# South Australia - Moomba

# Environmental Impact Report: Carbon Storage

## March 2021

PGER 00321

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| **DOCUMENT CONTROL SHEET**<br>**Cooper Basin Carbon Storage EIR** | | | | | | |
|---|---|---|---|---|---|---|
| **Document Reference** | **Revision Number** | **Revision Date** | **Compiled by** | **Checked by** | **Approved by** | **Comment** |
| Carbon Storage EIR | 0 | 29/06/2020 | GB | SM | PW | Draft for DEM review & consultation |
| Carbon Storage EIR | 1 | 22/10/2020 | LR | PW | TR GW | Final for submission |
| Carbon Storage EIR | 2 | 11/03/2021 | LR | PW | CW | Final incorporating Government feedback |

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| | |
|---|---|
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| bcf | Billion Cubic Feet |
| BoM | Bureau of Meteorology |
| CCS | Carbon, Capture and Storage |
| $CH_4$ | Methane |
| $CO_2$ | Carbon Dioxide |
| CSA | Contaminated Site Assessment |
| CSP | Crude Separation Plant |
| DEM | Department for Energy and Mining (South Australia) |
| DCWO | Drilling, Completion and Well Operation |
| EGSC | Effective Geological Sequestration for Carbon |
| EHR | Enhanced Hydrocarbon Recovery |
| EHS | Environment, Health and Safety |
| EIR | Environmental Impact Report |
| EOR | Enhanced oil recovery |
| EPA | Environment Protection Authority (South Australia) |
| EPBC Act | Environment Protection and Biodiversity Conservation Act 1999 |
| ETP | Ethane Treatment Plant |
| GAB | Great Artesian Basin |
| GIS | Geographic information system |
| Gt | Gross Tonnage |
| HSHS | Health and Safety Hazard Standards |
| HSR | Health and Safety Representative |
| ICAM | Incident Cause Analysis Method |
| IMS | Incident Management System |
| IOR | Improved Oil Recovery |
| IPCC | Intergovernmental Panel on Climate Change |
| ISR | Impacted Site Review |
| JHA | Job hazard analysis |
| LDB | Lower Daralingie Beds |
| LRP | Liquids Recovery Plant |
| MAS | Migration Assisted Storage |
| mD | milliDarcies |
| Mt | Million Tonnes |
| MSC | Moomba South Central |
| $N_2$ | Dinitrogen |
| NEPM | National Environment Protection Measure |
| NPW Act | National Parks and Wildlife Act 1972 (South Australia) |

| | |
|---|---|
| PEA | Preliminary Environmental Assessment |
| PEL | Petroleum exploration licence |
| PGE Act | South Australian Petroleum and Geothermal Energy Act 2000 |
| PPL | Petroleum Production Licence |
| ppm | Parts per million |
| PPO | Production and Processing Operations |
| PRL | Petroleum Retention Licences |
| REM | Roseneath, Epsilon and Murteree |
| RO | Reverse Osmosis |
| SACBJV | South Australian Cooper Basin Joint Venture |
| SEO | Statement of Environmental Objectives |
| SMS | Santos Management System |
| TDS | Total dissolved solids (measure of water salinity) |
| WIMS | Well Integrity Management System |
| WPTW | Wellsite Permit to Work |

# 1 Introduction

The intent of this Environmental Impact Report (EIR) is to facilitate the storage of measurable quantities of carbon dioxide ($CO_2$) in subsurface geological formations (defined as 'carbon storage') at Santos' Cooper Basin operations in South Australia.

Carbon storage is the sequestration of $CO_2$ in geological formations and is the final stage in carbon capture and storage (CCS). This process will involve the capture of carbon emissions ($CO_2$) from industrial sources and injecting them into formations deep underground. Utilisation followed by storage has the additional step of using injected $CO_2$ for a specific beneficial purpose (such as enhanced hydrocarbon recovery) resulting in the subsidiary or consequential storage of this $CO_2$ in the geological formations.

Implementation of CCS will contribute to a significant reduction in $CO_2$ emissions in the Cooper Basin. There is also the future potential to store the equivalent of almost 4% of national carbon emissions in suitable geological formations within the Cooper Basin for other industrial players, making an even greater contribution to Australia's emissions reduction targets (refer Section 2.3).

Santos has a long term aspiration to achieve net-zero emissions from its operations by 2050. The company aims to achieve this through growth in export of liquified natural gas, reduction in emissions from operations and investment in technology and innovation. The development of Santos' flagship, commercial-scale carbon capture and storage project is an important step in meeting this commitment.

The project will initially capture emissions from the Moomba Gas Plant in northern South Australia, where there is existing equipment to separate $CO_2$ from sales gas. The captured $CO_2$ will be dehydrated, compressed, and then transmitted via pipelines to suitable locations, where it will be injected into target geological formations deep underground.

The $CO_2$ may be stored in hydrocarbon bearing formations, deep saline geological formations or other geological targets and may occur following utilisation of the $CO_2$.

The focus of this EIR is to assess the environmental risks of the storage of $CO_2$. This operation is a regulated activity under the South Australian *Petroleum and Geothermal Energy Act 2000* (PGE Act) and is also referred to as 'carbon storage' and 'geological sequestration'. This EIR has been prepared in accordance with the PGE Act and Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2013* (the Regulations).

The EIR does not address already approved activities such as oil and gas field activities and carbon capture and utilisation aspects as discussed in Section 1.1.

## 1.1 Scope

This EIR (and the accompanying Statement of Environmental Objectives (SEO)) specifically cover operations for carbon storage which is defined as the storage of measurable quantities of $CO_2$ in subsurface geological formations. This also may include carbon storge following the cessation of EOR activities.

The following activities, including, but not limited to $CO_2$ capture, treatment, transmission and injection (including utilisation for enhanced hydrocarbon recovery), are addressed in the Santos Drilling, Completions and Well Operations (DCWO) EIR and SEO (Santos 2015a and 2015b) and the Production and Processing Operations (PPO) EIR and SEO (Santos 2017a and 2017b):

- production and processing operations including pipelines, satellites and the Moomba Plant (including water flood and water reinjection)
- well site and access track construction
- drilling, well completions and workovers
- gas and oil systems on well leases
- well and zonal decommissioning
- restoration of well sites and access tracks
- geophysical investigations
- supporting activities and infrastructure.

### 1.1.1 Outline of this EIR

Table 1-1 below provides a brief outline of the content of each section of this document.

*Table 1-1: Environmental Impact Report outline.*

| Section | Title | Content |
|---|---|---|
| 1 | Introduction | ▪ Introduces the purpose and format of this document. |
| 2 | Background | ▪ Provides background history, includes resource and operations information and identifies the location of Cooper Basin carbon storage target geological formations. |
| 3 | Legislative Framework | ▪ Provides a brief description of the relevant legislation and assessment process. |
| 4 | Carbon Capture and Storage | ▪ Describes CCS operations as they relate to existing operations and EIRs and carbon storage in detail. |
| 5 | Existing Environment | ▪ Describes the existing physical, biological, hydrogeological and social environment in the Cooper Basin. |
| 6 | Consultation | ▪ Documents consultation undertaken for development of the EIR. |
| 7 | Environmental Risk Assessment | ▪ Identifies hazards and their consequences and risk minimisation strategies.<br>▪ Outlines risk assessment process and summarises results of the risk assessment. |
| 8 | Management of Environmental Risks | ▪ Outlines Santos Environment, Health and Safety Management System and relevant management strategies. |
| 9 | References & Further Reading | ▪ Lists reference material utilised in the preparation of this document. |
| Appendix A | Stakeholder Consultation | ▪ Contains comments from stakeholder consultation and Santos responses |

# 2 Background

## 2.1 Cooper / Eromanga Basin

The Cooper Basin and the overlying Eromanga Basin are located in north-east South Australia and south-west Queensland. The region forms Australia's largest onshore oil and gas development and is one of Australia's major oil and gas producing provinces.

The Cooper Basin currently meets over one third of the demand for domestic gas in eastern Australia, as well as producing crude oil and petroleum liquids for both Australian and overseas markets. Natural gas produced from the Cooper Basin has a key role to play in a lower-carbon future as it produces 50% less greenhouse gas emissions than coal when used to generate electricity, can significantly improve air quality and is the perfect partner for renewable energy sources.

Until 1999, the South Australian Cooper Basin Joint Venture (SACBJV), operated by Santos, held the Petroleum Exploration Licences (PELs) 5 and 6 which covered the north-east of the state, surrounding the Moomba processing facility. Today, PELs, Petroleum Retention Licences (PRLs) and Petroleum Production Licences (PPLs) in the Cooper Basin are held by Santos (and parties to joint ventures in the Cooper Basin operated by Santos) as well as by other operators (see Figure 2-1).

## 2.2 Santos Cooper Basin Operations

A proudly Australian company, Santos is a leader of the Australian natural gas industry, with more than 60 years of responsible gas exploration development and production across the nation, since its establishment in Adelaide in 1954.

The Cooper Basin currently supplies approximately 30% of South Australia's natural gas needs, 30% of the NSW gas market and about 5% of Queensland's demand as well as producing commercial quantities of crude oil and petroleum liquids for both Australian and overseas markets. Santos currently has an interest in approximately 150 PPLs in the South Australian Cooper Basin surrounding the Moomba processing facility

Santos exploration and production acreage is centred around Moomba, which is located approximately 800 km north-east of Adelaide. The Moomba processing facility processes oil and natural gas from surrounding fields, made up of more than 1000 producing wells. The oil and gas is piped to Moomba where it is refined and distributed via pipelines to markets in South Australia, New South Wales, Queensland, and other domestic and international markets. The Moomba processing facility also includes underground storage for processed sales gas and ethane.

Full descriptions of drilling operations in the Cooper Basin are provided in the Drilling Completions and Well Operations EIR (Santos 2015a). The production and transmission facilities and activities including the Moomba plant are described in the Petroleum Production Operations EIR (Santos 2017a).

Sustainability is an integral part of Santos' operating ethos and Santos is committed to responsibly managing the company's environmental impact. As part of making low-emissions technologies like CCS a reality, in 2019 Santos invested A$10m to advance carbon storage technology with the testing of $CO_2$ enhanced oil recovery, and a business model to support the development of carbon storage in the Cooper Basin. A further A$10m has been committed in 2020 to progress planning, design of facilities and injection targets for CCS in the Cooper Basin.

### 2.3 Carbon Storage in the Cooper Basin

Santos' carbon storage will target the capture $CO_2$ emissions from the Moomba Plant, where there is existing equipment to separate $CO_2$ from sales gas. The captured $CO_2$ will be dehydrated, compressed, and then transported via new or existing pipelines to suitable locations where it will be injected into target geological formations deep underground. Injected $CO_2$ will become trapped in geological formations through natural mechanisms: physical or buoyancy trapping against an impermeable barrier; residual trapping in pore spaces by relative permeability and capillary pressures; dissolution into formation water (or residual oil); or re-deposition as newly-formed minerals (Carbon Storage Task Force 2009). This trapping is known as geological sequestration. Further detail of the proposed carbon storage project is provided in Section 4.

The 'National Carbon Mapping and Infrastructure Plan – Australia' undertaken by the carbon taskforce in 2009 (Carbon Taskforce 2009), estimated the Cooper and overlying Eromanga basins have a carbon storage potential of 16 Gt, which represents almost 30 years of Australia's total carbon emissions at 2019 levels. Santos has estimated there is the potential to ramp up injection to 20 Mt per annum for in excess of 50 years within the Cooper Basin (the equivalent of storing almost 4% of Australia's current annual carbon emissions), making a significant contribution to Australia's emissions reduction targets.

Carbon dioxide is naturally occurring in the Cooper Basin. Formation fluid content is variable in hydrocarbon reservoirs, and can include dry gas, wet gas, volatile oil, black oil, or mixtures with $CO_2$ contents ranging from less than 2% to more than 45%. Groundwater in and proximal to conventional and unconventional hydrocarbon reservoirs contains traces of hydrocarbons due to their formation and migration from source rocks to reservoirs, through aquifers and water-bearing zones, over geological time. Similarly $CO_2$ (and related chemical changes) is part of the natural groundwater chemistry (Kuske *et al* 2010).

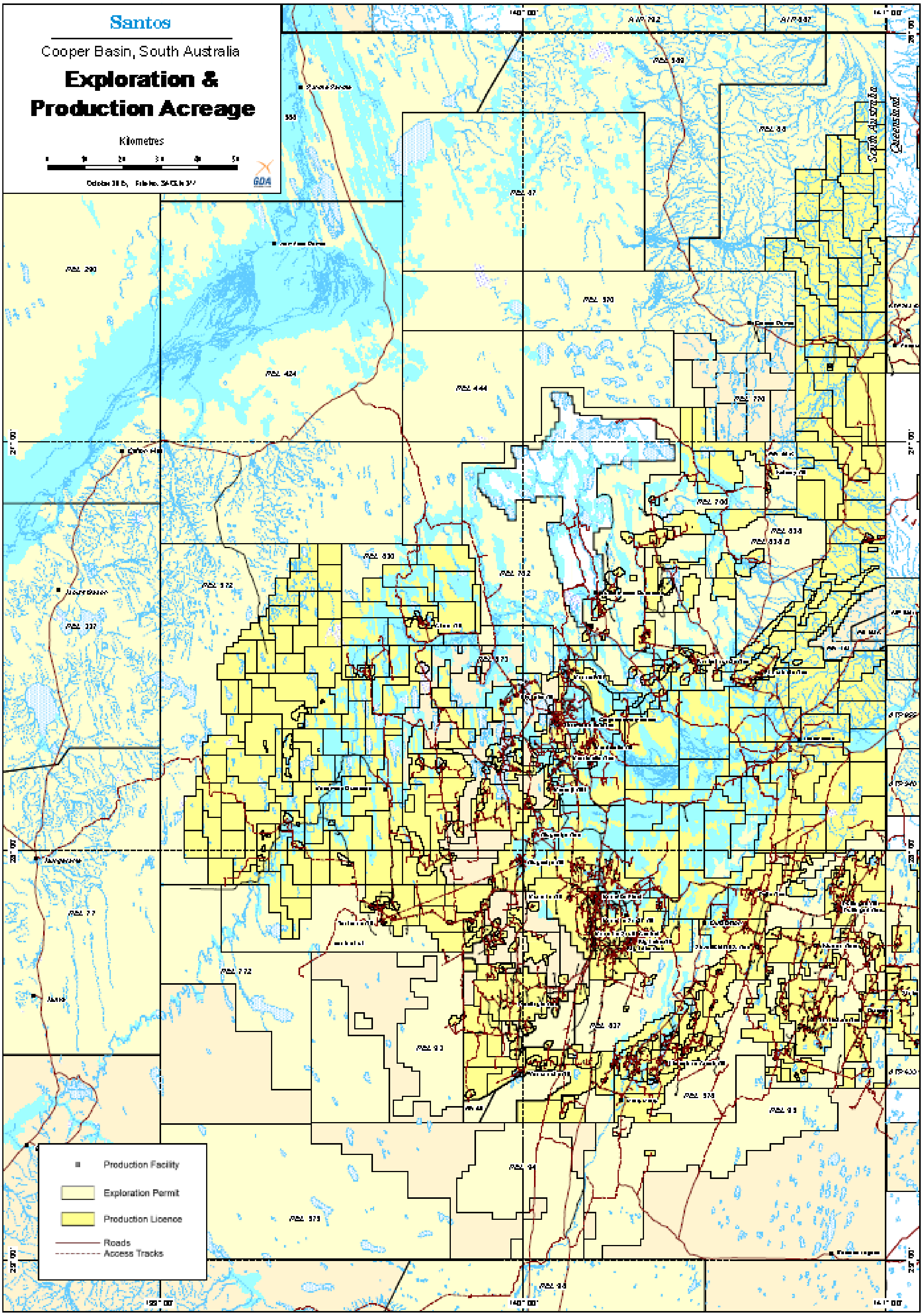


*Figure 2-1: Exploration and production permits in the Cooper and Eromanga Basins.*

# 3 Legislative Framework

This section briefly describes the legislative framework that currently applies to petroleum licensing in South Australia.

The Department for Energy and Mining (DEM) is the government agency responsible for the regulation of petroleum operations in South Australia, to ensure that they occur in an environmentally, technical and economically responsible manner and align with leading practice.

## 3.1 Petroleum and Geothermal Energy Act and Regulations

The *Petroleum and Geothermal Energy Act 2000* and *Petroleum and Geothermal Energy Regulations 2013* (the Act and Regulations) form the primary legislation governing onshore petroleum exploration and production in South Australia.

Key objectives of the legislation include:

- creating an effective, efficient and flexible regulatory system for exploration and recovery or commercial utilisation of petroleum and other regulated resources (including geothermal resources and natural reservoirs suitable for storage or production purposes).
- minimising environmental damage from activities involved in exploration and recovery or commercial utilisation of petroleum and other regulated resources.
- establishing appropriate consultative processes involving people directly affected by regulated activities and the public generally.
- protecting the public from risks inherent in regulated activities.

Environmental objectives, as defined in Part 12 of the Act are:-

- to ensure that regulated activities that have (actually or potentially) adverse effects on the environment are properly managed to reduce environmental damage as far as reasonably practicable
- to eliminate as far as reasonably practicable risk of significant long term environmental damage
- to ensure that land adversely affected by regulated activities is properly rehabilitated.

Regulated resources, as defined in Part 1 of the Act, are:

- a naturally occurring underground accumulation of a regulated substance
- a source of geothermal energy or
- a natural reservoir.

A reference in the Act to petroleum or another regulated substance extends to a mixture of substances of which petroleum or other relevant substance is a constituent part. Regulated substances as defined in Part 1 of the Act are:

- petroleum
- hydrogen sulphide
- nitrogen
- helium

- carbon dioxide
- any other substance that naturally occurs in association with petroleum
- any substance declared by regulation to be a substance to which the Act applies.

Part 3 of the Act addresses the licensing requirements of regulated activities, and defining what are regulated activities.

Regulated activities, as defined in Section 10 of the Act, are:

- exploration for petroleum or another regulated resource
- operations to establish the nature and extent of a discovery of petroleum or another regulated resource, and to establish the commercial feasibility of production and the appropriate production techniques
- production of petroleum or another regulated substance
- utilisation of a natural reservoir to store petroleum or another regulated substance
- production of geothermal energy
- construction of a transmission pipeline for carrying petroleum or another regulated substance
- operation of a transmission pipeline for carrying petroleum or another regulated substance.

Section 4(3) states that for the purposes of the Act, **storage** of a regulated substance may include circumstances where it is intended that the regulated substance be held **indefinitely** in a natural reservoir.

### 3.1.1 Environmental Impact Report

The EIR provides an assessment of the potential impacts of regulated activities on the environment and provides the basis of information for development of the SEO (unless activities are classified as 'high impact').

Part 12, Division 3 of the Act provides for the preparation of an EIR and the classification of regulated activities. The EIR is provided by the licensee and contains an assessment of the potential impacts of an activity on the environment. In accordance with Section 97 the EIR must:

- take into account cultural, amenity and other values of Aboriginal and other Australians in so far as those values are relevant to the assessment.
- take into account risks to the health and safety of the public inherent in the regulated activities.
- contain sufficient information to make possible an informed assessment of the likely impact of the activities on the environment.

In accordance with Regulation 10 of the Petroleum Regulations the EIR must provide:

- A description of the regulated activities to be carried out under the licence (including their location).
- A description of the specific site features of the environment that can reasonably be expected to be affected by the activities, with particular reference to the physical and biological aspects of the environment and existing land uses.

- An assessment of the cultural values of Aboriginal and other Australians which could reasonably be foreseen to be affected by the activities in the area of the licence, and the public health and safety risks inherent in those activities (insofar as these matters are relevant in the particular circumstances).
- If required by the Minister, a prudential assessment of the security of natural gas supplies.
- A description of the reasonably foreseeable events associated with the activity that could pose a threat to the relevant environment (including events during the construction, operational and decommissioning stages, atypical events, estimated frequency of events and the basis of predictions).
- An assessment of the potential consequences of these events on the environment, (including size and scope, duration, cumulative effects (if any), the extent to which these consequences can be managed or addressed and proposed management actions).
- An explanation of the basis on which these consequences have been predicted.
- A list of all owners of the relevant land.
- Information on consultation undertaken during the preparation of the EIR.

### 3.1.2 Statement of Environmental Objectives

Pursuant to section 96 of the Act, a regulated activity can only be conducted if an approved SEO is in force. The SEO outlines the environmental objectives that the regulated activity is required to achieve and the criteria upon which the objectives are to be assessed. The SEO is developed on the basis of information provided in an EIR.

Part 12, Division 4 of the Act describes the requirements for an SEO and how it is assessed and approved, with the content requirements outlined in section 100. Further detail on preparation and required content of the SEO is provided in the Regulations (regulation 12 and 13), with the review process outlined in regulation 14. The SEO must be reviewed at least once every 5 years.

### 3.1.3 Assessment and Approval

Pursuant to an environmental significance assessment, DEM assess whether the activities described in the EIR are of ‘low’, ‘medium’ or ‘high’ impact classification. DEM’s assessment is undertaken in accordance with the guideline *Criteria for classifying the level of environmental impact of regulated activities* (DEM 2019).

These classifications determine the level of consultation required prior to final approval by DEM of the SEO:

- Low impact activities do not require public consultation and are subject to a process of internal government consultation and comment on the EIR and draft SEO prior to approval.
- Medium impact activities require a public consultation process for the EIR and draft SEO, with comment sought for a period of at least 30 business days.
- High impact activities are required to undergo an environmental impact assessment under the provisions of the Planning, Development and Infrastructure Act 2016. An SEO for high impact activities must be prepared on the basis of this environmental impact assessment.

The level of impact of a particular activity is assessed on the basis of the predictability and manageability of the impacts on the environment. Where the environmental impacts are predictable and readily managed, the impact of the activity is considered low. Where the environmental impacts are less predictable and are difficult to manage, the impact of the activity is potentially high.

Once the approval process is complete, all documentation (including this EIR and its associated SEO) must be entered on an environmental register. This public Environmental Register is accessible to the community from the DEM website.

## 3.2 Other Legislation

A variety of legislation applies to petroleum activities. Potentially relevant legislation for carbon storage operations is listed below (note: this is not an exhaustive list of potential legislation).

Commonwealth

*Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

South Australia

*Environment Protection Act 1993*

*Fire and Emergency Services Act 2005*

*National Parks and Wildlife Act 1972*

*Native Vegetation Act 1991*

*Landscape South Australia Act 2019*

*South Australian Public Health Act 2011*

*Work Health and Safety Act 2012*

*Dangerous Substances Act 1979*

*Explosives Act 1936.*

*Environment Protection and Biodiversity Conservation Act (EPBC Act)*

Approval under the Commonwealth EPBC Act is required for activities that will have or are likely to have a significant impact to matters of national environmental significance including World Heritage properties, National Heritage places, wetlands of international importance (listed under the Ramsar Convention), listed threatened species and ecological communities, migratory species and a water resource, in relation to coal seam gas development and large coal mining development.

There are no matters of national environmental significance directly relevant to underground storage activities. There are no current approvals in place that affect surface activities conducted under the DCWO and PPO SEOs in the South Australian Cooper Basin.

*Environment Protection Act*

The *Environment Protection Act 1993* imposes a general duty of care not to undertake an activity that pollutes, or might pollute the environment unless all reasonable and practicable measures have been taken to prevent or minimise any resulting environmental harm. Environmental authorisations are required to undertake activities prescribed under the Act. Santos holds EPA licences for its Cooper Basin production and processing operations.

The Environment Protection Act does not apply to petroleum exploration activity undertaken under the Petroleum and Geothermal Energy Act or to wastes produced in the course of an activity (not being a prescribed activity of environmental significance) authorised by a lease or licence under the Petroleum and Geothermal Energy Act when produced and disposed of to land and contained within the area of the lease or licence.

*Landscape South Australia Act*

Drilling of new water sourcing bores or conversion of petroleum wells to water supply wells typically requires a permit under the *Landscape South Australia Act 2019* (which replaced the Natural Resources Management Act in July 2020). Extraction of groundwater within the Far North Prescribed Wells Area generally requires a licence / allocation under this Act, however there is an authorisation in place to take groundwater for drilling, construction and testing of hydrocarbon wells. This Act and the SA Arid Lands Regional Natural Resources Management Plan (SAAL NRM Board 2017) also set out a number of water affecting activities that must not be undertaken without a permit. These are usually avoidable by careful planning and siting of infrastructure to maintain water flows.

*National Parks and Wildlife Act*

The *National Parks and Wildlife Act 1972* provides for the establishment and management of reserves and the conservation of wildlife in a natural environment. Innamincka Regional Reserve is established under this Act, which provides the Department for Environment and Water rights as landowner and direct involvement in the approval of Petroleum and Geothermal Energy Act licences and Statements of Environmental Objectives that cover the regional reserve.

# 4 Description of Carbon Storage Operations

This section provides an overview of carbon storage in the Cooper Basin which is defined for the purposes of this EIR as storage of measurable quantities of $CO_2$ in deep geological formations.

Operations which facilitate carbon capture, processing, transmission and injection, including utilisation for enhanced hydrocarbon recovery (EHR), are described below for additional context. These operations are not within the scope of this EIR (and accompanying SEO) as they covered by the existing DCWO EIR and SEO (Santos 2015a and b) and the PPO EIR and SEO (Santos 2017a and b).

## 4.1 Grouping of Operations

The operations considered in this EIR relate specifically to the storage (geological sequestration) of measurable quantities of $CO_2$ in deep geological formations.

Section 4.2 and Section 4.4 describe carbon storage and are the basis for the environmental impact and risk assessment in Section 5.

A general description of carbon capture, treatment, transmission and injection and EHR is also provided in Section 4.3 to provide context for the carbon storage discussion only. These activities are not assessed in this EIR as these are covered by existing EIRs and SEOs, as detailed in Table 4-1.

*Table 4-1: Summary of carbon capture, utilisation and storage activities addressed in EIRs and SEOs*

| Activity Grouping | Activity Detail | Relevant EIR/SEO |
|---|---|---|
| Capture, treatment, transmission, and injection of $CO_2$ | $CO_2$ capture and treatment at Moomba Gas Plant<br>$CO_2$ transmission to injection wells via pipelines<br>Design, construction, and operation of plant and pipelines<br>$CO_2$ injection for EHR<br>Installation or conversion of production wells for $CO_2$ injection<br>Assessment and management of well integrity | Production, Processing and Operations (Santos 2017a and b)<br>Drilling, Completions and Well Operations (Santos 2015a and b) |
| Carbon storage | Storage, geological formation selection, modelling and risk assessment<br>Monitoring, Reporting and Verification of $CO_2$ in storage | Carbon Storage (this EIR/SEO)<br>Carbon Storage (this EIR/SEO) |

## 4.2 Overview of Carbon Capture and Storage

Carbon capture and storage is a process consisting of the separation of $CO_2$ from sources, transport to storage location and long-term isolation from the atmosphere (IPCC 2005). Carbon storage in deep geological formations involves injecting captured carbon where natural trapping mechanisms contain it within the rock matrix and formation fluids, i.e. geological sequestration. The security of this containment is the focus of environmental impact and risk assessments of carbon storage projects.

