Leigh Creek Energy

Environmental Impact Report

ISG Demonstration Plant

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Revision History

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Leigh Creek Energy acknowledge the Adnyamathanha people, the traditional owners of the land on which our operations occur and pay our respects to their Elders past and present.

Contents

Tables

Figures

Plates

Summary

Leigh Creek Energy plans to produce energy from coal using a process known as in situ gasification (ISG) in the Leigh Creek Coalfield in northern South Australia. The ISG process converts coal from its solid state into a gaseous form, resulting in the generation of synthesis gas (syngas) containing methane, hydrogen and other valuable components. The syngas can be either used to produce electricity directly or further refined into a variety of products including synthetic methane and ammonia.

Both locally and internationally ISG is also known as underground coal gasification (UCG), however the terms ‘in situ gasification’ or ‘ISG’ are used in South Australia to describe the process. ISG has been used in this document to provide consistency with the terminology outlined in the *Petroleum and Geothermal Energy Act 2000*, which is the legislation governing ISG in South Australia.

To obtain information to inform the design for a potential commercial facility, LCK proposes to construct, operate and decommission a small-scale ISG demonstration plant. This facility will involve the construction of an above ground plant (and associated service infrastructure) and the establishment of a below ground single ISG gasifier chamber. The demonstration plant would be commissioned and operated for a short period (approximately 2-3 months) to produce syngas, so that the technical and environmental performance of the process can be confirmed. The demonstration is regulated as an exploration activity under the *Petroleum and Geothermal Energy Act 2000* and as an exploration activity the syngas produced is unable to be sold for commercial use, and will therefore be thermally destroyed on site in a thermal oxidiser as part of the process. This Environmental Impact Report has been prepared under the Petroleum and Geothermal Energy Act to cover the proposed demonstration plant activities.

In the simplest ISG configuration, two wells are drilled into a coal seam, one for an inlet well for the addition of air and water, and the other for the outlet well for the extraction of syngas. A combination of horizontal and vertical wells will be used for the demonstration plant gasifier to create a direct linked system in which the two wells meet. Hydraulic fracturing (fracking), a well stimulation technique in which rock is fractured by a pressurised liquid, will not be used to connect the inlet and outlet wells. The inlet and outlet well have been designed to meet international petroleum industry standards for the pressures, temperatures, operational stresses and loads that will occur during operation of the gasifier.

For the ISG reactions to commence, air is introduced through the inlet well and an initiation device is used to create very high temperatures. As the temperature and oxygen concentration reach optimum levels, a series of reactions convert the solid fuel into syngas, which is then extracted through the outlet well. The ISG process is a chemical conversion from solid coal to gas rather than a combustible conversion (‘burning’) which would create heat and carbon dioxide rather than syngas. The area in the coal seam where the gasification takes place is referred to as the gasifier chamber, and the reactions that form syngas typically occur at temperatures of between 900°C and 1200°C.

The demonstration plant will be located in the heavily modified Leigh Creek Coalfield, between the Main Series and Upper Series pits and waste rock stockpiles. The site is approximately 8.5 km from Copley and 12 km from Leigh Creek. The gasifier chamber will be approximately 540 m depth and will be approximately 30 m long, 30 m wide and 15 m high at the conclusion of operations.

During stakeholder engagement activities it was recognised that the five main areas of concern of the community relate to potential impact to cultural heritage, air quality (including odour), groundwater, surface water and ground stability. Therefore, in assessing the suitability for an ISG demonstration plant, independent third-party consultants were engaged to review existing data,

undertake field studies and commence environmental monitoring to address these areas of concern.

As the northern Flinders Ranges region is culturally significant to, and the traditional lands of, the Adnyamathanha people a cultural heritage agreement was signed with the Adnyamathanha Traditional Lands Association (ATLA). To protect and manage cultural heritage a Work Area Clearance of the proposed activities as described in this document has been undertaken with ATLA. A Cultural Heritage Discovery Procedure is in place to ensure that Aboriginal sites, objects and remains, as well as non-Aboriginal Heritage sites and or items are protected if they are discovered during site activities.

The occurrence of odours at Copley has been raised by several stakeholders (before any ISG activities with the potential to release odour has commenced). It is recognised that odour from the coalfield is occasionally present in Copley and that the coalfield odour has been observed as far south as the Leigh Creek township. To address concerns regarding air quality the current (existing) air quality conditions were measured, and modelling was undertaken to assess potential impacts to local residents. Studies showed that background odour is present from the coalfield as well as from Copley (such as the caravan park wastewater irrigation area). The modelling indicated that the surrounding air quality from emissions from the demonstration plant will remain within relevant health-based air quality criteria. Odour from non-routine venting could occur if venting of syngas is required when winds are blowing towards receptors. This is unlikely to occur and if this occurred, it would be short term (e.g. 30-60 minutes).

As water is a vital resource in regional communities, studies were undertaken to address potential impacts to groundwater and surface water which considered the number and type of aquifers present, the ability for groundwater to move vertically and horizontally (permeable pathways), and the presence of persons or environment that may be impacted (receptor). Groundwater studies completed show that there are no aquifers present at or near the demonstration site, the gasifier is surrounded by very low permeability aquitards, there are no groundwater receptors present and no credible pathways exist to groundwater receptors.

The demonstration plant site is isolated from natural surface water systems by the mine pits and waste rock stockpiles. Activities at the demonstration plant site will not impact surface water off the mine site.

To address concerns regarding ground stability geotechnical studies were undertaken which considered the risks in siting the ISG gasifier in relation to existing geological structures (such as faults), the potential for failure (collapse) of the gasifier roof rock and subsequent subsidence, and the potential for the gasifier to fracture the surrounding rock and form pathways for chemical migration. Studies completed show that the geotechnical risk is low and that the physical attributes of the Leigh Creek Coalfield meet the recommended requirements for an ideal ISG site as outlined by the Independent Scientific Panel[1].

It is important to acknowledge that due to the presence of the coal (and other naturally occurring hydrocarbon rich rocks) that the soils, rocks and groundwater naturally contain chemicals that might otherwise be referred to as contaminants. In this environment these chemicals are referred to as chemicals of potential concern, as they are intrinsic to the environment and as such are not contamination resulting from an activity.

[1] The Queensland Independent Scientific Panel for Underground Coal Gasification was established in 2013. The Panel's role was to analyse, assess and evaluate technical and environmental factors and to report the outcomes of UCG trial activities including recommendations on the prospects and future management of UCG in Queensland.

The Leigh Creek Coalfield has a long history of mining commencing at a commercial scale in the 1940s, initially under the auspices of the South Australian Engineering and Water Supply and then the newly formed Electricity Trust of South Australia. Over a period of 80 years different owners (both public and private) have operated the mine under different regulatory, social and environmental expectations. In addition to the naturally occurring hydrocarbons and other chemicals of potential concern, there has been documented soil and groundwater contamination resulting from mining activities which has been assessed and documented with the South Australian Environment Protection Authority. These soil and groundwater impacts, whilst on the mine are not known or expected to occur in the area of the demonstration plant. Further sampling at the site is planned to document this.

As part of a robust quality assurance program a large amount of data will be collected during the lifecycle of the demonstration plant, encompassing both technical performance and environmental aspects. The main stages of the project include baseline (now completed), pre-commissioning (construction and testing), operations, and post-operation (closure and monitoring). During these stages, various monitoring and data collection activities will occur on the in situ gasification performance of the coal, groundwater information, environmental data and geotechnical data for verification of baseline and modelling, future interpretation, and planning and design of a potential commercial facility. Sampling and analysis of groundwater will be undertaken for a range of diagnostic chemicals which are indicative of ISG operations during the operational stage and continue into the post-operation stage to confirm that site activities do not pose a risk to aquifers or third party users of groundwater.

Occupational monitoring of gases during commissioning and operation of the demonstration plant will be undertaken using hand held monitors to detect levels that could impact occupational health. Ambient air quality and odour measurements will be undertaken at locations around the project site and at selected sensitive receptors on several occasions throughout the project lifecycle.

The Independent Scientific Panel provide a summary of attributes of an ideal site for ISG. These ideal site attributes include adequate depth below aquifers, thick and impermeable overlying strata, absence of vertical connectivity, low dip angle, mechanically competent overlying rock and few faults. The demonstration plant site meets these ideal site attributes. Although the geomechanical risk has been assessed as low, near surface settlement markers will be installed and survey-monitored during operation and decommissioning.

An environmental risk assessment has been undertaken as part of this Environmental Impact Report. It indicates that the level of risk is manageable and relatively low for the key areas of concern identified by stakeholders (cultural heritage, air quality, groundwater, surface water and ground stability). No high or unacceptable risks have been identified. Leigh Creek Energy will implement engineering design in accordance with relevant standards, risk assessment and management procedures and environmental management systems to ensure that all risks are appropriately managed.

Stakeholder engagement will continue to be an ongoing activity and a number of specialised workshops have been held with key stakeholders where project overview presentations and updates have been given, with particular attention given to the proposed demonstration works plan.

A targeted online community portal has been developed where community members can easily login and share their experiences of the project, leave feedback, and locate or request information. The portal offers enhanced two-way communication where community users can track the progress of any requests they make and add reminders so that their questions are answered in a timely manner.

The Community Portal can be accessed through the Leigh Creek Energy website's 'Contact Us' section (www.lcke.com.au/contact) and direct through http://lcke.c3register.com/.

Leigh Creek Energy is committed to open and transparent communication with stakeholders and encourages community members to use the Community Portal to ask questions and leave feedback regarding this document.

1 Introduction

Leigh Creek Energy Ltd (LCK) is the owner and proposed operator of the Leigh Creek Energy Project, located at Leigh Creek in South Australia, 550 km north of Adelaide. The project is located within Petroleum Exploration Licence 650 (PEL 650), which overlies the Leigh Creek Coalfield, and will develop deep coal resources that are unable and uneconomic to be accessed by open-cut mining.

LCK plans to produce energy from coal using a process known as in situ gasification (ISG). The ISG process converts coal from its solid state into a gaseous form, resulting in the generation of synthesis gas (syngas) containing methane, hydrogen and other valuable components. The syngas can be either used to produce electricity directly or further refined into a variety of products including synthetic methane and ammonia.

The Leigh Creek Energy Project aims to produce commercial quantities of pipeline quality gas (methane), fertiliser and electricity using ISG.

As the initial stage of the project, a small-scale ISG demonstration plant is proposed to be constructed to obtain information to inform the design for a possible commercial facility. The demonstration plant will involve establishment of a single gasifier chamber and above-ground infrastructure to produce syngas for a short period (approximately 2-3 months), so that the syngas composition and performance of the process can be confirmed. Environmental and geotechnical data will also be collected during operation of the demonstration plant to support any commercial plant approvals process. Syngas produced by the demonstration plant will be combusted following analysis.

This document addresses the proposed demonstration plant.

The location of the Leigh Creek Energy Project and proposed demonstration plant is shown in Figure 1-1.

1.1 Project Proponent

Leigh Creek Energy is an emerging gas company focussed on developing the Leigh Creek Energy Project in northern South Australia. Leigh Creek Energy is listed on the Australian Securities Exchange (ASX) under the ASX code of LCK and is headquartered in Adelaide, South Australia.

LCK (through wholly owned subsidiary Leigh Creek (Operations) Pty Ltd) holds PEL 650, which covers an area of 93 km^2 over the Leigh Creek Coalfield, and Gas Storage Exploration Licence (GSEL) 662 which covers the same area. LCK also hold Petroleum Exploration Licence Application (PELA) 647 adjacent to PEL 650.

1.2 About this Document

This document has been prepared to satisfy the requirements of an Environmental Impact Report (EIR) under the *Petroleum and Geothermal Energy Act 2000* for the proposed ISG demonstration plant. It has been prepared in accordance with the current legislative requirements, in particular Section 97 of the Act, and Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2013*.

A Statement of Environmental Objectives (SEO) for the project will be prepared based on this EIR[2].

This EIR covers:

- construction, operation and decommissioning of a small-scale ISG demonstration plant
- well design, completion (excluding drilling activity), operation, maintenance and eventual decommissioning of the inlet, outlet and observation wells associated with the demonstration plant.

Drilling of the inlet, outlet and observation wells is covered by an existing SEO for drilling (SAPEX 2013) and is not described in by this EIR[3]. These wells will not be drilled until the SEO for the demonstration plant is approved.

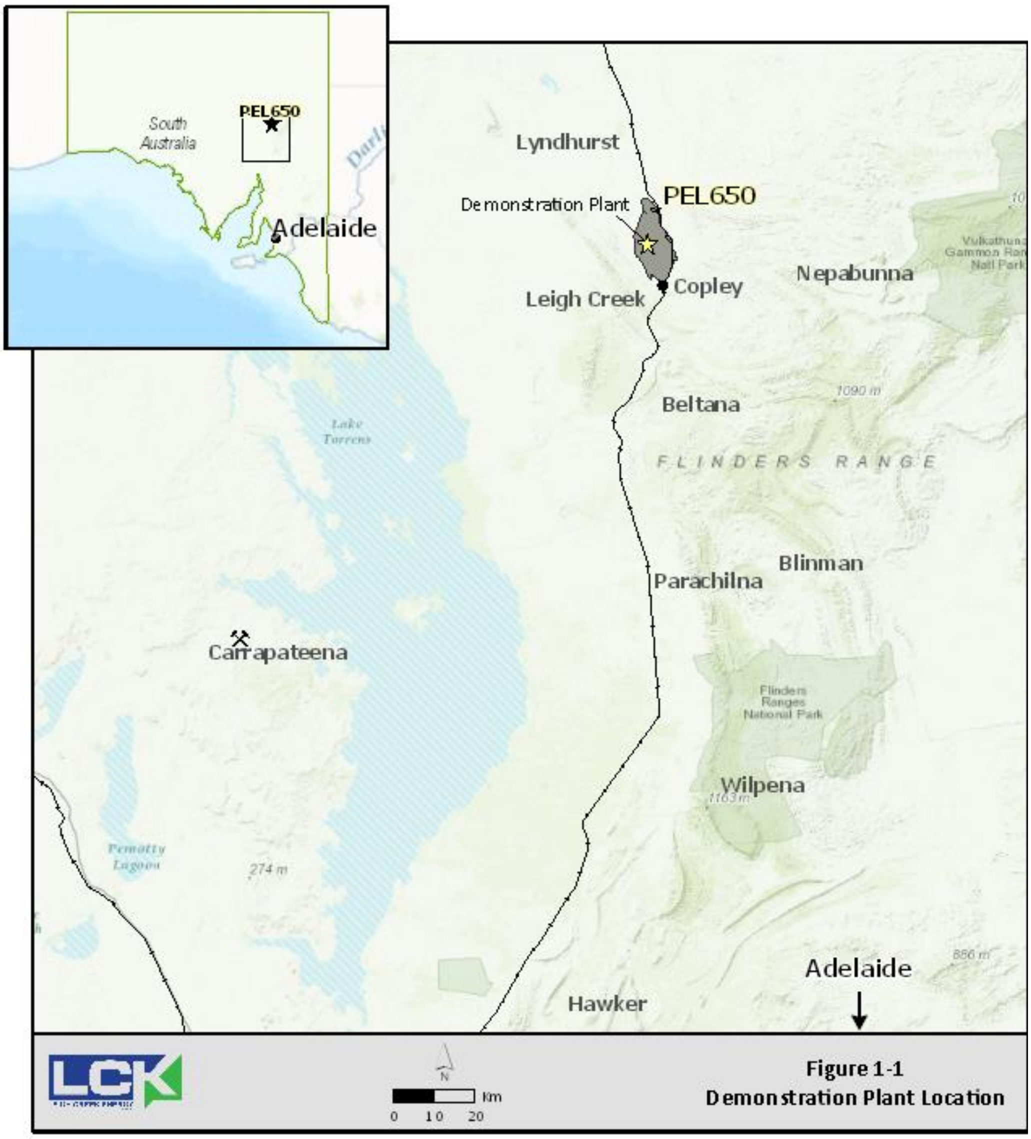

Figure 1-1
Demonstration Plant Location

[2] Or the SEO may be required to be prepared on the basis of an environmental impact assessment under the Development Act, depending on the classification of the activities under Section 98 of the *Petroleum and Geothermal Energy Act 2000*, as discussed in Section 2.1.

[3] Approval for drilling under the coverage of the existing SEO is managed through the Activity Notification / Approval process outlined in Section 2.1.4.

2 Legislative Framework

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

2.1 Petroleum and Geothermal Energy Act

Petroleum[4] exploration and production activities are governed by the South Australian *Petroleum and Geothermal Energy Act 2000* and the *Petroleum and Geothermal Energy Regulations 2013*. This legislation is administered by the Energy and Resources Division of the Department of Premier and Cabinet (DPC).

2.1.1 Statement of Environmental Objectives

As a requirement of Part 12 of the Act, a regulated activity can only be conducted if an approved Statement of Environmental Objectives (SEO) has been developed. 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 Environmental Impact Report (unless activities are classified as 'high impact' as discussed below under 'Assessment and Approval').

2.1.2 Environmental Impact Report

In accordance with Section 97 of the Act, 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.

As per Regulation 10 of the *Petroleum and Geothermal Energy Regulations 2013* the following information must be provided for the purposes of an EIR:

- 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)
- a description of reasonably foreseeable events associated with the activity that could pose a threat to the relevant environment (including events during the construction, operational

[4] The definition of petroleum under the Petroleum and Geothermal Energy Act includes coal or shale occurring in circumstances where the use of techniques for in situ gasification would be appropriate and also includes hydrocarbons that are a product of coal gasification (produced below or above ground) for the purposes of the production of synthetic petroleum.

and abandonment 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.

2.1.3 Assessment and Approval

The EIR is submitted to DPC and an Environmental Significance Assessment is undertaken to determine whether the activities described in the EIR are to be classified as 'low', 'medium' or 'high' impact. A corresponding draft SEO is prepared, reflecting the impacts and measures identified in the EIR or other assessments that may be required as determined by the classification.

The classification also determines the level of consultation DPC will be required to undertake prior to final approval of the SEO as follows:

- Low impact activities do not require public consultation and are subjected 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 *Development Act 1993*. A draft SEO for high impact activities must be prepared on the basis of this environmental impact assessment.

The level of environmental impact of a particular activity is assessed and classified by DPC on the basis of predictability and manageability criteria required by s.98 of the Act (DMITRE 2013).

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 DPC website.

Referral of Project Applications to the IESC

South Australia is a signatory to the National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development, and as a consequence, coal seam gas and large coal mining projects must be referred by DPC to the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) for advice. Where projects under the Petroleum and Geothermal Energy Act are to be referred under the South Australian referral protocol[5], it would generally be when an EIR and draft SEO are available.

Although small scale ISG is not clearly captured by the National Partnership Agreement, DPC may refer this EIR (and the resulting draft SEO) to the IESC for advice. Consequently, this EIR aims to provide the information necessary to support such a referral.

[5] *South Australian Protocol for the referral of project applications to the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development.*

2.1.4 Activity Notification / Approval Process

Prior to commencing a regulated activity, Section 74(3) of the Petroleum and Geothermal Energy Act requires that:

- the Minister's prior written approval is required for activities requiring high level supervision (as per Regulation 19), and
- notice of activities requiring low level supervision is to be given at least 21 days in advance (as per Regulation 18).

The application for the Minister's approval and notification of activities must provide specific technical and environmental information on the proposed activity and include an assessment to demonstrate that it is covered by an existing SEO.

Consequently, this activity notification process provides an additional opportunity for DPC to ensure that the proposed activities and their impacts can be effectively managed and are consistent with the approvals obtained in the EIR and SEO approval process.

2.2 Other Legislation

A variety of legislation applies to petroleum exploration activities, and those of particular relevance to the proposed demonstration plant are listed below (note that this is not a comprehensive list of all applicable legislation).

