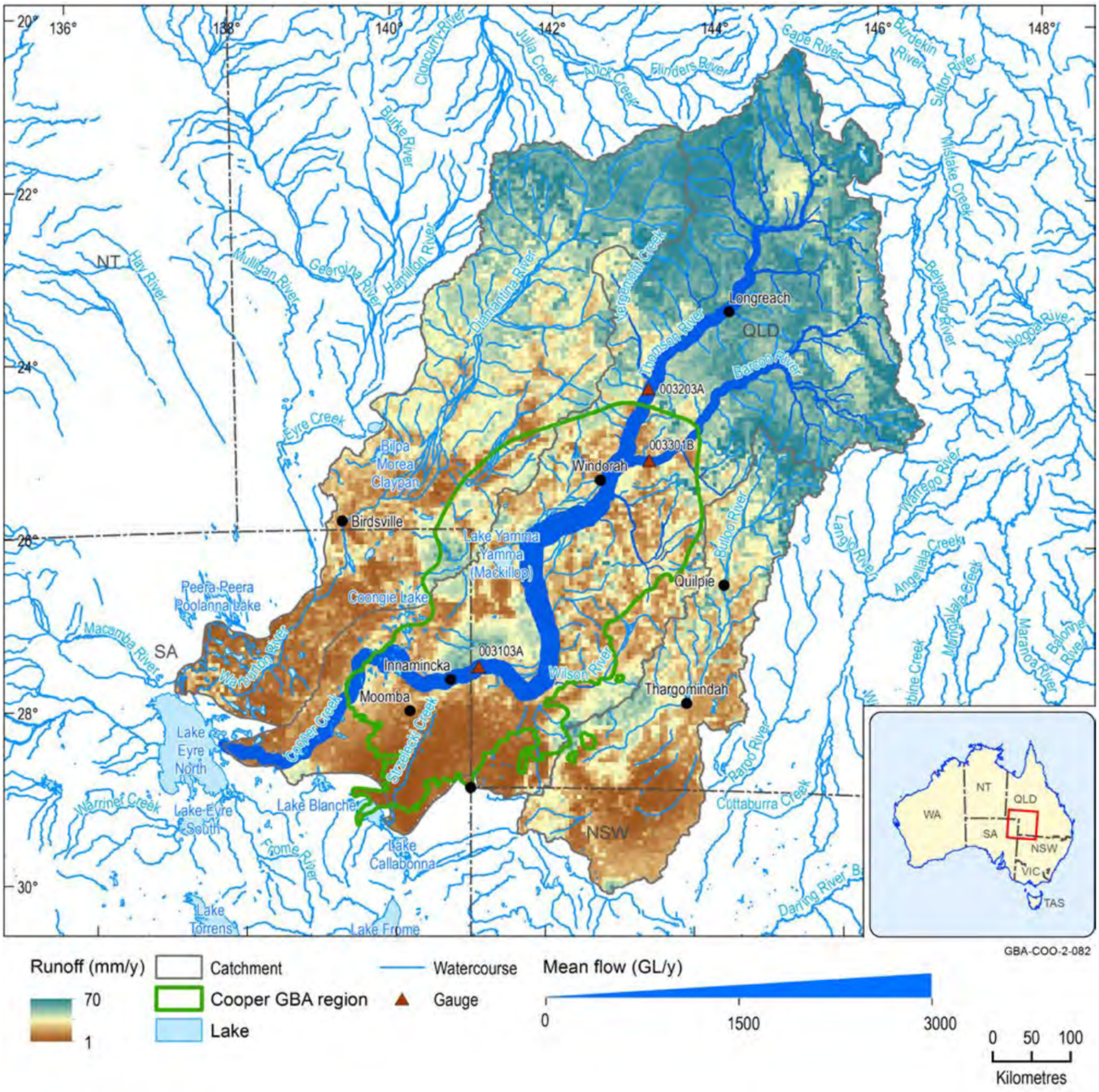


**Figure 40 Surface water conceptualisation across the Cooper Creek catchment and Diamantina and Bulloo river catchments**