### 4.2.1 International and Australian Experience with Carbon Storage

Carbon capture and storage is established internationally. The first project involving large-scale capture and injection of $CO_2$ commenced in 1972 in the Sharon Ridge oilfield in Texas, USA, where $CO_2$ was used for enhanced oil recovery ($CO_2$ EOR) (Global CCS Institute 2018). The first dedicated carbon storage project was initiated in the 1990s in Norway after the introduction of a $CO_2$ tax on offshore gas production. Since the 1970s over 230 Mt of anthropogenic $CO_2$ has been captured and stored with the USA (150 Mt), Canada (40 Mt) and Norway (20 Mt) the main contributors. With the exception of Norway, the vast majority of $CO_2$ stored was as a result of $CO_2$ EOR, Norway's contribution being entirely made up of $CO_2$ injected for storage.

The development of greenhouse gas emissions trading schemes, tax incentives for carbon capture and other regulatory instruments encouraging reduction in net carbon emissions has led to an increasing focus on carbon capture and storage. According to the Global CCS Institute (2018) there were 43 active carbon capture and storage projects globally in 2018; eighteen of these were in operation, five in construction, and twenty in various stages of development.

In addition to the Cooper Basin project (in development), the following carbon capture storage projects were active in Australia during 2019:

- Chevron's Gorgon natural gas and carbon ($CO_2$ produced with the natural gas) storage in a deep saline geological formation (operational in 2019)
- CTSCo's Surat Basin Carbon Capture and Storage Project to store $CO_2$ from multiple coal fired power stations in a deep geological formation (at feasibility and engineering design stage) (CTSCo 2019)
- Western Australian government's South West Hub project which is looking to store $CO_2$ from multiple industrial sources in a deep saline reservoir (in development)
- CarbonNet Gippsland carbon storage in depleted off-shore oil and gas reservoirs is being developed in conjunction with a hydrogen generation (from brown coal) project in the onshore Latrobe Valley (in development)
- $CO_2$CRC Otway carbon storage demonstration in depleted gas reservoir (complete) and saline geological formation (active).

### 4.2.2 Carbon Storage Mechanisms

Carbon storage involves injecting $CO_2$ into depleted hydrocarbon bearing formations or deep saline geological formations where it re-pressures and/or displaces the existing formation fluids (typically water). At original reservoir conditions in the Cooper Basin, $CO_2$ would typically be in a supercritical phase with a density greater than natural gas but less than oil or water. $CO_2$ will tend to behave in a manner similar to natural gas in deep geological formations due to its relatively low density and viscosity.

The movement of $CO_2$ may be affected by a number of processes (IPCC 2005):

- pressure gradients created by the injection process driving $CO_2$ flow
- buoyancy driven vertical $CO_2$ flow
- diffusion
- dispersion and fingering caused by heterogeneities in the rock fabric and viscosity and density contrasts between $CO_2$ and reservoir fluids
- natural hydraulic gradient driven fluid flow
- $CO_2$ dissolution into formation fluids
- mineralisation
- pore space trapping

- $CO_2$ adsorption onto organic material.

In a typical Cooper Basin reservoir, pressure and buoyancy are expected to be the major controls on the distribution of $CO_2$ through the reservoir. $CO_2$ will migrate in response to pressure, controlled by reservoir permeability. $CO_2$ will migrate vertically due to buoyancy and will be trapped by the reservoir seal or cap rock, which is an impermeable layer overlying the reservoir.

Storage of $CO_2$ is achieved by a number of trapping mechanisms as shown in Figure 4-1 (IPCC 2005):

- structural and stratigraphic trapping (also called buoyancy trapping (USGS 2013)) by the same or similar geological features that trap oil and gas (including $CO_2$) in reservoirs
- residual (pore space) trapping resulting in $CO_2$ becoming trapped in pore spaces by capillary forces causing the $CO_2$ to become immobile in the reservoir, i.e. residual saturation
- solubility trapping where $CO_2$ dissolves into formation fluids
- mineral trapping where the $CO_2$ is mineralised and becomes part of the reservoir rock.

These processes occur over varying time scales ranging from years (in the case of buoyancy and residual trapping) to millennia (solubility and mineral trapping). Hence the dominant trapping mechanism typically changes over time, tending from physical to geochemical processes. The rates and relative contribution of these mechanisms will be formation specific.

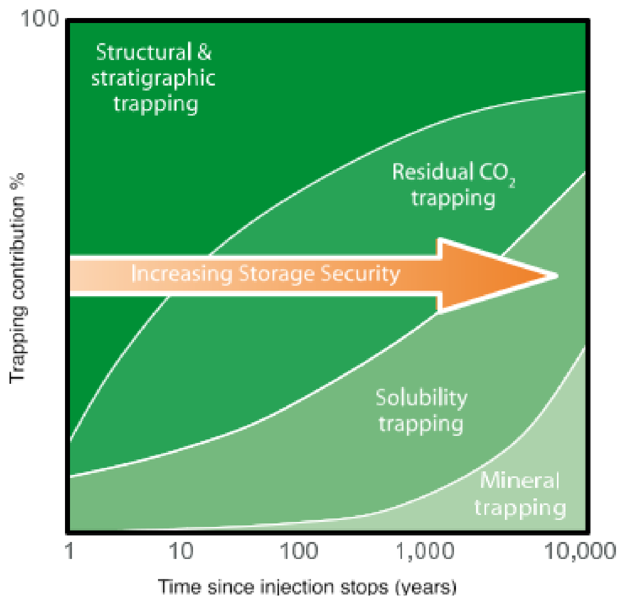


*Figure 4-1: Processes of residual $CO_2$ trapping changes over time (after IPCC 2005)*

### 4.2.3 Carbon Storage During Enhanced Hydrocarbon Recovery (EHR)

$CO_2$ is often used for EHR during secondary and tertiary production from reservoirs. The injection of $CO_2$ into the reservoir can mobilise hydrocarbons by:

- Displacement of hydrocarbons towards production wells.
- Dissolving into hydrocarbon (or some chemical fractions of the hydrocarbon) reducing its viscosity and / or increasing its mobility enabling it to flow through the reservoir to production wells. This is called miscible $CO_2$ EHR.

$CO_2$ injection can be used alone or it can be alternated with water injection depending on the reservoir and hydrocarbon characteristics and production requirements.

Up to 50% of $CO_2$ injected during EHR becomes trapped in the reservoir by the mechanisms described above for carbon storage. Final volumes stored will be quantified through the monitoring, reporting and verification plan.

## 4.3 Carbon Capture, Treatment, Transmission, and Injection

As noted above, the PPO EIR and SEO (Santos 2017a and b) and the DCWO EIR and SEO (Santos 2015a and b) adequately cover the potential environmental impacts and risks related to $CO_2$ separation, capture and treatment at Moomba, and surface activities such as pipelines wells, injection and ancillary surface infrastructure. This section provides a general overview of these activities to provide context for the carbon storage discussion.

### 4.3.1 Moomba Gas Plant

The Moomba Gas Plant is located approximately 800 kilometres north of Adelaide and comprises plant and equipment to receive and process raw gas, hydrocarbon condensate and crude oil from the gas and oil fields in the Cooper and Eromanga Basins.

*Gas Processing*

Gas satellites in the Cooper and Eromanga Basin receive raw gas from nearby gas-producing wells, and separate the gas into three component phases (gas, hydrocarbon liquid and water), in separator vessels. The separated gas is compressed and cooled, and then flows to Moomba Gas Plant via nine gas trunklines which include the sales gas reinjection/withdrawal line from the Moomba South Central Gas Satellite.

Incoming raw gas streams are directed to the inlet separation section of Moomba Gas Plant, which provides three-phase separation of gas, hydrocarbon-condensate and water.

Inlet separation facilities include the:

- raw gas inlet header
- slug catchers
- condensate / water coalescer
- high pressure (HP) separators.

Condensate is further processed in the crude stabilisation plant. The separated water is sent to the oily water system for treatment.

The separated gas is transferred from the HP separators to the Benfield Plants for $CO_2$ removal using continuous hot potassium carbonate solution to absorb $CO_2$. The potassium carbonate solution is regenerated allowing the potassium carbonate solution to be reused. The $CO_2$ released from the Benfield Plants will be captured and transferred through compressors to dehydration units that will remove any moisture before the $CO_2$ is piped out into the field for injection and storage (sequestration) in deep geological formations.

The $CO_2$ Removal Plant consists of five parallel Benfield trains which meet the $CO_2$ removal requirements for the current throughput of raw gas at Moomba Gas Plant. Additional $CO_2$ removal capacity may be required depending on future $CO_2$ load forecasts. The natural gas leaving the $CO_2$

removal plant, called 'sweet' gas, contains less than 3.0 mol% $CO_2$ and less than 1 ppm hydrogen sulfide ($H_2S$). This gas is fed to the Liquids Recovery Plant (LRP) via the dehydration facilities.

The purpose of the LRP is to recover liquid hydrocarbons from Moomba Gas Plant gas feed, and is achieved by cryogenic distillation that separates ethane and heavier hydrocarbons. After passing through the LRP, the residue gas (demethaniser overheads) is recompressed prior to entering the sales gas pipelines to Adelaide, Sydney and Wallumbilla.

During periods of low customer demand, sales gas and ethane can be sent to Moomba South Central (MSC) satellite by pipeline to be reinjected (and stored) into underground storage formations, the Lower Daralingie Beds (LDB), which is located at Moomba South (10 km south of the plant). This geological formation has the capacity to hold up to 85 bcf of product for storage. During periods of high demand, the reinjected gases are withdrawn from the LDB to supplement processed sales gas.

Ethane from the LRP de-ethaniser is fed to the Ethane Treatment Plant (ETP), to reduce the $CO_2$ content in ethane to <400 ppm, which is a suitable quality for petrochemical feedstock. The ETP utilises an amine adsorption process for $CO_2$ removal and a molecular sieve dehydration unit. Ethane is sent to Sydney via a dedicated ethane pipeline. Ethane from the LRP can also be directed to sales gas or re-injected into underground storage for future processing.

*Liquid Processing*

Liquid hydrocarbons at Moomba Gas Plant are either recovered from the raw gas, or are pumped/trucked to Moomba from the oil satellites. Oil satellites receive well fluids from nearby oil producing wells, separate water from the oil, dispose of the water and then transfer the oil to Moomba Gas Plant via five trunklines.

Crude oil produced at the oil satellites is either sufficiently stable to store in tankage, i.e. 'Block Oil' in TK-1000, or requires processing through the Crude Stabilisation Plant (CSP) to remove volatile fractions, i.e. 'Unit Oil' from the northern oil satellites (e.g. Tirrawarra). The stored 'Block Oil' is directed to the CSP for processing, as required.

The CSP removes volatile hydrocarbons and water from the crude oil and condensate. The CSP includes flashing vessels and a distillation column, with the lighter fractions primarily recovered as fuel gas.

A single pipeline transfers crude oil and natural gas liquids to the Liquids Processing Plant at Port Bonython.

### 4.3.2 Wells

All wells utilised as part of carbon storage operations will be required to meet PGE Act requirements for design, construction, operation and decommissioning as per the DCWO EIR and SEO (Santos 2015a and b). In accordance with these requirements, wells must be fit for purpose and not allow reservoir fluids to flow between geological formations.

### 4.3.3 Pipelines

A network of pipelines, consisting of flowlines and trunklines, directs crude oil, condensate and gas from the production wells to the Moomba Gas Plant via satellite facilities. These pipelines are referred to as gathering systems. There are over 4000 km of Santos pipelines in SA Cooper Basin.

The existing pipeline network consists principally of:

- flowlines, which are pipelines from the well head to field manifolds, nodal compressors, pumps or a satellite facility
- trunklines, which are generally larger diameter pipelines that receive production from flowlines, nodal compressors or satellite facilities for transfer to Moomba.

New and / or existing pipelines will be required to transfer captured and treated $CO_2$ from the source to injection wells for storage. The configuration of these transmission systems will be similar to the existing gathering systems. Initially, it is expected that the Moomba Gas Plant will be the major source of $CO_2$ and will be connected to injection wells via smaller field facilities – comprising a manifold(s) and injection skids – located in existing satellites or the fields receiving $CO_2$. Injection wells and satellites will be capable of being individually controlled or isolated depending on injection demand or operational requirements.

Pipelines may be above ground or buried. Pipeline markers are installed to identify the location of buried services. Santos' Geographic Information System (GIS) is used to capture buried and above ground pipeline routes, and licensed pipelines are captured by published mapping (Great Southern Press 2014, 2015).

Santos' pipelines are managed (designed, constructed, maintained, operated and decommissioned) in accordance with relevant Santos management standards and procedures and the applicable Australian Standards (e.g. AS 2885: Pipelines – Gas and liquid petroleum). AS 2885 covers design and operation of pipelines containing $CO_2$ and will remain appropriate for pipelines related to carbon storage activities.

### 4.3.4 $CO_2$ Metering

Metering of produced gas is undertaken at various points in the existing gathering and processing system.

$CO_2$ will be metered at junctions along the capture, transmission and injection flow process (Figure 4-2). It is anticipated that primary metering will be installed at the Moomba Gas Plant $CO_2$ discharge with additional metering at field facilities and injection wells as required. Routine assessment of the $CO_2$ stream composition will take place at the discharge from the Moomba Gas Plant.

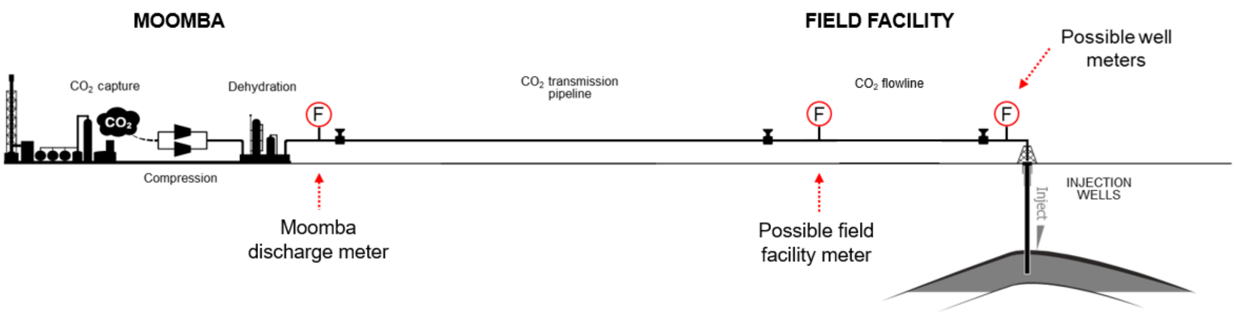


*Figure 4-2: Carbon capture and storage process overview.*

### 4.3.5 Oil and Gas Satellites

Oil and gas satellites receive hydrocarbon fluids producing wells where the gas and water is separated from oil (where present) through the use of dewatering tanks. Oil and gas is then transferred to Moomba Gas Plant via a trunklines or oil may also be transported by truck. Currently all $CO_2$ separation is performed at the Moomba Gas Plant. Recovery of $CO_2$ from oil produced through $CO_2$ EOR may be considered to enable reinjection of $CO_2$. This may occur at the satellite facility or Moomba Gas Plant. Quantification of $CO_2$ in oil produced from $CO_2$ EOR will be regularly measured to support calculations of stored $CO_2$ for monitoring, reporting and verification.

Additional infrastructure such as compression, metering and monitoring facilities would be installed where required at satellites or fields where $CO_2$ injection is undertaken, in accordance with the PPO EIR and SEO.

### 4.3.6 $CO_2$ Enhanced Hydrocarbon Recovery

Improved and Enhanced Oil Recovery (IOR / EOR) and Enhanced Gas Recovery (EGR) can collectively be termed Enhanced Hydrocarbon Recovery (EHR). These secondary and tertiary production techniques are used to increase the volume of hydrocarbons that can be recovered from a reservoir. Common techniques include waterflooding, gas injection, chemical injection and/or thermal processes which are described in the PPO EIR and summarised below.

Waterflooding is a technique used to maintain or increase reservoir pressures and improve the displacement of oil through a reservoir. Fluid for waterflooding activities can be sourced from production wells, converted production wells or water supply bores or from produced formation water ponds from nearby satellites. The quality of water used for injection must be of similar quality to that of the target formation to minimise the potential for degradation of reservoir conditions. In each scheme, the water undergoes a level of treatment for removal of solids, biocide dosing and other chemical treatments.

Gas injection is an alternative technique and serves the dual purpose of maintaining reservoir pressure and improving displacement of oil through the formation pore structure. Gas injection schemes can be immiscible or miscible depending on the purpose of the scheme. Immiscible schemes maintain reservoir pressure and displace oil. Miscible schemes involve dissolving injected gas into reservoir oil to improve the mobility of oil through a reservoir.

In the Cooper Basin, gas used in gas injection schemes is sourced from nearby satellites. Prior to injection into the reservoir, the gas is subject to biocide and corrosion inhibitor dosing and filtration. The gas for a dedicated $CO_2$ EHR scheme would be sourced from Moomba as described above.

An injection well may be a converted production well or a well specifically drilled for injection purposes. Injection wells are designed analogously to wells intended for production from the target formation(s). The location of injection wells within a field may change over the course of the life of the $CO_2$ EHR scheme to ensure that optimum pressure gradients are maintained, and hydrocarbon recovery and carbon storage are maximised through optimum sweep patterns.

Injection wells are managed using the same management system as production wells. The Santos Well Integrity Management System (WIMS) is used to maintain the asset in a ‘fit-for-purpose’ state and to protect people and the environment.

Chemical or isotope tracers may be used to monitor the progress of injected water or gas through the reservoir. A small volume of the tracer is added at an injection well and subsequent sampling of the production stream at offset wells is monitored to observe tracer breakthrough. Selection of the tracer and survey design depends on the target geological and hydrogeological environment, the injection and production well locations and $CO_2$ EHR history.

Following the completion of any EOR activity, $CO_2$ remaining in the reservoir could be viewed as permanently stored. This would be managed in line with the Carbon Storage SEO and associated monitoring, verification requirements and international standards.

## 4.4 Storage of $CO_2$ in Geological Formations

This section provides additional detail relevant to the storage of measurable quantities of $CO_2$ in deep geological formations within the Cooper and Eromanga Basins, including:

- natural occurrence of $CO_2$
- selection and characterisation of potential carbon storage target formations (including evaluation of potential $CO_2$ migration pathways and reservoir modelling)
- monitoring, reporting and verification.

### 4.4.1 Natural Occurrence of $CO_2$

$CO_2$ is naturally occurring in the Cooper and Eromanga Basins, formed by natural processes that also produced hydrocarbons. Gas from the Cooper Basin has been observed to contain up to 47% $CO_2$ by mole.

Hydrocarbon reservoirs are the result of natural accumulation and containment of buoyant fluids in geological formations. These fluids formed in deeper source rocks and migrated up through the geological strata. Where this upward migration is stopped by less permeable strata in a form that prevents lateral migration, the hydrocarbons become trapped by their own buoyancy forming a reservoir. The low permeability strata act as caps or seals. Over geological time reservoirs filled to the point where hydrocarbons spilled from the structure and the overflow continued to migrate vertically and laterally.

This process of fluid migration and reservoir filling over geological time has resulted in residual amounts of hydrocarbons (and $CO_2$) becoming trapped in all the formations it has migrated through by either residual trapping in pore spaces or solution trapping (dissolved in groundwater) or, in the case of $CO_2$, carbonate mineralisation. Section 5.3 discusses the source, migration and accumulation in reservoirs of hydrocarbons.

The extent to which hydrocarbons and $CO_2$ are naturally present outside of reservoirs is evident in the groundwater chemistry from hydraulically connected aquifers.

### 4.4.2 Carbon Storage Reservoir Selection and Characterisation

Santos will assess and select geological formations for carbon storage based on:

- potential $CO_2$ storage capacity
- containment mechanisms and their capacity for storage
- injectivity (number of injection wells required and safe injection rates to economically fill the storage capacity).

Containment will involve identification and assessment of potential pathways by which $CO_2$ could migrate to non-target geological formations and environmental receptors.

These assessments will largely be based on the extensive knowledge gained through production history in the Cooper Basin with additional analytical modelling where required. Deep saline geological formations will use a combination of geology, hydraulic testing and analytical modelling.

#### 4.4.2.1 Evaluation of Potential $CO_2$ Migration Pathways

The security of carbon storage (the extent to which the injected carbon remains sequestered in the geology) is a fundamental aspect considered in the planning and design process. Security of storage is necessary to satisfy carbon accounting requirements and to avoid causing impact to sensitive aspects of the environment or people, collectively called receptors.

A risk-based approach to the assessment of each target formation will be undertaken prior to carbon storage operations commencing. This will involve identifying and evaluating potential migration pathways by which $CO_2$ could potentially migrate from a carbon storage formation to the atmosphere or to sensitive receptors, as discussed below.

*Well Bores*

The identification and evaluation of existing well bores is undertaken early in the planning and design phase for carbon storage schemes. Inadequate well bore integrity can result in connection of the storage formation with overlying strata or surface and near surface environments providing a potential migration pathway for $CO_2$.

Prior to commencing a carbon storage scheme, the integrity of well bores within target formations will be assessed in the context of the scheme. If necessary, wells may be subject to workover or decommissioning to ensure potential migration pathways are appropriately managed.

Well integrity will be managed under the Santos Drilling and Completions and Well Integrity Management standards, with particular consideration of the effects of $CO_2$ (which as noted previously is a current consideration for many of the wells in the region due to naturally higher $CO_2$ content).

*Faults and Fractures*

Santos will review geologic, seismic, operating and other evidence to identify potential permeable structures that may penetrate or are connected to storage formations and have potential to act as $CO_2$ migration pathways to shallower non-target formations or to surface.

Depleted hydrocarbons reservoirs will generally have ample evidence regarding the presence and hydraulic properties of such structures. Given the initial condition of hydrocarbon containment, the likely focus when assessing these structures will be on their production history and if it could have changed the permeability of such structures.

*Previous Production Operations*

There have been more than 2500 petroleum wells drilled in the South Australian sector of the Cooper and Eromanga Basins, providing extensive geological knowledge. Well drilling, operations, and decommissioning are all subject to regulatory approvals requiring wells to be fit for purpose and preventing flow of fluids between geological formations.

Review of previous operations, including enhanced or improved hydrocarbon recovery using injection of gas or water, will be used to inform the condition (integrity) of the reservoir for storage.

*Aquitard or Seal*

The potential for migration of stored $CO_2$ through the pore spaces in the rock that forms the barrier to upward vertical flow will be assessed. For groundwater this barrier is called an aquitard. For hydrocarbon reservoirs it is called a seal. Evaluation will be based on extensive available information such as seal capacity, pressure, hydrocarbon and groundwater water chemistry and fluid flow information from nearby and overlying hydrogeological units and hydrocarbon operations.

The presence of multiple aquitards and seals in overlying geology will be also considered as they represent additional barriers to migration of $CO_2$.

*Pressure changes in shallower aquifers*

Injection of $CO_2$ is not expected to cause pressure changes within the shallower aquifers due to the segregation of the Permian target reservoir by overlying sealing intervals providing containment.

If injecting $CO_2$ into the Hutton/Numur intervals a short-term localised pressure increase is expected. However, this is predicted to dissipate to near-initial conditions following closure. Storage of $CO_2$ is not expected to cause the depletion of pressure in any reservoir or aquifer.

*$CO_2$ stream composition*

The composition of $CO_2$ currently vented from the Moomba Plant, is well understood from decades of operations. As such, the most significant gas impurities would be light hydrocarbons and trace amounts of other naturally occurring substances originating from reservoirs within the Basin. These impurities comprise only a very minor portion of the total volume to be stored. Although these impurities will have a small impact on the critical point of the $CO_2$, this is not considered material and is not expected to have an impact on the phase behaviour of the $CO_2$ at final storage pressure.

#### 4.4.2.2 Reservoir Modelling

Modelling of reservoirs for carbon storage will be undertaken to assist with risk assessment and design.

Reservoir characterisation and modelling will estimate the $CO_2$ storage capacity of a target formation and be used to manage and monitor the injection regime and progress of storage. Simulation modelling can also be used to assess migration scenarios under a range of operating conditions.

The modelling workflow will follow petroleum industry best practice and utilise the available geological and production history data. The level of detail in the modelling workflow will reflect the complexity of the reservoir under study. For depleted hydrocarbon reservoirs with well-established production history, simple analytical methods may be sufficient.

For more complex target formations, numerical simulation models may be required to adequately predict the behaviour of fluids. These models provide a mathematical representation that incorporates known geological and historical production data. Simulations represent the flow of each fluid phase ($CO_2$, hydrocarbon liquids, water and gas), changes in fluid content (saturations), equilibrium between phases (compositional changes), and pressure changes over time. Modelling may be used in both the design phase of the project to predict the reservoir response to carbon injection activities and during the operational phase, until injection ceases, to optimise and monitor the performance of storage. The models and monitoring data may be used to predict the future behaviour of the stored $CO_2$ after injection ceases and support the case for closure of the storage activities, i.e. cessation of monitoring and end of regulation.

### 4.4.3 Decommissioning and Closure

Following the completion of $CO_2$ injection and storage activities, surface infrastructure and wells will be decommissioned in accordance with applicable regulatory requirements (i.e. the Petroleum and Geothermal Energy Act and the DCWO and PPO EIRs and SEOs).

Reservoir modelling, informed by monitoring data, will be used to identify the point at which stored carbon is considered to be in storage with minimal risk of causing harm to identified sensitive receptors or becoming unacceptable fugitive greenhouse gas emissions (for the foreseeable geological future). At this point, monitoring can cease, relevant tenements handed back to the regulator, and regulation of the carbon storage activity can cease. This will be the point where effective geological sequestration of carbon has occurred and is discussed further under *Monitoring Timeframes* in Section 4.4.4 below.

### 4.4.4 Monitoring for Carbon Storage Operations

Monitoring, reporting and verification requirements will be designed to meet agreed federal, state, international, contractual, and/or fit for purpose industry practice as required.

*Monitoring Area*

Monitoring areas will be defined by carbon storage geological target formations (or storage complexes[1]) in use, i.e. active $CO_2$ injection and / or closed (filled) $CO_2$ target formations. For each target formation the monitoring area will be the area of the geological target plus a defined buffer which may increase as subsequent targets in a field come into operation.

*Monitoring Timeframes*

Carbon storage closure (storage or sequestration) will be defined for each geological target (or storage complex) as the point in time where:

- carbon injection ceases
- the likely stable extent (based on modelling) of the injected free phase $CO_2$ is unlikely to migrate such that it could pose an unacceptable risk of harm to identified sensitive receptors (people or sensitive environments) or result in future surface migration.

This will become the definition of Effective Geological Sequestration for Carbon (EGSC) in the given target formation or complex.