Table 2-1: **Summary of applicable legislation**

Jurisdiction	Legislation
Commonwealth	*Aboriginal and Torrens Strait Islander Heritage Protection Act 1984* *Environment Protection and Biodiversity Conservation Act 1999* *Native Title Act 1993*
South Australia	*Aboriginal Heritage Act 1988* *Crown Land Management Act 2009* *Dangerous Substances Act 1979* *Electricity Act 1996* *Environment Protection Act 1993* *Fire and Emergency Services Act 2005* *Heritage Places Act 1993* *National Parks and Wildlife Act 1972* *Native Title (South Australia) Act 1994* *Native Vegetation Act 1991* *Natural Resources Management Act 2004* *Road Traffic Act, 1961* *South Australian Public Health Act 2011* *Work Health and Safety Act 2012*

2.2.1 Commonwealth Environment Protection and Biodiversity Conservation Act

Referral and approval under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is required for actions that will have, or are likely to have a significant impact on matters of national environmental significance including World Heritage properties, National Heritage places, Ramsar wetlands of international importance, listed threatened species and ecological communities, listed migratory species and a water resource, in relation to coal seam gas development and large coal mining development.

The proposed demonstration plant is a small scale project, and as discussed in Sections 4 and 5, there are no matters of national environmental significance present or likely to be significantly impacted. There is no 'water resource' present in the Main Series Coal (the target of gasification), or overlying strata and consequently this matter of national environmental significance is not relevant to the project. Consequently, LCK believes that a requirement for referral and approval under the Act is not likely to be triggered. LCK will continue to review proposed activities against the EPBC Act triggers and will submit a referral under the Act if necessary.

2.2.2 Environment Protection Act

The *Environment Protection Act 1993* imposes a "general environmental 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.

The Environment Protection Act does not apply to 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 licence under the Petroleum and Geothermal Energy Act, when produced and disposed of to land and contained within the area of the licence.

Although incineration by thermal oxidation is a prescribed activity under Schedule 1 of the Act, this is an exploration activity and therefore the Environment Protection Act does not apply.

2.2.3 Native Vegetation Act

The *Native Vegetation Regulations 2017* permit clearance of vegetation incidental to exploratory operations authorised under the Petroleum and Geothermal Energy Act. Under Regulation 15, clearance is permitted if it is undertaken in accordance with approved industry standards that are directed towards minimising impact and encouraging regrowth of any native vegetation that is cleared.

All activities will be undertaken in accordance with a Statement of Environmental Objectives, which is the approved industry standard for activities under the Petroleum and Geothermal Energy Act.

2.2.4 Natural Resources Management Act – Water Management

The *Natural Resources Management Act 2004* applies to a range of aspects of natural resource management. Of particular relevance to this project is its applicability to activities that affect surface water and groundwater resources:

- Drilling of new water wells (or modification to or decommissioning of existing water wells) requires a permit under this Act.
- A permit is required to drain or discharge water directly or indirectly into a well, under Section 127(3)(c) of the Act. This requirement may apply to the proposed activities.
- This Act and the SA Arid Lands Regional Natural Resources Management Plan (SAAL NRM Board 2017) set out a number of other water affecting activities that must not be undertaken without a permit. These are usually avoidable by planning and siting of infrastructure to maintain surface water flows. A requirement for a permit for other water affecting activities will not be triggered by the proposed activities.

PEL 650 lies within the non-prescribed surface water and groundwater resources area of the South Australian Arid Lands Natural Resources Management (SAAL NRM) Region (Penney 2015).

It is outside the Far North Prescribed Wells Area and there is no Water Allocation Plan in place over the project area (SAAL NRM Board 2009).

2.2.5 Native Title Act

The Commonwealth *Native Title Act 1993* and the *Native Title (South Australia) Act 1994* provide for the recognition and protection of native title. Native title can be claimed on some areas of land or water (e.g. on vacant or unallocated crown land) but is extinguished by freehold land tenure and certain other forms of land title. Native title is discussed further in Section 4.12.3.

3 Description of Activities

The demonstration plant is a small-scale and short-term program. It involves establishment of an underground gasifier at a depth of approximately 540 m in the Main Series Coal at the Leigh Creek Coalfield, and operation of the gasifier and associated above-ground equipment for period of approximately 2-3 months. Gas produced will be analysed and then incinerated in a thermal oxidiser.

The purpose of the demonstration plant is to collect data on the in situ gasification performance of the Main Series Coal. Information collected will include:

- syngas composition, flowrates, temperature and pressures
- coal gasification performance and gasifier physical properties
- gasifier optimisation properties pressure, flowrate and reactants
- condensate and organic liquid phase volumes, properties and constituents
- environmental data
- other relevant data for the subsequent design of a possible commercial facility.

This section provides a general overview of the in situ gasification process and then provides detailed descriptions of the proposed activities associated with the demonstration plant. Technical terms used in this section are explained in the Glossary (Section 9).

3.1 Overview of ISG Process

In situ gasification (ISG) is a technique in which solid coal underground is converted *in situ* (‘in position’) into a gaseous product known as synthesis gas (syngas). Syngas is composed mainly of carbon dioxide, hydrogen, carbon monoxide, methane, nitrogen, steam and gaseous hydrocarbons. It can be used for a variety of downstream applications, such as power generation, or as a feedstock for recognised chemical products like methanol, ammonia, fertilizers, synthetic natural gas and liquid fuels. ISG enables the development of deep coal resources where open-cut and underground mining are not feasible or are uneconomic.

ISG is also known as underground coal gasification (UCG), however the terms ‘in situ gasification’ or ‘ISG’ are used throughout this report for consistency with the *Petroleum and Geothermal Energy Act 2000*.

In the simplest ISG configuration, two wells are drilled into a coal seam, one for the inlet and the other for the outlet (Figure 3-1). A combination of horizontal and vertical wells is often used to create a direct linked system. Hydraulic fracturing (fracking), a well stimulation technique in which rock is fractured by a pressurised liquid, will not be used to connect the inlet and outlet wells.

An oxidant (some combination of air, pure oxygen and water) is introduced through the inlet well and an initiation device is used to start the ISG reactions in the coal seam. As the coal is consumed, a series of reactions convert the solid fuel into syngas, which is then extracted through the outlet well. The underground void in the coal seam that forms where the gasification takes place is referred to as the gasifier chamber. The gasification reactions typically occur at temperatures of between 900°C and 1200°C but may reach up to 1500°C (Moran *et al.* 2013).

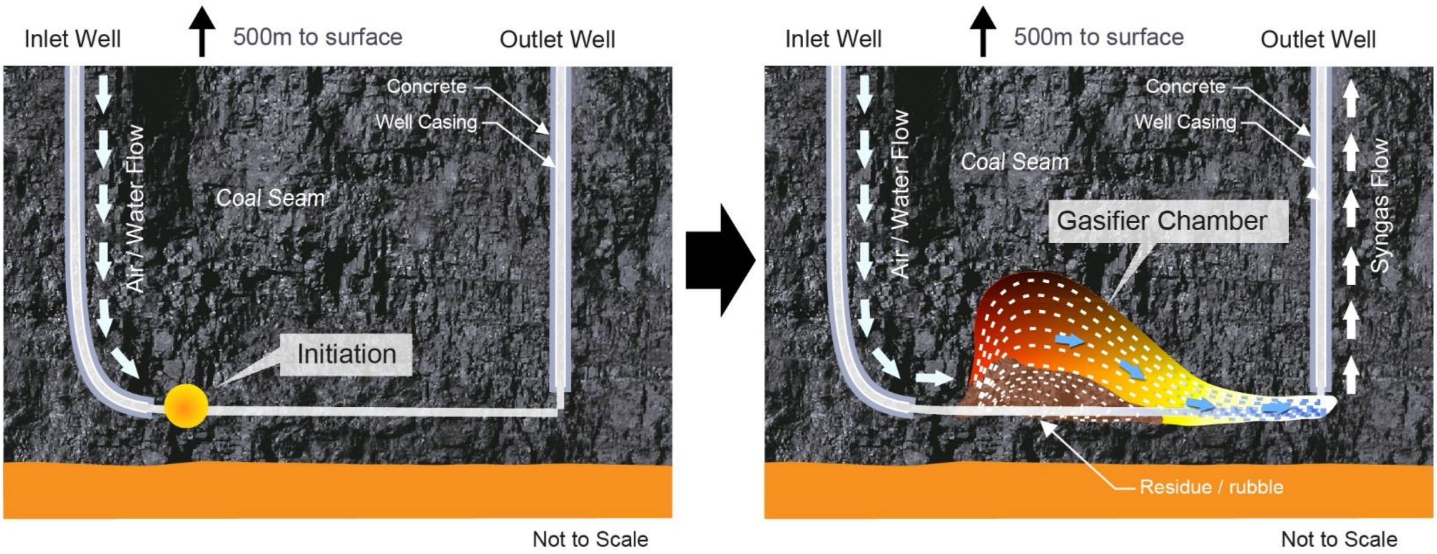

Figure 3-1: Example of a typical ISG process

The ISG process is controlled by using the inlet and outlet wells to manipulate the flow of oxidant and the pressure in the gasifier chamber. The pressure in the gasifier chamber is kept below the surrounding groundwater pressure to avoid an outward pressure gradient that could result in movement of water and chemicals of potential concern (COPC) away from the gasifier chamber. The process can be stopped by shutting off the oxidant supply from the inlet well, as the ISG reactions will cease within 48 hours without the injection of oxidant.

At the end of the ISG process, the oxidant supply at the inlet well is shut off and the process quenched with water to decrease the temperature below the threshold whereby pyrolysis products are produced (see Section 3.1.1) and the ISG reactions cease.

The ISG process produces a variety of COPC such as BTEX compounds (benzene, toluene, ethylbenzene, xylene), phenols and aromatic hydrocarbons, some of which will remain in the gasifier chamber after shutdown, depending on factors such as operation and optimisation of the ISG process and gasifier shutdown procedures (Camp and White 2015). During decommissioning of the gasifier, steam (via water injection) is typically generated in the gasifier chamber to remove these chemicals from the chamber via the gas flow out of the outlet well as the chamber cools.

3.1.1 Gasification Reactions

The conversion of solid coal into syngas works by reacting coal at high temperatures in an oxygen controlled environment. By restricting the oxygen, full combustion is avoided. Instead, a limited quantity of coal is allowed to combust in order to generate heat and volatile gases. These exothermic (heat releasing) reactions then drive secondary, endothermic (heat absorbing) reactions that produce hydrogen, methane, carbon monoxide and other compounds (Camp and White 2015).

Most of these reactions take place in a thin zone near the gasifier chamber wall (Figure 3-2). Camp and White (2015) describe the key stages of the reactions as:

1. *Drying*: The coal in the seam begins saturated with water. As heat is generated within the gasifier chamber, a thermal front is created which dries the coal near the gasifier and generates steam. Because the gasifier chamber pressure is typically less than the surrounding groundwater

pressure, a pressure gradient drives water towards the gasifier chamber, which encounters the thermal front and also converts to steam. The volume of water influx is controlled by the permeability of the strata, local groundwater pressure, and operating pressure of the gasifier chamber.

2. *Pyrolysis*: Pyrolysis is the thermal decomposition of organic material at elevated temperatures in the absence of oxygen. It occurs when the dry coal reaches 200–500°C. Volatile compounds are released and the coal turns to char. The simplified chemical equation for pyrolysis is:

$$\text{Coal} \rightarrow \text{Char} + \text{Ash} + \text{Hydrocarbons} + CH_4 + H_2 + H_2O + CO + CO_2$$

The pyrolysis occurs in a thin layer around the boundary of the gasifier chamber, just within the drying layer. The gaseous species are then free to migrate towards the open gasifier chamber, where they can participate in other reactions.

3. *Oxidation*: The volatile products and carbon-containing compounds in the char (C) react with injected oxygen. The simplified chemical reactions are:

$$C + O_2 \rightarrow CO_2$$

$$2C + O_2 \rightarrow 2CO$$

These exothermic (heat releasing) reactions release the necessary heat to drive the other, endothermic (heat absorbing) processes. The oxidation reactions (via air injection) mostly occur within the gasifier chamber itself, as oxygen is consumed near the inlet point. At the chamber wall, temperatures can reach 800–1200°C. Note that only a limited amount of oxygen is injected, just enough to produce the necessary heat and gases to drive the endothermic reactions. Steam may also be injected to provide additional water.

4. *Gasification*: The basic gasification reaction, which primarily occurs within the char layer at the gasifier chamber wall, is

$$C + H_2O \rightarrow H_2 + CO$$

The char gasification zone typically reaches 500–1100°C.

5. *Side reactions*: A number of side reactions also occur, depending on gasifier chamber conditions. These reactions can increase the methane and hydrogen content of the gas. These include:

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

$$C + 2H_2 \rightarrow CH_4$$

$$C + CO_2 \rightarrow 2CO$$

$$CO + H_2O \leftrightarrows H_2 + CO_2$$

The exact composition of the gas can be tuned (within limits) by controlling the oxidant feed rate, water injection, gas pressure, and other operational aspects.

The gas flow within the gasifier chamber is quite complex, involving factors such as reactive transport, turbulence and radiative heating. Typically, a rubble zone also forms at the bottom of the gasifier chamber, which also affects the gas flow within the chamber.

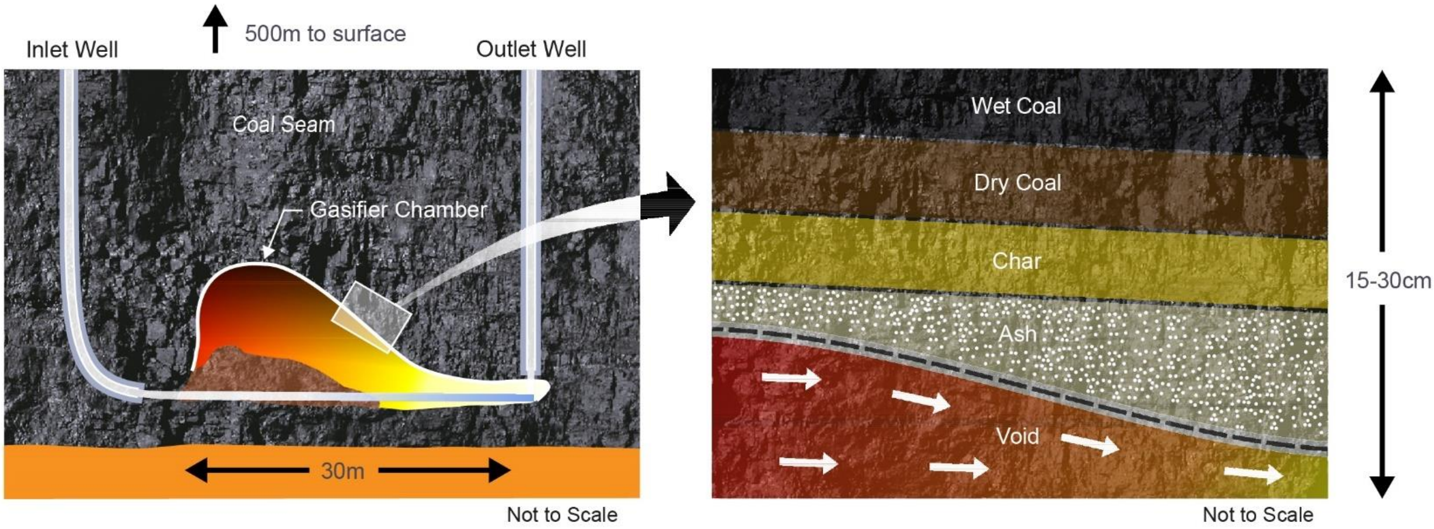

Figure 3-2: Layers in the gasifier chamber wall. The typical thickness from open gasifier chamber to saturated coal is 15 – 30 cm (heat affected zone).

The ISG process and the composition of syngas produced is similar to that produced by surface gasifiers. These have been used for many decades and processing technology for such gas compositions is readily available (Hyder 2012).

3.1.2 Gasification Chamber

As the ISG reactions proceed and coal is consumed, a chamber forms and grows in size. Growth of the gasification chamber is determined by factors such as the thickness and dip of the coal seam and turbulence of the oxidant, the arrangement of the inlet and outlet wells, the chemical makeup of the coal, oxidant type, injection rate and pressure, in situ stresses, isotropic aquifer conditions and the geomechanical properties of the coal and surrounding rocks.

The geomechanical properties of the surrounding strata determine the resistance to vertical gasifier chamber growth, which is a crucial characteristic of a good ISG site (Camp and White 2015). The potential for processes to occur such as spalling (small scale erosion of rock due to induced thermal stress) or large-scale geomechanical failure are particularly relevant. ISG projects are typically planned and operated to avoid large-scale collapse. If not designed for, large-scale collapse has the potential to suspend operations, cause surface subsidence, and open fracture pathways in the overburden (Camp and White 2015). Detailed geological characterisation and careful geotechnical design are therefore carried out to ensure that the geomechanical setting is suitable and the project design will allow safe and efficient operation.

3.1.3 ISG Products and Chemicals of Potential Concern

The ISG process generates compounds that could become contaminants if they escape the gasification chamber into the surrounding environment (Moran *et al.* 2013). Compounds that are potential contaminants (depending on background levels, where they are located and potential receptors) are termed 'chemicals of potential concern' (COPC) throughout this document, which is a terminology widely used in standard assessments of site contamination.

The compounds produced by the ISG process include compounds that are generated directly by the processes of pyrolysis, partial oxidation and gasification, and other compounds that may be generated indirectly by other physical and chemical processes.

Compounds generated directly by pyrolysis, partial oxidation and gasification are summarised in Table 3-1.

Table 3-1: Compounds directly generated by the ISG process

Phase	Group	Details
Gas phase components (non-condensables)	Major syngas constituents (concentrations of up to tens of percent by volume)	• carbon monoxide • carbon dioxide • hydrogen • water • methane • nitrogen (can be more than 40% in systems where air is injected)
	Minor syngas constituents (approx. 1% or less by volume)	• light hydrocarbons (range from ethane and ethylene compounds to volatile condensables (e.g. hexane and toluene) • hydrogen sulphide • ammonia • trace species
Condensable organic components ('tars')	Hydrocarbons	• paraffinic hydrocarbons • olefinic hydrocarbons • aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene, xylene, naphthalene) • mixed aromatic-aliphatic ring structures (e.g. tetralin, fluorene, indane)
	Oxygen-containing organics)	• phenolics • dihydroxybenzenes • trihydroxybenzenes • furans • ketones (e.g. acetone, butanone, cyclopentanone)
	Nitrogen-containing compounds	• aliphatic amines • nitrogen-containing heterocyclic organics • nitrogen-containing amines • aromatic amines (e.g. aniline)
	Sulphur-containing compounds	• carbonyl sulphide • methyl mercaptan • sulphur-containing heterocyclic aromatics (e.g. thiophen, benzothiophenes).

Source: Adapted from Camp and White (2015)

The syngas produced by the ISG process will also contain traces of other constituents, such as metals, that are naturally present in the coal that is consumed during the process.

Compounds that are generated indirectly from other physical and chemical processes can include:

- metals or organics leached from rock due to increased surface area of rock in the gasifier chamber (including particles and dust) and / or increased solubility due to elevated groundwater temperatures
- minerals and metals where solubility has increased due to changes in oxidation state within the ash and rock or changes in pH
- gases desorbed due to reduction in groundwater pressure.

During normal operation, the ISG process is contained within the immediate gasifier chamber system and products flow into the outlet well and to the surface processing facility. Within this contained process zone, many organics produced are 'destroyed' and are converted by reaction into compounds that are less potentially hazardous to the environment (Camp and White 2015).