Mean flow estimates (GL/year) are generated from the difference between precipitation and evapotranspiration (P-ET) (Figure 41).
Data: CSIRO (2015, 2014); Queensland Department of Natural Resources Mines and Energy (2018)
Element: GBA-COO-2-082

Figure 3 (Fig. 40 of Holland et al. (2020))

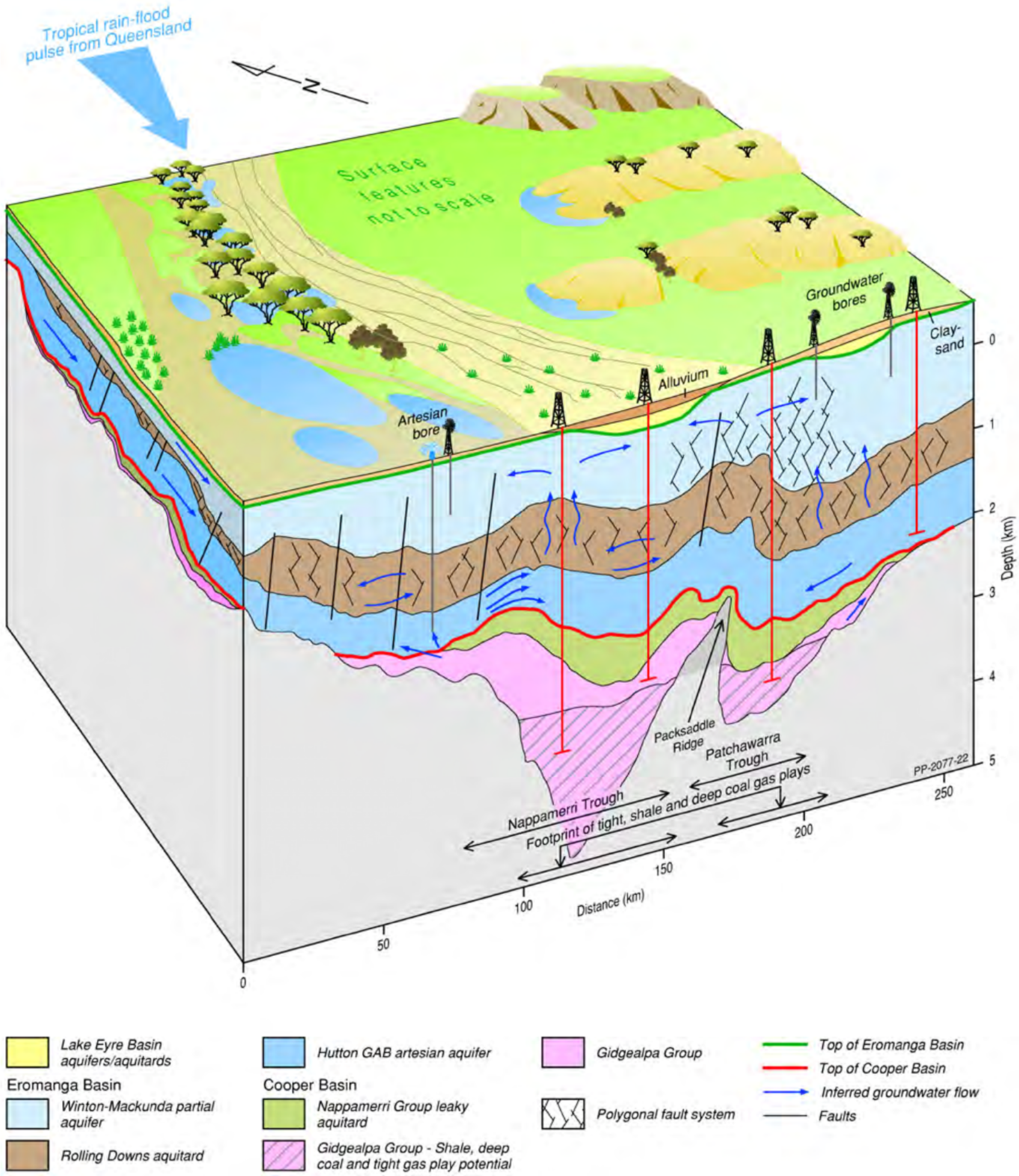


**Figure 4 Conceptualisation of Cooper and Eromanga basins**

Interactions include: leakage from rivers and lakes recharging regional aquifers during flood events; leakage to perched aquifers above the regional water table; leakage from shallow Cenozoic aquifers to deeper Cenozoic aquifers; regional south-westward directed groundwater flow in Cenozoic and Winton-Mackunda partial aquifers; upwards leakage from via polygonal faulting pathways; shallow groundwater extracting groundwater.
Element: GBA-COO-2-330