The case for ECSG and cessation of monitoring closure of the storage formation / storage complex will be based on numerical model simulations that:

- are calibrated based on (hydrocarbon) production and / or carbon storage monitoring data
- indicate long term (geological time) stability of the free-phase $CO_2$ remaining contained within the target formation and surrounding geology without posing an unacceptable risk of harm to sensitive receptors or becoming unacceptable fugitive greenhouse gas emissions
- all well bores penetrating the target formation are or will be decommissioned in a manner unlikely to result in potential future migration.

[1] A carbon storage complex may include multiple carbon storage geological formations in proximal geological formations, and related seals

*Monitoring, Reporting, and Verification Plans*

Carbon storage monitoring, reporting and verification plans will be implemented to align with the levels of assurance and transparency necessary to meet regulatory, commercial and carbon credit market obligations. International standards for CCS (and any Australian standards that are developed) will provide a framework for developing these plans.

Monitoring Systems

Santos will have monitoring systems to establish baseline conditions for carbon storage target formations and environmental receptor conditions prior to carbon storage activities and to enable effective quantification of the mass of $CO_2$ captured, injected, and stored, including any losses which may occur in the process. Monitoring systems will be selected to meet required environmental and assurance objectives based on their technical feasibility and economic value for the information they provide. This may include one or a combination of the following:

- $CO_2$ concentration, pressure, temperature and flow metering in the capture, transmission systems
- Pressure, temperature and flow monitoring during injection
- Surface and downhole geophysical surveys
- Wireline logs (for porosity/saturation measurement)
- Pressure tomography to measure induced pressure pulses in storage formations
- Modelling to predict the distribution and mass of $CO_2$ in the storage formation

If any potentially complete exposure pathways to sensitive receptors are identified through modelling, monitoring systems may also include:

- Monitoring (new or existing) wells to sample or remotely sense $CO_2$ / carbonate in groundwater in overlying or hydraulically connected (to the storage formation) sensitive aquifers
- New monitoring wells located near identified critical pathways for $CO_2$ migration (where required)
- Shallow (vadose zone) and / or air quality monitoring proximal well bores that are identified as having a higher risk of becoming a $CO_2$ pathway from the storage formation to the atmosphere.

Reporting and Verification

Santos' reporting and verification will provide the necessary transparency and assurance of the quantities of $CO_2$ captured and stored. Reporting will be based on regulatory obligations and may include:

- mass of $CO_2$ captured, injected, stored and lost to atmosphere after capture
- the methods used to quantify $CO_2$ entering capture systems, lost through transmission and the amount in storage
- the accuracy and uncertainties in monitoring data
- progress of injected volumes to assessed storage capacity.

# 5 Existing Environment

The Cooper Basin covers a total area of 130,000km$^2$, of which approximately 50,000km$^2$ lies within north-east South Australia (refer to Figure 5-1). The South Australian region of the Cooper Basin can generally be described as arid with a uniform climate. It contains a diversity of land systems that are defined by geological, geomorphological and hydrological influences.

This section provides a description of the specific features of the Cooper Basin environment relevant to the assessment of potential environmental impacts from carbon storage. The Cooper Basin environment is described in detail in the DCWO and PPO EIRs and as carbon storage relates predominantly to the deep subsurface, descriptions in this section have been summarised where appropriate. Features relevant to carbon storage (e.g. geology and hydrogeology) are included in detail.

## 5.1 Climate

The region has an arid climate, with low average rainfall and high evaporation. Seasons are generally characterised by hot dry summers and mild dry winters. Rainfall is typically less than 200 mm / year with no distinct seasonal pattern and rain may not fall for several years. Rainfall events are often localised and intense (associated with thunderstorms) and can deliver annual rainfall in one event. Average annual evaporation may exceed 3,500 mm. (Gibbs et al, 2012). A summary of climate records for Moomba Airport (Station 017123; BoM 2019) is provided in Table 5-1.

*Table 5-1: Temperature and rainfall records for Moomba.*

| Weather & Rainfall Data | J | F | M | A | M | J | J | A | S | O | N | D | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Daily Max (°C) | 39.0 | 37.2 | 34.1 | 29.4 | 23.9 | 19.9 | 19.8 | 22.6 | 27.2 | 30.9 | 34.2 | 36.8 | 29.6 |
| Mean Daily Min (°C) | 24.9 | 23.7 | 20.6 | 15.8 | 10.8 | 7.4 | 6.4 | 8.0 | 12.1 | 15.8 | 19.5 | 22.4 | 15.6 |
| Mean Rainfall (mm) | 14.3 | 26.1 | 22.5 | 6.9 | 10.2 | 10.5 | 12.8 | 4.5 | 15.1 | 8.6 | 19.3 | 13.7 | 170.1 |
| Median Rainfall (mm) | 3.2 | 6.5 | 2.2 | 0.8 | 3.8 | 5.8 | 0.8 | 0.9 | 1.2 | 2.1 | 7.5 | 6.0 | 155.6 |

## 5.2 Biophysical Environment

The six major types of land systems in the Cooper Basin licence areas comprise dunefields, floodplains, gibber plains, wetlands, salt lakes and tablelands. The characteristics of these land systems, including geology, landform, soils, hydrology, flora and fauna are described in detail in the DCWO and PPO EIRs.

## 5.3 Geology

The Eromanga and Cooper Basins are located in central and eastern Australia. The Eromanga Basin extends over one million square kilometres in Queensland, New South Wales, South Australia, and the south-east of the Northern Territory.

The Eromanga Basin is overlain by the Lake Eyre Basin, a succession of Tertiary and Quaternary age sediments occurring extensively throughout central Australia. In the north-east of South Australia, the Lake Eyre Basin consists of the sediments described in the preceding sections on floodplains, wetlands, tablelands, gibbers, salt pans. At depth, units include the Yandruwantha Sand (medium to coarse grained sand), the Namba Formation (deltaic and lacustrine clay, silt and sand), and the Eyre

Formation (sandstone and shale). The thickness of Lake Eyre Basin sediments in the Moomba area is generally in the range 200 m to 300 m (Drexel and Preiss 1995).

Eromanga Basin sediments were deposited during the Jurassic-Cretaceous period, and reach a maximum thickness of between 1200m and 2700m over the Cooper Basin (Gallagher and Lambeck 1989). These sediments were deposited under fluvial, lacustrine and (later) shallow-marine conditions, and are broadly continuous across the basin (Vine, 1976) (refer to Figure 5-2). These sediments are gently folded in some areas and contain a succession of aerially-extensive sandstone formations that serve as oil reservoirs and regional aquifers. The Eromanga Basin is the largest of the group of basins that constitute the Great Artesian Basin (GAB). The Eromanga Basin is the only part of the GAB that lies within South Australia, the other sections being in Queensland and in part in New South Wales.

Beneath, and entirely covered by the Eromanga Basin, is the Permian – Triassic Cooper Basin, limited in its distribution by bounding faults and pinch-out edges. The Cooper Basin extends over a much smaller area than the Eromanga covering about 153,000km$^2$ in north-east South Australia and south-west Queensland (Stanmore, 1989). Total Cooper Basin sediment accumulations exceed 1500m in places and are characterised by fluvial, deltaic and swamp deposits that include some coal measures (Thornton, 1979). These sediments contain petroleum reservoirs (mainly gas) and limited aquifers. The South Australian end of the Cooper Basin includes several north-east to south-west-trending depocentres, including the Patchawarra and Nappamerri Troughs. In the deepest and most central portion of the Cooper Basin (the Nappamerri Trough), high pressure gas cells with reservoir pressures in excess of 7000psi are present.

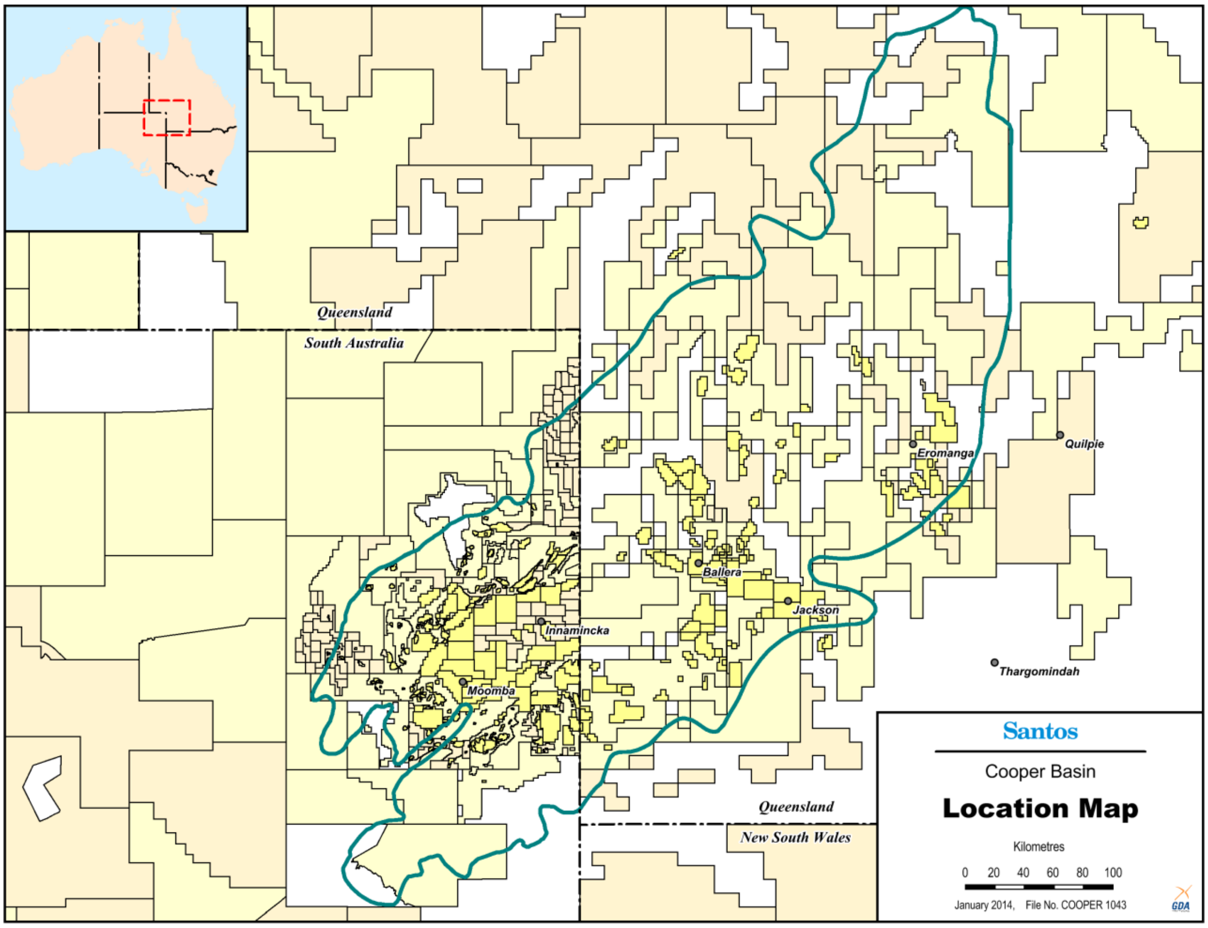


Figure 5-1: Cooper Basin location map.

The tectonic history of the Cooper and Eromanga Basins is complex and has been characterised by several periods of rift-related subsidence and compressional uplift and erosion. This history has resulted in the Cooper Basin being subdivided into a number of large scale sub-troughs separated by fault bounded ridges. The historical evolution of the Cooper and Eromanga Basins is discussed by Kuang (1985), Finlayson *et al*. (1988), Gallagher (1988), Hunt *et al*. (1989) and Stanmore (1989). The groundwater flow in the region is described in terms of the GAB (Habermehl 1980). From 10 to 5 million years ago a phase of structuring in the Eromanga uplifted the margins of the basin (particularly in the east), raising the ground surface to a slightly higher level than the present-day elevation and instigated the groundwater flow pattern within the GAB which is described in detail by Habermehl (1980, 1986).

Geothermal gradients in the Cooper and Eromanga range from 30°C per km on the margins to 60°C per km in the Nappamerri Trough, some of the highest recorded gradients worldwide in hydrocarbon-bearing basins. Here temperatures in the basal Cooper sediments reach approximately 250°C.

The Cooper and Eromanga Basins are currently subject to a regionally compressive stress regime. Motion along fault bounded basement blocks results in strong local stress variations. Evidence from well bore geomechanics shows that conditions for movement on faults are present and that the structural evolution of the area is ongoing. The relative stress magnitudes and orientations that make up the stress regime are an important consideration in hydraulic stimulation as they define the direction of fracture propagation and its vertical extent.

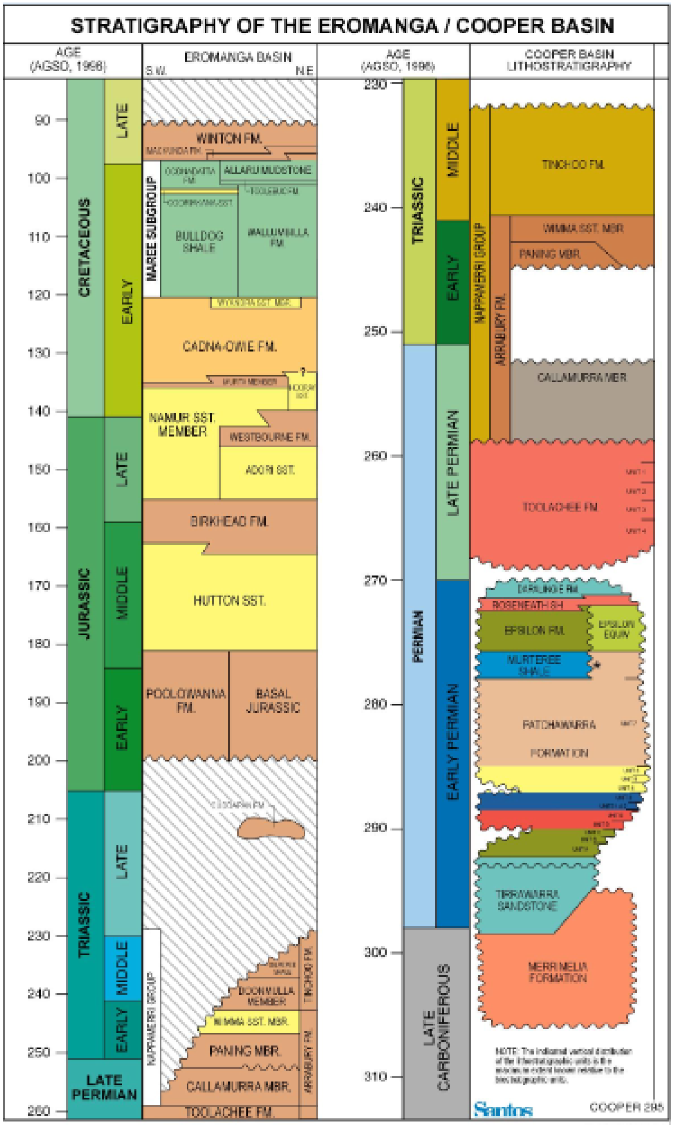


*Figure 5-2: Cooper Basin stratigraphy.*

### 5.3.1 Hydrocarbon Reservoir Formations

*Conventional Oil*

Conventional oil is found in sedimentary (sandstone) basins, and can be extracted using traditional methods, with relatively few wells required. The oil resources are usually from another formation but move into the sandstone and are trapped by an impermeable 'cap' rock. Conventional oil resources are extracted using traditional methods of drilling down through the 'cap' rock and allowing petroleum to flow up the well.

*Sources of Natural Gas*

Natural gas is found in in a number of geological settings and within various rock types. All natural gas, whether it is described as conventional or unconventional, is composed predominantly of methane ($CH_4$), with varying, usually minor, quantities of other hydrocarbons and inert compounds ($N_2$, $CO_2$ etc.). The descriptor of conventional versus unconventional refers to the rocks or formations that the gas is found.

*Conventional Gas*

Conventional gas is trapped in porous and permeable reservoir rocks, such as sandstones, in favourable geological structures or traps and within sedimentary basins. To date, most of the gas that has been produced, globally and in Australia, has been conventional gas. Conventional gas will flow naturally at economic rates from wells drilled into the gas bearing formations.

*Unconventional Gas*

Unconventional gas is natural gas but, rather than migrating from the source rock to a conventional structural trap, the gas remains in the source rock. This may include coal seams and shale.

*Tight gas*

Tight gas is not dissimilar to conventional gas, in terms of geological setting and that the gas has migrated to the trap, except that the reservoir rock has a low permeability, meaning that it is more difficult to extract the gas than is the case for conventional, higher permeability sands. To extract the gas economically, the permeability has to be enhanced through stimulation such as hydraulic fracturing. Tight gas has been produced in Australia in the Cooper Basin for over 30 years.

### 5.3.2 Conventional Oil (Eromanga Basin)

The conventional oil reservoirs in the study area are associated with sandstone formations of the Eromanga Basin. The oil is present in discontinuous oil reservoirs (in the sandstone units of the Cadna-Owie, Murta, Poolowanna and Birkhead formations) within interbedded sandstone beds or larger sandstone formations (in the Hutton and Namur Sandstone) with reservoirs typically comprising structural and stratigraphic traps. Figure 5-3 presents a map of South Australian oil and gas fields in the Patchawarra, Nappamerri and Allunga Troughs.

The sandstone reservoirs are generally interbedded with shales, mudstones, siltstones and coals, which act as intra-formational seals. The primary oil reservoir formations are separated by low permeability formations comprising shale-mudstone-siltstones of the Eromanga Basin, themselves situated at depth within a thick sequence of highly variable sedimentary rock types (Figure 5-4).

The porosity found in sandstone reservoirs is preserved primary intergranular porosity. Water and oil commonly occur together, having a film of water separating the pore boundaries from the oil. Oil production wells in the Eromanga Basin most commonly have little to no associated gas, either dissolved in the oil or as a separate gas cap over the oil. This means that oil rarely flows to the surface under its own energy and needs to be assisted by an artificial lift or pumping system. Water movement, either from below the reservoir in thick sandstones, or laterally in the case of thin sandstones is the main drive mechanism and results in water being produced along with the oil. Some reservoirs, such as the Birkhead Formation, are not connected to an aquifer and the only drive mechanism is by fluid expansion. In this situation, only about 3% of the oil is recovered unless assisted by pumping more water into the reservoir (water flooding) to maintain pressure and sweep oil from an injector well towards a production well.

Figure 5-4 presents the main occurrences of oil pools in the Eromanga Basin, South Australia. In general, oil accumulates around the margins of the buried Cooper Basin where the sealing Nappamerri Formation has been eroded. Oil also accumulates along faults, where it can naturally migrate upwards through the Nappamerri formation. The cross section (Figure 5-6) shows stacked, multiple pools of oil where it can migrate upwards through the Eromanga succession through imperfect seals (from Drexel and Preiss (eds), 1995).

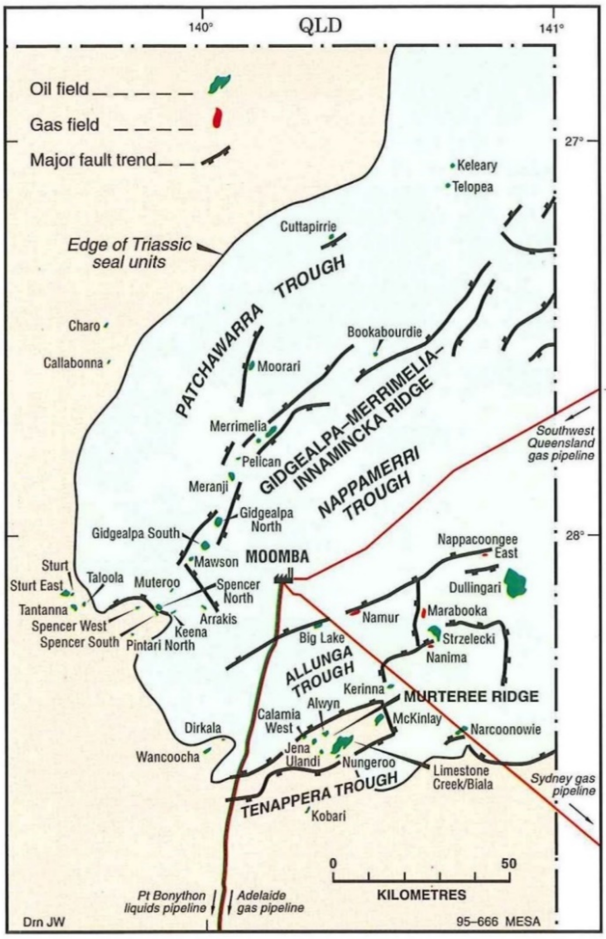


*Figure 5-3: Oil and gas fields of the South Australian Patchawarra, Nappamerri and Allunga Troughs.*

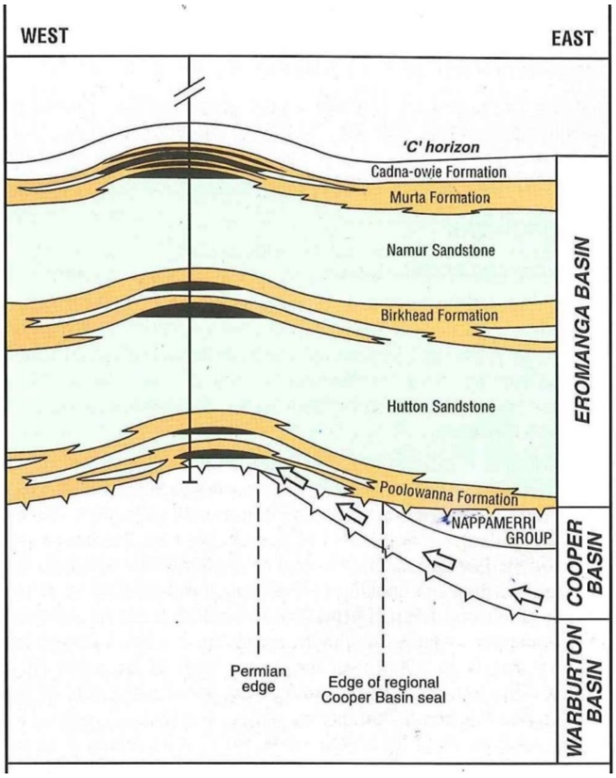


*Figure 5-4: Oil accumulations in the Eromanga Basin, South Australia (from Drexel and Preiss (eds) 1995).*

### 5.3.3 Conventional Gas Production

Conventional gas is produced predominantly from stacked sands of the Toolachee and Patchawarra Formations (Gidgealpa Group), which lie within the Cooper Basin (Figure 5-5). The fluvial sandstone reservoirs are separated by shales and coals, which act as intra-formational seals. Minor gas production also occurs from other sediments within the Gidgealpa Group (e.g. the Epsilon Formation) from various localised sediments within the overlying Nappamerri Group (also part of the Cooper Basin), and from the Hutton Sandstone (within the Eromanga Basin). Generally, however, the Nappamerri Group shales act as a regional top-seal for gas.

Gas is predominantly stored as free gas within pore spaces in the sandstone reservoirs. Much of the porosity found in sandstone reservoirs is preserved primary intergranular porosity. The sandstone reservoirs often have low permeabilities (usually of the order of 1 to 10 milliDarcies (mD), equivalent to a hydraulic conductivity range of $10^{-2}$ to $10^{-3}$m/d), such that Hydraulic stimulation is essential in order to achieve economic flow-rates and production volumes.

When a conventional gas well is completed with its final production string, pressure drawdown (i.e. differential pressure between the reservoir and well bore) is created by opening up the well to the gathering system. Gas is then able to flow by virtue of the conductive path to the well via the formations permeability. In general, most gas reservoirs naturally deplete through a gas expansion drive mechanism.

### 5.3.4 Unconventional Gas Production

Unconventional gas plays in the Cooper Basin are comprised of shales, deep Permian coals or tight sandstones which are largely characterised as self-contained systems (providing the full petroleum system of source, seal, reservoir and trap), with the presence of gas not influenced by any such structural (anticlinal) setting. It is important to note that because the unconventional reservoirs lie within the same stratigraphy as that of the conventional reservoirs, the hydrocarbon produced is the same as that of a conventional gas well. A distinguishing feature of unconventional resources is their very low permeabilities, ranging from ultra-tight sub-micro ($10^{-6}$D) to nanodarcy ($10^{-9}$D) permeability.

Unconventional gas plays often exist as large, continuous and predictable accumulations such as the Roseneath, Epsilon and Murteree (REM) package in the Moomba/Big Lake area. They may also exist in either normally-pressured or over-pressured deep trough areas of the Cooper Basin, such as in the Nappamerri Trough.

The key enabler for the commercialisation of unconventional gas formations is stimulation such as hydraulic fracturing.

### 5.3.5 Carbon Storage Formations

Carbon storage formations will include hydrocarbon reservoirs, deep saline geological formations and other suitable geological formations. These formations are capable of storing low density fluids on the scale of geological time by a combination of buoyancy, residual, solubility and mineral trapping.

Deep saline geological formations have the potential for buoyancy trapping and / or migration assisted storage (MAS), a combination of residual trapping and solubility trapping. Typically this will involve finding areas within saline formations with similar stratigraphic or structural features to hydrocarbon reservoirs. This will enable buoyancy trapping of $CO_2$ as well as MAS.

*Cooper Basin*

Target carbon storage reservoirs in Cooper Basin strata include stratigraphic and structural traps in the Tirrawarra Sandstone, Patchawarra, Epsilon and Toolachee Formations. Hydrocarbon reservoirs developed in higher porosity and permeability strata in these formations where they were overlain by low permeability strata preventing upward migration of buoyant hydrocarbons, called 'seals'. Often the seals are interbedded shale, siltstone, mudstone, coal, or other low permeability rock with the formations. In addition the lacustrine shale deposits of the Murteree and Roseneath Formations and the Callamurra Member act as seals in the Cooper Basin stratigraphy.

Formations in the Cooper Basin containing hydrocarbon trapping features are typically also aquifers in other locations. The reservoirs being localised buoyancy traps where hydrocarbons have become trapped beneath seals with the remainder of the formation being fully saturated with groundwater which is typically saline.

*Eromanga Basin*

Target carbon storage reservoirs in Eromanga Basin strata include stratigraphic and structural traps in the Hutton Sandstone, lower Birkhead Formation, Namur Sandstone and equivalent McKinlay Member, Wyandra Sandstone, and Cadna-owie Formation. As well as interbedded low permeability strata within these formations the lacustrine shale deposits of the upper Birkhead Formation, shales of the Murta Member, and the regionally extensive Bulldog Shale units and equivalents all act as seals or aquitards. Groundwater in the Eromanga Basin is typically fresh to brackish.

## 5.4 Hydrogeology

### 5.4.1 Aquifers and Aquitards

The Eromanga and Cooper Basins can be broadly subdivided into aquifers and confining beds (aquitards and seals).

Aquifers are porous and permeable units that are able to store and transmit water. Similar to petroleum reservoirs, they have the capacity to store fluids as well as enable fluids to pass through them. In several instances, porous-permeable units are both aquifers and petroleum reservoirs.