3.1.4 Containment

The key aspect to ensuring an environmentally safe and socially acceptable ISG operation is to provide certainty of containment and/or removal of the COPC produced (Moran *et al.* 2013). COPC in gas and water produced by the ISG process will be contained within the gasifier chamber and its close confinement zone if pressure gradients are inward, or there is no path or permeability for gas to escape (Camp and White 2015, Creedy *et al.* 2001, Burton *et al.* 2013).

It is essential to manage pressures in the gasifier chamber so that the gradients driving flow are inward. However, if the pressure gradients are not properly managed, process gas and COPC carried with it can still be contained if the surrounding formation has low permeability (Camp and White 2015). This aspect of site selection provides additional assurance of containment. Best practice will choose a site with suitable (low) permeability barriers.

Appropriate well design and integrity management are also important in ensuring containment. Well design and site selection are discussed further in Sections 3.2 and 3.3

3.1.5 Shutdown and Decommissioning

Shutdown and decommissioning are achieved by stopping the flow of oxidant to the gasifier, injection of water to quench the reactions and rapidly reducing gasifier chamber pressure to increase groundwater inflow. This produces steam at the gasifier chamber margins and 'steam cleans' the chamber to remove the remaining COPC from the chamber (via the gas flow out of the outlet well) as far as reasonably achievable. The gas, steam and COPC are then destroyed by the thermal oxidiser.

The process is controlled and monitored to ensure that pressures are managed (to manage underground fluid flow) and that additional pyrolysis is minimised.

A clean shutdown procedure will remove as much of the chemical inventory as possible, that otherwise would have stayed in the underground system. Field trials and demonstrations out of the USA have provided reasonable evidence that the approach, dubbed 'clean cavern', has been successful in reducing the inventory of contaminants left underground, maximising their removal from the gasifier chamber immediately after operations, and containing them in the years after (Camp 2017, Camp and White 2015, Moran *et al.* 2013).

More locally in Queensland, the Carbon Energy Limited Bloodwood Creek UCG Trial project has been acknowledged by the Queensland Chief Scientist as having demonstrated safe and effective decommissioning in accordance with the recommendations of the final Independent Scientific Panel[6] report (Garrett 2016).

3.2 Well Design and Integrity

The inlet and outlet wells and the observation well (which will ultimately penetrate the gasifier chamber) will be drilled and constructed in accordance with Petroleum and Geothermal Energy Act requirements, and industry best practice for the construction of petroleum wells.

The design and installation of the wells ensures that their integrity is maintained under the operating conditions that they are expected to experience. Well design has been undertaken by a specialist engineering firm and ensures that the wellhead and steel casing are suitable to withstand the elevated temperatures involved.

The wells will be constructed of a series of metal casing strings that are installed and cemented into the ground to various depths. The size, strength and material of the casing and wellhead and the specifications for the cement are determined through a design process which takes into

[6] The Queensland Independent Scientific Panel for Underground Coal Gasification was established in 2013. The Panel's role was to analyse, assess and evaluate technical and environmental factors and to report the outcomes of UCG trial activities including recommendations on the prospects and future management of UCG in Queensland.

account the geological environment and operational temperatures and pressures, as well as industry standard design safety factors. Premium production casing, made of corrosion-resistant carbon steel will be used for the inlet, outlet and observation wells. Premium casing has metal to metal gas-tight seals and is commonly used in high temperature applications.

Figure 3-3 shows the expected well design for the inlet, outlet and observation wells. The wells include the following layers of casing:

- the conductor casing, which is installed at the surface and provides a clean access through the first 20 m of soil and gravel
- the surface casing string, which extends from the surface to approximately 100 m. This casing string is fully cemented up the outside and forms part of the pressure containment system providing a second barrier during construction and operations
- the production casing string, which is inside the surface casing, runs from the surface to the total depth of the well and is also cemented to surface up the outside. The production casing and cement provide the primary barrier during operations.

The surface casing and production casing are pressure tested after installation and the annulus (the space) between the casing strings is fully contained in the wellhead. The wellhead is also pressure tested during manufacture and after installation.

The wells will also have internal coil tubing installed inside the main pressure casing, which will be specific to the well's purpose. The inlet well will have an injection line from the surface to the inlet point, and may also have initiation and ancillary access tubing where required. The outlet well may also have additional access and access tubing installed inside the main pressure casing. Pressure and temperature monitoring instrumentation will be installed in the wells.

The outlet well will be vertical and be drilled prior to the inlet well. The inlet well will be vertical initially from the surface and will then be directionally drilled to enter in the coal seam at a high angle and then follow the coal seam to intersect the outlet well at a designated depth.

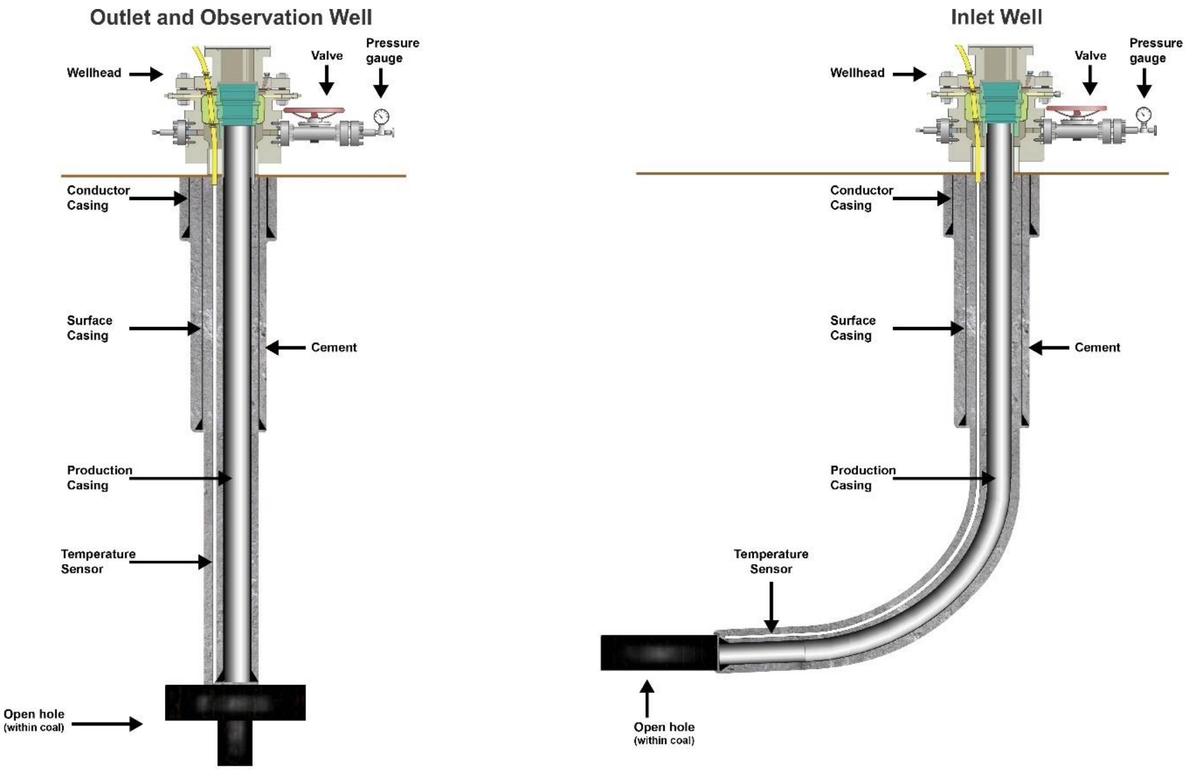

Figure 3-3: Indicative well design of inlet, outlet and observation wells

Each casing string is cemented into the drill hole. The cement isolates any aquifers (if present) along the drill hole and prevents fluid or gases moving up the drill hole outside the casing. Cement integrity is verified by observation of the cement returning back to the surface as per the design, monitoring pump pressures during the cement job and by running tools such as cement bond logs on the production casing. Casing centralisation, cement slurry design, spacer fluids, volumes and pumping parameters are also carefully controlled to ensure a good seal between the casing and the well bore.

The well sections that may be exposed to high temperatures including the inlet, outlet, and observation wells will be cemented with a specially engineered high temperature cement that resists cracking under high temperature.

Wells are pressure tested prior to commencing operations, to confirm the integrity of the casing and cement. Well integrity is managed during the operational life of the well by ongoing monitoring and testing the integrity of the valves, casing, packers, wellheads and tubing (if present), with repairs undertaken where required.

At the end of their operational life, wells will be decommissioned in accordance with Petroleum and Geothermal Energy Act requirements, which require cement plugs to be installed in the well at specified locations (usually between any hydrocarbon zones and aquifers (where present) and at the surface), and the well head to be removed.

The inlet, outlet and observation wells for the demonstration plant are likely to be retained for some time following the operation of the demonstration plant, and may be utilised as monitoring wells in the future.

Monitoring wells are also designed to meet relevant Petroleum and Geothermal Energy Act requirements and industry standards in order to ensure that they do not present a potential pathway for gas escape. However, the temperatures and pressures they are required to be designed to meet are generally less than the inlet, outlet and observation wells.

3.3 Site Selection

3.3.1 Leigh Creek Coalfield Location

The project location at the Leigh Creek Coalfield was initially chosen as a result of a screening process that evaluated potential sites around the world for an ISG project, using criteria that covered environmental, technical and commercial aspects.

The chosen location at the Leigh Creek Coalfield is highly favourable for ISG development. The coal resource is technically suitable for ISG, it is well serviced by infrastructure and most importantly, the site is suitable for undertaking ISG in a manner that is safe and minimises environmental risk.

The Independent Scientific Panel (Moran *et al.* 2013), noted that selection of an appropriate site is considered to be the most important risk mitigation strategy for an ISG project. The demonstration plant site is consistent with all the recommendations for ISG site attributes made by Moran *et al.* (2013), as discussed below (Section 3.3.3). In particular, the depth of the coal and the geology and hydrogeology of the site ensure that the ISG process can be safely contained, and the location avoids sensitive features such as aquifers with beneficial uses and values, residents or towns in close proximity, intensive surface infrastructure, sensitive land uses or sites of high environmental value.

Other favourable factors that influenced the location of the Leigh Creek Energy Project include:

- high quality existing infrastructure (road, rail, water and power)
- nearby service centre at Leigh Creek township
- strong local community and potential workforce
- extensive information base for the Leigh Creek Coalfield
- existing disturbed mine site (minimising disturbance footprint)
- distant from environmentally sensitive areas or conservation reserves.

While the location within the footprint of a coal mine that is undergoing closure and rehabilitation introduces some operational complexities, these are considered to be manageable and are far outweighed by the advantages of the site. The demonstration plant site itself is located in an area where there is expected to be minimal activity during the mine closure and rehabilitation phase.

The location of the site and surrounding features are shown in Figure 1-1 (in Section 1) and Figure 4-1 (Section 4).

3.3.2 Demonstration Plant Site

The specific demonstration plant location was chosen based on the following factors:

- the depth and dip of the coal seam is suitable for ISG demonstration
- the site is greater than 100 m from potential faults
- the site is more than 100 m from potential leakage pathways (old drill holes)
- the site is level and stable and uses existing access roads
- there is extensive existing disturbance with no environmentally sensitive features present (e.g. natural drainage (see Section 4.8), aquifers with beneficial uses and values (see Section 4.7), significant vegetation or habitat (see Section 4.9), known cultural heritage sites (see Section 4.2))
- there is limited ongoing mine-related activity at the site

- sufficient space is available to safely undertake activities
- separation of the site from the mine pits and waste rock dumps is sufficient to ensure safe operation
- the site is readily accessible from the main access road (with no need to traverse mine pits or stockpiles).

3.3.3 Recommended Attributes for ISG Sites

The Independent Scientific Panel report (Moran *et al.* 2013) recommends that an ISG site should, as a general guide, include at least the attributes outlined below (Table 3-2). The demonstration plant site includes all these recommended attributes, as indicated by the comparison in this table.

Table 3-2: Comparison of demonstration plant site with Independent Scientific Panel's recommended site attributes

ISP recommended site attributes for ISG (Moran *et al.* 2013)	Demonstration plant site	Comment
Coal seam at sufficient depth to ensure that any potential environmental contamination can be demonstrated to have minimal environmental consequences. With deeper coal, there are fewer useable aquifers and, if appropriate sealing horizons are present above the gasification depth, there is a much lower probability of materials (gas or liquid) moving to the surface.	✓	Coal is deep (approx. 540 m) with no aquifers in the vicinity.
Coal seam sufficiently thick to sustain gasification with reasonable likelihood of economic viability.	✓	Coal thickness is in the order of 12 m and considered suitable for gasification.
Rank of coal should be lignite to non-swelling bituminous coal.	✓	Coal is of sub-bituminous / lignite rank and is suitable for ISG.
Hydraulic head sufficient to contain efficient gasification.	✓	Hydraulic head above the coal seam has been measured at 490 m using data collected from vibrating wire piezometers and is sufficient to contain gasification.
Coal seam capped by impermeable rock.	✓	Coal seam is capped by 530 m thickness of low permeability carbonaceous mudstone, an aquitard with respect to groundwater.
Target coal located so that there is sufficient thickness between the target coal seam / measure and any valuable aquifer higher up the geological succession.	✓	There are no aquifers within 500 m vertically or laterally of the Demonstration Plant.
Sufficiently distant from rivers, lakes, springs and seeps to avoid contamination should chemical escape the cavity.	✓	No rivers, lakes, springs and seeps are located near the demonstration plant site (refer to Section 4.7). Pre-mining creek alignments across the broader mine site have been blocked by earthen walls, waste rock stockpiles and mine pits.
Absence of faulting or intrusions in the vicinity of the site. This is dependent on the size of the cavity.	✓	Site is located approximately 100 m south of inferred fault, which does not penetrate the full depth of the Main Series Overburden and is likely closed with respect to potential for movement of gas or groundwater.

ISP recommended site attributes for ISG (Moran *et al.* 2013)	Demonstration plant site	Comment
Sufficient distance from the nearest town and / or intensive surface infrastructure, e.g., irrigation or feedlots, and areas of significant environmental value, e.g., world heritage forests or wetlands, to avoid contamination should chemicals escape the cavity and to minimise impacts of odours.	✓	Site is over 8.5 km from Copley and 12 km from Leigh Creek township. No sensitive land-use or areas of significant environmental values are present at or near the site. (Site is within the former Leigh Creek Coalfield).

Camp and White (2015) also provide a summary of attributes of an ideal site for ISG. These ideal site attributes include adequate depth below aquifers, thick and impermeable overlying strata, absence of vertical connectivity, low dip angle (5 to 25 degrees), mechanically competent overlying rock and few faults. The demonstration plant site meets these ideal site attributes.

3.4 Demonstration Plant Design and Layout

3.4.1 Infrastructure and Equipment

The demonstration plant facilities will include both subsurface and surface infrastructure.

Subsurface infrastructure will include the inlet and outlet wells (as described in Section 3.2), a number of monitoring wells and a gasifier observation well. Inlet, outlet, observation and monitoring wells will all contain instrumentation to monitor temperature and/or pressure.

At the surface, the majority of the infrastructure will be installed adjacent to the inlet and the outlet wells, which will be approximately 300 to 350 m apart at the surface. A combination of wired and wireless instrumentation equipment will be installed to communicate between the two sites and the control room.

At the inlet well, equipment will include:

- the inlet wellhead
- piping and valves
- flow control and metering equipment
- diesel-powered compressors to inject air into the well
- pumps for water injection
- tanks for water storage prior to injection
- diesel generator(s)
- diesel storage tank(s) for compressor and generator
- electrical and control equipment
- control room
- site office and amenities
- vehicle parking
- truck off-loading area
- equipment storage and maintenance facilities.

At the outlet well, equipment will include:

- the outlet and observation wellheads
- piping, valves and pressure safety valves
- flow metering and pressure control equipment
- gas analysis and sampling equipment
- gas clean-up equipment
- condensate storage vessel and transfer pumps
- tanks for storage of outlet condensate and water

- thermal oxidiser
- cold vent
- nitrogen storage vessels (for inert blanketing of vessels and purging of pipelines)
- diesel generator(s)
- diesel storage tank(s)
- LPG cylinders
- truck off-loading and loading area
- pumps for water injection
- tanks for water storage prior to injection
- electrical and control equipment
- vehicle parking.

Where roads do not exist, all-weather access roads will be constructed to the site from the main sealed access road, between the inlet and outlet well sites, and to each of the monitoring wells.

The demonstration plant surface facilities will utilise standard oil and gas and petrochemical components. Many of these will be pre-assembled and skid-mounted to facilitate installation at the site and later removal.

Fuels, oils and chemicals will be stored in accordance with applicable standards and guidelines (e.g. AS 1940, EPA guideline 080/16 *Bunding and Spill Management*).

The sites will be fenced with stock-proof fencing to exclude larger wildlife and to control personnel access.

Figure 3-4 shows the indicative layout of the site. (Note: Maps showing the location of the site in relation to the Leigh Creek Coalfield and surrounds are contained in Section 4.4).

Figure 3-5 and Figure 3-6 show the expected layout at the inlet and outlet wells.