Figure 4 (Fig. 4 of Evans et al. (2020))

# Appendix B

## Potential Impacts from activities in the LEB

The comprehensive lists of potential impacts from all economic activities that could occur in the LEB, as compiled in the SEP review, include:

1. Direct loss, degradation and fragmentation of habitats (rivers, wetlands, riparian trees and habitat, remnant vegetation) from the disturbance footprint associated with linear and static infrastructure.
2. Direct impacts to threatened species that reside in permanent waterholes.
3. Declines in water pressure and changes to water quality, water level, temperature and ecosystem structure (including GDEs) in the GAB through groundwater drawdown.
4. Changes to groundwater quality in upper aquifers from leaks into overlying aquifer from production casing or via offset wells vertical migration of fluid along faults/ fractures improperly completed or plugged offset wells.
5. Surface water and groundwater quality impacts from well failure as a result of induced seismicity (from hydraulic fracturing and dewatering of coal seams).
6. Groundwater quality impacts from reinjection of flowback water and produced water, including induced seismicity.
7. Groundwater and surface water impacts from spills of drilling fluids, fracturing fluids, flowback and produced water during treatment and disposal.
8. Changes to surface water quality from treated/untreated CSG water discharges to watercourses.
9. Unauthorised releases of poor-quality water from open cut mines during flooding events.
10. Changes to the quantity of water flowing through ephemeral watercourses resulting from direct discharges of CSG water.
11. Potential changes to overland flow paths through subsidence.
12. Altered flow paths to wetlands resulting from infrastructure placement and design.
13. Loss of connectivity from linear infrastructure (roads, pipelines, wells, water ponds, pits etc.) creating barriers on floodplains diverting flows away from natural wetlands or water dependent species and communities.
14. Groundwater and surface water level/quality impacts from produced water leaching or overflowing from pits/storage ponds or leaking from pipelines (from flooding/ structural failure).
15. Groundwater level impacts from CSG and mine dewatering and associated impacts on GDEs and springs.
16. Watercourse diversions and realignment from mines.
17. Abandoned storage ponds/pits remain onsite with contamination at base (due to evaporation) and potential groundwater quality impacts through leaching.
18. Groundwater impacts from acid mine drainage and leaching of tailings dams and other extraction/processing waste storage areas.

This list includes impacts that are not unique to the LEB and are well understood and controlled by existing mechanisms. All petroleum leases (which concern both oil and gas extraction activities) and mining leases require a site-specific Environmental Authority (EA) with conditions that will mitigate these risks if the development application proceeds:

- Impact 8: Changes to surface water quality from treated/untreated CSG water discharges to watercourses
  EAs can contain conditions prescribing how releases of poor-quality water to the receiving environmental can occur, to minimise risks to environmental values.
- Impact 9: Unauthorised releases of poor-quality water from open cut mines during flooding events
  The risk of non-compliant releases is minimised through conditions related to regulated structures, which impose freeboard requirements ahead of the wet season.
- Impact 10: Changes to the quantity of water flowing through ephemeral watercourses resulting from direct discharges of CSG water
  As above, EA conditions would mitigate this impact.
- Impact 11: Potential changes to overland flow paths through subsidence
  This would only apply to underground mining and will be controlled by a Subsidence Management Plan (if the mine were to proceed).
- Impact 16: Watercourse diversions and realignment from mines
  There are specific technical guidelines to govern design of such structures, with strict monitoring conditions.
- Impact 17 and 18: Groundwater impacts from acid mine drainage and leaching from tailings dams or ponds
  Risk of leaching is mitigated by conditions related to regulated structures; EA conditions include the requirement to analyse and manage risks from acid mine drainage.

These risks are not specific to the LEB and there are existing mechanisms to analyse and control them, they will not be discussed further..

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