Confining beds (aquitards) are rock units that impede the movement of water, and in general have low hydraulic conductivities or permeability. In some Cooper Basin aquitards, the conductivity is so low that no fluid permeates them under natural pressure conditions. Seals are proven by their ability to trap and hold gas under pressure.

The pressure in the liquid of an aquifer can be described as having a specific measure of liquid pressure or hydraulic head. In general, the hydraulic head drives the flow of water from one part of an aquifer to another, (i.e. from high to low).

Differences in head potential between aquifers occur when a confining layer is present and the flow in each aquifer occurs independent of the other. In this situation, the hydraulic head difference will drive water through the confining bed until equilibrium is established. The volume of water moving through a confining bed is generally very small compared with the lateral flow in the aquifers. The rate of movement through the confining bed depends on its thickness, its vertical hydraulic conductivity (related to lithology) and the head difference. Flow through confining beds can also occur along faults.

Under normal conditions, fluid flows from high pressure (hydraulic head) to low pressure. If the pressure is the same in two aquifers that are separated by a confining bed or seal, fluids between the aquifers will not mix even if the aquifer is breached.

A geological formation can contain both aquifers and aquitards. For example, the Cadna-owie Formation has been described as one of the main aquifers of the GAB. However, the bottom three quarters of the Cadna-owie Formation is siltstone and shale and acts as an aquitard while the upper quarter of the unit is a sandstone that may act as an aquifer where it is not cemented or too silty.

Within the Eromanga Basin, large parts of the Poolowanna, Birkhead, Murta and Westbourne formations and most of the Wallumbilla Formation and the Bulldog Shale, Allaru, Toolebuc and the Oodnadatta formations are aquitards. Within the Cooper Basin, trapping of gas indicates that most of the aquitards are seals. The entire Murteree Shale and Roseneath Shale are seals. The Patchawarra, Epsilon and Toolachee formations are composed of sandstone-shale-coal cycles each of which contain potential aquifer / reservoir systems and a seal or aquitard. In these systems the formations as a whole act as seals. The Nappamerri Formation, which overlies the coal measures, is a regional seal to the gas sands of the Cooper Basin, except around the eastern southern and western margins of the Cooper where it has been eroded. As a seal, it prevents the vertical movement of gas and oil, diverting the hydrocarbons laterally until they reach the eroded edge of the Nappamerri, where the hydrocarbons can resume their natural vertical movement.

Many aquitards are naturally discontinuous, either due to erosion or faulting. Where this occurs, large scale mixing of the aquifers has taken place and hydraulic equilibrium has or is being reached.

Aquifers include the Eyre Formation of the Lake Eyre Basin, some parts of the Winton, Coorikiana, Cadna-owie, Murta, Birkhead formations, and large parts of the Mackunda, Namur, Adori, Hutton, Poolowanna and Cuddapan formations, and all of the Eromanga Basin. In the Cooper Basin, parts of the Nappamerri Group, Toolachee, Daralingie, Epsilon, Patchawarra and Merrimelia formations, and all of the Tirrawarra Sandstone, may act as aquifers. Hydraulic conductivities measured within aquifers range between 0.1 and 10m/day (Audibert, 1976). Observed porosity values within the sandstone aquifers are about 0.3m/day (Senior and Habermehl, 1980).

Table 5-2 provides a summary of the pressure, permeability and salinity characteristics of these aquifers and regional geological cross sections are shown in Figure 5-5 and Figure 5-6.

Based on the geological data available, the aquifers can be grouped into seven largely regional hydrogeological cells, labelled from the top down as follows:

- The Meteoric Recharge Zone (the top water table or unconfined aquifer).
- The Eyre Formation, which in places overlaps and is coincident with the surface Meteoric Recharge zone.
- Parts of the Winton and most of the Mackunda Formations (non-flowing, uppermost GAB aquifer system (K aquifer of Habermehl, 1980).
- Coorikiana Sandstone (non-flowing aquifer restricted to the western parts of the Eromanga Basin).
- Uppermost part of the Cadna-owie Formation, parts of the Murta Formation, a large part of the Namur Sandstone, parts of the Westbourne and Birkhead formations and most of Hutton Sandstone and Poolowanna Formations – all within the GAB and collectively called the J Sands by Habermehl (1986).

- The Cooper Basin (normal pressure) (largely the shallower parts of the basin and around its margins.
- The Cooper Basin (abnormal pressure) (largely the deeper, hotter parts of the basin such as the deep Nappamerri Trough.

Whilst the data available strongly supports this interpretation, it is recognised that in some areas the data to prove the regional interpretation is unavailable. Where this occurs, the well data provides adequate delineation of the cells within a well bore.

The distribution of these cells across the Cooper and Eromanga Basins show how in several areas the aquifer / reservoirs of the basins are in direct communication. However, all cells do not necessarily exist in all parts of the basin. Towards the margins of the Cooper Basin and along some intra-basin highs, the GAB and Cooper Basin cells are in connection and the Cooper Basin (abnormal pressure) does not exist. It is also noted that the Coorikiana Sandstone is only known from the southern and western Eromanga Basin.

Geochemical correlation between source rocks and petroleum reservoirs is inconclusive and there is some question as to whether Eromanga hydrocarbons were sourced by either Eromanga or Cooper sediments (Heath *et al*., 1989). Most of the oil pools in the Eromanga Basin are located over and adjacent to the margins of the Permian-Triassic Cooper Basin (Heath *et al*., 1989). Stratigraphically, the Eromanga fields are characterised by vertically stacked pools, with the largest accumulation of oil usually located just below the deepest, most competent seal. Heath *et al*. (1989) considers that much of the oil and gas in the Eromanga Basin was actually sourced from the underlying Cooper rocks. Oil pools stack vertically within anticlines, which demonstrate that the seals between the sands are imperfect and that fluids can migrate vertically. In this situation, the mudstones are best described as aquitards, where flow is impeded but not prevented.

In the Cooper Basin, the location of oil and gas fields is closely related to the distribution of maturity in the source rocks; most gas fields are located in or near the 'hot' Nappamerri Trough, whereas the 'cooler' Patchawarra Trough is home to many of the oil fields in the Cooper reservoir rocks (Kanstler *et. a*l. 1983; Hunt *et. al*. 1989). The distribution of hydrocarbons and hydrogeological cells in a well bore can guide the effective management of the impact of drilling and production on the hydrocarbon and water resources of the region.

*Table 5-2: Summary of salinity, pressure and permeability characteristics.*

| Formation | Use | Extent | Salinity | Pressure System | Permeability |
|---|---|---|---|---|---|
| Phreatic aquifer comprising dunes of Simpson Sand plus associated older dunes, inter-dunes, lakes and channels. | Generally limited to stock watering and petroleum exploration | Basin wide, except where older, underlying units are exposed | Highly variable, 1000 up to 20000 ppm or more | Fully unconfined | High |
| Eyre Formation | Limited use for petroleum exploration | Basin wide, except where eroded on topographic highs | Unclear, probably variable, like the phreatic aquifer above (1000 – 20000+ppm) | Uppermost aquifer. Unknown, but less than GAB | High |
| Winton Formation (multiple sands and aquitards) | | Basin wide, but sands may be of limited extent | As above | As above | High |
| Mackunda Formation | | Basin wide | Unclear, probably high (>9000ppm) | Uppermost GAB or K aquifer. Known to be less than GAB J aquifer (Della 20 evidence) | High |
| Coorikiana Sandstone | Potential hydrocarbon reservoir | Restricted to southern marginal and eastern areas of Basin | Unclear, probably high (>9000ppm) dataset, may be high or low | Aquifer between Bulldog Shale and Oodnadatta Formation. One data point apparently less than GAB. Not in communication with GAB in Cooper area | Generally low but local areas up to moderate |
| Cadna-owie Formation (aquifer in the Wyandra SS at top of formation) | Known aquifer in uppermost part of formation only | Basin-wide | Limited data – possibly 2000 – 5000ppm | Part of main GAB J aquifer system, on a common water pressure system | Often low, locally high |
| Murta Formation (multiple sands and aquitards) | Known hydrocarbon reservoir | Basin wide, but sands may be limited in extent | Limited data (3000-4000ppm) for Murta sands | Part of main GAB J aquifer (Algebuckina Sandstone equivalent). Data pressures variable and source not verifiable. May be issues with mixing McKinlay Member data. | High |
| Namur Sandstone (includes McKinlay member of Murta Fm) | Known aquifer and hydrocarbon reservoir | Basin wide | 300-4000ppm | Part of main GAB aquifer (Algebuckina Sandstone equivalent). May have local depleted zones | High |
| Adori Sandstone | Known aquifer and hydrocarbon reservoir | Restricted to northern part of basin | 300-4000ppm | Part of main GAB aquifer (Algebuckina Sandstone equivalent). May have local depleted zones | High |
| Birkhead Formation (multiple sands) | Known hydrocarbon reservoir | Basin wide but sands separated by aquitards | 300-4000ppm | Part of GAB J aquifer. May have local depleted zones | Highly variable |
| Hutton Sandstone | Known aquifer and hydrocarbon reservoir | Basin wide | 300-4000ppm | Part of main GAB aquifer (Algebuckina Sandstone equivalent). May have local depleted zones | High |

| Formation | Use | Extent | Salinity | Pressure System | Permeability |
|---|---|---|---|---|---|
| Poolowanna Formation | Known hydrocarbon reservoir | Basin wide | 3000-4000ppm in Cooper Basin area, but in excess of 9000 ppm in northern areas | Part of GAB J aquifer. May have local depleted zones. | High |
| Cuddapan Formation | Known hydrocarbon reservoir | Local channels only between Nappamerri and Jurassic units | Unknown | | High |
| Nappamerri Group (multiple sands and seals) | Known hydrocarbon reservoir | Extensive with erosion from the top to the west south and east of Moomba, but sands of local extent. Degree of interconnection across basin unclear | 3000-7000ppm. Local variations appear to depend on connection with GAB | May be same or greater or less than GAB. May have local depleted zones | Highly variable |
| Toolachee Formation (multiple sands and seals) | Known hydrocarbon reservoir | Extensive, top eroded on structural highs, but sands of local extent. Complex interconnections across basin. | 1500 to 15,000ppm apparently depending on connection with GAB. Data set combined with Daralingie. | Potential for very high pressures in centre of basin. May be same or greater or less than GAB. May have local depleted zones. Can prove connection with GAB in Munkarie Brumby area. | Highly variable |
| Daralingie Formation (multiple sands and seals) | Known hydrocarbon reservoir | As above | Data combined with Toolachee. | Potential for very high pressures in centre of basin. May be same or greater or less than GAB. May have local depleted zones. | Highly variable |
| Epsilon Formation (multiple sands and seals) | Known hydrocarbon reservoir | As above | Limited dataset, 2000 to 10,000ppm apparently depending on connection with GAB. | As above | Highly variable |
| Patchawarra Formation (multiple sands and seals) | Known hydrocarbon reservoir | As above | 2000 to 18,000ppm. Low salinities in Weena / Tinga Tingana Trough | As above | Highly variable |
| Tirrawarra / Merrimelia Formation | Known hydrocarbon reservoir | Basin wide except for south east and around local highs | Limited dataset for Tirrawarra 5000 to 17,000ppm no data for Merrimelia | As above | Highly variable |
| Pre Permian Basement | Known hydrocarbon reservoir | Basin wide | Unknown | Potential for very high pressures in centre of basin. May be same or greater or less than GAB | Highly variable, may include natural fractures |

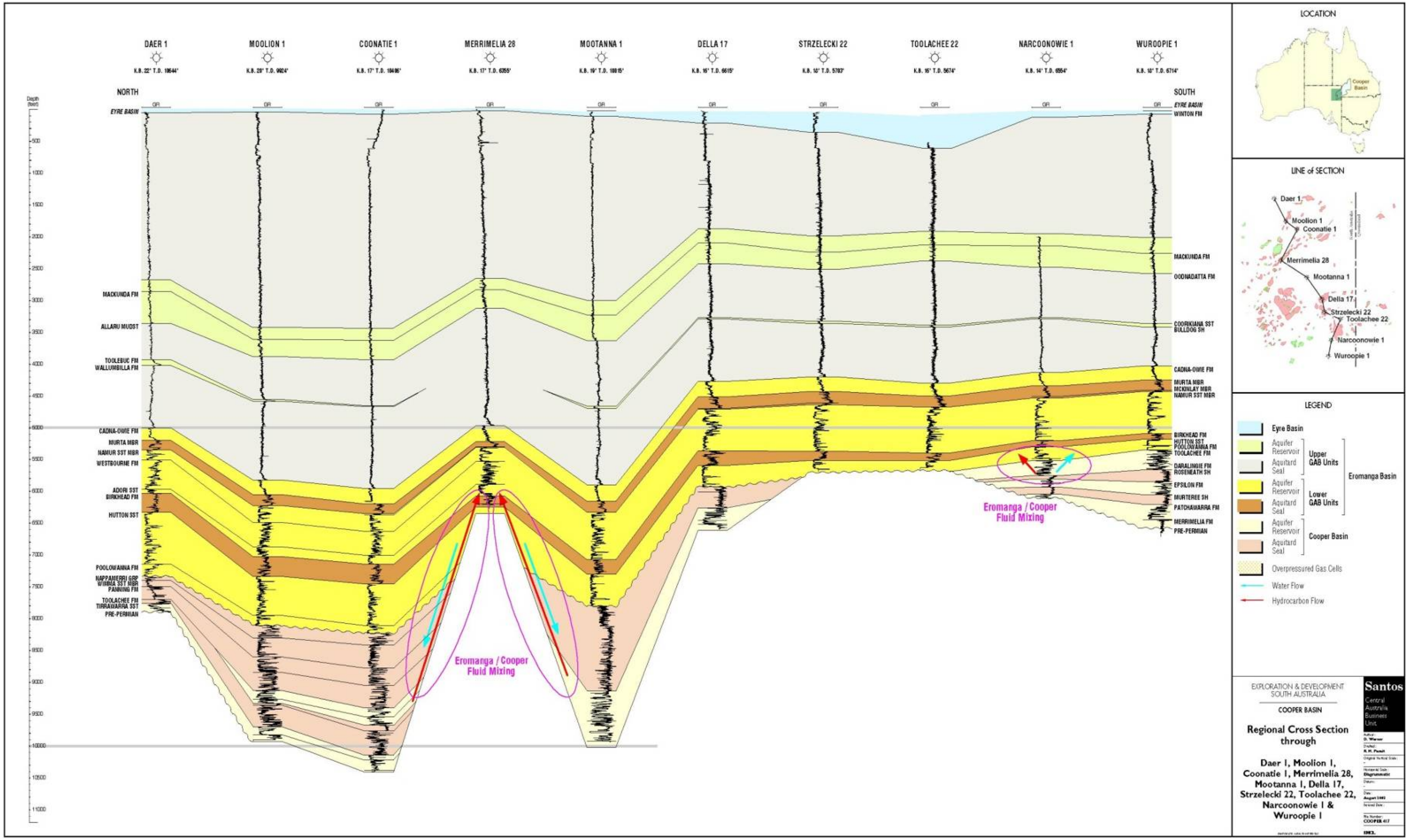


*Figure 5-5: Regional geological cross-sections of the Cooper-Eromanga Basin area (a).*

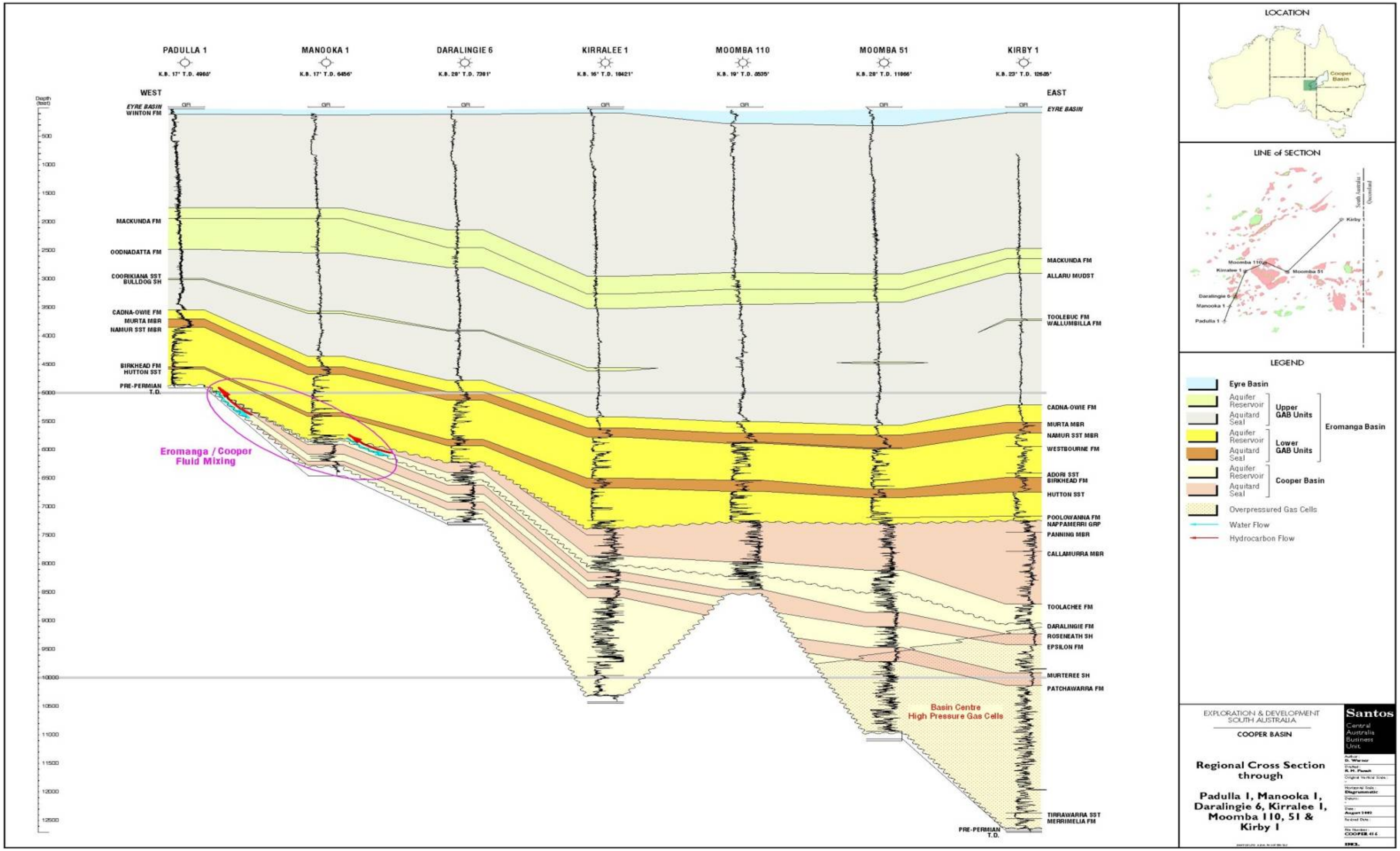


*Figure 5-6: Regional geological cross-sections of the Cooper-Eromanga Basin area (b).*

## 5.5 Groundwater Use

Due to the dry climate of the Cooper Basin region in South Australia, groundwater is an important resource. Land use is generally restricted to low intensity stock grazing, and where accessible and of acceptable quality, groundwater is used for domestic and stock watering purposes. It is noted however, that in most cases groundwater for domestic uses such as potable or camp use is treated using reverse osmosis (RO) to improve quality. Other industries reliant on groundwater resources in the region include oil and gas exploration and production and other resource extraction such as mining. The quality of the water required for these activities is variable, and accessibility to water of appropriate quality may restrict land uses in some locations.

Aquifers support the GAB springs which occur around the margins of the Eromanga Basin. There are a number of GAB springs that occur near the southern extent of the Cooper Basin. The communities that are dependent on this groundwater are listed under the EPBC Act list of Threatened Ecological Communities.

In accordance with water bore licences Santos is able to extract approved volumes of water for petroleum activities from shallow aquifers, GAB aquifers and other deeper aquifers. The majority of oil producing reservoirs in the Cooper and Eromanga Basins are classified as 'water drive' reservoirs. Oil pools are usually found in formations that also contain water. As a result of the differing physical properties of oil and water, over time the oil sits above the water. These formations usually exist under pressure so when they are accessed by drilling a bore hole, the oil will flow to the surface. Over time, water will take the place of the produced hydrocarbons and rise up the bore hole with the oil. As production from the reservoir continues, this water content will gradually increase until it is a significant proportion of the total production. This water is considered a by-product, is separated from the oil stream at satellite stations for re-use or managed in surface evaporation ponds.

Due to the depth of the artesian aquifers at the centre of the basin, the majority of pastoral water use from these aquifers in South Australia occurs along the southern and western margins where bores intersect artesian aquifers at less than 600 m (GABCC, 1998). On the western margin, these bores coincide approximately with the Oodnadatta Track and there is a number of flowing artesian bores used for stock watering along the Birdsville Track. The use of artesian water in the central portions of the Cooper Basin is generally limited to converted petroleum wells due to the expense associated with drilling bores to the depth required to intersect freshwater aquifers.

Water quality requirements for various industries vary depending on specific needs. Salinity is used as a guide to the suitability for water use and is usually expressed as total dissolved solids (TDS), a measure of the weight of dissolved solids in water. Groundwater quality in the shallow (water table) aquifers in the Moomba region is generally not suitable for potable or stock watering purposes due to a high salt content. The ANZECC Water Quality Guidelines (ANZECC, 2000) indicate that water of up to 5000 mg/L TDS is generally acceptable for stock watering, with levels of TDS higher than may be tolerable and at higher levels still may result in a loss of production and decline in animal health (ANZECC, 2000). The salinity of shallow groundwater resources in the north-east of South Australia is often significantly higher than this value. Likewise, the salinity of water in the uppermost GAB aquifer (Eyre, Winton and Mackunda formations) is also generally too saline for use. However, the salinity of the main flowing GAB aquifer is lower (600 – 2000mg/L TDS) in the eastern part of South Australia, and is suitable for stock watering purposes.

## 5.6 Social Environment

The Cooper Basin area has Aboriginal cultural and European historical significance. There are a range of current land use types within the area including conservation, tourism, and oil and gas production, with pastoral activities being the predominant land use. The area is very sparsely populated. While the permanent population has decreased in recent decades, commercial and tourist numbers have increased. It is noted however, the region remains generally undeveloped in terms of infrastructure and roads.

### 5.6.1 Aboriginal Cultural Heritage

The north-east desert region historically sustained a significant Aboriginal population, particularly in the area surrounding Cooper Creek and its many channels (Santos 1998).

Sites of Aboriginal heritage can be identified within the region and include features of spiritual and archaeological importance, for example, middens, artefact scatters, rock engravings, arrangement sites, burial sites and quarries (Blackley *et al*. 1996). Part of the Cooper Creek region has been proclaimed a State Heritage Area because of its association with Aboriginal and European history as well as its environmental significance. The area encompasses Innamincka and a 1 km strip either side of Cooper Creek, totalling 120 $km^2$ and four locations within this area are also listed on the National Heritage List, as noted below. The central archives maintained by Aboriginal Affairs and Reconciliation currently holds records for approximately 930 Aboriginal sites, objects and remains within Santos' Cooper Basin and Eromanga Basin Operations Area of Interest. Additional undiscovered and/or undocumented Aboriginal sites, objects and remains may also be present within these areas.

Santos has executed Cultural Heritage Management Plans (CHMP) consistent with The *South Australian Aboriginal Heritage Act 1988 (SA)* in place with the Yandruwandha Yawarrawarrka and Dieri native title parties. These management plans are utilised to obtain cultural heritage approvals for project activities.

It is also acknowledged that the Wangkangurru Yarluyandi party features over southern portions of the Cooper Basin but fall outside of the current project area. No consultation was undertaken with this native title group as part of this project.

Further detail on Aboriginal heritage, including information on the processes for cultural heritage management for surface activities, is provided in the DCWO and PPO EIRs.

### 5.6.2 Non-Aboriginal Heritage

Non-indigenous heritage in the region dates back to European exploration during the 1840s. Most historical sites in the region are associated with exploration, including the failed Burke and Wills expedition of 1860–61, the establishment of transport routes, expansion of pastoralism throughout the north-east deserts and subsequent settlement of inland South Australia and Queensland (Planning SA 2009; AHPI 2014).

A number of sites in the region are listed on the State Heritage Register, including the Australian Inland Mission Nursing Home at Innamincka and the Innamincka/Cooper Creek State Heritage Area (a section 1 km either side of the Cooper Creek channel from the Queensland border to 14 km west of Innamincka). Four locations within this area (Will's Site, King's Site, Burke's Tree and Howitt's Site) are included on the National Heritage List as part of the Burke, Wills, King and Yandruwandha National Heritage Place.

### 5.6.3 Native Title

There are currently three native title claim groups in the South Australian Cooper Basin. Details of each claim are presented in Table 5-3.

*Table 5-3: Native title claims in the South Australian Cooper Basin*

| Title | Location | Status |
|---|---|---|
| Yandruwandha/ Yawarrawarrka Native Title Claim | North east corner of South Australia (SA) extending south to Lake Blanche | Determined SCD2015/003 |
| Dieri Native Title Claim | From Marree in the south to Cameron Corner in the east, to Hadden Corner in the north-east, following the Queensland border to Lake Teetatobie, south-west of Gypsum Cliff, west to Lake Eyre, south to Marree | Determined SCD2012/001 |
| Wangkangurru/Yarluyandi Native Title Claim | Northern South Australia and Queensland | Determined SCD2014/005 |

Santos has two primary Aboriginal stakeholders in the South Australian Cooper Basin, the Dieri and Yandruwandha/Yawarrawarrka Native Title Groups. The Dieri are recognised as native title holders for an area of Santos operations that includes the Tirrawarra and Charo fields.

The Yandruwandha/Yawarrawarrka are recognised as native title holders for an area that incorporates the Dulingarri, Moomba (South and East) and Limestone Creek fields and most of the Nappa Merrie Trough Unitisation Zone.

Santos has various native title agreements in place with the native title parties.

### 5.6.4 Land Use and Tenure

The primary land uses in the Basin are pastoralism, oil and gas exploration and production, conservation and tourism. Sixty percent of the region is used for pastoral production and the majority of the remainder falls within Regional Reserves.

*Pastoral Land Use*

The main pastoral enterprise in the region is beef cattle production on native pasture. Pastoral properties located within the South Australian Cooper Basin include Merty Merty, Gidgealpa, Cordillo Downs, Innamincka, Clifton Hills, Mungeranie, Bollards Lagoon, Mulka and Lindon.

Sections of pipeline operations in the South Australian Cooper Basin are carried out on properties that are certified under programs such as the Livestock Production Assurance On-Farm Quality Assurance (LPAQA) program. Some properties may also be certified as organic/biodynamic through bodies such as OBE Organic Beef.