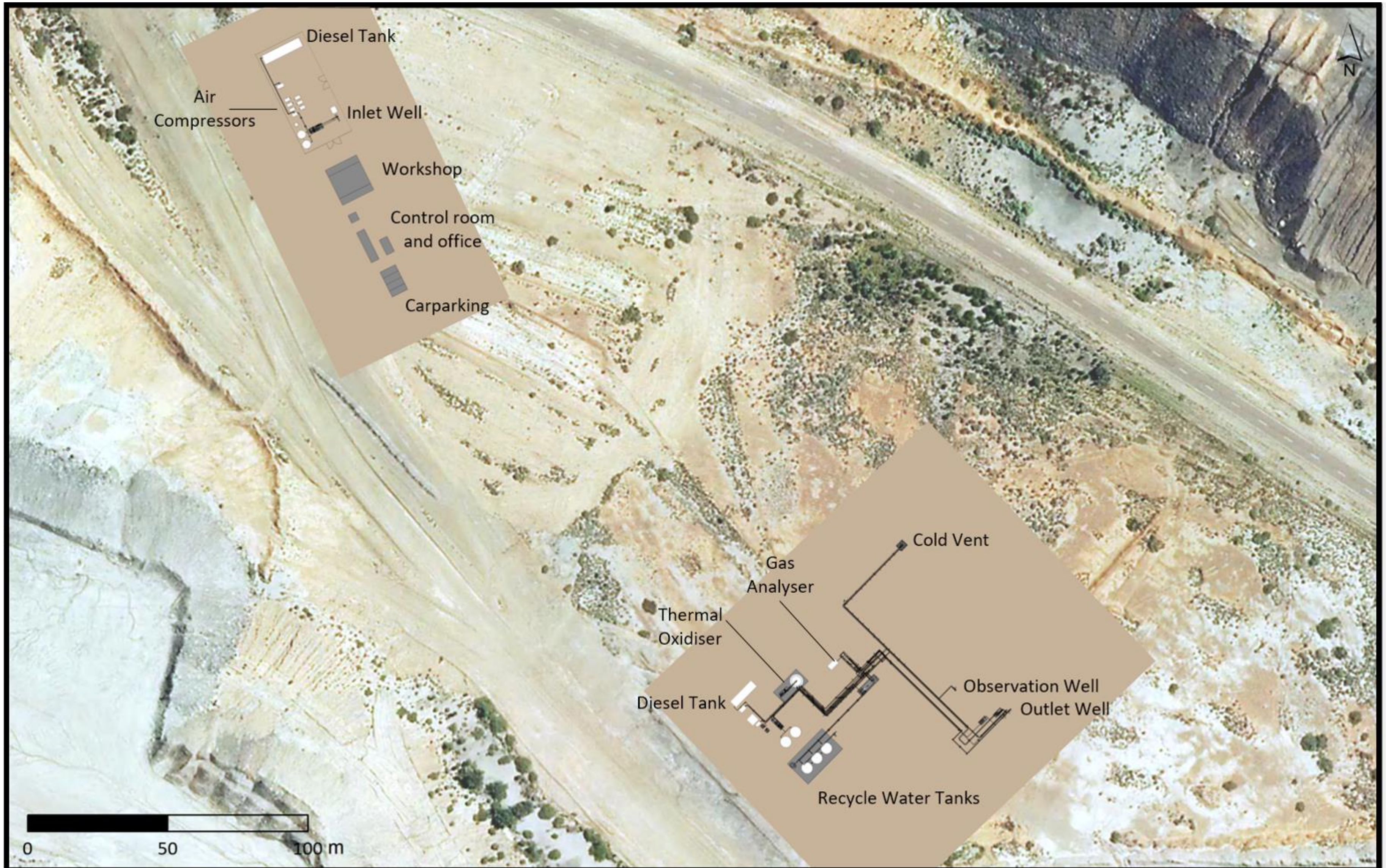

Figure 3-4
Indicative Demonstration Plant Layout

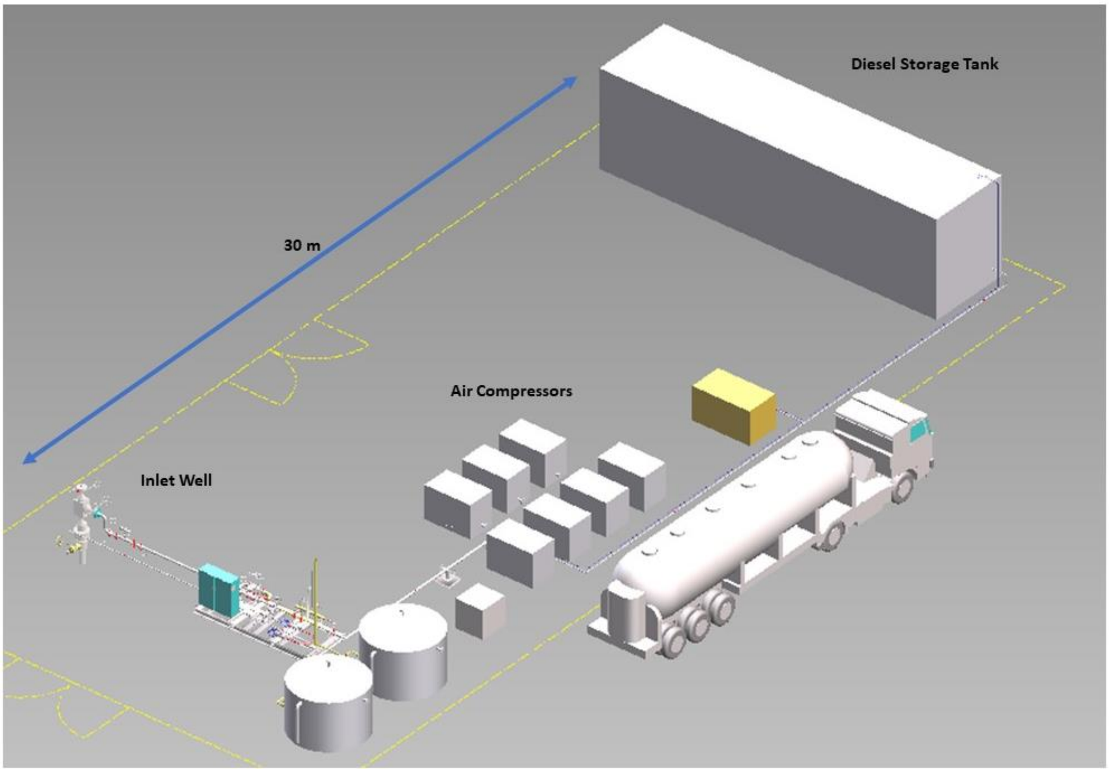

Figure 3-5: Three-dimensional model of equipment at the inlet well

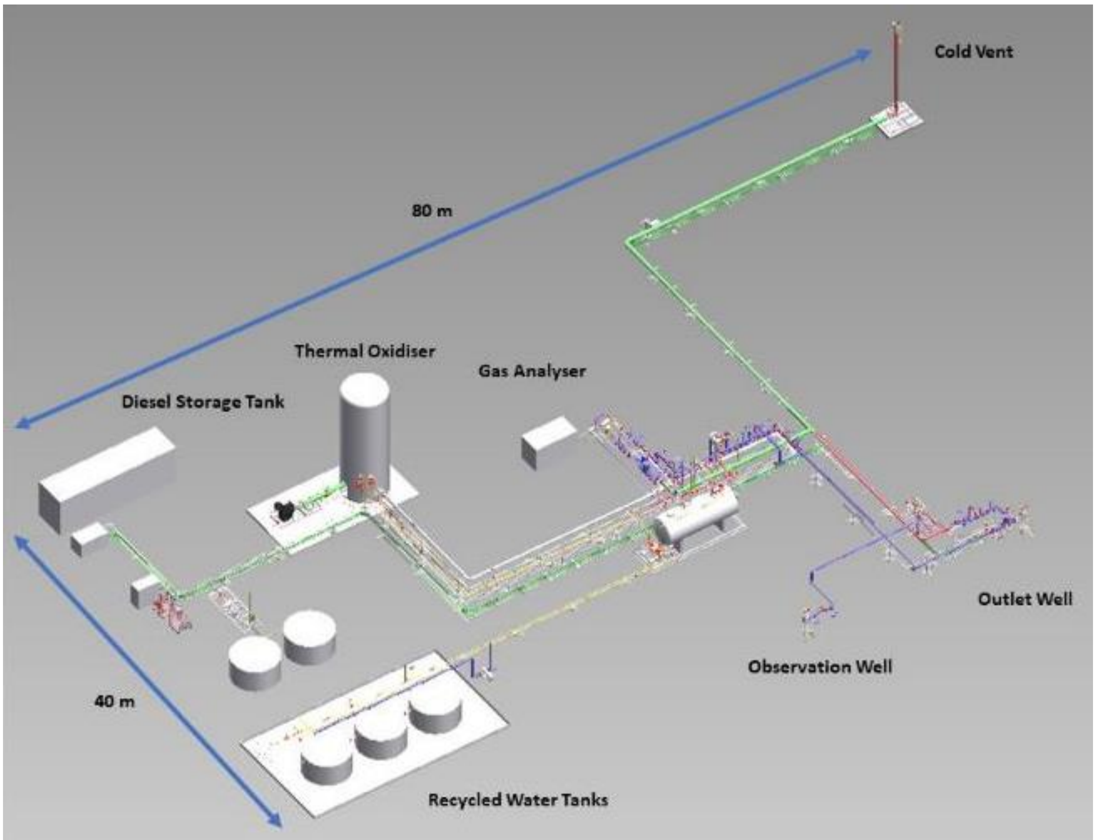

Figure 3-6: Three-dimensional model of equipment at the outlet well

3.4.2 Gasifier Arrangement

The demonstration plant gasifier chamber (the underground void where ISG takes place) will be of a single dual Linked Vertical Well type with vertical inlet, observation and outlet wells linked by directionally drilling the final inlet well section of the inlet well within the coal seam. The injection point at the end of the inlet well tubing casing will be approximately 30 m from the outlet well, within the Leigh Creek Main Series Coal seam at a depth of approximately 540 m below ground surface. This is shown in Figure 3-7.

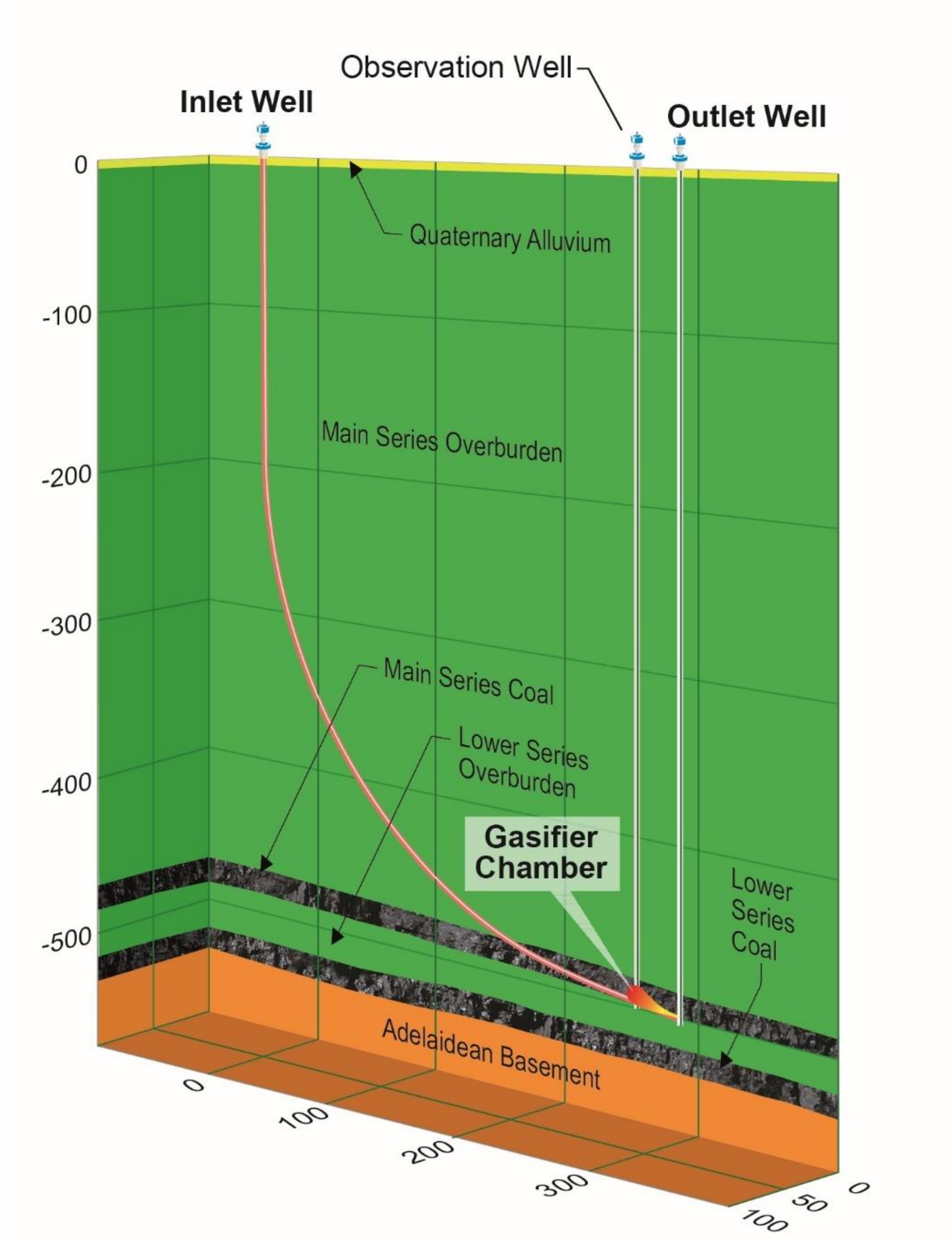

Figure 3-7: Schematic showing the depth and shape of the inlet well

The gasifier will be a single chamber gasifier, which will be operated continuously during operation of the demonstration plant.

As the demonstration plant will operate over a short time frame (2 to 3 months), the injection point will remain in the same position (i.e. it will not be retracted to allow the ISG process to access more coal as would typically be the case for commercial operation).

Based on geotechnical investigations to date and experience from previous gasification trials at other sites, the gasifier chamber is expected to be a tear drop shape in the order of 30 m by 30 m laterally and approximately 15 m in height at the end of the demonstration plant operation.

3.4.3 Demonstration Plant Design Process

The demonstration plant will be designed and operated in accordance with relevant Australian and International Standards, including those listed in Table 3-3.

Table 3-3: Selected relevant Australian and International Standards

Document Number	Title
AS1940	The Storage and Handling of Flammable and Combustible liquids
ASME B16.5	Pipe flanges and flanged fittings
AS3000	SAA Wiring Rules
AS3008	Electrical Installations – Selection of Cables
AS3788	Pressure equipment – in-service inspection
ASME B31.3	Process Piping
AS 4041	Pressure piping
AS4100	Steel Structures
AS4343	Pressure equipment – hazard levels
AS/NZ ISO 31000	Risk Management – Principles and Guidelines
AS60079	Electrical apparatus for explosive atmosphere
API STD 520 – Part 1	Sizing, selection and installation of pressure relieving devices in refineries Part 1
API STD 521	Pressure – Relieving and Depressuring Systems
API RP520 – Part 2	Sizing, Selection, and Installation of Pressure Relieving Devices in Refineries Part 2 Installation
AS1210	Pressure Vessels

The engineering design will include various Safety in Design (SID) processes to minimise hazards during construction and operation of the plant. These SID processes will include:

- Design Reviews
- Hazard and Operability (HAZOP) study
- Risk Assessments
- Safety Integrity Level (SIL) analysis
- Hazard Construction (HAZCON) study
- Bow-tie risk analysis[7] or equivalent (e.g. Layers of Protection Analysis (LOPA)).

The risk analysis and mitigation approach used in the engineering design will meet or exceed the recommendations of the Independent Scientific Panel, which recommended the following as

[7] Bow-tie is a risk assessment method similar to the LOPA method, used by the process industry to assess the adequacy of the preventative controls and mitigating strategies for an activity, and ensure that process risk is successfully mitigated to an acceptable level.

appropriate controls and strategies for ISG projects: site selection, process design, process control, critical alarms, safety instrumented systems, pressure relief systems, physical protection, plant emergency response and community emergency response.

Table 3-4 summarises how the project design addresses each of these recommended controls and strategies.

Table 3-4: Preventative controls and mitigation strategies for the demonstration plant

Control or Strategy	Description
Site selection	Site selected is disturbed, has no beneficial use aquifers, no sensitive environmental features, no sensitive land uses, is distant from nearby towns and has thick, low permeability layers above the target coal
Process design	The process system design will utilise relevant Australian and International standards for piping, vessel and valving. All systems will be designed to cater for the expected operating conditions with a factor of safety applied for design conditions. All equipment will be quality assured to meet the design conditions and pre-tested prior to operation
Process control	The plant will be automatically controlled using Programmable Logic Controller (PLC) to ensure equipment operates within the expected operating parameters
Critical alarms	Alarms will be provided from the control system, warning operations personnel that the plant is operating outside preferred targets in order for the operators to take appropriate action
Safety instrumented systems	The control system will automatically interlock or override control of equipment where undesired operating conditions occur. A Safety Integrity Analysis in accordance with AS61508 will be performed to determine where Safety Instrumented Systems are required and the Safety Integrity Level (SIL) required
Pressure relief systems	Mechanical protection via pressure safety valves will provide protection against excessive pressure. Emergency gas relief will bypass the main processing plant to a dedicated cold vent
Physical protection	Equipment will be configured to generally allow remote operation. Offices and control rooms will be located away from the main process plant. Fences will be used to control access to the process plant areas
Plant emergency response	LCK will implement an emergency response plan to cater for emergency situations
Community emergency response	The emergency response plan will cover any actions required to protect the community in emergency situations. There is a very low likelihood of an emergency situation involving the community due to the location of the site away from any populated area.

3.5 Site Preparation and Earthworks

Site preparation activities[8] will include the following:

- stripping of soil and clearing of vegetation from operational areas
- earthworks, including grading of plant areas and installation of hardstand where required
- construction of an unsealed access road from the adjacent sealed mine access road to provide a stable road base.

[8] Site preparation and installation of surface infrastructure are expected to be undertaken under a separate activity approval under an existing SEO. See Section 1.2 and 2.1.

Areas of hardstand will be graded at the inlet, observation and outlet wells. Hardstand areas may be built up above the existing surface level to minimise the potential for inundation, and additional drainage (e.g. a culvert) may be installed under the unsealed road to the lower-lying area west of the site to minimise water pooling at the site.

Ground disturbance and clearing will be limited to the minimum necessary. Topsoil will be stripped and stockpiled prior to construction for use in rehabilitation.

Minimal excavation is expected to be required as the plant components (most of which will be skid-mounted) will be designed to be installed directly on the hardstand or on concrete blocks without the need for footings where possible (with the exception of the thermal oxidiser and cold vent due to their design standards). Piping and cabling are expected to be installed on pipe supports or in a metal cable tray supported above ground on concrete or timber blocks.

Borrow pits may be established to provide hardstand and road construction material if suitable material is not available from existing sources (e.g. from existing borrow pits at the mine).

3.6 Construction

The demonstration plant will be constructed from pre-fabricated or packaged plant where possible, to minimise the amount of on-site fabrication and construction. Installation of above-ground components of the plant is expected to take 6 weeks.

3.7 Commissioning

A commissioning approach based on process engineering risk management will be implemented, as recommended by the Independent Scientific Panel (Moran *et al.* 2013). Commissioning will involve best practice for risk management in process industries using recognised process risk based methods, including all the controls to ensure that the inherent risks are minimised from the outset.

Detailed pre-commissioning and commissioning plans will be developed. The main process commissioning stage involves the following steps:

- dry-out of the gasifier chamber using compressed air (outlet flow directed to cold vent)
- insertion of initiation tool and subsequent initiation under pressure
- monitoring the composition of initial gas released to detect products of gasification with gases flowing to cold vent
- once gasification has established and oxygen levels fall to pre-determined value, the gases will be combusted in the thermal oxidiser
- ramp-up of oxidant (air) flow and on-going gas composition analysis.

Following initiation of the gasification reactions, the injection flow and gasifier chamber pressure and system performance will be monitored and adjusted in accordance with the operation and test plan regime.

The initiation tool is likely to be a thermal lance, which is a conventional casing-cutting technology used in the oil and gas industry. A thermal lance is a tool that heats and melts steel in the presence of pressurised oxygen to create very high temperatures to initiate the gasification reactions. The initiation tool consists of a long steel tube packed with alloy steel rods, sometimes mixed with aluminium rods to increase the heat output. One end of the tube is placed in a holder and oxygen is fed through the tube.

Other possible initiation tools, sourced from conventional suppliers in the petroleum industry, could include electric coil (heater) or gas torch devices. Initiation device selection will be dependent upon tool availability at the time of initiation.

3.8 Operation

Once commissioning is completed and gasification has commenced, the demonstration plant will be operated continuously for a period of approximately 2-3 months. It will be staffed on a 24-hour per day basis.

3.8.1 Process

The demonstration plant process involves the following steps. The process is shown schematically in Figure 3-8.

Injection of air and water into the gasifier via the inlet well. Air compressors (which will be diesel powered for the demonstration plant) are used to pump air under pressure into the inlet well. Water will also be injected, to provide water required for the gasification reactions and make up shortfall in availability from groundwater in the coals.

Gasification in the gasifier chamber (see Section 3.1 for discussion)

Outflow of syngas from the outlet well. Syngas flows under pressure from the gasifier to the surface via the outlet well. Valves at the surface control the pressure in the gasifier chamber and the flow rate of gas. The outlet well will allow for water to be injected at the base of the well to cool the syngas prior to its transport to the surface if required.

Separation of liquid and / or solid particulates from the syngas in the syngas clean-up equipment (a vapour-liquid separator knock-out drum). Liquid discharge (condensate) from the knock-out drum will be fed to the thermal oxidiser for destruction or to a condensate vessel for temporary storage. Condensate from storage may be destroyed in the thermal oxidiser or sent to tankage for off-site disposal if required.

Gas metering and let down. Syngas flow and pressure are recorded and syngas pressure is reduced prior to being sent to the thermal oxidiser for destruction.

Gas analysis and mass balance sampling are undertaken on a side stream of the syngas. Syngas is fed to the gas chromatograph which analyses the composition. Samples of the syngas can also be taken for trace analysis. A small flow of syngas will also be cooled to condense the water and condensable organic components in the syngas and allow sampling and analysis.

The thermal oxidiser will be used to oxidise gases before release. Thermal oxidisers are used for pollution control of industrial gas streams; decomposing hazardous air pollutants and volatile organic compounds by thermal combustion at high temperature. Hydrocarbon based pollutants are chemically oxidised to form carbon dioxide and water. Excess water from the process may also be disposed of through the thermal oxidiser. The thermal oxidiser will allow for disposal of syngas even at low flow rates. Diesel fired burners will also be included to maintain the temperature required for destruction of the syngas under all foreseeable operating conditions.

The cold vent will be installed to vent syngas in system upset conditions or emergency situations or if the thermal oxidiser is off-line. The cold vent may also be used for brief periods during initiation or shutdown procedures. Venting during gasifier initiation is required to let oxygen levels in the syngas drop below levels where a potentially explosive mixture could be present in the surface equipment. A pilot gas ignition source will be incorporated into the cold vent design to enable the syngas to be combusted, which will be utilised in the event that the thermal oxidiser is not available and in accordance with standard operating procedure which details Abnormal or Emergency Situations.

Most of the scenarios that would require use of the cold vent during operations (e.g. detection of high oxygen concentrations, process trips (e.g. high pressure or temperature)) are expected to have a duration in the order of 30-60 minutes and if they occur, would be infrequent. The thermal oxidiser is a high reliability system and is expected to operate for the duration of the demonstration without requiring major maintenance (i.e. being shut down). Minor maintenance of the unit, which could be required during commissioning, would typically require venting for less than 60 minutes. If venting for extended periods is required (e.g. in the unlikely event that the thermal oxidiser requires major maintenance), ignition of the flow from the cold vent using the pilot gas ignition source would significantly minimise the potential for odour. A supplementary fuel (LPG) is included in the design of the cold vent ignition system to allow combustion of low calorific value syngas. If the thermal oxidiser was to be unavailable for a prolonged period, flow rates would be reduced and an assessment undertaken to decide whether the gasifier operation should continue, based principally on capacity for storage of produced fluids (as well as any potential for odour impacts).

3.8.2 Process Control

The process will be monitored and controlled on site by LCK operators and engineers. Process control and operation of all components will allow both automatic and manual control. Automated and manual emergency shutdown will be provided where needed on the demonstration plant.

During the operation of the demonstration plant, process parameters such as water and air injection rates and gasifier pressures will be varied to investigate the performance of the gasifier under varying conditions. This will be carried out in accordance with a testing schedule developed during the detailed design phase.

Intensive monitoring will be carried out to monitor process and environmental parameters. Monitoring is discussed further in Section 3.10. Air and water injection rates, gasification temperature and pressure in the downhole and surface equipment will be the main parameters used in control of the gasification process.

A number of control actions will override the operation if the plant parameters move outside the desired operating range. For example, the control system will override air injection if the gasifier pressure or temperature rises above the pre-defined set-point.

The plant will have provisions for emergency shutdown (ESD) which will shut off injection of oxidant and divert gas from the outlet well to the cold vent. The ESD system covers the inlet (oxidant injection) and outlet end plant sections. When activated, the ESD system will place safety critical instruments into fail safe position. The philosophy of the ESD system is described below:

- Injection ESD: The philosophy of the injection ESD is to isolate oxidation air and water from the gasifier, resulting in cessation of ISG reactions.
- Plant ESD: The philosophy of the Plant ESD is to isolate the outlet end plant from the gasifier and direct gasifier flow to the cold vent for disposal as well as initiating the injection ESD.

As noted in Section 3.1, the ISG reactions will quickly cease without the injection of oxidant.

After the demonstration plant has run for an appropriate length of time to gather adequate data on performance of the process in the Main Series Coal, the gasifier will be shut down. A **trial restart** of the gasifier may be carried out, in order to gather data that will be relevant for future operations. The restart process will be similar to the commissioning process described in Section 3.7.

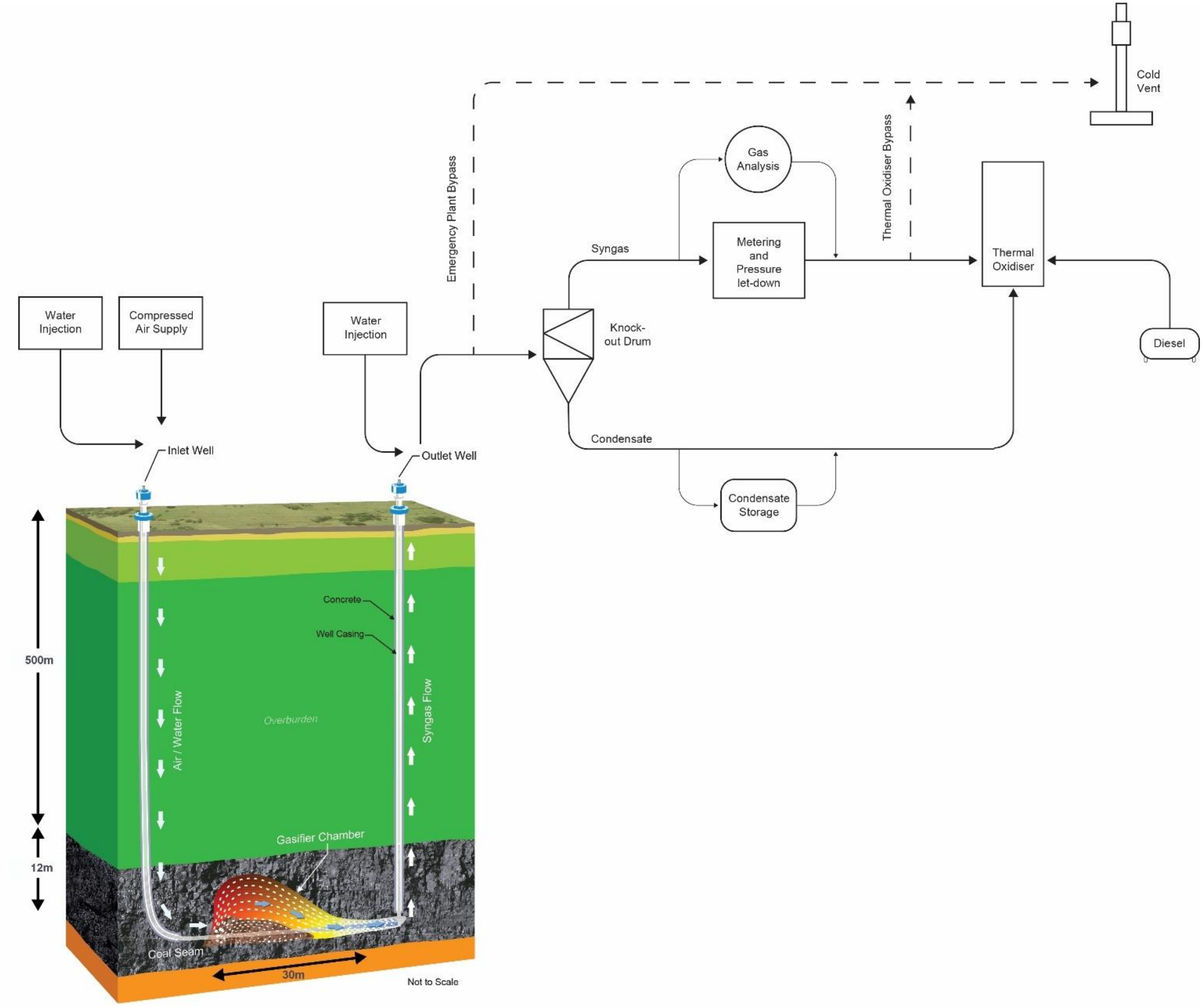

Figure 3-8: Demonstration plant overall process

3.8.3 Expected Syngas Composition and Flow Rate

Table 3-5 summarises the expected composition of the syngas that will be produced, based on analysis of the coal and modelling. Confirmation of syngas composition under varying conditions and over the life of the gasifier is one of the prime objectives of demonstration plant operation, as noted in Section 1; consequently, concentrations of various components may vary from the values shown.

Table 3-5: Expected composition of syngas produced by the demonstration plant

Property	Units	Min	Max	Normal
Hydrogen	Vol %	5	25	22.0
Methane	Vol %	1	15	2.9
Carbon Monoxide	Vol %	2	15	10.7
Ethane	Vol %	0	2	<1
Ethylene	Vol %	0	2	<1
Hydrogen Sulphide	Vol %	0	0.06	0.03
Oxygen	Vol %	0	20 (dry-out purging)	<1
Carbon Dioxide	Vol %	5	50	17.5
Nitrogen	Vol %	35	45	41.3
Water	Vol %	0	30	10
Condensate	w/w %	0	10	4.0
Temperature	ºC	50	325	200
Pressure	barg	20	35	30

The expected flowrate of syngas is 10,000 Sm^3/h on average with a maximum of 18,000 Sm^3/h (standard conditions are referenced to 0°C and 1 atmosphere pressure).

3.9 Decommissioning and Rehabilitation

Once the demonstration plant has generated the necessary data, injection of air will be stopped and the gasifier will be decommissioned as described in Section 3.1.5. Syngas will continue to be analysed and processed at the surface as syngas outflow slowly declines. Downhole temperature and pressure will be monitored throughout decommissioning.

When gasification reactions have ceased (which is expected to take no more than 48 hours) the outlet well will continue to be used to allow syngas to flow to the surface. This syngas, through the steam cleaning process described in Section 3.1.5, will carry some of the COPC out of the gasifier chamber. The syngas and any COPC produced will be destroyed in the thermal oxidiser. Once the gasification processes have ceased, the chamber is expected to contain mostly residual carbon dioxide, an inert gas. Once the flow rate and gasifier pressure reaches a target low level, the wells will be shut in. Water will be allowed to return to the chamber and regular samples taken if technically feasible.

Additional investigations to provide further data to inform potential future commercial operations may be undertaken within several months to several years of shut-in of the gasifier chamber, including:

- A drill rig may re-enter the observation well to core through the ash pile at the base of the gasifier chamber. The core samples would be tested for COPC and physical properties.

- Geophysical logging of the observation and outlet wells to assess the performance of the selected casing and grouts.
- Geophysical imaging techniques such as seismic, electrical techniques or other techniques may be used to image the chamber from surface.
- Geophysical and optical imaging techniques may be used in the observation and outlet wells.

When no longer required, infrastructure at the surface will be removed and the site rehabilitated. The surface will be reprofiled and stockpiled topsoil will be respread. Any areas of contamination (e.g. from spills) will be managed consistent with the principles of the NEPM[9] and relevant EPA guidelines.

Equipment removed from the site will be disassembled and inspected for corrosion and wear. Where suitable for reuse it will be stored either on site at a designated laydown area, or off site. Equipment that is not suitable for reuse will be transported to an appropriately licensed facility for recycling (where possible) or disposal.

The wells will remain in place until they are no longer required for monitoring duties, at which time they will be decommissioned in accordance with Petroleum and Geothermal Energy Act requirements. The well decommissioning program will include placement of a cement plug in the surface casing, removing the well head, cutting the casing off below ground level and installation of an above ground plaque. Decommissioning programs are submitted to DPC for prior approval.

3.10 Monitoring and Data Collection

A large amount of data will be collected during the lifecycle of the demonstration plant, encompassing both technical performance and environmental aspects as part of a robust quality assurance program. The main stages of the project include the baseline (site characterisation), pre-commissioning (construction and testing), operations, and post-operation (closure and monitoring).

During these stages, various monitoring and data collection activities will occur on the in situ gasification performance of the Main Series Coal, groundwater information, environmental data and geotechnical data for verification and future interpretation, and planning and design of a possible commercial facility. An important aspect of the planned monitoring is to demonstrate that there has been containment of COPCs generated by the ISG process within the gasifier chamber.

The planned monitoring and data collection is summarised below.

Stratigraphy: Detailed logging of the drill core as part of baseline studies will provide information on the various rock units that occur above, within and below the demonstration plant site. This will enable the optimum siting of the demonstration plant, demonstrate that low permeability rock formations are continuous laterally and vertically and provide information on potential geological structures such as fractures, faults and other discontinuities that could impact the performance of the demonstration plant and migration of COPC.

Coal analysis: Laboratory analysis of the drill core will be undertaken as part of baseline studies to determine the basic gasification potential of the coal at the project, model gasification behaviour, and relate gasification results to testwork plan outcomes.

Geotechnical test work: Geotechnical drilling has been undertaken as part of a current drilling program to provide information to allow further assessment of rock conditions adjacent to the

[9] *National Environment Protection (Assessment of Site Contamination) Measure (1999)* amended in 2013

gasifier and to also allow the recovery of geotechnical samples for testing. In addition, each section of core has been carefully examined, photographed and geotechnically logged to allow an understanding of the condition of the geological defects, potential presence of faults, shears or adverse geological features.

Near surface settlement markers will be installed prior to commissioning and will be monitored by way of high resolution survey during operation of the gasifier and decommissioning to assess whether settlement, attributable to the demonstration plant, occurs.

Post-decommissioning access of the chamber via the pre-drilled observation well is proposed if technically feasible to monitor the actual configuration of the chamber (top height, geometry and location) for comparison with expected geometry and for use in design of the commercial operation.

Groundwater quality: The chemistry of groundwater in the demonstration plant area will be assessed by sampling and laboratory analysis for a range of chemicals prior the commencement of site activities. Sampling and analysis will also be undertaken for a range of diagnostic chemicals which are indicative of ISG operations during the operational stage and continue into the post-operational stage to confirm that site activities have not caused the introduction of COPC from the ISG process to groundwater that could result in an adverse impact on the environment and third party users of groundwater. Groundwater quality monitoring also provides for the detection of COPC and implementation of corrective action, in the unlikely event of escape from the gasifier area.

A groundwater monitoring plan will be developed which will specify the location, depth, frequency and analytical suite for groundwater monitoring, detail the water quality parameters for reporting and outline the methodology for assessing whether there has been an adverse impact on background water quality. Monitoring wells are planned to include:

- sentinel monitoring wells located in and adjacent to the coal seam approximately 50 m laterally from the gasifier upgradient and downgradient
- sentinel monitoring wells located in the Main Series Overburden above the gasifier at approximately 80 m below the surface.

A monitoring well (referred to as the operational monitoring well) will also be installed as close as possible to the gasifier chamber to provide information on the environment immediately adjacent to the chamber. This well (which will be designed and constructed to manage the potential pressures and temperatures expected within the chamber) is intended to be within the area where changes are likely to occur and would not be used for assessing achievement of environmental objectives.

Monitoring is expected to continue for a period of three years, with sentinel monitoring wells sampled monthly for 12 months, if stable reducing to quarterly for 12 months, and then six monthly for 12 months. The operational monitoring well is planned to be sampled weekly during operations, reducing to monthly after three months post shutdown, and then following the same frequency as the sentinel monitoring wells thereafter. At the end of three years if the operational monitoring well and sentinel wells show that groundwater quality has not been adversely impacted then monitoring will cease.

Groundwater pressure: Real time monitoring of the groundwater pressure will be undertaken in monitoring wells surrounding the demonstration plant (see Figure 3-9) during baseline, pre-commissioning, operation and post-operation to confirm that the groundwater pressure around the demonstration plant is higher than the operating gasifier pressure in order to avoid outward pressure gradients which could cause COPC to migrate away from the gasifier.

Groundwater temperature: Monitoring of temperature in the monitoring wells will be undertaken to provide baseline data during pre-commissioning, operation, and post-operation to provide an indication of the lateral and vertical extent of heating as initial studies have suggested that heating of the rock mass can cause changes to the rock mass, such as delamination, and cause a change to the solubility of the COPC.

Soil chemistry: The near surface soils in the demonstration plant area will be sampled and laboratory analysis undertaken for a range of chemicals prior to the commencement of site activities to determine existing baseline conditions. Following completion of site activities, the near surface soils in the demonstration plant area will be re-sampled and laboratory analysis undertaken to confirm that site activities have not resulted in an increase of COPC that could cause an adverse impact on the environment.

Soil vapour: Soil vapour monitoring wells will be installed in the demonstration plant area (see Figure 3-9) to enable sampling of gases in the sub-surface, initially to provide baseline information on gases that may be present naturally (baseline levels), pre-commissioning, during operation, and post-operation to provide information on whether there has been any migration of gases from the gasifier.

Air quality: Real time monitoring of wind intensity and direction is proposed to be undertaken throughout the project and visual monitoring undertaken to assess dust generation due to operations. The integrity of piping will be tested prior to commissioning through pressure testing to ensure the risk of fugitive emissions is minimised. Occupational monitoring of gases during commissioning and operation of the demonstration plant will be undertaken using hand held monitors to detect levels that could impact occupational health. Ambient air quality and odour measurements will be undertaken at locations around PEL 650 and at selected sensitive receptors on several occasions throughout the project lifecycle.

Operating Conditions: Temperature, pressure and flow in the inlet and outlet wells will be measured and used in control of the gasifier, and to ensure operating conditions for the gasifier and above ground plant are maintained within design limits. Temperature and pressure will continue to be measured post operations as part of the decommissioning and closure.

Syngas composition: Data on syngas chemical composition will be collected during operations under varying conditions to correlate modelled coal gasification performance (based on coal analysis data collected during the baseline), to understand the performance of ISG for the deposit, and to provide the major and minor gas constituent analysis for determination of gas processing and handling requirements during a commercial scale gasification project.

Mass balance: Mass balances will be performed during operations using the measured flows and syngas composition to back-calculate the amount of coal being gasified.

Planned monitoring and data collection are summarised in Table 3-6.

<u>Rationale for Groundwater Monitoring Frequency</u>

As groundwater movement through formations around the gasifier is likely to be very slow (a few millimetres to a few metres per year), it is highly unlikely that any detection of COPC from a gasifier loss of containment will be made using a groundwater quality monitoring program. Since groundwater pressure changes can be transmitted through the formation much faster than groundwater flow and chemical movement, real time monitoring of the gasifier will be undertaken using vibrating wire piezometers (VWPs) installed in wells around and above the gasifier.

In the event of a potential loss of containment, water quality in the operational monitoring well (which is installed as close as possible to the gasifier chamber) can be used to assess the rate and magnitude of any COPC release to the formation. This well will not be used for assessing achievement of environmental objectives , but rather as an indicator well, as it would be located within the operational zone of influence.

The sentinel monitoring wells (installed at a distance of approximately 50m laterally from the gasifier) are intended to detect any change in COPCs relative to background in the event of a potential loss of containment before they move beyond the 100 m operational zone.

On this basis the proposed groundwater monitoring frequencies are:

- groundwater pressure (piezometer) wells – VWP data will be collected continuously and reviewed live. Any sustained increase in pressure in the VWP network will trigger a review and response action for gasifier operation
- operational monitoring well - water quality sampling will occur weekly and results reviewed in the context of gasifier operations, VWP data, and background well data
- sentinel monitoring wells – water quality sampling will occur monthly and be reviewed in the context of background well data and to identify if there are any significant changes over the seasonal cycle.

Table 3-6: Demonstration plant project lifecycle monitoring and data collection

	Frequency	Project Lifecycle Stage			
		Baseline	Pre-Commissioning	Operation	Post-Operation
Stratigraphy	Once	✓			
Coal analysis	Once	✓			
Geotechnical test work	Pre and post operations	✓			✓
Groundwater quality	Monthly* (weekly in operational monitoring well)	✓	✓	✓	✓
Groundwater pressure	Continuous, real time	✓	✓	✓	✓
Groundwater temperature	Continuous	✓	✓	✓	✓
Soil chemistry	Pre and post operations	✓			✓
Soil vapour	Monthly*	✓	✓	✓	✓
Air quality	Monthly*	✓	✓	✓	✓
Inlet well pressure	Continuous			✓	✓
Outlet well pressure	Continuous			✓	✓
Inlet well temperature	Continuous			✓	✓
Outlet well temperature	Continuous			✓	✓
Air and syngas flow	Continuous			✓	
Injection water flow	Continuous			✓	
Syngas composition	Continuous			✓	

* Monthly sampling during operations. Will reduce following the completion of site activities.