*Conservation*

The region contains some of South Australia's largest conservation reserves dedicated under the *National Parks and Wildlife Act 1972*. The main parks and reserves of the broader region include the Innamincka Regional Reserve, Strzelecki Regional Reserve, Simpson Desert Regional Reserve and Conservation Park, and the Coongie Lakes National Park.

Regional Reserves are areas proclaimed for the purpose of conserving native fauna, natural or historical features while allowing responsible use of the area’s natural resources (including oil and gas production). The Coongie Lakes National Park was proclaimed to conserve significant wetlands, provide tourism experiences and ensure that the core component of the Coongie Lakes system is protected from grazing, petroleum and mining activities. Part of the Cooper Creek system is also proclaimed as the Coongie Lakes Wetland of International Importance under the Ramsar Convention.

*Oil and Gas Production*

The area of land used for oil and gas production is small, but the supporting infrastructure extends within much of the central and north-east portion of the Cooper Basin in South Australia.

Santos is the largest petroleum company in the area, operating a total of 36 gas and oil satellites and nodals, the Moomba petroleum processing plant and associated infrastructure. Other operators, including Beach Energy and Senex Energy, operate smaller production facilities in the region, which generally deliver produced oil or gas to Moomba via road or pipelines.

### 5.6.5 Socio-Economic

The Cooper Basin region is very sparsely populated, with a small number of residents working in the pastoral industry and over 2000 petroleum industry workers, largely based (on FIFO rosters) at Moomba and surrounding areas.

Moomba and Innamincka are the main population centres.

Santos operates and maintains:

- Moomba airport (with contracted air services) to transport the workforce and small freight to and from Adelaide
- a number of workforce accommodation villages: Moomba, Dullingari and Tirrawarra (SA) and Ballera and Jackson Operating Villages (QLD)
- a waste management facility, licensed to receive waste from the greater Cooper Basin area.

The population of Innamincka was recorded as 131 during the 2006 Australian Census (ABS 2007) and 44 in the 2016 census (ABS 2020). The population of the Marree SSC (which covers the north-east corner of the state, including the town of Innamincka) was 634 in the 2011 Australian Census (ABS 2013).

Based on DPTI traffic counts (J Gerblich, DPTI, 2015, pers. comm., 9 July), it is estimated that more than 20,000 tourists visit the region annually. The Strzelecki Track, Innamincka Regional Reserve and Coongie Lakes wetlands are tourist attractions. It has been previously estimated that over 34,500 visitors enter the Innamincka Regional Reserve annually (DEH 2008).

Infrastructure in the region is minimal. Unsealed roads service the district and the Strzelecki and Birdsville tracks are the major routes through the region. Most roads and tracks associated with oil and gas fields have no public access.

Santos contributes significant investment in the Cooper Basin region, including maintaining and upgrading roads, road and tourism signage, fencing, the Moomba Waste Management Facility, the Moomba Airport, emergency response and associated medical facilities.

The Cooper Basin operations contribute over $50 million in royalties to South Australia each year.

# 6 Consultation

Effective consultation allows for an exchange of information and provides an opportunity to promote understanding and reconciliation of competing interests.

Santos recognises the importance of working with its stakeholders in the Cooper Basin. Santos has been operating in the region for over 50 years and has consulted with relevant stakeholders throughout that period. Santos has a long history of mutually beneficial relationships with pastoral stakeholders in the Cooper Basin and also continually engages with traditional owner groups.

The following section outlines the consultation that has been undertaken in the development of this EIR and the accompanying SEO.

## 6.1 Development of the EIR and SEO

Santos has undertaken stakeholder consultation during the development of the Carbon Storage EIR and SEO. To date this has included:

- Discussions and meetings with the regulator DEM, DEW and the SA EPA
- Provision of draft documents to DEM for review
- Circulation of the draft EIR and SEO to key stakeholders and government agencies for comment (coordinated by Santos)
    - Consultation period 23 days

Santos continually engages with its Cooper Basin stakeholders and is an active member of regional bodies such as the SA Arid Lands NRM Group. Feedback from ongoing consultation with pastoral stakeholders, traditional owner groups, regional bodies and other oil and gas operators will also be incorporated in the review and revision of the EIR and SEO. A list of stakeholders contacted is presented in Table 6-1. Of these stakeholders we received comments from the following;

- Department for Environment and Water
- South Australian Environmental Protection Authority
- Department of Health and Wellbeing
- Department for Infrastructure and Transport
- Beach Energy
- Outback Communities Authority
- Safe Work SA
- Senex Energy
- DPC Aboriginal Affairs and Reconciliation

Appendix A provides details on written response received following circulation of the EIR and SEO to key stakeholders facilitated by Santos.

*Table 6-1: Stakeholders consulted in EIR and SEO development.*

| Stakeholder Group | Stakeholder |
|---|---|
| State Government | DPC Aboriginal Affairs and Reconciliation |
| | Department for Health |
| | SafeWorkSA |
| | DPTI |

| Stakeholder Group | Stakeholder |
|---|---|
| | DPTI - Outback Communities Authority |
| | PIRSA Pastoral Unit |
| | Landscapes SA Board |
| | Department for Infrastructure and Transport |
| Traditional Owners | Yandruwandha Yarrawarrka |
| | Dieri |
| Landholders | Gidgealpa |
| | Merty Merty |
| | Mungerannie |
| | Lake Hope |
| | Clifton Hills |
| | Cordillio Downs Station |
| | Bollards Lagoon |
| | Innamincka Station |
| | Innamincka and Strezelecki Regional Reserves |
| | Lindon Station |
| Community Non-government Groups | Innamincka Progress Group |
| | Conservation Council SA |
| | Nature Foundation SA |
| Other Government Bodies | Outback Communities |
| | SAAL NRM Group |
| | Great Artesian Basin Coordinating Committee |
| Third Parties | Beach Energy |
| | Sennex Energy |
| | ReNu Energy |
| | Clean Energy Australasia |
| | Vintage Energy |
| | Alligator Energy |
| | Epic Energy |
| | APA |
| | DPTI (Dept of Planning, Transport & Infrastructure) |

# 7 Environmental Risk Assessment

This section discusses potential environmental impacts associated with Santos' carbon storage in hydrocarbon reservoirs, deep saline geological formations and other suitable geological formations. The discussion is supported by an environmental risk assessment.

Section 7.1 provides an overview of the risk assessment methodology. Section 7.2 contains discussion of identified environmental risks and tabular summary of the risk assessment and management strategies for Santos' carbon storage activities in the Cooper Basin.

## 7.1 Risk Assessment

Identified potential impacts are assessed based on the potential for harm (consequences) to receptors and the residual risk of this harm occurring after all management measures are considered. Management measures focus on avoiding or minimising potential for migration and exposure pathways.

### 7.1.1 Environmental Risk Assessment Process

Environmental risk is a measure of the likelihood and consequence of environmental harm occurring from an activity. Environmental risk assessment is used to differentiate minor acceptable risks from major risks and to provide a basis for the further evaluation and management of major risks.

An environmental risk assessment of activities involved with carbon storage has been undertaken in accordance with the Santos Management System (SMS) Risk Management Standard, the Environmental Hazard Controls Procedure and the Incident Reporting, Investigation and Learning procedure. The Risk Management Process is based on accepted principles and applicable Australian standards. This framework is based on the principles of Australian Standard AS/NZS ISO 31000 Risk Management. The risk assessment process is summarised in Figure 7-1.

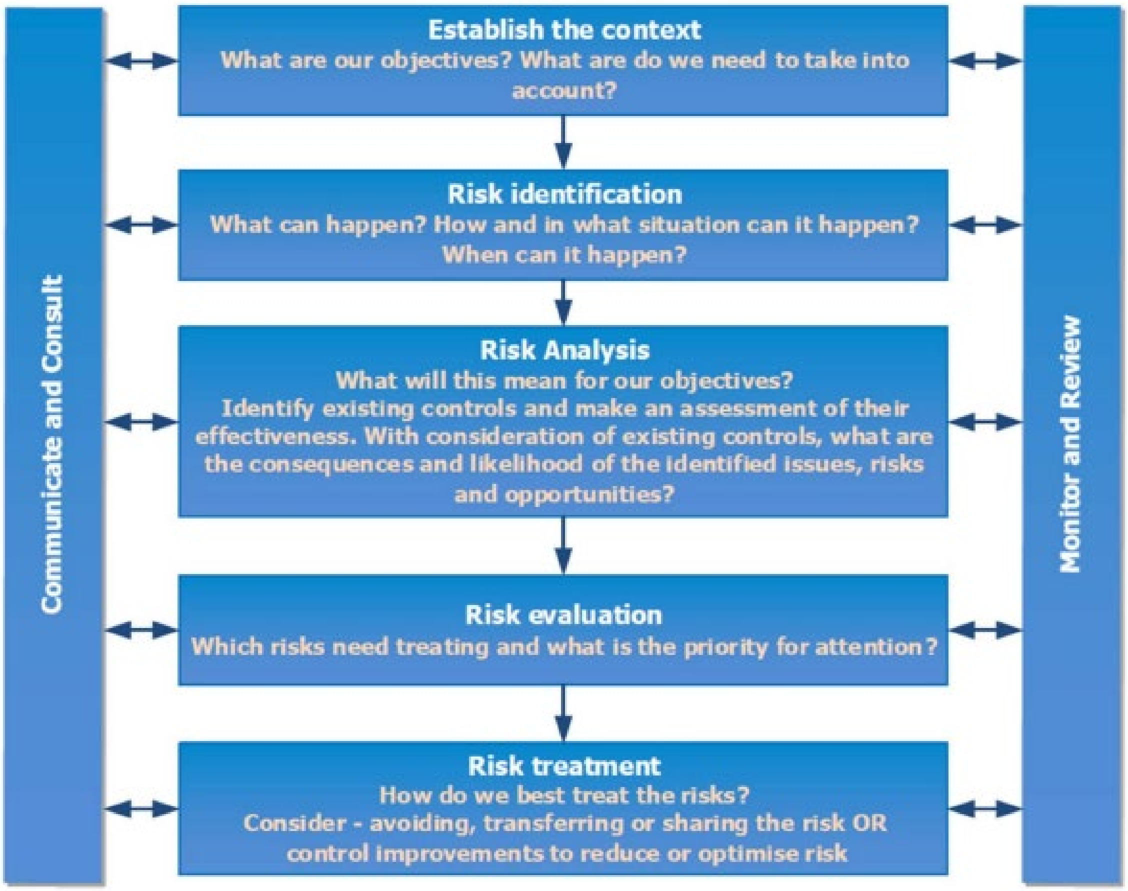


*Figure 7-1: Framework for environmental risk assessment. (Source: Santos SMS)*

The environmental risk assessment for carbon storage (i.e. storage of a measurable quantity of $CO_2$ in subsurface geological formations) has been undertaken based on the assumption that the requisite management practices for existing authorised activities that are discussed in this EIR are in place (i.e. the risk assessment presents the residual risk).

The risk assessment has been developed by Santos personnel, based on extensive knowledge of the Cooper Basin environment and operating experience in the Cooper Basin. The Cooper Basin operation is an existing operation and the environmental hazards and existing management measures are well understood.

The potential risk to the environment as a result of carbon storage has been evaluated using the Santos Operational Risk Matrix. Table 7-1 presents the Operational Risk Matrix used to evaluate risk.

This uses:

- six levels of environmental consequence to describe the severity, scale and duration of potential impacts;
- six levels of likelihood of potential environmental consequences occurring. The likelihood refers to the probability of the particular consequences eventuating, rather than the probability of the hazard or event itself occurring; and
- a risk matrix to characterise the resultant risk into one of five levels.

The following sections discuss the potential hazards and consequences resulting from carbon storage and present the results of the risk assessment.

*Table 7-1: Santos risk matrix consequence*

**Consequence Criteria**

- A consequence level should be chosen on the basis of the expected (most likely) impact on Santos and its stakeholders taking into account current controls and their effectiveness.
- Choose the highest relevant consequence for the basis of the rating.

| Level | Financial (EBITDAX) | People | Environment and community | Reputation | Legal |
|---|---|---|---|---|---|
| VI | >$300m loss or gain | Multiple fatalities or significant irreversible effects on 10's of people | Regional and long term impact on an area of significant environmental value. Destruction of an important population of plants and animals with recognised conservation value. Complete remediation impossible. Complete loss of trust by affected community leading to long-term social unrest and outrage. | Prominent international media coverage over several days. Long term impact on share price leads to changes at executive level. Shareholders desert the stock. | Public inquiry taking up considerable resources and executive time. Major litigation or prosecution with damages / fines of >$100m+ plus significant costs. Custodial sentence for a manager. |
| V | >$30m - <$300m loss or gain | Single fatality and/or severe irreversible disability to multiple people | Destruction of an important population of plants or animals or of an area of significant environmental value. Complete remediation not practical or possible. Prolonged community outrage that impacts the viability of the business. | National media coverage over several days. Shareholders and Board exercise control. Potential for class action. | Major litigation or prosecution with damages or fines of >$10m+ plus significant costs |
| IV | >$3m - <$30m loss or gain | Extensive injuries or irreversible disability or impairment in one person | Extensive and medium-term impact to an area, plants or animals of recognised environmental value. Remediation possible but may be difficult or expensive. High potential for complaints from interested parties. | State media coverage over several days. Involvement by regulator and shareholders | Litigation or prosecution costing >$1m. Investigation by regulatory body. Litigation involving weeks of senior management time. |
| III | >$300k - <$3m loss or gain | Medium term reversible disability to one or more persons. Significant medical treatment, disabling or lost time injury. | Localised and medium term impact to areas, plants or animals of significant environmental value. Remediation may be difficult or expensive. Immaterial effect on the community. | State media coverage. Interest by regulator. | Major breach of regulation with punitive fine. Involvement of senior management. |
| II | >$30k - <$300k loss or gain | Injury requiring medical treatment with no lost time | Localised and short term impact to areas, plants or animals of significant environmental value. Readily treated. One-off community protest requiring intervention and management attention. | Local media coverage. One or two community complaints. | Breach of regulation with investigation or report to authority with possible prosecution and fine. |
| I | <$30k loss or gain | Minor injury, minor medical / first-aid treatment or no effect | Localised and short term environmental or community impact - readily dealt with. | Kept on site. No media or community interest. | Minor legal issue, non-compliances and breaches of regulation. |

**Likelihood Criteria**

Consider the likelihood of the risk event:
WITHOUT CONTROLS to determine INHERENT RISK
WITH CONTROLS to determine RESIDUAL RISK

| Level | | Likelihood Criteria |
|---|---|---|
| Almost Certain | f | - It is expected to occur in most circumstances, or<br>- Could occur within days to weeks |
| Likely | e | - Could occur in most circumstances, or<br>- Could occur within weeks to months |
| Occasional | d | - Has occurred before in Santos, or<br>- Could occur within months to years |
| Possible | c | - Has occurred before in the industry, or<br>- Could occur within the next few years |
| Unlikely | b | - Has occurred elsewhere, or<br>- Could occur within decades |
| Remote | a | - Requires exceptional circumstances and is unlikely, even in the long term<br>- Only occurs as a '100 year event' |

*Figure 7-2: Santos risk matrix likelihood*

| Likelihood Criteria | I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| f | Low | Medium | High | Very High | Very High | Very High |
| e | Low | Medium | High | High | Very High | Very High |
| d | Low | Low | Medium | High | High | Very High |
| c | Very Low | Low | Low | Medium | High | Very High |
| b | Very Low | Very Low | Low | Low | Medium | High |
| a | Very Low | Very Low | Very Low | Low | Medium | Medium |
| | **Consequence Criteria** | | | | | |

*Figure 7-3: Santos risk matrix*

## 7.2 Carbon Storage Risk Assessment

As noted previously, the PPO and DCWO EIRs cover the potential environmental impacts and risks related to $CO_2$ separation, capture and treatment at Moomba, and surface activities such as pipelines, wells, injection, utilisation and ancillary surface infrastructure.

The following sections discuss and assess the risks from carbon in storage. The assessed hazard is storage of $CO_2$. The potential for risk of impact to identified sensitive receptors depends on an exposure pathway for the $CO_2$ to migrate to that receptor.

The potential environmental impacts for storage of $CO_2$ in the Cooper Basin were identified and risks assessed based on:

- identified sensitive receptors
- existing and proposed Santos processes and procedures including well integrity and reservoir management
- global industry experience; and
- literature review of carbon storage following EOR, depleted hydrocarbon reservoirs and deep saline geological formations.

The Cooper and Eromanga Basins are geologically well defined with predictable pressure gradients throughout. Guidelines, procedures, safety practices and design considerations have been developed over the course of 50 years, with experience in drilling more than 2500 wells, and processing, transmission and injection of gas to minimise the potential for risks to the environment and people.

Guidelines and procedures combined with appropriate certification of trained individuals involved in drilling operations and gas processing, transmission and injection means that the risk issues resulting in environmental impact are significantly reduced.

### 7.2.1 Identification of Sensitive Receptors and Exposure Pathways

Sensitive receptors are people, ecosystems, resources (such as water) or some other aspect of the environment that could be impacted if exposed to $CO_2$. Outside of identified storage formations, introduced $CO_2$ may have the potential to change groundwater chemistry or create anoxic atmospheres or, if reaching the atmosphere, negatively impact greenhouse gas emission abatement.

If exposure was to occur, the potential for impact and the extent of impact is dependent on the sensitivity of the receptor to $CO_2$ exposure, the concentration and rate of $CO_2$ flux and the duration of exposure.

As $CO_2$ is a natural part of the carbon cycle all environments have varying capacity to absorb or otherwise respond to $CO_2$ introduction. The rate of air exchange or groundwater movement in receiving environments are critical in determining whether introduced $CO_2$ could result in adverse impacts, as these have the potential to dissipate the $CO_2$.

Sensitive receptors for carbon storage in the Cooper Basin include:

- people who access subsurface and low lying structures and topographic lows in areas where $CO_2$ could concentrate
- stock and fauna in topographic lows where $CO_2$ could concentrate
- flora where $CO_2$ could concentrate in the vadose (root) zone

- shallow groundwater (water table), soil and surface water where $CO_2$ could affect water pH and mobilise previously immobile and potentially toxic naturally occurring chemical constituents
- groundwater chemistry.

For there to be a risk of impact to a receptor there must be a complete exposure pathway. Potential pathways for $CO_2$ to migrate and impact sensitive receptors include:

- well bores
- permeable geological structures such as open faults and fractures
- diffusion through a reservoir seal or aquitard
- lateral migration (via reservoir spill points due to overfilling)
- drilling through the storage formation (at a future point in time).

Each potential migration or exposure pathway is assessed below.

### 7.2.2 Well Bores

Well bores represent a potentially complete exposure pathway for migration of $CO_2$ via well bores if well integrity is not appropriately managed. Well bores include all existing and new wells drilled or completed into or through the carbon storage formation including: producing (and injection), cased and suspended, decommissioned, and suspended / inactive wells and any non-petroleum drill holes.

Inadequate well integrity includes circumstances where hydraulic connection between a storage reservoir and other fluid bearing (oil, gas, or groundwater) formation(s) and / or the surface occurs via a well bore due to incorrect or inadequate completion, operation or decommissioning.

The seriousness of potential impacts, should they occur, would be dependent on whether a receptor was present or not, the rate and duration of $CO_2$ migration, the sensitivity of the receptor and any resultant mixing in the relevant media (water, air, soil). Impacts on flora and fauna would be expected to be relatively localised. Changes in shallow groundwater pH and $CO_2$ concentration would also be expected to be relatively localised, and not likely to impact groundwater users given the generally high salinity and relatively low utilisation of shallow groundwater in the region. The potential for impact to third parties is also limited due to the very low population density and restrictions on public access in the region, particularly in operating areas.

Third party groundwater users extract water from deeper aquifers in the GAB (i.e. the Eromanga Basin strata), however as noted in Section 5.5 the use of these aquifers in the central portions of the Cooper Basin is quite limited due to the depth of drilling required. Migration of $CO_2$ into these formations could change the groundwater pH which could result in secondary impacts on pumps and well casing, should this change be significant relative to the background chemistry of groundwater. Any change in groundwater quality as a result of $CO_2$ migration from storage would likely be localised due to the natural mechanisms by which $CO_2$ moves through formations and becomes trapped (see Section 4.2.2 and the natural movement of groundwater dispersing dissolved $CO_2$. As described in Section 4.4 of the DCWO EIR (Santos 2015), the design and execution process followed by Santos throughout well construction ensures casing strings are designed using the relevant load cases and casing design software, and are designed to withstand well fluid and gas composition and installed in line with current industry best practice. Casing integrity during injection activities is maintained through the monitoring of operational pressures and ensuring that maximum surface pressures are within the limitations of the casing itself.

As discussed in Section 4.4.2 above, identification and evaluation of existing well bores is undertaken early in the planning and design phase for carbon storage schemes and where necessary, wells may be subject to workover or decommissioning to ensure their integrity is maintained and they do not present a potential migration pathway.

During the production and carbon injection phases of well operations, controls on well integrity (including those outlined in the DCWO EIR) include:

- Effective barriers to maintain well control and prevent crossflow between separate aquifer systems, target formations and hydrocarbon reservoirs.
- Operational reports verify that barriers have been set and/or remedial cement work carried out in accordance with the work program as submitted to and/or agreed by DEM.
- Cased hole cement bond logs to confirm quality of cement job in the production casing string.
- Well integrity management system and checks to confirm well integrity through well life.
- Production operator checks during well life - regular site and well inspection and air quality monitoring at all well head locations in active carbon storage reservoir area.
- Pressure monitoring during injection to ensure surface casing integrity and movement of $CO_2$ into the target formation or reservoir as modelled.
- Consultation with relevant regulatory agencies where required.
- Relevant response plan in place in the event of loss of well integrity or abnormal reservoir pressure event.

The management strategies and control measures described above ensure that residual risk of inadequate well integrity resulting in $CO_2$ migration to and adversely impacting non-target formations or other receptors is low.

### 7.2.3 Vertical Migration of $CO_2$

Migration of $CO_2$ from storage reservoirs should permeable geological structures (such as open faults and fractures) exist, is a potential pathway to groundwater, near surface or surface receptors or the atmosphere. However, as evidenced by the extensive geological knowledge and the ability of structure controlled hydrocarbon reservoirs to hold hydrocarbons for millions of years, this pathway is considered unlikely for appropriately selected reservoirs and target formations.

Migration through the diffusion of $CO_2$ through inadequate reservoir seals or aquitards is a potential pathway for $CO_2$ to move from the target formation. However where $CO_2$ is stored in natural hydrocarbon reservoirs this is not considered a valid pathway due to the inherent nature of the reservoir seal to contain such gas over millions of years.

As discussed in section 5.4, deep saline geological formations in the Cooper Basin are largely separated from the overlying aquifers in the Eromanga Basin formations as indicated by differences in formation pressures (Cooper Basin abnormal pressure) and groundwater chemistry. Note that this is not the case near the margins of the Cooper Basin and in areas of basin highs where there is evidence of localised connection between deeper Cooper Basin and GAB water bearing zones. The areas where there is clear separation of groundwater is indicative of effective aquitards and seals to prevent vertical migration of fluids (gas, $CO_2$ or water) through permeable geological structures or diffusion.

Mitigating factors include:

- Storage formation selection and characterisation to further assess and affirm low risk of migration
- Hydrocarbon reservoir characteristics
- Hydrogeological characteristics (groundwater not mixing across aquitards, potential for buoyancy trapping and residual and solubility trapping)
- monitoring of the injection network to identify unexplained pressure changes and trigger investigations to determine the cause.

Given the extensive geological understanding of the local and regional geology gained over 50 years of operations and through drilling over 2500 wells, data and information to inform adequate formation selection is available. This risk is therefore considered low.

### 7.2.4 Lateral Migration of $CO_2$

Lateral migration of $CO_2$ can occur where storage reservoirs are within geological formations that are also regional aquifers without structural containing features and the injected $CO_2$ mass exceeds the buoyancy trapping and residual trapping capacity for the reservoir. Should migration occur then there is the potential for a change in background water quality to occur. The extent of any such change will be limited by the amount of $CO_2$ available to move into groundwater and the residual trapping and solute trapping capacity of the receiving stratigraphy.

Mitigating factors include:

- Geological and hydrogeological characterisation
- injection and monitoring well network design
- monitoring of the injection network to identify unexplained pressure changes and trigger investigations to determine the cause
- monitoring and quantification of the mass of $CO_2$ injected

Given the mitigating measures described above the risk for a complete lateral migration out of storage reservoirs is considered low.

### 7.2.5 Previous Operations Creating Permeable Pathways

Previous activities in hydrocarbon reservoirs have the potential to create permeable pathways or otherwise change the storage capacity of reservoirs. Production, hydraulic stimulation, improved and enhanced oil recovery schemes and drilling history all have the potential to change reservoir characteristics. Drilling history is addressed in Section 7.2.1 in terms of inadequate well integrity.

Santos' extensive production experience and history in the Cooper Basin means knowledge of reservoir and subsurface conditions will enable detailed reservoir characterisation and injection program design and monitoring.

Equipment design and monitoring for $CO_2$ injection will also ensure that injection pressures remain below the fracture gradient, which also avoids the potential for creating new permeable pathways.

The risk of carbon storage in unsuitable reservoirs is considered low.

### 7.2.6 Seismicity

The Eromanga Basin or Cooper Basin target region has a low natural background seismic hazard and is mapped in the lowest category of earthquake hazard in Australia (Geoscience Australia 2012). Operations over the last 60 years have not experienced any incidents as a result of naturally occurring seismicity.

The potential for carbon storage to induce seismic events is considered low. This conclusion is reached on the basis of experience with hydraulic fracturing which uses significantly higher injection pressures than carbon storage. Fracture stimulation has been carried out in the Cooper Basin for nearly 50 years without any incidents of induced seismic events being experienced as a result of this common practice. As noted above, equipment design and monitoring will ensure that injection pressures remain below the fracture gradient.

In addition to the absence of significant risk posed by carbon storage operations, there is very low population density and little infrastructure that would be sensitive to small seismic events.

### 7.2.7 Drilling Through the $CO_2$ in Storage

IPCC (2005) identifies uncontrolled drilling into carbon storage formations as a potential risk. In South Australia the drilling of exploration and production wells is subject to regulatory approval. As such, any future drilling into or through carbon storage formations and storage complexes would require the proponents to identify and assess all risks resulting from the proposed drilling program. Information on any carbon storage activities that have been undertaken would have been submitted by the operator under the Petroleum and Geothermal Energy Regulations and recorded in relevant regulatory databases. The risks related to drilling into or through a carbon storage formation would be therefore considered as part of the regulatory approvals for the activities for future drilling proponents at that time and are not assessed in this EIR.