Figure 3-9 Indicative Monitoring Well Locations

3.11 Other

3.11.1 Water Supply / Use

The ISG process is expected to require in the order of 0 to 8 kL of water per hour to supplement the water that is present in the coals, and to assist with cooling the syngas prior to entering the outlet well. This requirement will be investigated further by hydrogeological investigations into the Main Series Coal and will be confirmed during the operation of the demonstration plant by undertaking a series of trials to assess the optimal water flow rate within the parameters of the available water supply.

Water for injection is expected to be sourced from the existing mine industrial catchment (i.e. the same water used currently to water roads) with potable quality water potentially supplied by a third party supplier (such as SA Water or others) injected into the outlet well as well as used for cementing of wells. Water will be either trucked to the demonstration plant site and stored on-site in tanks, the capacity of which will be equivalent to approximately two days' supply, or supplied from a pipeline joining the SA Water pipeline feeding the Flinders Power offices.

Potable water for use in the site office and ablutions block will be transported by truck from Leigh Creek or the Flinders Power mine supply and stored in tanks on site (as described above).

3.11.2 Power Supply

Power will be supplied by diesel generators at the site. It is expected that there will be generators at both the inlet and outlet wells, each of approximately 200 kVA capacity.

3.11.3 Waste Management

A range of wastes will be generated during the proposed operations. Expected wastes are summarised in Table 3-7.

As the demonstration plant will only operate for a short timeframe, the quantities of waste generated during the demonstration will be relatively limited.

Generation of domestic waste (e.g. food waste and packaging, paper, plastics, cans and glass) will be limited as personnel will be accommodated off site (see Section 3.11.6). All domestic waste will be disposed of at the Leigh Creek Township EPA licensed landfill (which is currently operated by The Outback Communities Authority).

Waste streams will be segregated on site and collected and stored in covered bins before being transported to appropriate facilities for reuse / recycling (where possible) or disposal. Waste management practices will be guided by the principles of the waste hierarchy (i.e. avoid, reduce, reuse, recycle, recover, treat, dispose).

Table 3-7: Typical waste streams and their management

Waste Type	Disposal Options
Domestic Waste	
Sewage and grey water	Collected in an approved holding tank, periodically emptied and removed for disposal by a licensed contractor.
Food waste	Collected for disposal to licensed facility.
Paper and cardboard	Collected at the site for recycling where possible or disposal to licensed facility.
Plastic, glass and cans	Collected at the site for recycling where possible or disposal to licensed facility.

Waste Type	Disposal Options
Non-domestic Waste	
Maintenance waste (oil, rags, filters)	Collected for disposal to licensed facility.
Chemical bags and cardboard packaging	Compacted and collected at site for disposal to licensed facility.
Scrap metals	Collected in designated skip for recycling or to licensed facility.
Used chemical and fuel drums	Collected in designated skip for return to supplier or recycling.
Used filters	Collected for disposal to licensed facility (following analysis of captured particulates from the gas stream where relevant).
Chemical wastes	Licensed waste depot or return to supplier.
Timber pallets	Recycled or licensed disposal facility.
ISG Products	
Syngas	Thermal oxidation
Condensate	Thermal oxidation
Produced water	Thermal oxidation or used as cooling water in inlet and outlet wells.
Impacted soil (if required e.g. from spills or leaks)	Bioremediation on site as required and reuse or disposal off-site to licensed facility.

3.11.4 Fuel and Chemical Storage and Management

A variety of fuels and chemicals will be required for the proposed operations. These include fuel (diesel), oils, paint, solvents and corrosion inhibitors. Fuel, oils and chemicals are stored in accordance with applicable standards and guidelines (e.g. AS 1940, EPA guideline 080/16 *Bunding and Spill Management*), typically in approved containers in lined bunded areas or on self-bunded pallets.

Approximately 170,000 L of diesel will be stored on site to provide fuel for the compressors, generators and thermal oxidiser. This will be stored in accordance with AS 1940, in bunded tanks or double-skinned tanks. Drip bunds will be used under hose connections during refuelling. Diesel transfer will be performed by appropriately trained personnel from reputable diesel suppliers.

Total diesel use over the period of operation of the demonstration plant is expected to be in the order of 1.1 ML.

3.11.5 Spills and Emergency Response

Appropriate spill containment and clean-up equipment will be maintained on site, including chemical and hydrocarbon spill kits. If spills occur they will be contained, reported (internally and to regulatory agencies where required) and cleaned up by treatment in situ or elsewhere on the demonstration plant site where appropriate, or by removal off-site for treatment or disposal. A spill response and emergency response plan will be in place detailing actions to be taken to minimise the impacts of accidents and incidents. In relation to the emergency response services in the region, the following are also available:

- Leigh Creek Country Fire Service (CFS) and State Emergency Services (SES): fully equipped Fire appliance including Breathing Apparatus (BA) with HAZMAT and road crash rescue capabilities and trained volunteers
- Leigh Creek South Australian Ambulance Service SAAS: fully equipped Ambulance and trained volunteers

- Leigh Creek Health Services: medical clinic staffed by two fulltime, remote-area nurses, providing a 24/7 on call service. The Leigh Creek Health service also provides a General Practitioners service once weekly.
- Leigh Creek South Australian Police (SAPOL): fulltime staffed police station
- Royal Flying Doctors Service (RFDS): emergency flights based out of Adelaide and Port Augusta
- Hawker Memorial Hospital: fully operational regional hospital, 156 km south of Leigh Creek, providing both medical and surgical hospital services
- Flinders Power (currently available on site) Volunteer Emergency Response Team: fully equipped Ambulance, fully equipped Fire Appliance, HAZMAT Response.

In addition, LCK provides an auto defibrillator, remote-area first aid kits, portable burns kit and portable eyewash station. LCK also plans to have a least one staff member on site, who is trained to Occupational First Aid level (as a minimum) at all times.

3.11.6 Workforce and Accommodation

A workforce of approximately 15 to 20 will be required during construction and commissioning of the demonstration plant. This will reduce to approximately 15 during operation.

The workforce will be accommodated in existing accommodation at Leigh Creek and/or Copley.

3.11.7 Access and Transport

The site will be accessed via the sealed public road network and the sealed main access road into the Leigh Creek Coalfield.

The demonstration plant equipment will be delivered to site via the road network. With the exception of the thermal oxidiser, all components are expected to be able to be transported as standard loads and significant disruption or closure of roads will not be required. The thermal oxidiser will be an oversized load and will be transported in accordance with any necessary permits obtained under the *Road Traffic Act 1961.*

During operation of the demonstration plant, traffic will largely be restricted to light vehicles with a limited number of truck movements required, primarily for fuel deliveries and transport of water or waste.

3.12 Integration of Learnings from Previous Projects

Approximately one hundred experimental, pilot and demonstration ISG operations have been undertaken globally in the last eighty years (Hyder 2012, Camp and White 2015, Burton *et al.* 2013). These have shown the process to be technically feasible, and over this time the technology and understanding of the process has continually improved (Camp and White 2015).

The potential for adverse impacts to groundwater is recognised as a key risk for ISG. Historical experience with ISG includes a small number of cases in which serious groundwater contamination occurred and many cases with little to no environmental impact (Camp and White 2015, Burton *et al.* 2013). The demonstration plant project will apply learnings from previous ISG projects to ensure that environmental risks are identified and appropriately managed, and that the project does not result in significant adverse impacts.

In particular, the project will follow the recommendations of the Independent Scientific Panel (Moran *et al.* 2013) and other recently published information (e.g. Hyder 2012, Camp and White 2015, Camp 2017). All publicly available results and reports of recent pilot projects in Queensland have also been reviewed by LCK personnel, and learnings have been incorporated into the design of this project.

A key aspect of the Leigh Creek Energy Project that differentiates it from the Queensland pilot projects is site selection. As discussed in Section 3.3, the demonstration plant site in the Leigh Creek Coalfield is considered highly suitable for ISG, and the factors that have been raised as issues in some of the Queensland trials (e.g. shallow depth of coals, sensitive land use and presence of aquifers with beneficial uses) do not occur at the Leigh Creek site. In addition, techniques that have been raised as potentially problematic in some Queensland pilots, such as fracturing of the coals to create a pathway between inlet and outlet wells, will not be used for this project (instead, inlet and outlet wells will be linked by directionally drilling the final section of the inlet well within the coal seam).

As noted previously (Section 3.1.5), the Carbon Energy pilot in Queensland did meet the recommended requirements of the Independent Scientific Panel, and demonstrated safe and effective decommissioning of the pilot panel (Garrett 2016).

3.13 Future Strategies for Greenhouse Gas Management

Developing suitable strategies for management of greenhouse gases, particularly carbon dioxide (CO_2), will be an important element in planning for any future commercial-scale ISG development.

A key outcome from the demonstration plant is an understanding of the composition of the gases produced, their volumes, temperature, pressure and flowrates. The information developed on CO_2 production will allow LCK to identify the most appropriate mitigation strategies and CO_2 capture technology for any future development.

There are a number of CO_2 mitigation strategies that will be assessed once the required data is obtained from operating the demonstration plant, including geological sequestration in disused gasifier cavities underground, use in the production of urea (a valuable fertiliser), or combination using waste heat to form liquid fuels. These are discussed further below.

<u>Sequestration</u>

Geological sequestration of CO_2 involves the emplacement of CO_2 deep into the ground where it cannot move back to the surface. While it is yet to be investigated for technical viability at the Leigh Creek site, two opportunities for storage at the site exist, these being within disused gasifier cavities using the installed pipework and drillholes, or deeper into the fractured basement underlying the coal formations.

The carbon capture process usually involves four stages:

1. CO_2 is captured and separated from industrial emissions
2. CO_2 gas is compressed into a liquid-like form
3. CO_2 is transported along a pipeline to a suitable storage site
4. CO_2 is injected deep underground into secure geological formations for long-term storage.

LCK holds Gas Storage Exploration Licence 662 (GSEL662) under which it intends to explore for and test the suitability of geological sequestration of CO_2 at the Leigh Creek site. LCK would look to partner with specialist bodies such as the CSIRO, which has a National Geosequestration Laboratory in Perth and/or the Global Carbon Capture Institute in Melbourne.

<u>Urea production</u>

One of the potential commercial product streams that will be assessed on completion of the demonstration plant will be the production of ammonia and ammonia products (urea).

Urea accounts for almost 50 per cent of the world's nitrogen fertiliser production. It is produced by combination of ammonia and CO_2 at high pressure and temperature. Urea production is considered a 'captive' use of CO_2 (i.e. CO_2 is produced and then used within the same industrial process). Urea can also be used to produce urea-ammonium nitrate (UAN) one of the most common forms of liquid fertiliser.

Forecast total worldwide urea fertiliser demand in 2018 is anticipated to be 200 million metric tonnes, with approximately 1.9 million tonnes is used in Australia, 1.7 million tonnes of which is imported.

Fuel production

Using waste heat from other processes on the site, CO_2 can be readily converted to fuel products using the Sabatier reaction in which CO_2 combined with hydrogen creates methane and water. This has been demonstrated by Carbon Recycling International (outside Reykjavik in Iceland) who have developed methanol from CO_2 emissions from a power station combined with hydrogen obtained from electrolysis of water.

Besides use as a liquid fuel, methanol can then be converted to formaldehyde, which is further treated to form resins, glues and various plastics, and for the production of acetic acid which is then used for the production of polyester fibres and PET plastics.

Forecast total worldwide methanol demand is likely to surpass 95 million metric tonnes by 2021, with approximately 1.5 million tonnes is used in Australia, all of which is now imported.

4 Existing Environment

4.1 Overview

The proposed demonstration plant site is located within the Leigh Creek Coalfield in northern South Australia. Coal was initially discovered at Leigh Creek in 1888 and intermittent testing and mining took place with limited success over the next 55 years. Open cut mining officially commenced in 1943 under the management of the Engineering and Water Supply Department (EWS) until the Electricity Trust of South Australia (ETSA) took control of the Coalfield in 1948 as part of the process of developing the Port Augusta Power Station.

The Leigh Creek Coalfield was originally defined as comprising three distinct basins; Copley Basin (Lobes A and E), Telford Basin (Lobe B) and Northfield Basin (Lobes C and D). Three of these Lobes (Lobes B, C and D) have been actively mined. The Copley Basin (Lobes A and E) were not included in any mining operations and are excluded from LCK's PEL 650.

Open cut mining commenced in 1943 in Lobe B, which was known as the 'Telford Open Cut'. Mining at Lobe D and Lobe C to the north began in 1948 and 1963, respectively. These deposits were mined until September 1977 using conventional open cut mining methods with overburden broken by blasting, and dragline cuts into coal.

The coalfield was enlarged after the decision in the 1970s to build an additional power station at Port Augusta. This involved new methods to extract deeper coal, increasing production, building a retention dam to divert Leigh Creek and prevent possible flooding of the field and diverting the main highway around the coalfield. The Leigh Creek township was relocated from the coalfield to its current location. Open pit strip mining was employed at the pits on Lobes C and D of the Leigh Creek Coalfield until the early 1990s when the terrace (or haulback) mining method was adopted to extend the life of the Lobe B mine (PIRSA 1997).

Mining ceased in November 2015, following a decision by Alinta Energy to close the mine as it had become uneconomic. Flinders Power Partnership (previously a subsidiary of Alinta Energy) is currently undertaking closure activities at the Leigh Creek Coalfield.

The Leigh Creek Coalfield includes the following components, which are shown in Figure 4-1:

- Lobe B (the Telford Basin) which is the largest and deepest of the basins in the coalfield; it encompasses the large Main Series Pit, the smaller Lower and Upper Series pits, extensive waste rock dumps (which cover an area of over 10 km^2), the remnants of the original township of Leigh Creek and mine site offices and other buildings
- Lobes C and D to the north, including pits and waste rock dumps
- numerous access roads, power lines, train loading facilities and the train line to the east
- the Retention Dam to the south of Lobe B, which captures and diverts the flow of Leigh Creek around the site and is also used by the public for recreational activities
- a town landfill to the west of Lobe B.

Other features of note in the area include the townships of Copley and Leigh Creek to the south, and associated infrastructure including the airport and Aroona Dam, which provides the town water supply.

The proposed demonstration plant site is located within Lobe B, between the Main Series and Upper Series pits (between the waste rock dumps). The site has been highly disturbed as a result of previous mining activities, including earthworks across the site, depressurisation and dewatering of aquifers in the Telford Basin (to the south of the Upper Series Pit), diversion of natural surface water flows, and significant disturbance to native vegetation. At present there are no ongoing coal mining operations and the coalfield has entered into closure planning and implementation. Copley is located approximately 8.5 km from the proposed demonstration plant site and Leigh Creek 12 km, and the presence of the pits and waste rock dumps effectively enclose and buffer the site from the area outside the coalfield.

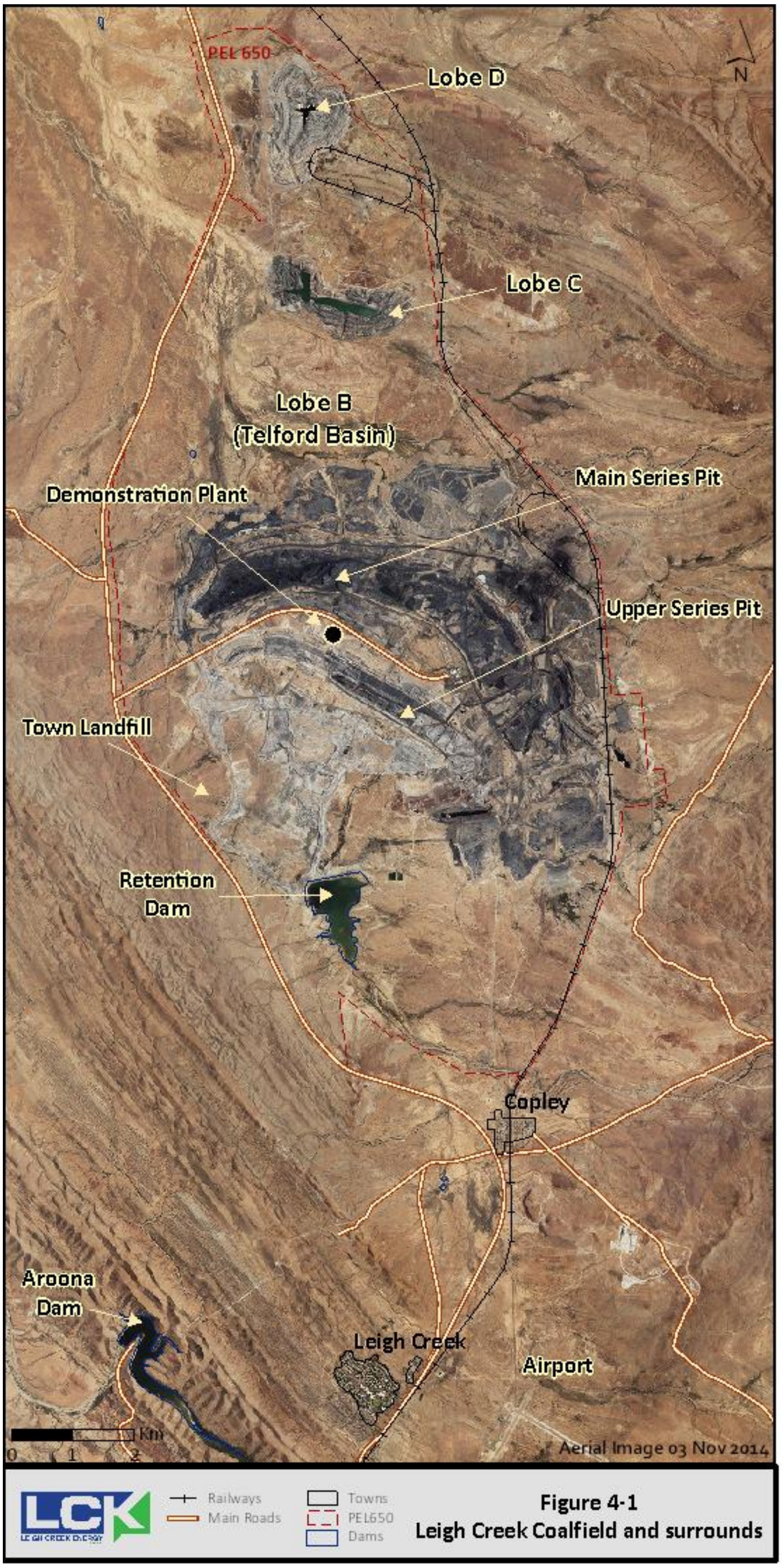

Figure 4-1: Leigh Creek Coalfield and surrounds

Plate 4-1: Upper Series Pit at the Leigh Creek Coalfield

Plate 4-2: Typical waste rock stockpiles at the Leigh Creek Coalfield

4.2 Cultural Heritage

4.2.1 Aboriginal Cultural Heritage

PEL 650 is located in the northern Flinders Ranges region which is culturally significant to the Adnyamathanha Aboriginal People. The Adnyamathanha have a long history of occupation in this region which was significantly disrupted when the country was opened up to pastoral settlement and mining following European exploration during the 1840's (Northern Flinders Ranges SCB 2004).

The Adnyamathanha maintain a strong connection to the project region including ownership of the Myrtle Springs and Leigh Creek pastoral stations adjoining PEL 650, the community of Neppabunna and Igawarta, management of the Nantawarrina Indigenous Protected Area (IPA) located approximately 50 km south-east and co-management of the Vulkathunha - Gammon Range National Park located 50 km to the east. The IPA and national park are of great cultural significance as traditional tribal territory and places of culturally important sites. Areas of cultural heritage significance to the Adnyamathanha people and evidence of long term occupation in the region include song lines, stone arrangements, rock art, occupation sites, graves and ochre quarries (DoE 2013; DEH 2006). The Leigh Creek area forms part of the Adnyamathanha Dreaming journey of Yulu the Kingfisher Man to Wilpena Pound (Ikara).

A search of the Central Archive, which contains the Register of Aboriginal Sites and Objects (DSD-AAR 2016) indicated that there are 22 registered or reported sites within 10 km of PEL 650. One registered site and two reported sites are located within the PEL. Site types on the Register identified in the region include objects, archaeological sites, engravings, quarries, and ceremonial and burial sites. Two of the sites located outside the PEL are identified as restricted sites.

The landform and ground surface at the site of the demonstration plant is heavily disturbed and has been at least partially graded. Old roads, excavations, small stockpiles and other disturbance are prevalent across the site. There are no Aboriginal cultural heritage sites registered at or in the immediate vicinity of the demonstration plant site (however undiscovered Aboriginal sites may still be present in areas which have been previously disturbed).

The Aboriginal Heritage Act applies to the entirety of the Leigh Creek Coalfield (including PEL 650) and provides for the protection of all Aboriginal sites, object and remains, including recorded, reported, or undiscovered heritage. The protection extends to Aboriginal sites, object and remains which may exist in areas which have been disturbed in the past and / or subject to a cultural heritage survey or work area clearance.

LCK has signed a cultural heritage agreement with the Adnyamathanha Traditional Lands Association and cultural heritage clearances have been undertaken.

4.2.2 Non-Aboriginal Heritage

Non-Aboriginal heritage in the region dates back to early exploration of the region by Edward Eyre beginning in 1839 and the subsequent opening up of the area through pastoral expansion and small scale mining. By the end of the 1850's many mines (mostly copper) had been established in the Northern Flinders Ranges. Coal bearing shales were discovered at Leigh Creek in 1888 and later abandoned, and it was not until the 1940's that the deposits were reconsidered for exploration. Many of the historical sites in the region are associated with early mining exploration and production works (Northern Flinders Ranges SCB 2004).

A number of sites relating to the early pastoral and mining history in the broader region are listed on the South Australian Heritage Register (DEWNR 2016b). The closest to PEL 650 is the Copper King Copper and Ochre Mine located 15 km to the south. Other sites include:

- Paull's Consolidated Mine - 27 km east of the PEL
- Sliding Rock Mine - 30 km south-east
- Beltana Stage Heritage Area - 30 km south
- Beltana Station HS - 32 km south.

There are also sites of palaeontological and geological interest listed on the South Australian Heritage Register situated within the region; the closest being the Ajax Mine Fossil Reef, approximately 21 km south of PEL 650, and the most significant being the Ediacara Fossil Reserve Palaeontological Site located 39 km south-west of PEL 650. The Ediacara Fossil Site – Nilpena, which is entered on the National Heritage List is located a further 20 km to the south of this location (DEWNR 2016b, AHPI 2016).

There are no registered sites of non-Aboriginal heritage significance within PEL 650. There are potentially some heritage values associated with parts of the original Leigh Creek township and mine (e.g. the cemetery), which are 2 km from the demonstration plant site.

There are no non-Aboriginal heritage values associated with demonstration plant site.

4.3 Climate

The site is located in the Northern Flinders Ranges, which has an arid climate with hot, very dry summers, cool to mild winters, and a low annual rainfall. In the hotter part of the year (late November to March), mean maximum temperatures exceed 30°C while mean minimum temperatures in the cooler months can drop below 5 °C. Frost days recorded at Leigh Creek are most common from June to August (Northern Flinders Ranges SCB 2004).

The average annual rainfall at Leigh Creek is 224 mm and the median annual rainfall (which is a more appropriate measure where rainfall is erratic) is 200 mm. Rainfall can occur at any time of year, is highly variable and widespread significant rainfall is infrequent. Rainfall in the warmer months is highly erratic, and most often in the form of heavy showers associated with thunderstorms (Northern Flinders Ranges SCB 2004). Average annual evaporation is over 2400 mm (BOM 2016).

A summary of climate records for Leigh Creek Airport (Station #017110) for the period 1982 - 2016 is provided in Table 4-1 (BOM 2016).

Table 4-1: Temperature and rainfall records for Leigh Creek

	J	F	M	A	M	J	J	A	S	O	N	D	Annual
Mean Max Temp (°C)	35.6	34.6	31.2	26.3	21.1	17.0	16.6	19.2	23.5	27.1	30.8	33.2	26.3
Mean Min Temp (°C)	20.8	20.5	17.4	13.0	8.9	5.5	4.7	6.1	9.4	12.6	16.2	18.7	12.8
Mean Rainfall (mm)	22	27.1	20.2	14.7	18.3	16.7	16.4	15.0	17.2	17.1	18.6	23.2	224.2
Median Rainfall (mm)	6.5	17.6	5.3	6.4	9.4	9.2	8.4	8.0	8.7	13.5	11.2	19.2	200.4
Mean Daily Evaporation (mm)*	14.5	13.2	10.5	7.0	4.3	3.0	3.3	4.8	7.2	9.7	11.9	13.4	8.6

* Evaporation data are from Woomera Aerodrome, Station 016001, for the period 1967-2016

Prevailing winds are from the south and east, with northerly winds also relatively common. Figure 4-2 shows the wind rose for Leigh Creek Airport. Each branch of the rose represents wind coming from that direction.

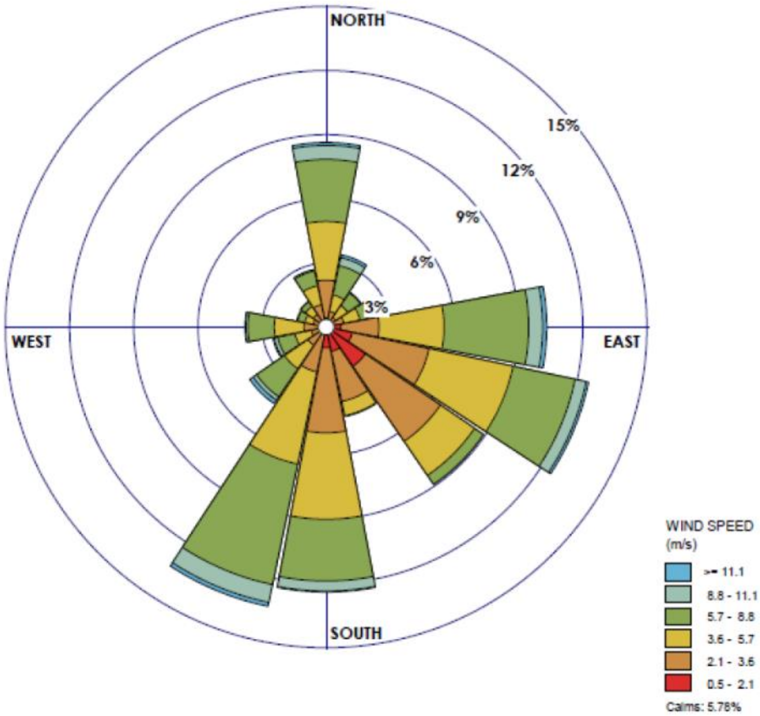

Figure 4-2: Wind rose for Leigh Creek Airport (2010/2011).

4.4 Bioregions, Land Systems and Soils

4.4.1 Bioregional Setting

PEL 650 is located on the boundary of the Stony Plains biogeographical region (or bioregion) and the Flinders Lofty Block bioregion[10].

The western half of PEL 650 lies in the southern-most section of the Stony Plains bioregion, in the Murnpeowie subregion, which is characterised by stony downs and alluvial plains. The eastern half of PEL 650 (and the extreme south-western margin of the PEL) lies in the Flinders Lofty Block bioregion, in the Northern Flinders subregion which is characterised by ranges and hills with rock outcrops, stony pediments and small basin plains, narrow valleys with some gorges, and some remnants of stony downs.

The IBRA subregions can be further divided into land systems[11], which provide a smaller mapping unit. Three land systems have been mapped in PEL 650: Paradise (in the western half of PEL 650), Morris (in the eastern half of the PEL), and Umberatana (on the extreme south-western margin of the PEL), as shown in Figure 4-3.

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[10] Bioregions and subregions are defined by the Interim Biogeographic Regionalisation for Australia (IBRA) Version 7.0. Bioregions are broad landscape units based on major geomorphic features.

[11] Land systems are an area, or group of areas, throughout which there is a recurring pattern of geology, topography, soils and vegetation (DEH 2005). Land systems used in this document are based on the SA Land Systems data that was developed as part of land system mapping of the pastoral areas of South Australia (DWLBC 2007, Naturemaps 2016b).

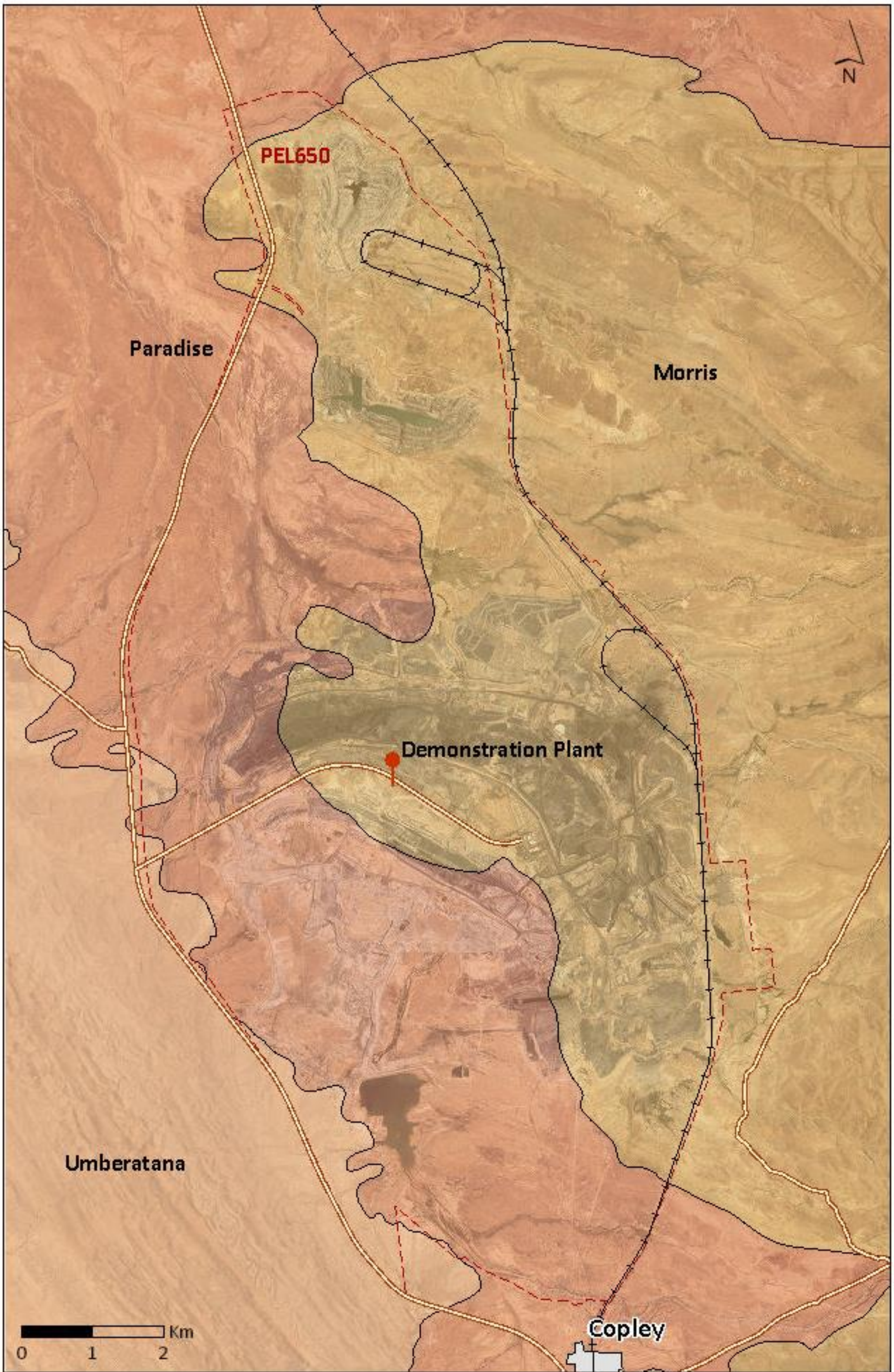


Figure 4-3
Land Systems

Descriptions of these land systems are provided in Table 4-2. It is noted that across a significant proportion of PEL 650, these land systems have been heavily modified and little of the natural land form or vegetation remains intact.

Table 4-2: Land systems in PEL 650

Bioregion	Land system	Description
Stony Plains	Paradise	Flood outs, stony flats and alluvial plains; clay loam soils. Large creeks - River Red Gum, Coolibah, Broughton Willow, River Cooba, Plumbush and Prickly Wattle Floodouts - Old Man Saltbush, Cottonbush, Samphire, Plategrass, Swamp Canegrass Stony hills and flats - Bladder Saltbush, Blackbush, Mitchell grass and Bindyis.
Flinders Lofty Block	Umberatana	Hills and low hills - shallow, skeletal fine-textured soils; Dead Finish, Prickly Wattle, Rock Fuchsia Bush, Bullock Bush woodland over Copperburrs and grasses Stony calcareous plains - Low Bluebush, Bladder Saltbush and annual grasses Creeks - River Red Gum, Prickly Wattle and White Tea-tree.
	Morris	Low hills and rises with sandy loam soils - Low Bluebush and Bladder Saltbush shrublands; patches of Red Mallee or Blackoak woodland flats with annual, Wards Weed and Bottlewashers.

4.4.2 Landform and Soils in PEL 650

PEL 650 and the Leigh Creek Coalfield are located at an elevation of approximately 200 m. In the immediate area of the PEL, the landform is generally a gently undulating plain comprised of reddish powdery calcareous soils and low rocky outcrops. At the base of the nearby ranges alluvial fans and closely spaced dunes of crusty red duplex soil and loose aeolian sands extend over the plains (AECOM 2016).

The majority of the landform and ground surface within the coalfield in PEL 650 has been heavily disturbed and modified by over 70 years of open cut coal mining activities. The coalfield is dominated by the main Lobe B with the large Main Series Pit located north of the demonstration plant site (which is up to 200 m deep), and the smaller Upper and Lower Series Pits located to the south and east of the site respectively. The smaller Lobe C and D pits are located 5 km and 8 km north of Lobe B.

The pits within the coalfield are surrounded by extensive mine spoil piles and waste rock dumps. Other earthworks have also been undertaken extensively across the coalfield site, including construction of the retention dam and numerous berms around the site to modify water flows, and construction of numerous access tracks. Two quarries (now water-filled) are located south of the Lobe B Upper Series Pit.

The pits and other main features associated with Lobe B of the coalfield are shown in Figure 4-4.

Aerial Jan - Mar 2017

Figure 4-4
Leigh Creek Coalfield Lobe B

4.4.3 Demonstration Plant Site

The demonstration plant site is located in a relatively flat area between waste rock stockpiles on the southern side of the main mine access road, within the Leigh Creek Coalfield. It is significantly disturbed and a substantial proportion of the site has been previously graded. Haul roads, old road alignments, excavations, stockpiles and other disturbances are prevalent across the site. Aerial photographs indicate that the site is located west of the original path (before mine development) of the Leigh Creek floodplain.

The edge of the Lobe B Upper Series Pit is approximately 400 m south of the outlet well, and top of the deeper Main Series Pit is approximately 600 m to the north of the outlet well.

Soils at the site are predominantly a red / brown gravelly clay loam with patchy gibber scatter, and are consistent with the Telford Gravels. Some lower lying areas and drainage paths have a thin veneer of grey, silty material that has been washed off adjacent stockpiles. Soils at the site have relatively low permeability due to the high clay content and cementing in the gravels and water readily pools across the site after rain.

There are no erosion issues on the site itself, however some adjacent stockpiles exhibit significant erosion, with deep gullies present.

The demonstration plant site and surrounds are shown in Figure 4-5, Plate 4-3 and Plate 4-4.

Aerial Jan - March 2017

Figure 4-5
Demonstration plan site and surrounds

Plate 4-3: Panorama of demonstration plant site looking south across site from adjacent stockpile

Plate 4-4: Panorama across southern part of demonstration plant site, looking west

4.5 Existing Site Contamination

Historical mining activities and associated infrastructure have involved numerous potentially contaminating activities at a range of locations (see Figure 4-6). Areas and activities across the Leigh Creek Coalfield that may have had potentially contaminating activities include the original Leigh Creek township, spur line infrastructure, old railway yards (also referred to as the Telford Facility), mine spoil dumps, areas where mine water / runoff has accumulated, magazine areas, areas where transformers are used or stored, refuelling areas, fuel storages or workshops, domestic waste dump, asbestos dumps, tyre dump, areas of historical infrastructure (including brickworks, powerhouse, sewer farm) and the fire-fighting training area (AECOM 2016).

In addition, Flinders Power submitted a Voluntary Site Contamination Assessment Proposal (VSCAP) to the Environment Protection Authority for the Leigh Creek Coalfield. Flinders Power engaged Coffey Environments Pty Ltd (Coffey) to undertake a site contamination assessment to determine the nature and extent of exiting site contamination and the actual or potential risk to human health or the environment resulting from such contamination.

A number of reports exist in relation to existing site contamination, including:

- *Burns & Roe Worley Pty Ltd (2000) Flinders Power Land Contamination Issues*
- *Parsons Brinckerhoff (2005) Groundwater Monitoring Event March 2005, Telford Rail Siding*
- *Parsons Brinckerhoff (2011) Groundwater Monitoring Event – Telford Rail Siding, Leigh Creek Coal Field*
- *Parsons Brinckerhoff (2012) Groundwater Monitoring Event – Telford Rail Siding, Leigh Creek, SA*
- *Parsons Brinckerhoff (2013) Groundwater Monitoring Event – Telford Rail Siding, Leigh Creek, SA*
- *Parsons Brinckerhoff (2015) Groundwater Monitoring Event – Telford Rail Siding, Leigh Creek, SA*
- *Coffey Environments Australia (2016) Flinders Power Partnership, Leigh Creek Coal Mine (Lobe B) Preliminary Site Investigation*
- *Coffey Environments Australia (2016) Flinders Power Partnership, Leigh Creek Coal Mine (Lobes C and D) Addendum Preliminary Site Investigation*
- *Coffey Environments Australia (2016) Flinders Power Partnership, Leigh Creek to Port Augusta Railway, Preliminary Site Investigation*
- *Coffey Environments Australia (2016) Flinders Power Partnership, Detailed Site Investigation, Leigh Creek Coal Mine (Lobe B).*

The Detailed Site Investigation of the Leigh Creek Coal Mine (Lobe B) identified 14 areas of environmental concern including former crusher refuelling facility, firefighting area, Telford rail siding fuel storage tanks, asbestos landfill, permanent and temporary refuelling tanks, transformer graveyard, mining operations area, mobile transformers, solvent evaporation pond, town landfill and explosive storage compounds.

COPC that may be present in the Leigh Creek Coalfield as a result of these historical activities are summarised in Table 4-3. For specific details of existing site contamination refer to *Detailed Site Investigation of the Leigh Creek Coal Mine (Lobe B)*.