*Table 7-2: Carbon Storage risk assessment*

| Identification | | | | Control Strategy and Management Measures | Assessment | | |
|---|---|---|---|---|---|---|---|
| **Activity** | **Risk Issue** | **Cause** | **Potential Consequences** | **Controls**<br>**(may include one or a combination of any of the Controls listed)** | **Risk** | | |
| | | | | | **Consequence** | **Likelihood** | **Residual Risk** |
| Carbon Storage | Uncontrolled release of $CO_2$, hydrocarbons and other substances to the atmosphere, surface and / or near-surface environments | Migration of $CO_2$ through well bore as a result of inadequate well integrity. | ▪ Anoxic ($CO_2$ rich) atmospheres adversely impacting:<br>○ Native vegetation<br>○ Livestock and native fauna<br>○ People<br>▪ Reduced environmental values[2] of surface water, shallow (phreatic zone or water table) groundwater and soils due to presence of elevated $CO_2$, hydrocarbons and other substances<br>▪ Localised reduction in air quality<br>▪ Decreased abatement of greenhouse gas emissions | *Design:*<br>▪ Well design in accordance with DCWO SEO, such as:<br>○ Aquifers isolated behind casing string(s) cemented in place.<br>○ Casing string and cement slurry designed by qualified and competent engineers and confirmed by senior engineers or external consultants where necessary.<br>○ Appropriately designed casing and wellhead installed on new wells drilled and retained for use.<br>▪ Identification and evaluation of existing well bores and where necessary, workover or decommissioning undertaken to appropriately manage integrity.<br>*Appropriate procedures and monitoring such as:*<br>▪ Well drilling, completions, operations, integrity management and decommissioning in accordance with the requirements of the DCWO SEO, including:<br>○ Effective barriers exist to maintain well control and prevent crossflow between separate aquifer systems or hydrocarbon reservoirs outside of the defined storage complex.<br>○ Operational reports verify that barriers have been set and/or remedial cement work carried out in accordance with the work program as submitted to and/or agreed by DEM.<br>○ Cased hole cement bond logs to confirm quality of cement job in the production casing string.<br>○ Well integrity management system and checks to confirm well integrity through well life.<br>▪ Reporting and records of loss of well integrity events and corrective actions are in accordance with the requirements of the DCWO SEO.<br>▪ Production operator checks during well life - regular site and well inspection and air quality monitoring at all well head locations in active carbon storage reservoir area.<br>▪ Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring $CO_2$ chemistry).<br>▪ Pressure monitoring during and post injection in accordance with the Monitoring, Reporting and Verification Plan.<br>▪ In the event of an environmental incident resulting from a loss of well integrity, SMS requirements will be implemented as outlined in the DCWO SEO. | III | b | 2 - low |
| Carbon Storage | Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formations | Loss of well integrity leading to chemical change in groundwater | ▪ Reduced environmental values of groundwater due to presence of elevated $CO_2$, crossflow or migration of hydrocarbons – impact to environmental and or human health receptors<br>▪ Reduced ability of third party groundwater users to undertake their respective activities | *Design:*<br>▪ Well design in accordance with DCWO SEO.<br>▪ Identification and evaluation of existing well bores and where necessary, workover or decommissioning undertaken to appropriately manage integrity.<br>*Appropriate procedures and monitoring include:*<br>▪ Well drilling, completions, operations, integrity management and decommissioning in accordance with the requirements of the DCWO SEO.<br>▪ Reporting and records of loss of well integrity events and corrective actions are in accordance with the requirements of the DCWO SEO.<br>▪ In the event of an environmental incident resulting from a loss of well integrity, SMS requirements will be implemented as outlined in the DCWO SEO. | III | b | 2 - low |

[2] "environmental values" are determined based on the environmental, social and economic uses of groundwater in accordance with Environment Protection (Water Quality) Policy 2015

| Identification | | | | Control Strategy and Management Measures | Assessment | | |
|---|---|---|---|---|---|---|---|
| **Activity** | **Risk Issue** | **Cause** | **Potential Consequences** | **Controls**<br>**(may include one or a combination of any of the Controls listed)** | **Risk** | | |
| | | | | | **Consequence** | **Likelihood** | **Residual Risk** |
| | | | | ▪ Any nearby groundwater users are identified and considered in the design and operation of carbon storage schemes to reduce potential adverse impacts.<br>▪ Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring $CO_2$ chemistry). | | | |
| Carbon Storage | Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formation | Vertical flow of $CO_2$ through permeable geological structures and materials | ▪ Reduced environmental values of groundwater due to presence of elevated $CO_2$, hydrocarbons and other substances – impact to environmental and or human health receptors<br>▪ Inability of third party reservoir and groundwater users to undertake their respective activities | *Appropriate procedures and guidelines may include:*<br>▪ Evaluation of reservoirs and target formation before carbon storage commences including:<br>  ○ geological risk assessment including review of production history<br>  ○ reservoir modelling to determine storage capacity and injection scheme design.<br>▪ Pressure monitoring during and post injection in accordance with the Monitoring, Reporting and Verification Plan.<br>▪ Reservoir modelling calibrated with pressure measurements to support modelling.<br>▪ Response plan in place for abnormal pressure events during injection.<br>▪ Any nearby groundwater users are identified and considered in the design and operation of carbon storage schemes to reduce potential adverse impacts.<br>▪ Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring $CO_2$ chemistry).<br><br>*Pre-existing conditions that mitigate risk for **Cooper Basin** storage formations:*<br>▪ Minimal connecting faulting noted on seismic acquired within the basin.<br>▪ The low permeability Nappamerri Group siltstones act as a basin wide seal.<br>▪ Aquifer and Upper Permian reservoirs pressure differential indicates no communication. | III | a | 1 – very low |
| Carbon Storage | Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formations | Lateral flow of $CO_2$ from storage reservoirs | ▪ Reduced environmental values of groundwater due to presence of elevated $CO_2$, hydrocarbons and other substances – impact to environmental and or human health receptors<br>▪ Inability of third party groundwater users to undertake their respective activities | *Appropriate procedures and guidelines for storage reservoirs may include:*<br>▪ Evaluation of reservoirs and target formation before carbon storage commences including:<br>  ○ geological risk assessment including review of production history<br>  ○ reservoir modelling to determine storage capacity and injection scheme design.<br>▪ Pressure monitoring during and post injection in accordance with the Monitoring, Reporting and Verification Plan.<br>▪ Reservoir modelling calibrated with pressure measurements to support modelling.<br>▪ Response plan in place for abnormal pressure events during injection.<br>▪ Nearby groundwater users are identified and considered in the design and operation of carbon storage schemes to reduce potential adverse impacts.<br>▪ Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring $CO_2$ chemistry).<br><br>*Pre-existing conditions that mitigate risk for **Cooper Basin** storage reservoirs:*<br>▪ No use of groundwater (too deep and saline) from Cooper Basin aquifers. | III | a | 1 – very low |
| Carbon Storage | Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formations | Preferential flow through permeable pathways created by previous oil and gas operations (i.e. | ▪ Reduced environmental values of groundwater due to presence of elevated $CO_2$, hydrocarbons and other substances – impact to environmental and or human health receptors<br>▪ Inability of third party reservoir and groundwater users to undertake their respective activities | ▪ Geological risk assessment includes review of production history<br>▪ Reservoir modelling to determine storage capacity and injection scheme design.<br>▪ Pressure monitoring during and post injection in accordance with the Monitoring, Reporting and Verification Plan.<br>▪ Reservoir modelling calibrated with pressure measurements to support modelling. | III | b | 2 – low |

| Identification | | | | Control Strategy and Management Measures | Assessment | | |
|---|---|---|---|---|---|---|---|
| Activity | Risk Issue | Cause | Potential Consequences | Controls<br>(may include one or a combination of any of the Controls listed) | Risk | | |
| | | | | | Consequence | Likelihood | Residual Risk |
| | | inadequate well integrity or decommissioning | | ▪ Response plan in place for abnormal pressure events during injection.<br>▪ Any nearby groundwater users are identified and considered in the design and operation of carbon storage schemes to reduce potential adverse impacts.<br>▪ Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring $CO_2$ chemistry). | | | |
| Carbon Storage | Seismicity | $CO_2$ injection | ▪ Activation of faults or fractures creating permeable pathways for uncontrolled $CO_2$ release in non-target geological formations<br>▪ Reduced environmental values of groundwater due to presence of elevated $CO_2$<br>▪ Reduction in reservoir formation pressure<br>▪ Ground disturbance | ▪ Geological risk assessment<br>▪ Equipment design and monitoring to ensure injection pressures remain below fracture gradient. | I | a | 1 – very low |

# 8 Management of Environmental Risks

The Santos Management System (SMS) sets out the requirements for how we do business at Santos across our key activities and functions, including Environment, Health and Safety (EHS) requirements. The SMS is readily available to employees and contractors via the Santos intranet 'Discover'.

The SMS Framework provides structured, comprehensive and efficient EHS practices for Santos' activities and operations and is compliant with both AS/NZS ISO 45001 Occupational Health and Safety Management Systems—Requirements with Guidance for Use and AS/NZS ISO 14001 Environmental Management Systems – Requirements with Guidance for Use.

The Framework of the SMS is multi-layered and comprises, policies, code of conduct, management standards, processes and procedures. The upper layer of the framework comprises the overarching SMS policies which outline Santos' objectives and the behaviours expected of anyone who works for or with and demonstrates the commitment Santos has made to continual improvement in respect of EHS performance. These policies include an Environment, Health and Safety Policy which applies to all Santos operations within Australia, are available on the Santos website (www.santos.com).

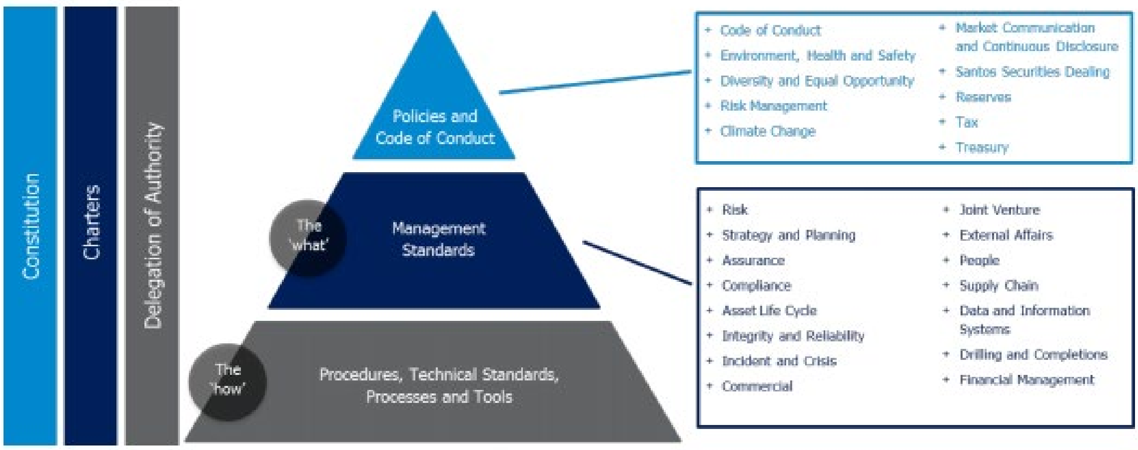


*Figure 8-1: Santos EHMS framework.*

## 8.1 Management Standards

Management Standards, developed as part of the SMS, set out the minimum and mandatory requirements in relation to key business processes, operational matters and assurance activities. The requirements necessary to ensure that environmental, health and safety risk is effectively managed are included in the relevant management standards. The Standards include, but are not limited to:-

- SMS-MS1 Risk
- SMS-MS2 Data and Information Systems
- SMS-MS3 Drilling and Completions
- SMS-MS4 Compliance
- SMS-MS5 Strategy and Planning
- SMS-MS6 External Affairs
- SMS-MS7 Commercial

- SMS-MS8 Joint Venture
- SMS-MS9 Asset Life Cycle
- SMS-MS10 Financial Management
- SMS-MS11 Incident and Crisis
- SMS-MS12 Integrity and Reliability
- SMS-MS13 Supply Chain
- SMS-MS14 People
- SMS-MS15 Assurance

## 8.2 Other Applicable Standards

Santos' activities comply with the following applicable Australian and international standards:-

- AS/NZS ISO 31000 Risk Management
- AS/NZS ISO 45001 Occupational Health and Safety Management Systems—Requirements with Guidance for Use
- AS/NZS ISO 14001 Environmental Management Systems – Requirements with Guidance for Use
- AS 1940 The storage and handling of flammable and combustible liquids.

The Health and Safety Standard has been developed to manage hazards and risks associated with all of Santos operations. The intent of the standard is to prevent injury or illness to all employees, contractors, customers and the public who may be affected by Santos work activities. Health and Safety Hazard Standards (HSHS) include:

- HSHS02 – Land Transportation
- HSHS08 – Chemical Management
- HSHS09 – Radiation
- HSHS12 – Occupational Noise.

## 8.3 Job Safety Analysis and Permit to Work

Job Hazard Analysis (JHA) is a practical risk assessment tool used by workers to identify and document hazards associated with a job / task and what will be done to control the risks associated with the hazards.

Santos and its contractors perform a JHA before conducting a job / task if:

- The job / task is not a routine low-risk job / task.
- There is not a documented risk assessment for the job / task that:
  - identifies reasonably foreseeable EHS hazards
  - details required control measures including who is responsible for each control measure
  - includes a process to ensure that the information in the documented risk assessment is clearly communicated and understood by all those undertaking the job/task.

- There are other material risks that may present when the work is conducted (e.g. other work being conducted in close proximity (simultaneous operations), that would not be covered in an existing documented risk assessment for the job / task.

Santos and its contractors use the multi-purpose industry accepted Wellsite Permit to Work (WPTW) system. WPTW is a safe work planning and control system for the review and authorisation of work on Australian and other onshore well leases. The WPTW System applies to drilling, completions, work over or other well intervention activities such as hydraulic stimulation.

The WPTW system is used in conjunction with applicable regulatory requirements, good industry practice and project specific documentation, and forms part of the Santos and Contractor Environmental Health and Safety Management Systems.  Work assessed with anything other than a low risk, and/or work that is not regularly performed, must be undertaken with a WPTW in place.

## 8.4 Training

Prior to commencing work in field operations field personnel are required to undertake an EHS induction specific to the work site, to ensure they understand their role with regard to protecting their safety, and safety of others, and with regard to protecting the environment.

Induction records are maintained.

Appropriately trained personnel will be on site during operations, with lease access restricted to only necessary personnel during pressure pumping activities.

A copy of the contractors training matrix is maintained and available on site.

## 8.5 Emergency Preparedness

Santos uses the Emergency Response Plan to provide Santos and Contractor personnel with guidance for responding to an emergency at or near a well site. The Well Site Emergency Response Plan is an Emergency Response Plan for all Santos onshore well sites and related activities within the Cooper Basin and Central Australia.

The plan provides an overview of:

- how to prepare for and respond to an emergency at a well site or while moving between well sites
- the basic guidelines for an emergency response
- the interface with other Santos emergency and incident plans.

Santos and Contractor personnel are required to undertake emergency response drills to practice and prepare for potential incidents on site.

## 8.6 Incident Response and Management

In the event of an incident, incident response procedures, developed in accordance with the Santos Management System SMS-MS11 Incident and Crisis are employed. Figure 8-2 describes the core process as per SMS-MS11 – ST2 Incident Reporting, Investigation and Learning.

EHS incidents are recorded in the Santos EHS Toolbox incident management system (IMS) which is a platform for reporting and management of incidents and incident investigations. Santos has adopted a two-tiered approach to EHS incident investigation, based on actual and potential consequence of an incident. Incidents with lower actual or potential consequence will capture basic causal and corrective information/actions; and incidents with higher actual or potential consequence, or present a learning opportunity may require a formal investigation.

The main focus of investigating incidents is to:-

- reduce overall risk and harm,
- prevent reoccurrence of events that can cause serious harm.

Incidents (including near misses) with higher potential consequence are subject to major investigation, using a process such as TapRoot®, ICAM or DEM. Incidents with lower potential are subject to minor investigation, to capture basic information for trending and determine whether risk controls should be revised.

The system also provides a mechanism for recording Reportable incidents, as defined under the Act and associated regulations.

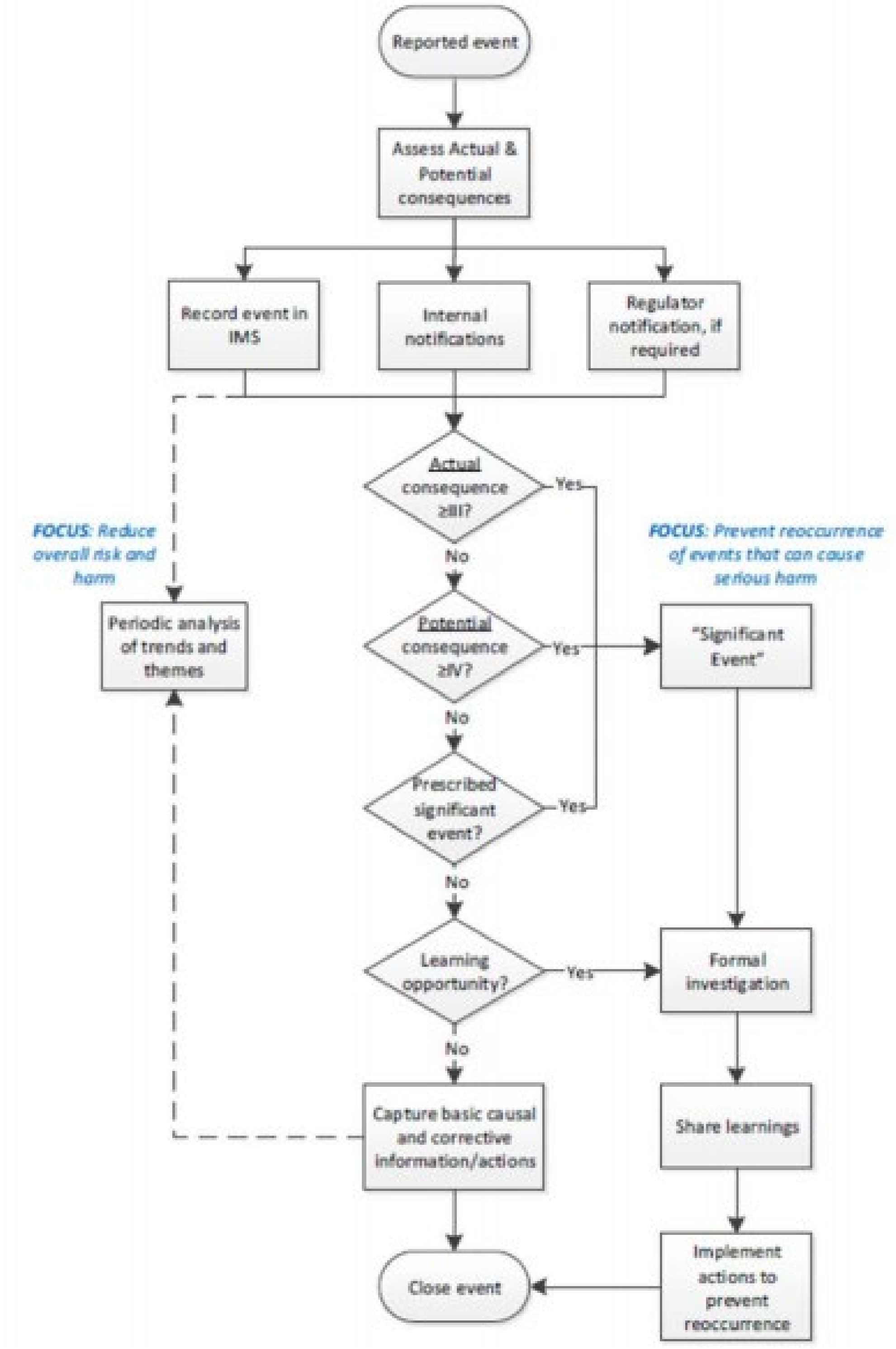


*Figure 8-2: Incident reporting, investigation and learning process (Santos SMS)*

Further details of each stage of the Incident Response Framework are outlined below:

*Immediate Response Following an Incident*

- Upon becoming aware of an incident, actions must be initiated to:
- ensure safety of all persons in the area and site
- make the site safe and secure
- notify the person responsible for the site or activity and the relevant supervisor as soon as reasonably practicable
- minimise risk of further impact or incidents.
- In the event of an environmental incident such as a loss of containment, the requirements will be implemented as follows:
- follow existing emergency response procedures (make safe, secure site)
- preliminary assessment of risks posed (environmental, safety, stakeholder)
- complete a preliminary environmental assessment (PEA), including:
  - assessment of site topography and soil type(s);
  - identification of presence and proximity to any sensitive receptors in incident area, including:
    - surface water bodies including creeks, wetlands, depressions, drainage channels (wet or dry), tidal flats, ponds, springs;
    - flora and fauna, including habitat (e.g. large trees, endangered species)
  - desktop groundwater assessment (approximate depth, if known)
  - livestock (presence and access to)
  - nearby building and other infrastructure
  - areas of cultural or heritage significance
  - other notable sources of risk.

*Incident Notification and Classification*

- Once the site is secured and the initial response actions implemented, the relevant supervisor must notify relevant persons (e.g. Health and Safety Representatives (HSRs), Environmental Advisers, Safety Advisers).
- As part of this notification process the relevant supervisor:
  - Must ensure details of the incident are entered into the Santos IMS as soon as reasonably practicable.
  - Classify the incident in accordance with Santos and relevant Regulatory requirements.

*Internal Incident Investigation*

- As soon as practicable following notification and classification, an internal investigation is to be undertaken in accordance with SMS MS11 and should commence as soon as practicable.

*Recommended Actions and Reporting*

- In order to appropriately learn from incidents and prevent reoccurrence, the following incident recommendations and reporting requirements are to be implemented:
  - Recommended actions from incident investigations must be reviewed by the responsible person.
  - Recommended actions from investigations are assigned via the IMS.
  - Outcomes from investigations are communicated to the workgroups involved.
  - Following initial notifications, site assessment up works and completion of the PEA, an assessment to determine if the site has been impacted will be undertaken (impacted site review (ISR)) . Pending the outcomes of the ISR a contaminated site assessment (CSA) may be undertaken in accordance with the Site Contamination National Environmental Protection Measure (NEPM) and consider the EPA Guidelines for the assessment and remediation of site contamination.

## 8.7 Environmental Monitoring and Audits

The SMS is subject to an internal audit program to review implementation and effectiveness of the management system against the requirements of the standards.

Ongoing monitoring and auditing of operations is undertaken to evaluate the extent to which environmental risks are being managed, minimised and where reasonably practicable, eliminated in accordance with relevant SEOs. Opportunities for improvement identified as part of the audit process inform a management strategy to address potential hazards where appropriate. Opportunities for improvement identified as part of the audit system inform a management strategy to address potential hazards where appropriate.

Carbon Storage monitoring will be undertaken as per the Carbon Storage Monitoring, Reporting and Verification Plan for assurance $CO_2$ is being stored and contained within the limits of the storage reservoirs and to enable accurate quantification and verification of carbon in storage. Further auditing of carbon storage may be undertaken as required under future contracts or government schemes for reduction and storage of greenhouse gases.

## 8.8 Reporting

External reporting (e.g. Serious or Reportable incidents, annual reports) is carried out in accordance with the requirements of the *Petroleum and Geothermal Energy Act 2000* and the applicable SEO.

Santos must implement internal and external reporting procedures to ensure that environmental issues and/or incidents are appropriately responded to. Internal reporting should cover:-

- number, severity and close out status of incidents
- monthly summaries of incidents
- progress against key performance indicators
- audit schedule and findings
- works in progress
- site and task force meetings

- external meetings and / or liaison with key stakeholders (e.g. DEM).

Carbon Storage reporting will be in accordance with requirements of the SEO, Santos public commitments and relevant international standards.

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# Appendix A Stakeholder Consultation

| | |
|---|---|
| **From:** | Briscoe, Marla (Marla) |
| **Cc:** | Cooper Environment; Mayfield, Mark (Mark) |
| **Subject:** | Santos" Cooper Basin Carbon Capture Storage Project and five yearly review of Drilling, Completions and Well Operations SEO - for comment |
| **Date:** | Thursday, 17 September 2020 9:26:37 AM |
| **Attachments:** | Mimecast Large File Send Instructions.msg |

I'm using Mimecast to share large files with you. Please see the attached instructions.

Dear All,

As you would be aware Santos operates a number of exploration and production petroleum tenements within the Cooper Basin, centred around Moomba, located approximately 800 km north-east of Adelaide.

Santos is currently progressing EIR and SEO consultations for two activities, one is a new activity for the Carbon Capture Storage Project and the other is revision of the existing *South Australia Cooper Basin Statement of Environmental Objectives: Drilling, Completions and Well Operations Statement of Environmental Objectives* (SEO). As an important stakeholder, Santos is seeking comment and feedback on these draft SEO and EIR for each of these activity prior to finalisation. A short summary of each is provided below.

**Carbon Capture and Storage Project**

As a proudly Australian company, Santos has a long term aspiration to achieve net-zero emissions from its operations by 2050. The company aims to achieve this through a reduction in emissions from operations and investment in technology and innovation. The development of Santos' flagship, commercial-scale carbon capture and storage project within the Cooper Basin, near Moomba is an important step in meeting this commitment.

To facilitate this project, Santos is seeking regulatory approvals for the storage of measurable quantities of carbon dioxide ($CO_2$) in subsurface geological formations (defined as 'carbon storage') associated with Santos' Cooper Basin operations in South Australia. This operation is a regulated activity under the South Australian Petroleum and Geothermal Energy Act 2000 (PGE Act) and is also referred to as 'carbon storage' and 'geological sequestration'.

An Environmental Impact Report (EIR) for storage has been prepared in accordance with the PGE Act and Regulation 10 of the Petroleum and Geothermal Energy Regulations 2013 (the Regulations). The EIR provides an assessment of the potential impacts of the activity on the environment.

A Statement of Environmental Objectives for storage has been developed in accordance with Regulations 12 and 13 of the Regulations. The SEO outlines the environmental objectives that the activity is required to achieve and how they will be achieved. The SEO is developed on the basis of information provided in an EIR.

Santos already holds approvals for existing activities including, but not limited to $CO_2$ capture, treatment, transmission, drilling and completions, injection and production and processing operations.

**Drilling, Completions and Well Operations**

The *South Australia Cooper Basin Statement of Environmental Objectives: Drilling, Completions and Well Operations* (SEO) was approved in 2015 under the *Petroleum and Geothermal Energy Act 2000*. It covers the regulated activities of drilling, completions and well operations undertaken by Santos in the Cooper Basin. Regulation 14 of the *Petroleum and Geothermal Energy Regulations 2013* requires that an approved SEO must be reviewed at least once in every five years and, as such, Santos has recently undertaken a review and revision to the SEO and supporting Environmental Impact Report (EIR) and a short Explanatory Report has also been prepared providing a summary of the revisions to the SEO and EIR.

Copies of these documents can be accessed/downloaded through the Mimecast link included in this correspondence.

Please provide any comment via email to cooper.environment@santos.com on or before **9 October 2020**. Alternatively if you have any queries or wish to discuss, please do not hesitate to contact Mark Mayfield or myself on details provided below.

Kind regards,

Santos

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| Document | Section No. | Stakeholder | Comments | Santos Comments |
|---|---|---|---|---|
| EIR | 4.4.2.1 Evaluation of Potential CO2 Migration Pathways | Department for Environment and Water | Further discussion is required on why pressure changes in (shallower) GAB aquifers is not expected | Further information added into section 4.4.2.1. Pressure changes within the shallower aquifers are not expected due to the segregation of the Permian target reservoir by overlying sealing intervals providing containment.<br>If injecting $CO_2$ into the Hutton/Numur intervals a short term localised pressure increase is expected. However this is predicted to dissipate to near-initial conditions following closure. Storage of $CO_2$ is not expected to cause the depletion of pressure in any reservoir or aquifer. |
| EIR | 4..4.2.1 Impurities within the CO2 to be injected | South Australian Environmental Protection Authority | Further discussion is required on the potential impurities in the $CO_2$ and how this may affect the phase of the $CO_2$ and ultimate fate of the $CO_2$ | Further information added into section 4.4.2.1. The near term opportunity would inject $CO_2$ currently vented from the Moomba Plant, the composition of which, is well understood from decades of operations. As such, the most significant gas impurities would be light hydrocarbons and trace amounts of other naturally occurring substances originating from reservoirs within the Basin. These impurities comprise only a very minor portion of the total volume to be stored. Although these impurities will have a small impact on the critical point of the $CO_2$, this is not considered material and is not expected to have an impact on the phase behaviour of the $CO_2$ at final storage pressure. |
| EIR | Section 4.3.6 CO2 Enhanced Hydrocarbon Recovery<br>1.1 Scope | South Australian Environmental Protection Authority | Further discussion is required on the transition from Enhanced Oil Recovery and CCS. This may be in reference to international standards and / or the Monitoring, Verification and Reporting program, but more information requested | Further information added into Section 4.3.6. As detailed in Section 1.1 EOR activities are already covered under the existing Production and Processing EIR and SEO. Injection and production volumes during EOR operations would be metered. Following the completion of any EOR activity, $CO_2$ remaining in the reservoir could be viewed as permanently stored. This would be managed in line with the Carbon Storage SEO and associated monitoring, verification requirements and international standards. |
| SEO and EIR | All | Department of Health and Wellbeing | Thanks for the opportunity to review and comment on these.<br>After reviewing and as the 'Scopes' explain this seems to be specifically related to carbon storage operations. I did not see anything related to the generation of any 'public health' related wastewater in either the SEO or EIR. As with many other areas assume this is addressed in Santos' other related SEO's and EIR's which is fine. | Noted |

| Document | Section No. | Stakeholder | Comments | Santos Comments |
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| | | | Under the other related SEO's and EIR's Santos always provides good reference to our relevant Legislation and Codes so I am sure that if the carbon storage operation requires any mobile camps and the like to be set up then they will follow correct procedure for the collection, treatment, storage and disposal of wastewater.<br>If in the future you wish to liaise with me on any public health matters this project may encounter then please fee l free to contact me. | |
| SEO and EIR | All | Department for Infrastructure and Transport | The documents are supported, however it is unclear if Santos would have any infrastructure (i.e. pipeline/s) to be installed under the Commissioner of Highways (CoH) road/s as part of the Carbon storage proposal. Santos is required to seek authorisation from the CoH to install and maintain the infrastructure. | All infrastructure including pipelines is covered under the existing Processing and Production SEO and Drilling, Completions and Well operations SEO and such is not within the scope of the Carbon Storage EIR and SEO.<br>Santos has plans and procedures to ensure other approvals are in place as required for crossings of third-party infrastructure by Santos activities. |
| SEO and EIR | All | Beach Energy | Thanks for the opportunity for Beach to review the proposed amendments to Santos' EIR and SEO for drilling, completions and well operations in the SA Cooper Basin.<br>Our environmental team have reviewed the documents, and they have replied that Beach has no issues or concerns with the proposed amendments in these revised versions of the EIR and SEO. | Noted |
| SEO and EIR | All | Outback Communities Authority | Thank you for providing the Outback Communities Authority with an opportunity to comment on the Santos Cooper Basin Carbon Storage EIR & SEO.<br>I have review both documents. The Outback Communities Authority commends Santo on its efforts to reduce its carbon footprint. We have no comment on either document. | Noted |
| EIR | Section 1 | Safe Work SA | Comment:<br>Noted – "*The project will initially capture emissions from the Moomba Gas Plant in northern South Australia, where there is existing equipment to separate CO2 from sales gas. The captured CO2 will be dehydrated, compressed, and then transmitted via pipelines to suitable locations, where it will be injected into target geological formations deep underground.*" | Noted |
| EIR | 3.2 Other Legislation | Safe Work SA | Comment:<br>• Work Health and Safety Act 2012 | Noted |

| Document | Section No. | Stakeholder | Comments | Santos Comments |
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| | | | Persons conducting a business or undertaking (PCBU) has a duty to manage and control health and safety risks, including risks associated with hazardous chemicals as per requirements of the Work Health and Safety Act 2012 (SA) and Regulations, Codes of Practice and the relevant schedules.<br>• Dangerous Substances Act 1979<br>General duties for a person include avoid endangering the health and safety of any person or the safety of property and preventing the risk of environmental harm.<br>• Explosives Act 1936 (SA)<br>Includes carriage, storage and use of explosives and reference to AS 2187. | |
| EIR | 7.2.2 Bores | Safe Work SA | 4th Paragraph …. *"Casing integrity during injection activities is maintained through the monitoring of operational pressures and ensuring that maximum surface pressures are within the limitations of the casing itself."*<br>*……."Pressure monitoring during injection to ensure surface casing integrity and movement of CO2 into the targe formation or reservoir as modelled."*<br>Comment:<br>• A system of work needs to be maintained for regular calibration of operational pressure monitoring equipment ( e.g. mechanical gauges, digital pressure gauges, pressure transducers and pressure transmitters)<br>• Refer National Association of Testing Authorities, Australia (NATA) and Metrology Society of Australia (MSA) guidance. | Noted - Activities relating to the integrity and other downhole infrastructure are covered under the Drilling, Completions and Well Operations SEO and are not within the scope of the Carbon Storage EIR and SEO. |
| EIR | 7.2.5 Previous Operations Creating Permeable Pathways | Safe Work SA | *"Equipment design and monitoring for CO2 injection will also ensure that injection pressures remain below the fracture gradient, which also avoids the potential for creating new permeable pathways."*<br>Comment:<br>• The Safety in Design (SID) processes would include Hazard and Operability (HAZOP) study, Risk Assessments, Safety Integrity Level (SIL) Analysis and Hazard Construction (HAZCON) study.<br>• The PCBU has a duty to ensure compliance with WHS legislation and safe design and operations of pressure systems associated with the project. Project management should assess the regulatory requirements for pressure equipment as per the Work Health and Safety Act 2012 (SA). | Noted: Activities relating to infrastructure are covered under the existing Production and Processing Operations SEO and is not within the scope of the Carbon Storage EIR and SEO. |

| Document | Section No. | Stakeholder | Comments | Santos Comments |
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| | | | • For pressure vessels there is a requirement for design registration and in many instances plant item registration is required.<br>• For pressure equipment that is not required to be design or plant registration there is a requirement to ensure that it is designed to be safe whilst it is intended to be used.<br>• For piping there is a guidance standard AS 4041 Pressure piping. The definition for pressure equipment includes all supports, attachments, gauges, controls, and pressure relief devices.<br>• SafeWork SA notes that:<br>Under corresponding WHS law Petroleum and Geothermal Energy Act 2000 and Regulations 2013 Regulation 29 – Pipelines and flowlines, unless otherwise approved by the Minister, the design manufacture, construction, operation, maintenance, testing and abandonment of pipelines and flowlines must be carried out in accordance with the relevant requirements of AS 2885 Pipelines-Gas and Liquid petroleum American Society of Mechanical Engineers ASME B16.5 and ASME B31.3 standards for Pipe flanges and flanged pipe fittings and process piping ("the plant") is referenced in Table 3-3; Page 34 and the plant would need to be verified by an authorised ASME Inspector.<br>• Inspection requirements for pressure plant and equipment falls under the code of practice AS/NZS 3788 In-service inspection for pressure equipment. This will necessitate engaging a third party inspector to ensure compliance.<br>• The Hazard and Risk assessment should consider all the pressure systems that may be incorporated into the project. This would typically include safe operating procedures while the equipment is in use and de-energising the system for safe shut down and isolation for adjustments, maintenance, repair and any other reasons to access the pressure systems.<br>• The environment is likely to be corrosive and corrosion management procedures should be in place to monitor the effects of corrosion on the pressure system together with regular draining of the system to minimise the effects of corrosion on a regular basis.<br>• A dedicated method for lock out and isolation for the pressure system should be considered. This could be taken into account at the time of design so that it can be sectioned for ease of access | |

| Document | Section No. | Stakeholder | Comments | Santos Comments |
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| | | | and minimise disruption where sections need to be made available for maintenance, repair or modification | |
| EIR | 7.2.7 Drilling Through the $CO_2$ in Storage | Safe Work SA | Comment:<br>Noted ……" *any future drilling into or through carbon storage formations and storage complexes would require the proponents to identify and assess all risks resulting from the proposed drilling program."* | Noted |
| EIR | 8.5 Emergency Preparedness | Safe Work SA | Comment:<br>Noted….*"Santos and Contractor personnel are required to undertake emergency response drills to practice and prepare for potential incidents on site*. | Noted |
| EIR | 8.6 Incident Response and Management | Safe Work SA | Comment:<br>• The Health and Safety Management System must provide a mechanism for reporting, recording and remediating "Notifiable incidents", as prescribed under the Work Health and Safety Act 2012 (SA).<br>• There are duties to report Notifiable Incidents (serious injuries, illness and dangerous incidents) to SafeWork SA as per Section 35 and Section 36 of the WorkHealth and Safety Act 2012 (SA).<br>• There are duties for the person with management or control of a workplace to preserve incident Sites as per Section 39 of the Work Health and Safety Act 2012 (SA). | Noted |
| SEO | Section 1.1 About Santos | Safe Work SA | Comment:<br>Noted – Drilling completion and Well Operations provided in EIR (Santos 2015a) and production and transmission facilities including the Moomba Plant are described in Petroleum Production Operations EIR (Santos 2017a) | Noted |
| SEO | Section 2.1 Objectives | Safe Work SA | Comment:<br>Noted – The environmental objectives for carbon storage include… *"1. No injuries, deaths or adverse health impacts to the public or third parties that could have been reasonably be prevented by the operator"* | Noted |
| SEO | Table 1: Environmental Objectives and assessment Criteria | Safe Work SA | Environmental Objective 2 - Assessment Criteria:<br>*"No death, serious injury and/or imminent risk to the health and safety of workers, the public or third parties occurs as a result of failure to identify or maintain a physical or procedural barrier, so far as reasonably practicable"* | Noted - The Carbon Storage EIR and SEO only applies to subsurface storage of $CO_2$– The management of above ground and down hole infrastructure, including integrity, construction and earthwork activities, is managed by the existing Production |

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| | | | Comment:<br>• Under the Work Health and Safety Act 2012 (SA), all Persons Conducting a Business or Undertaking (PCBU's) have responsibility and must discharge their duty to the extent to which they have the capacity to influence and control the matter, disregarding any attempt to "contract out" their responsibilities.<br>• Risks to health and safety of persons (including the Public) from hazards associated with the carbon storage activities must be managed and controlled. It follows that the PCBU in management and control of the Site and other PCBU's must discharge their duty to the extent to which they have the capacity to influence and control the risks of the hazards that could affect each other's simultaneous activities ("the same matter").<br>• When more than one person has a duty in respect of the same matter, each person with the duty must, so far as is reasonably practicable, consult, co-operate and co-ordinate activities with all other persons who have a duty in relation to the same matter.<br>• Section 17 of the Work Health and Safety Act 2012 (SA) requires the duty holder to eliminate risks to health and safety, so far as is reasonably practicable, or if not reasonably practicable, to minimise those risks so far as is reasonably practicable.<br>• Section 19 – Primary duty of care of the Work Health and Safety Act 2012 (SA) includes the requirements, amongst other matters, that a PCBU must ensure, so far as is reasonably practicable:<br>  o The provision and maintenance of a work environment without risks to health and safety,<br>  o The provision and maintenance of safe plant and structures,<br>  o The provision and maintenance of safe systems of work and<br>  o The provision of any information, training, instruction or supervision that is necessary to protect all persons from risks to health and safety arising from work carried out as part of the conduct of the business or undertaking.<br>• Each Person Conducting a Business or Undertaking (PCBU) retains responsibility and must discharge their duty to the extent to | and Processing Operations SEO and the Drilling, Completions and Well Operations SEO. |

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| | | | which they have the capacity to influence and control the matter, disregarding any attempt to "contract out" their responsibilities. The Operator has the capacity to influence traffic journeys to and from the Site of their own employees and other PCBU's, including contractors. The influence must extend to consultation with and alignment of various PCBUs health and safety policies, including managing fatigue which is a known causal factor of traffic incidents. Measures to mitigate the risks to the public would extend to journey management of workers in light of driver fatigue risks.<br>• Management and control of risk to health and safety of persons regarding dust would include mitigation of visibility hazards. Dust suppression control measures for fugitive dust emission from earthworks construction activities need to be managed and controlled. SafeWork SA advises the workplace exposure limit for respirable crystalline silica for an 8 hour time weighted average reduced from 0.1mg/M3 to 0.05mg/M3 effective 1 July 2020. Information is available on the SafeWork Australia website<br>• Fugitive emissions from flow testing equipment need to be managed and controlled by pressure testing of (pipe) lines prior to use to ensure integrity. Controls to monitor and withdrawal persons when combustion and odour emissions exceed the exposure standards' need to be managed.<br>• Compressor diesel combustion engines and the like need to be adequately located to minimise exposure of persons to diesel particulate matter.<br>• Consider earth moving machinery and mobile plant ("Plant") fire hazards– control measures including operator pre-start equipment checks, regular plant maintenance, inspected and tested on-board fire protection equipment and training of operators minimizes risk to health and safety of persons from Plant fire hazards and minimises risk of fire in the environment.<br>• Where PEL, Pastoral Lease or Extractive Mineral Lease activities interact there is a duty to consult with the relevant PCBU so as to manage and control risks to health and safety of persons. | |
| SEO | Section 3.1.2 Reportable Incidents | Safe work SA | Comment: | Noted |

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| | | | • The Health and Safety Management System must provide a mechanism for reporting, recording and remediating "Notifiable incidents", as prescribed under the Work Health and Safety Act 2012 (SA).<br>• There are duties to report Notifiable Incidents (serious injuries, illness and dangerous incidents) to SafeWork SA as per Section 35 and Section 36 of the Work Health and Safety Act 2012 (SA).<br>• There are duties for the person with management or control of a workplace to preserve incident Sites as per Section 39 of the Work Health and Safety Act 2012 (SA). | |
| EIR and SEO | All | Senex Energy | Thank you for your email below and giving us the opportunity to review these<br>documents.<br>I just wanted to let you know that we don't have any concerns regarding the SEO review or the CCS project that need to be addressed with you at this point in time.<br>Please let me know if you require anything further from us in regards to this in the future. | Noted |
| EIR | Section5.6.1 Aboriginal Cultural Heritage | Department of the Premier and Cabinet<br>Aboriginal Affairs and Reconciliation | Suggest change –<br>'There are a number of sites of Aboriginal heritage including relics, camp sites, quarries and engravings with several unique designs located around Cullyamurra waterhole'.<br>Suggest replace with –<br>'The central archives maintained by Aboriginal Affairs and Reconciliation currently holds records for approximately 930 Aboriginal sites, objects and remains within Santos' Cooper Basin and Eromanga Basin Operations Area of Interest. Additional undiscovered and/or undocumented Aboriginal sites, objects and remains may also be present within these areas.' | Noted – Text changed in section 6.5.1 Aboriginal Cultural Heritage |
| EIR | Section5.6.1 Aboriginal Cultural Heritage | Department of the Premier and Cabinet<br>Aboriginal Affairs and Reconciliation | Suggest change –<br>'Santos has executed Cultural Heritage Management Plans in accordance with The South Australian Aboriginal Heritage Act 1988 (SA) …'<br>Suggest replace with –<br>'Santos has executed Cultural Heritage Management Plans (CHMP) consistent with the requirements of the Aboriginal Heritage Act 1988 (SA) …' | Noted – Text changed in section 6.5.1 Aboriginal Cultural Heritage |

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| EIR | Section 5.6.1 Aboriginal Cultural Heritage | Department of the Premier and Cabinet<br>Aboriginal Affairs and Reconciliation | Comment –<br>A CHMP typically provides a heritage management 'framework' that steps out the ways in which heritage should be managed during a project; however, it cannot provide authority under the Aboriginal Heritage Act 1988 (SA) to damage, destroy interfere with or excavate Aboriginal heritage. Only the Premier can do this. | Santos has executed heritage agreements with the relevant parties that have been implemented over time, and we will continue to utilise these existing processes for Aboriginal Cultural Heritage requirements. |
| EIR | Section 5.6.1 Aboriginal Cultural Heritage | Department of the Premier and Cabinet<br>Aboriginal Affairs and Reconciliation | As discussed in AAR's cover letter, it is noted that Santos has Cultural Heritage Management Plans (CHMP) in place with the Yandruwandha Yawarrawarrka and Dieri Native Title parties. It is prudent for Santos to continue to liaise with these groups and the Wangkangurru Yarluyandi and Malyankapa Native Title parties through the duration of its operational and maintenance activities. | Santos acknowledge the rights and interests of these groups however they are not located directly in or within vicinity of Santos area of operations, noting the Yandruwandha Yawarrawarrka and Dieri are. |
| EIR | Section 5.6.3 Native Title | Department of the Premier and Cabinet<br>Aboriginal Affairs and Reconciliation | As discussed in AAR's cover letter, it is noted that Santos has previously engaged Yandruwandha Yawarrawarrka and Dieri Native Title parties and acknowledges the Wangkangurru Yarluyandi Native Title Claimants. AAR has on record that the Malyankapa Peoples Native Claim features in the very south east of the Cooper Basin. Santos is reminded that the views of all Traditional Owners of heritage should be ascertained and taken to account and that heritage interests for the Moomba area may go beyond that of the registered prescribed body corporate. | Noted |
| SEO | Section 2.1 Objectives | Department of the Premier and Cabinet<br>Aboriginal Affairs and Reconciliation | 'Minimise impacts to flora and fauna, livestock and groundwater dependent ecosystems in the event of unintended migration of CO2 to surface and shallow subsurface environments'.<br>Comment -<br>AAR notes the above statement should also incorporate Aboriginal sites/cultural landscapes. Tangible or intangible Aboriginal heritage values may be intrinsically linked to waterholes, mound springs, culturally significant stands of trees or other sensitive landforms that could be affected by excessive CO2 | Santos acknowledges the tangible or intangible Aboriginal heritage values that may be linked to landforms in the area. We would ensure the Traditional Owners are notified during this process and any requirement for cultural heritage assessment would be undertaken under the terms of the Cultural Heritage agreement. |
| SEO | Section 2.2 Objectives<br>Table 1 | Department of the Premier and Cabinet<br>Aboriginal Affairs and Reconciliation | 'Minimise impacts to flora and fauna, livestock and groundwater dependent ecosystems from the unintended migration of CO2 to surface and shallow subsurface environments.<br>• No impact to rare, vulnerable or endangered flora and/or fauna, or important vegetation due to unintended migration of CO2 to the surface or shallow subsurface. | Santos acknowledges the significance of aboriginal heritage values associated with surface and subsurface environments. By addressing the environmental requirement for having no adverse impacts to the afore mentioned environmental receptors the concerns regarding cultural values would also be addressed. |

<table>
<tr><th>Document</th><th>Section No.</th><th>Stakeholder</th><th>Comments</th><th>Santos Comments</th></tr>
<tr><td></td><td></td><td></td><td><ul><li>No adverse impact on groundwater dependent ecosystems (e.g. localised impact to groundwater that may provide base flow to nearby waterholes) as a result of impact on groundwater environmental values due to the unintended migration of CO2 to shallow subsurface receptors'.</li></ul>Comment –<br>Ensure that the Santos Carbon Storage SEO and cross-referenced DCWO and PPO SEOs account not just for avoidance and minimisation of physical impacts to Aboriginal heritage from drilling and operational works, but that surface or shallow subsurface CO2 presents no short or long-term impacts to waterholes, subsurface water, mound springs, significant stands of trees or other landforms/flora that may be significant to Aboriginal people of the region.</td><td></td></tr>
<tr><td colspan="5">DEM Consultation under the Petroleum and Geothermal Energy Act 2000</td></tr>
<tr><td>EIR</td><td>4.2.2 Carbon storage mechanisms<br>4.4.2.1 Evaluation of potential $CO_2$ migration pathways – aquitard or seal<br>7.2.3 Vertical migration of $CO_2$</td><td>Department for Environment and Water</td><td>COMMENT<br>'$CO_2$ will tend to behave in a manner similar to natural gas in deep geological formations due to its relatively low density and viscosity.'<br>'The potential for migration of stored $CO_2$ through the pore spaces in the rock that forms the barrier to upward vertical flow will be assessed.'<br>RESPONSE REQUIRED<br>Provide specific parameters that would demonstrate an adequate seal and successful containment. Validating whether the seal is adequate for gas is particularly important if injecting into historical petroleum plays.</td><td>Site Specific and risk-based monitoring and modelling will be outlined in the Monitoring, Reporting and Verification Plan(s) (MRV). This will be submitted to and approved by DEM prior to activities taking place as part of the Notification of Activity (NOA) Process. The MRV may be shared with co-regulators (e.g. DEW, EPA) for comment as relevant prior to approval.</td></tr>
<tr><td>EIR</td><td>4.4.2 Carbon storage reservoir selection and characterisation<br>5.3.5 Carbon storage formations<br>7.2.4 Lateral Migration of $CO_2$<br>Table 7-2: Carbon Storage risk</td><td>Department for Environment and Water</td><td>COMMENT<br>Target carbon storage reservoirs in Cooper Basin strata include stratigraphic and structural traps in the Tirrawarra Sandstone, Patchawarra, Epsilon and Toolachee Formations.<br>Target carbon storage reservoirs in Eromanga Basin strata include stratigraphic and structural traps in the Hutton Sandstone, lower Birkhead Formation, Namur Sandstone and equivalent McKinlay Member, Wyandra Sandstone, and Cadna-owie Formation.<br>RESPONSE REQUIRED<br>Nominate specific wells or areas where injection would occur. Present these spatially along with contextual information for basin margins and groundwater receptors</td><td>This document is basin wide and as such the location(s) of the storage activity and location(s) where injection is to occur will be identified through the notice of activity provided to DEM for approval prior to the activity occurring. This is the current practice for new hydrocarbon wells and other activities managed though other SEOs within the basin.</td></tr>
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| EIR | 4.4.4 Monitoring for Carbon Storage Operations<br>Table 7-2: Carbon Storage risk assessment - Uncontrolled release of CO2 into non-target geological formation | Department for Environment and Water | COMMENT<br>'For each target formation the monitoring area will be the area of the geological target plus a defined buffer which may increase as subsequent targets in a field come into operation.'<br>RESPONSE REQUIRED<br>It is acknowledged that the SEO includes monitoring of the injection and storage formation and identified sensitive receptors with a valid exposure pathway.<br>Confirm whether a buffer would be maintained between injection wells and existing third-party infrastructure (pastoral and other petroleum wells). | Noted - This is to be identified within the Monitoring, Reporting and Verification Plan(s) that will be developed by Santos and approved by DEM prior to activities taking place. |
| EIR | 3.2 Other legislation | Department for Environment and Water | Please note the Landscape South Australia Act 2019 sets outs the requirement for Water Affecting Activity (WAA) Control Policy. The WAA Control Policy will replace the WAA policy within the SA Arid Lands Regional Natural Resources Management Plan and it is expected that this policy will be gazetted next year. A new Regional Landscape Plan is also currently under development and will replace the Regional NRM Plan. | Noted |
| EIR | 5.5 Groundwater use | Landscape SA, SA Arid Lands | Please note the Water Allocation Plan for the Far North Prescribed Wells Area is with the Minister for adoption. The WAP further acknowledges Aboriginal water interests in the Far North and a strong focus on maintaining pressure to protect springs and soaks, and also protect significant non-spring ground water dependent ecosystems. | Noted |
| EIR | Consultation & update table 6.1 | Landscape SA, SA Arid Lands | The SA Arid Lands Landscape Board has replaced the SA Arid Lands NRM Board. The SAAL Landscape Board has maintained the district-based group model to provide an important link between local communities and the Board; the relevant landscape management group is the Marree-Innamincka Landscape Management Group. | Noted |
| EIR | 7.2.2 Well bores- | Landscape SA, SA Arid Lands | Impacts on flora and fauna would be expected to be relatively localised requires further clarification as localised impacts may have a significant impact if the species are threatened. | Noted - This is to be identified in more detail within the Monitoring, Reporting and Verification Plan that is to be developed by Santos and approved by DEM prior to activities taking place. |
| SEO | Table 1- Environmental objectives 3 and 4 | Landscape SA, SA Arid Lands | Environmental objectives 3 and 4 do not include any acknowledgement of impact to cultural values, these are intrinsically linked to sites such as mound springs. | Noted – updated objective with "*Minimise impacts to flora and fauna, Aboriginal cultural heritage sites and landscapes, livestock and groundwater dependent ecosystems in the event of unintended migration of $CO_2$ to surface and shallow subsurface environments*" to Table 1 within the SEO. |

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| SEO | Table 1- Environmental objective 3 | Landscape SA, SA Arid Lands | The Guide to how objectives can be achieved identifies only monitoring of well integrity, there is no monitoring identified for flora, fauna and groundwater dependent ecosystems (GDE's). It is difficult to assert no impact to threatened flora and/or fauna or important vegetation and no adverse impact to GDE's if there is no baseline and no ongoing monitoring as part of the operations. Identify monitoring to support assessment criteria. Noting the EIR identified flora and fauna as sensitive receptors where CO2 could concentrate in the vadose (root) zone and, for fauna, in topographic lows. | Noted - This is to be identified within the Monitoring, Reporting and Verification Plan that is to be developed by Santos and approved by DEM prior to activities taking place. |
| EIR | 5.6.1: Aboriginal Cultural Heritage | DPC Aboriginal Affairs and Reconciliation | Suggest change –<br>Mention of Wangkangurru Yarluyandi and Malyankapa Native Title parties and how they feature in the Cooper Basin<br>Suggest replace with –<br>'It is also acknowledged that the Wangkangurru Yarluyandi and Malyankapa Native Title parties feature over southern portions of the Cooper Basin, but these fall outside of the current project area. No consultation was undertaken with these two native title groups as part of this project. | Noted – The National Native Title Tribunal (NNTT) portal indicates the Malyankapa Native Title claim in South Australia has been discontinued as of 10/11/2020.<br>Added in "*It is also acknowledged that the Wangkangurru Yarluyandi party features over southern portions of the Cooper Basin but fall outside of the current project area. No consultation was undertaken with this native title group as part of this project*." to section 5.6.1. |
| EIR | Page 39 – Table 5-3 Native Title Claims in the South Australian Cooper Basin | DPC Aboriginal Affairs and Reconciliation | Suggest change<br>'Add Malyankapa Native Title Claim to Table.' | The NNTT portal indicates the Malyankapa Native Title claim in South Australia has been discontinued as of 10/11/2020. |
| EIR | 5.6.1: Aboriginal Cultural Heritage | DPC Aboriginal Affairs and Reconciliation | Suggest change –<br>'Add in paragraph referring to both the Wangkangurru Yarluyandi and Malyankapa Native Title parties and acknowledging their presence in the Cooper Basin area' | Noted - The NNTT portal indicates the Malyankapa Native Title claim in South Australia has been discontinued as of 10/11/2020.<br>Added in "*It is also acknowledged that the Wangkangurru Yarluyandi party features over southern portions of the Cooper Basin but falls outside of the current project area. No consultation was undertaken with this native title group as part of this project*." to section 5.6.1: |
| EIR | 5.6.1: Aboriginal Cultural Heritage | DPC Aboriginal Affairs and Reconciliation | Replace –<br>DPC Aboriginal Affairs<br>Replace with (and elsewhere in tables and text throughout the document) -<br>DPC Aboriginal Affairs and Reconciliation | Noted – Name changed as suggested in two locations within section 6.1: Stakeholder Engagement. |

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| EIR | Appendix A: stakeholder Consultation | DPC Aboriginal Affairs and Reconciliation | Suggest change –<br>Section 6.5.1<br>Suggest replace with –<br>Section 5.6.1 | Noted - change made in Appendix A. |
| EIR (SEO) | Page 76 – Appendix A: Stakeholder Consultation | DPC Aboriginal Affairs and Reconciliation | Suggest change –<br>'Minimise impacts to flora and fauna, livestock and groundwater dependent ecosystems in the event of unintended migration of CO2 to surface and shallow subsurface environments.'<br>Suggest replace with –<br>'Minimise impacts to flora and fauna, Aboriginal cultural heritage sites and landscapes, livestock and groundwater dependent ecosystems in the event of unintended migration of CO2 to surface and shallow subsurface environments.' | Noted - updated with " *Minimise impacts to flora and fauna, Aboriginal cultural heritage sites and landscapes, livestock and groundwater dependent ecosystems in the event of unintended migration of $CO_2$ to surface and shallow subsurface environments*" to Table 1 in the SEO. |
| EIR and SEO | EIR section 2.3 and 4.3.3 | Department for Infrastructure and Transport | The EIR and SEO documents have been reviewed and the reports make various mentions to the use of 'new' or 'existing' pipelines without specifically identifying if/were new pipelines could be installed to cater for the Carbon Capture and Storage operations (refer EIR section 2.3 and 4.3.3).<br><br>Should the applicant require any new infrastructure (i.e. pipeline/s) to be installed adjacent to/under the Commissioner of Highway's (CoH) road/s as part of the Carbon storage, Santos is required to seek authorisation from the CoH to install and maintain the infrastructure.<br><br>A DIT contact can be provided should the applicant require further information. | Noted- All infrastructure including pipelines is covered under the existing Processing and Production SEO and Drilling, Completions and Well operations SEO and such is not within the scope of the Carbon Storage EIR and SEO.<br>Santos has plans and procedures to ensure other approvals are in place as required for crossings of third-party infrastructure by Santos activities. |
| SEO | Section 2.2, Table 1 | South Australian Environmental Protection Authority | "Storage of measurable quantities of CO2 in deep geological formations is demonstrated in accordance with an approved Monitoring, Reporting and Verification Plan." | Noted - Inserted "*MRV Plan to be approved by DEM prior to commencement of carbon storage activities*" into Table 1 of the SEO. |
| SEO | Section 2.2, Table 1 | South Australian Environmental Protection Authority | EPA:<br>Under Objective 3 - *Minimise impacts to flora and fauna, livestock and groundwater dependent ecosystems from the unintended migration of CO2 to surface and shallow subsurface environments* | Noted - Added in the following to the guide to how achieve for Objective 3:<br>• Evaluation of target geological formation(s) before carbon storage commences including: |

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| | | | All the approaches suggested by Santos relate to evaluation and management of bore integrity. There needs to be additional approaches which address potential migration of $CO_2$ by other mechanisms (diffusion, fractures etc). | • geological risk assessment including review of production history<br>• Modelling to determine storage capacity and injection scheme design.<br>• Identification of nearby groundwater users and GDEs. Consideration of such users in the design and operation of carbon storage scheme and in the MRV Plan to reduce risk of potential adverse impacts.<br>• Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring $CO_2$ chemistry).<br>• Modelling calibrated with pressure measurements to support modelling.<br>• Injection and storage formation monitoring during and post-injection in accordance with the MRV Plan<br>• Response plan in place to respond to abnormal injection and storage performance conditions in accordance with the MRV Plan.<br>• Equipment design and monitoring to ensure injection pressures remain below overburden fracture gradient.<br>• Well drilling, completions, operations, integrity management in accordance with the requirements of the DCWO SEO.<br>• Any identified migration of $CO_2$ to non-target aquifers is controlled and minimised and potential impacts on third party groundwater users assessed and managed where appropriate to minimise the risk of adverse impact to users |
| SEO | Section 2.2, Table 1 | South Australian Environmental Protection Authority | EPA:<br>This objective should be expanded to cover the broader Environment Protection Act 1993 requirement to avoid, control and/or minimise pollution. Suggesting:<br>Avoid polluting or adversely affecting the environmental values of groundwater in non-target aquifers that reduces the ability of third-party groundwater users from undertaking their activities. | Noted - We have reviewed this, and it is our understanding that “adversely affecting the environmental values” is an all-encompassing term and would as such include adverse effects due to polluting in addition to other effects that could be considered. This in mind, we will leave as is to remain consistent with the terminology utilised in the *Petroleum and Geothermal* |

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| | | | | *Energy Act 2000*. Note polluting will be further defined in the Monitoring, Reporting and Verification Plan(s). |
| SEO | Section 2.2, Table 1 | South Australian Environmental Protection Authority | "Effective barriers exist to prevent crossflow between separate aquifer systems or hydrocarbon reservoirs in accordance with Drilling, Completions and Well Operations SEO requirements." - This is a control measure. How are effective barriers an assessment criterion? | Maintaining effective barriers to prevent crossflow between aquifer systems is a prerequisite of Drilling and Completions and Well Operations SEO and therefore already addressed. Removed from table 1 in the Carbon Storage SEO. |
| SEO | Section 3.3 | South Australian Environmental Protection Authority | Reference to reporting requirements should reflect that Section 83A of the Environment Protection Act 1993 (EP Act) requires that the EPA be notified of site contamination that affects or threatens groundwater. Section 83 of the EP Act requires that the EPA be notified of serious or material environmental harm from pollution is caused or threatened in the course of an activity. Both notification requirements should be appropriately considered in the SEO.<br>The EPA notes that the SEO states that reporting obligations under the EP Act do not apply to certain activities (derived from s7(4)(a-c) of the EP Act). The requirements of s83A should be considered by Santos in the event that site contamination affecting or threatening groundwater is identified. | Noted – Updated Section 3.3 to state the following "*Where applicable, incidents causing or threatening serious or material environmental harm under the Environment Protection Act 1993 must be reported to the EPA in accordance with section 83 of the Environment Protection Act 1993. Incidents of site contamination that affects or is threatening groundwater Environment Protection Act 1993 must be reported under section 83A of the Environment Protection Act 1993.*" |
| EIR | Section 7.2 Risk Issue: Uncontrolled release of $CO_2$ to the atmosphere, surface and / or near-surface environments | South Australian Environmental Protection Authority | RISK ISSUE<br>"Uncontrolled release of CO2 to the atmosphere, surface and / or near-surface environments"<br>This risk issue should be expanded to include release of hydrocarbons and other substances that may be entrained, displaced to the atmosphere, surface and / or near-surface environments.<br>"Uncontrolled release of CO2, hydrocarbons and other substances to the atmosphere, surface and / or near-surface environments into non-target geological formations" | Noted - added in "*hydrocarbons and other substances*" to the risk issue text. |
| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$ to the atmosphere, surface and / or near-surface environments | South Australian Environmental Protection Authority | CAUSE:<br>"Migration of CO2 [and potentially other substances] through well bore as a result of inadequate well integrity"<br>EPA:<br>It is not clear what a "well bore" is, as opposed to a well or a bore. Perhaps a typographical error?<br>Consider additional text to reflect potential for other substances (pollutants). | Noted: This is industrial terminology, well bores are discussed in section 7.2.2. |

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| EIR | Table 7.2<br>Risk Issue:<br>Uncontrolled release of $CO_2$ to the atmosphere, surface and / or near-surface environments | South Australian Environmental Protection Authority | POTENTIAL CONSEQUENCE<br>"Reduced environmental values of surface water, shallow (phreatic zone or water table) groundwater and soils due to presence of elevated CO2".<br>EPA:<br>Should consider the particular chemical and biological impacts of pollutants (CO2, hydrocarbons and potentially other substances) influx into groundwater and surface water and soil systems. | Noted: added in *"hydrocarbons and other substances"* to the risk issue text. |
| EIR | Table 7.2<br>Risk Issue:<br>Uncontrolled release of $CO_2$ to the atmosphere, surface and / or near-surface environments | South Australian Environmental Protection Authority | CONTROL STRATEGY<br>EPA:<br>Monitoring is listed as a control strategy.<br>Monitoring is not a control, it informs whether or not control measures are functioning correctly | The development of the Monitoring, Reporting and Verification Plan (MRV) to be approved by DEM prior to activities commencing is considered a control/management strategy. Updated column header to include management strategies for clarity. Risk assessment and monitoring are deemed management/controls to reduce risk levels. |
| EIR | Table 7.2<br>Risk Issue:<br>Uncontrolled release of $CO_2$ to the atmosphere, surface and / or near-surface environments | South Australian Environmental Protection Authority | RISK<br>Consequence "III"<br>Why is the consequence a "localised and medium term impact to an area, plants or animals of recognised environmental value"? | The consequence is based on Santos Cooper Basin experience for hydrocarbon wells.<br>Uncontrolled release of $CO_2$ to the atmosphere, surface and/or near-surface environments is considered to have a consequence of III. Impacts would be localised to the vicinity of the well bore with only a short to medium term impact to the plants or animals. This is due to the dispersive properties of $CO_2$ where it would dissipate after a short period of time. The medium-term impacts affect the area directly adjacent to the release, however the presence of the $CO_2$ would only be for a short time prior to be dispersed into the greater atmosphere. |
| EIR | Table 7.2<br>Risk Issue:<br>Uncontrolled release of $CO_2$ to the atmosphere, surface and / or near-surface environments | South Australian Environmental Protection Authority | RISK<br>Likelihood "b"<br>Where has it occurred elsewhere or why could it occur within decades? | The risk likelihood is based on Santos Cooper Basin experience for hydrocarbon wells. The Likelihood of migration through well bore as a result of inadequate integrity occurring is considered unlikely due to the controls in place such as well design, adhering to the DCWO SEO and identification and evaluation of existing well bores prior to the activity commencing. |

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| EIR | Table 7.2 Risk issue: Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | RISK ISSUE<br>"Uncontrolled release of CO2 into non-target geological formations"<br>EPA:<br>Given that the consequence considers hydrocarbons migration, the risk issue should be expanded to represent the wider scope:<br>"Uncontrolled release of CO2, hydrocarbons and other substances into non-target geological formations" | Noted: added in hydrocarbons and other substances to the risk issue text. The potential impacts of this are discussed further in Section 7.2.2 of the EIR. |
| EIR | Table 7.2 Risk issue: Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | POTENTIAL CONSEQUENCE<br>"Reduced environmental values of groundwater due to presence of elevated CO2, crossflow or migration of hydrocarbons – impact to environmental and or human health receptors"<br>EPA:<br>Should consider the particular chemical and biological impacts of pollutants (CO2, hydrocarbons and potentially other substances) influx into groundwater systems. | Noted: Statement already takes this into account "*... crossflow or migration of hydrocarbons ...*" |
| EIR | Table 7.2 Risk issue: Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | CONTROL STRATEGY<br>EPA:<br>Monitoring is included as a control strategy.<br>Monitoring is not a control, it informs whether or not control measures are functioning correctly. | The development of the Monitoring, Reporting and Verification Plan (MRV) to be approved by DEM prior to activities commencing is considered a control/management strategy. Updated column header in Table 7.2 to include management strategies for clarity. Monitoring is deemed a control/management strategy to reduce risk levels. |
| EIR | Table 7.2 Risk issue: Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | RISK<br>Consequence "III"<br>Why is the consequence a "localised and medium term impact to an area, plants or animals of recognised environmental value"? | The consequence is based on Santos Cooper Basin experience for hydrocarbon wells.<br>Consequences would be localised to the vicinity of the well in question with only a short to medium term impact. This is due to the rapid dilution based on the small volumes of $CO_2$ in relation to total aquifer volume. |
| EIR | Table 7.2 Risk issue: Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | RISK Likelihood "b" unlikely<br>Where has it occurred elsewhere or why could it occur within decades? | The likelihood is based on Santos Cooper Basin experience for hydrocarbon wells, Santos considers the likelihood of $CO_2$ release into non-target formations due to well integrity to be unlikely based control measures such as well design, adhering to the DCWO SEO, identification and evaluation of existing well bores prior to the activity commencing. |

| Document | Section No. | Stakeholder | Comments | Santos Comments |
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| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$ into non-target geological formation | South Australian Environmental Protection Authority | RISK ISSUE "Uncontrolled release of CO2 into non-target geological formations"<br>Given that the consequence considers hydrocarbons migration, the risk issue should be expanded to represent the wider scope:<br>"Uncontrolled release of CO2, hydrocarbons and other substances into non-target geological formations" | Noted: added in hydrocarbons and other substances to the text |
| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$ into non-target geological formation | South Australian Environmental Protection Authority | CAUSE: "Vertical flow of CO2 through permeable geological structures and materials"<br>This suggests loss of containment from the target geological formation(s). | Noted - During the evaluation of reservoirs and target formation we would seek suitable geology to maintain containment within the storage complex. |
| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$ into non-target geological formation | South Australian Environmental Protection Authority | POTENTIAL CONSEQUENCE "Reduced environmental values of groundwater due to presence of elevated CO2"<br>EPA:<br>Should consider the particular chemical and biological impacts of pollutants (CO2, hydrocarbons and potentially other substances) influx into groundwater systems. | Noted: added in hydrocarbons and other substances to the risk issues text. |
| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$ into non-target geological formation | South Australian Environmental Protection Authority | CONTROLS<br>"Evaluation of reservoirs and target formation before carbon storage commences including:<br>• geological risk assessment including review of production history<br>• reservoir modelling to determine storage capacity and injection scheme design.<br>• Pressure monitoring during and post injection in accordance with the Monitoring, Reporting and Verification Plan.<br>• Reservoir modelling calibrated with pressure measurements to support modelling.<br>• Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring CO2 chemistry)."<br>EPA:<br>These items are not control strategies. Risk assessments, modelling and monitoring inform decision making, including the selection of appropriate control measures. | The development of the Monitoring, Reporting and Verification Plan (MRV) to be approved by DEM prior to activities commencing is considered a control/management strategy. Updated column header in Table 7.2 to include management strategies for clarity. Geological risk assessment, reservoir modelling, pressure monitoring and pre-storage assessment are all deemed controls/management strategies to reduce risk levels. |

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| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$ into non-target geological formation | South Australian Environmental Protection Authority | RISK<br>Consequence "III"<br>Why is the consequence a "localised and medium term impact to an area, plants or animals of recognised environmental value"? | The consequence is based on Santos Cooper Basin experience for hydrocarbon wells.<br>Note - the Environmental consequence is likely lower at II however the assigned rating was influenced by the financial aspect of the risk matrix considering the impacts of investigating and quantifying. |
| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$ into non-target geological formation | South Australian Environmental Protection Authority | RISK<br>Likelihood "a" remote<br>Why is this only considered to occur in exceptional circumstances and unlikely, even in the long term? | The likelihood is based on Santos Cooper Basin experience for hydrocarbon wells. The Likelihood of vertical flow of $CO_2$ through permeable geological structures is considered remote. This is due to the controls in place such as evaluation of target formation (site selection) prior to commencing activities, pre-storage assessment and pre-existing conditions within the Cooper Basin formations. |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | RISK ISSUE<br>"Uncontrolled release of CO2 into non-target geological formations"<br>EPA:<br>"Uncontrolled release of CO2, hydrocarbons and other substances into non-target geological formations" | Noted: added in hydrocarbons and other substances to the risk issue text. |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | POTENTIAL CONSEQUENCE<br>"Reduced environmental values of groundwater due to presence of elevated CO2"<br>EPA:<br>Should consider the particular chemical and biological impacts of pollutants (CO2, hydrocarbons and potentially and other substances) influx into groundwater systems. | Noted: added in hydrocarbons and other substances to the consequence text. |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | CONTROLS<br>"Evaluation of reservoirs and target formation before carbon storage commences including:<br>• geological risk assessment including review of production history<br>• reservoir modelling to determine storage capacity and injection scheme design.<br>• Pressure monitoring during and post injection in accordance with the Monitoring, Reporting and Verification Plan. | The development of the Monitoring, Reporting and Verification Plan (MRV) to be approved by DEM prior to activities commencing is considered a control/management strategy. Updated column header in Table 7.2 to include management strategies for clarity. Geological risk assessment, reservoir modelling, pressure monitoring and pre-storage assessment are all deemed controls/management strategies to reduce risk levels |

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| | | | • Reservoir modelling calibrated with pressure measurements to support modelling.<br>• Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring CO2 chemistry)."<br>EPA:<br>These items are not control strategies. Risk assessments, modelling and monitoring inform decision making, including the selection of appropriate control measures. | |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | RISK<br>Consequence "III"<br>Why is the consequence a "localised and medium term impact to an area, plants or animals of recognised environmental value"? | The consequence is based on Santos Cooper Basin experience for hydrocarbon wells<br>Note the Environmental consequence is likely a lower at II however the assigned rating was influenced by the financial aspect of the risk matrix considering the impacts of investigating and quantifying. |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$ into non-target geological formations | South Australian Environmental Protection Authority | RISK<br>Likelihood "a" remote<br>Why is this only considered to occur in exceptional circumstances and unlikely, even in the long term? | The likelihood is based on Santos Cooper Basin experience for hydrocarbon wells<br>The likelihood is based on Santos Cooper Basin experience for hydrocarbon wells. The Likelihood of lateral flow of $CO_2$ from storage reservoirs is considered remote. This is due to the controls in place such as evaluation of target formation (site selection) prior to commencing activities, pre -storage assessment and pre-existing conditions within the Cooper Basin formations. |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formations | South Australian Environmental Protection Authority | RISK ISSUE "Uncontrolled release of CO2 into non-target geological formations"<br>EPA:<br>Given that the consequence considers hydrocarbons migration, the risk issue should be expanded to represent the wider scope:<br>"Uncontrolled release of CO2, hydrocarbons and other substances into non-target geological formations" | Noted: added in hydrocarbons and other substances to the risk issue text. |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$, hydrocarbons and other substances | South Australian Environmental Protection Authority | POTENTIAL CONSEQUENCE<br>"Reduced environmental values of groundwater due to presence of elevated CO2" | Noted: added in hydrocarbons and other substances to the consequence text. |

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| | into non-target geological formations | | EPA:<br>Should consider the particular chemical and biological impacts of pollutants ($CO_2$, hydrocarbons and potentially and other substances)<br>influx into groundwater systems. | |
| EIR | Table 7.2 Risk Issue Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formations | South Australian Environmental Protection Authority | CONTROL STRATEGY<br>• "geological risk assessment including review of production history<br>• reservoir modelling to determine storage capacity and injection scheme design.<br>• Pressure monitoring during and post injection in accordance with the Monitoring, Reporting and Verification Plan.<br>• Reservoir modelling calibrated with pressure measurements to support modelling.<br>• Pre-storage assessment / monitoring of identified sensitive receptors where appropriate to establish baseline (e.g. naturally occurring $CO_2$ chemistry)."<br>EPA: These items are not control strategies. Risk assessments, modelling and monitoring inform decision making, including the selection of appropriate control measures. | The development of the Monitoring, Reporting and Verification Plan (MRV) to be approved by DEM prior to activities commencing is considered a control/management strategy. Updated column header in Table 7.2 to include management strategies for clarity. Geological risk assessment, reservoir modelling, pressure monitoring and pre-storage assessment are all deemed controls/management strategies to reduce risk levels |
| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formations | South Australian Environmental Protection Authority | RISK<br>Consequence "III"<br>Why is the consequence a "localised and medium term impact to an area, plants or animals of recognised environmental value"? | The consequence is based on Santos Cooper Basin experience for hydrocarbon wells<br>Note the Environmental consequence is likely a lower at II however the assigned rating was influenced by the financial aspect of the risk matrix considering the impacts of investigating and quantifying. |
| EIR | Table 7.2 Risk Issue: Uncontrolled release of $CO_2$, hydrocarbons and other substances into non-target geological formations | South Australian Environmental Protection Authority | RISK<br>Likelihood "a" remote<br>Why is this only considered to occur in exceptional circumstances and unlikely, even in the long term? | The likelihood is based on Santos Cooper Basin experience for hydrocarbon wells<br>Santos considers the likelihood Preferential flow through permeable pathways created by previous oil and gas operations to be low based on control measures in place such as well design, adhering to the DCWO SEO, identification and evaluation of existing well bores prior to the activity commencing. Table 7.2 updated. |
| EIR | Table 7.2 Risk Issue: Seismicity | South Australian Environmental | RISK ISSUE | Noted - In this scenario seismicity is considered in the context of potential issues caused by $CO_2$ injection activities. It should be |

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| | | Protection Authority | "Seismicity"<br>Cause "CO2 injection"<br>EPA:<br>Suggest transferring the following from the Potential Consequences column:<br>Activation of faults or fractures creating permeable pathways for uncontrolled CO2 release in non-target geological formations | noted that this scenario is considered highly unlikely based on stable geology and experience within the Cooper Basin, however was included within the risk assessment for completeness. |
| EIR | Table 7.2 Risk Issue: Seismicity | South Australian Environmental Protection Authority | POTENTIAL CONSEQUENCES<br>Reduced environmental values of groundwater due to presence of elevated CO2<br>EPA:<br>Should consider the particular chemical and biological impacts of pollutants (CO2, hydrocarbons and potentially and other substances)<br>influx into groundwater systems. | Noted: added in hydrocarbons and other substances to the consequence text. |
| EIR | Table 7.2 Risk Issue: Seismicity | South Australian Environmental Protection Authority | POTENTIAL CONSEQUENCE<br>Ground disturbance<br>EPA:<br>This is potentially concerning. What information or data does Santos hold to suggest ground disturbance could occur? And to what extent? | This risk was added in for completeness within the assessment however based on Santos experience within the Cooper Basin is not considered plausible in the context of seismicity based on the depth of injection, injection pressures to be used and other controls in place. |
| EIR | Table 7.2 Risk Issue: Seismicity | South Australian Environmental Protection Authority | CONTROL STRATEGY<br>"Geological risk assessment<br>Equipment design and monitoring to ensure injection pressures remain below fracture gradient."<br>EPA:<br>These items are not control strategies. Risk assessments and monitoring inform decision making, including the selection of appropriate control measures. | The development of the Monitoring, Reporting and Verification Plan (MRV) to be approved by DEM prior to activities commencing is considered a control/management strategy. Updated column header in Table 7.2 to include management strategies for clarity. Geological risk assessment is deemed a control/management strategy to reduce risk levels |
| EIR | Table 7.2 Risk Issue: Seismicity | South Australian Environmental Protection Authority | "No incidents of induced seismic events from hydraulic stimulation activities."<br>EPA:<br>This is not a control strategy, it is an assessment criterion. | Noted: removed |
| EIR | Table 7.2 Risk Issue: Seismicity | South Australian Environmental | RISK<br>Consequence "I" | The consequence is based on Santos Cooper Basin experience for hydrocarbon wells |

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| | | Protection Authority | Why is the consequence a "localised and medium term impact to an area, plants or animals of recognised environmental value"? | Injection sites will be very deep any induced seismicity whilst highly unlikely would also be highly localised to the deep sub surface. |
| EIR | Table 7.2 Risk Issue: Seismicity | South Australian Environmental Protection Authority | RISK<br>Likelihood "b"<br>Where has it occurred elsewhere or why could it occur within decades? | The risk Likelihood in the EIR is actually set at (a) remote, not (b) as the comment suggests. Some damage from induced seismicity has occurred in the United States due to the injection of fluid into permeable reservoirs (overpressure) however Cooper basin geology and pressure design factors would suggest that this is highly unlikely. There have also not been any known incidents of damage from induced seismic events occurring from hydraulic stimulation activities in the Cooper Basin. |
| EIR | Section 8.6 Incident and Response Management | South Australian Environmental Protection Authority | Preliminary Environmental Assessment to be undertaken as part of the immediate response following an incident is documented to include a desktop groundwater assessment. The EIR should specify that based on the desktop assessment, intrusive groundwater monitoring/assessment may be triggered to determine if harm to groundwater has occurred. Groundwater assessment should be undertaken in accordance with the National Environment Protection (Assessment of Site Contamination) Measure 2013 and the EPA Guidelines for the assessment and remediation of site contamination 2019.<br>Given the documented variability of groundwater systems in the Cooper/Eromanga basins, as a part of determining sensitive receptors in an incident area, Santos should also determine environmental values of groundwater applicable to the impacted area. Environmental values from a site contamination perspective should be determined in accordance with the Guidelines for the assessment and remediation of site contamination 2019 (the GAR).<br>Incident notification and classification measures should include consideration of requirements, under sections 83 and 83A of the Environment Protection Act 1993, to notify the EPA of:<br>• site contamination which affects or threatens groundwater; or<br>• serious or material environmental harm caused or threatened in the course of an activity.<br>In determining if harm to water has occurred as a result of Santos activities the relevant environmental values of groundwater should be considered for each potentially impacted aquifer. | Noted: Incident reporting requirements are stated in the SEO and take into account Santos requirement under the Environmental Protection Act 1993. Requirements for adhering to the NEPM are stated in the Recommended Actions and Reporting section of Section 8.6.<br>Added in "*…and consider the EPA Guidelines for the assessment and remediation of site contamination*" to Section 8.8 of the EIR - Reporting states "External reporting (e.g. Serious or Reportable incidents, annual reports) is carried out in accordance with the requirements of the Petroleum and Geothermal Energy Act 2000 and the applicable SEO." Reporting under the EP Act is detailed within the SEO. |

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| | | | The EPA recognises that there will be instances where it is considered likely that the identification of elevated naturally occurring chemical substances present may represent background concentrations rather than site contamination. In such instances, background concentrations of contaminants of concern in the relevant aquifer should be determined in accordance with the EPA Guideline for the assessment of background concentrations (2018). | |