Table 4-3: Summary of potential chemicals of potential concern from historical activities at the Leigh Creek Coalfield

Activity	Occurrence in coalfield	Potential chemicals of potential concern
Stockpiling of mine spoil dumps	Widespread	Particulates and fugitive gases such as CO, H_2, CO_2, CH_4, H_2S and ammonia with traces of a wide range of organic compounds (e.g. phenols, organic acids, volatile and semi-volatile organic compounds). Hydrocarbons, PAHs, phenolic compounds, sulphurous compounds, nitrogen compounds, pH (acidic), metals (more mobile in acidic conditions).
Fuel storage	Locations across site	Hydrocarbons and PAHs, metals, potential for solvents.
Vehicle maintenance	Office and maintenance area and historical areas including spur line, old rail line, Lobes C and D	Hydrocarbons and PAHs, metals, potential for solvents.
Waste storage areas	Buried wastes in designated areas (e.g. asbestos, tyre dumps, domestic waste depot) and other materials stored directly on ground (e.g. transformers and drums in storage area)	Particulates and fugitive emissions of organic compounds and metals, high potential for pyrolytic products (e.g. VOCs, dioxins) if tyre dumps are ignited. Asbestos. Hydrocarbons, PAHs, solvents (SVOCs and VOCs) associated with fuels and oils of car bodies or drums stored on ground, metals. PCBs where old transformers are stored.
Magazine area	Designated area	Ammonium nitrate-fuel oil and fuel oils contributing source of ammonia and hydrocarbons.
Wastewater	Crib rooms, former sewage plant at original township, vehicle wash-down area	Nutrients associated with wastewater / biosolids, hydrocarbons associated with temporary refuelling tanks.
Fire-fighting training area	Designated area	Aqueous Film-Forming Foam contains persistent organic pollutants Perfluorinated Compounds (PFCs) primarily as perfluoro-octane sulfonate (PFOS) and perfluorooctanoic acids (PFOA).
Solvent disposal	Solvent evaporation pond	Solvents

Source: AECOM (2016) and Coffey (2016)

At the demonstration plant site, stockpiling of mine spoil has occurred extensively adjacent to the site, however most of the other activities listed above are not known to have been undertaken at the site and would be unlikely to have contributed to contamination in this location.

Baseline sampling at the demonstration plant site will be undertaken prior to construction of the plant to identify soil and groundwater conditions. Baseline chemistry and water quality data has also been collected for deeper geological units at the site and is summarised in Section 4.7.

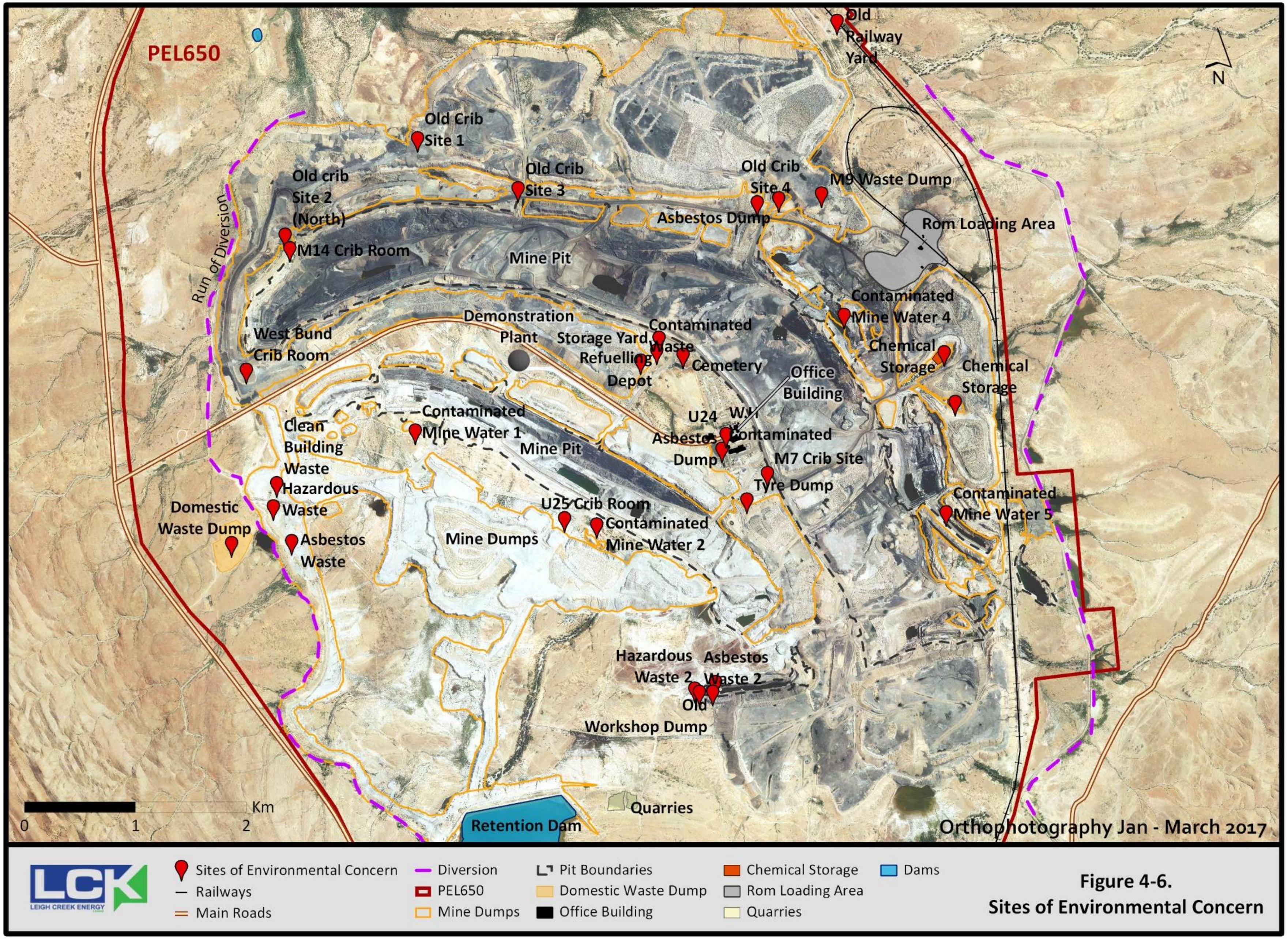


Figure 4-6.
Sites of Environmental Concern

4.6 Geology

4.6.1 Regional Geology

The geology of the Telford Basin and surrounds is previously described in Parkin (1953), Johns (1970) and Springbett (1995).

In general, the areas surrounding Leigh Creek are characterised by ranges and low undulating hills of variably weathered and folded rocks of the Adelaide Geosyncline. These Adelaidean aged basement rocks in the region include those of the Heysen Supergroup (the Wilpena Group and the Umberatana Group), and the Warrina Supergroup (the Burra Group). These rocks are generally well indurated (hardened) and are predominantly steeply dipping with the strike extent of the unit often readily identifiable at the surface. Lithologies, which are highly weathered, include laminated siltstone and shale, dolomitic siltstone, quartzitic boulder tillite, quartzite, and sandstone.

The Telford Basin is a Mesozoic (Late Triassic to Early Jurassic) basin hosted within the complexly folded Neoproterozoic Adelaidean metasediments of the Adelaide Geosyncline. The surrounding hills and ranges are often flanked by alluvium covered plains of Quaternary sands, gravels, silts and clays.

Figure 4-7 shows the surface geology of the Leigh Creek Coalfield and surrounding area.

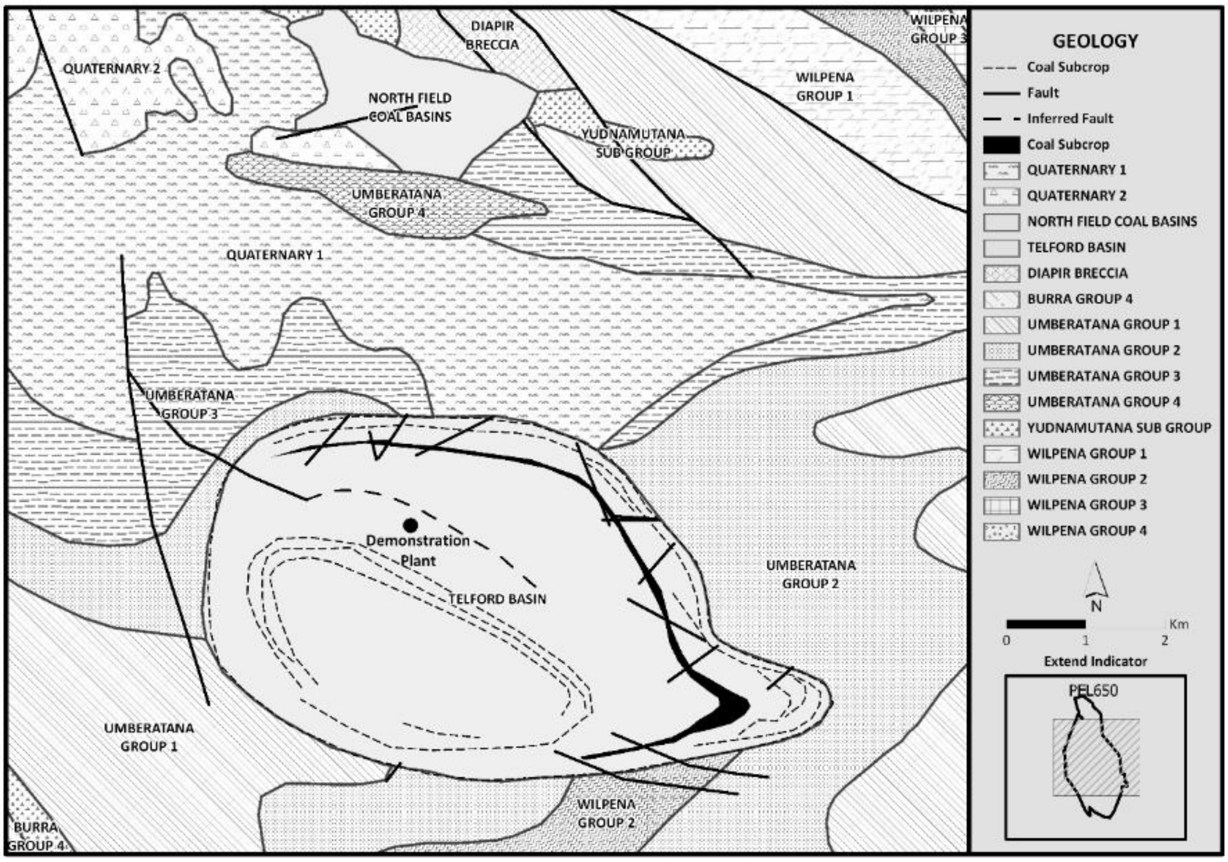


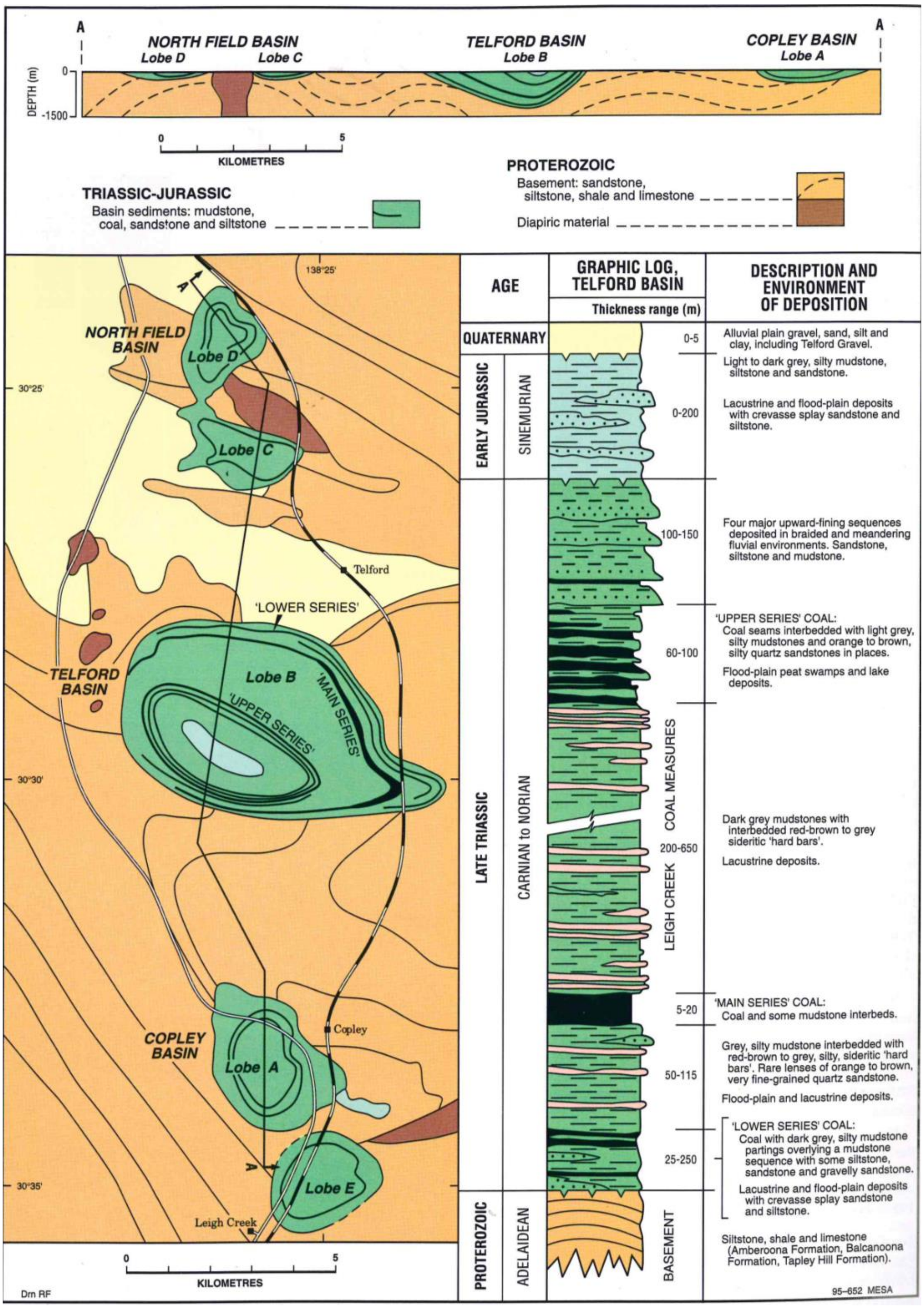
Figure 4-7: Surface geology of the Telford Basin and surrounding region

4.6.2 Local Geology of the Telford Basin

The Telford Basin (which is Lobe B of the Leigh Creek Coalfield) is the largest of the five basins in the area of Leigh Creek. These basins are structural depressions within the surrounding

Adelaidean aged basement rocks. The Telford Basin is an asymmetrical, ellipse shaped basin reaching depths of approximately 1,000 m.

Figure 4-8 shows the Telford Basin and other basins in the area of Leigh Creek and provides a graphic log of the stratigraphy within the basin.



Source: The Geology of South Australia: The Phanerozoic. GSSA Bul 54

Figure 4-8: Telford Basin Geologic Sequence

The Leigh Creek Coal Measures within the Telford Basin are a result of three depositional phases beginning in the Upper Triassic and concluding in the Middle Jurassic. The basin comprises predominantly fine-grained sediments and spans approximately 34 km^2 in surface area. A thin veneer of alluvium and gravel, collectively called the Quaternary Alluvium, covers most parts of the Telford Basin and areas of the surrounding basement rocks.

The Leigh Creek Coal Measures occurs in three main sequences, named informally in descending stratigraphic order as the Upper Series Coal, Main Series Coal and Lower Series Coal. The overall coal sequence typically comprises coal seams interbedded with carbonaceous shales, siltstones and mudstones with numerous sideritic (iron carbonate) hardbars. The Leigh Creek Coal Measures are described stratigraphically as follows:

- Upper Series Coals comprise approximately 100 m of interbedded mudstone, siltstone and numerous coal plies with minor fine-grained sandstone. A predominately sandstone sequence approximately 100 m thick with some siltstone, mudstone and minor thin coal plies overlie the Upper Series Coal.
- Main Series Coal comprises a 20 m thick zone of (predominately) coal separated from the Lower Series by approximately 50 to 100 m of grey carbonaceous mudstone containing thin, hard sideritic siltstone interbeds (hardbars).
- The Lower Series Coal contains two coal plies in a zone approximately 60 m thick underlain by approximately 50 m of mudstone and a thin basal gravelly sand.

After deposition, the Triassic and Jurassic sequence and the underlying Basement sequence has been subject to deformation and erosion, resulting in a bowl-shaped syncline. A thin veneer of alluvium and gravel, collectively called the Quaternary Alluvium, covers most parts of the Telford Basin and areas of the surrounding basement rocks.

The general stratigraphic section through the Telford Basin is described in Table 4-4. Indicative cross sections through the basin in the vicinity of the demonstration plant are shown in Figure 4-9, Figure 4-10 and Figure 4-11.

Table 4-4: Generalised stratigraphy of the Telford Basin

Period	Unit	Description
Quaternary	Telford Gravels	GRAVEL: reddish brown to white, rounded to sub-rounded cobbles and pebbles in red-brown silty clay soil. Often cemented by white to pale pink calcareous matrix. Unconformably overlies the Upper Series Overburden.
Lower to Middle Jurassic	Upper Series Overburden 1	CARBONACEOUS MUDSTONE: dark to light grey silty mudstone with abundant carbonaceous fragments and some carbonaceous beds. SANDSTONE: brown fine grained quartz sandstone with abundant silty laminations. Weakly cemented. Up to 5 m thick.
	Upper Series Overburden 2	COAL: dark brown to black, thin (200 mm) friable coal seams containing laminations of highly plastic clay. CARBONACEOUS MUDSTONE: dark grey to brown laminated silty mudstone with carbonaceous fragments. SILTY SANDSTONE: brown, fine grained, quartz sands with abundant sandy silt laminations. Weakly cemented. SANDSTONE: orange brown to white medium to coarse grained quartz sandstone. Crossbedded in some places, generally moderately well cemented.
	Upper Series Coal	COAL: dark brown to black, friable coal seam. Characterised by seam thickness and seam splitting (0-8 m thick). CARBONACEOUS MUDSTONE: dark grey silty mudstone with abundant carbonaceous fragments and laminations. Medium bedded (100-300 mm). SANDSTONE: orange to brown, fine grained silty quartz sandstone. Moderately to weakly cemented. Beds up to 2 m thick.
Upper Triassic	Main Series Overburden	CARBONACEOUS MUDSTONE: grey to dark grey silty mudstone, containing abundant carbonaceous fragments with some thin carbonaceous beds (30-100 mm). SIDERITIC HARDBANDS: red brown to grey silty siderite band 50 mm to 300 mm thick often containing disseminated pyrite.
	Main Series Coal	COAL: dark brown to black, hard, very low rank sub-bituminous or lignite A coal, with carbonaceous mudstone parting in some places.
	Lower Series Overburden	CARBONACEOUS MUDSTONE: grey to dark grey silty mudstone, containing abundant carbonaceous fragments and some thin carbonaceous beds (30-100 mm). SIDERITIC HARDBANDS: red brown to grey silty siderite band 50 mm to 300 mm thick often containing disseminated pyrite. SANDSTONE: orange to brown, fine grained silty quartz sandstone. Moderately to weakly cemented. Beds up to 2 m thick.
	Lower Series Coal	COAL: dark brown to black, hard, very low rank sub-bituminous or lignite A coal, often separated by carbonaceous mudstone parting. CARBONACEOUS MUDSTONE: grey to dark grey silty carbonaceous mudstone containing abundant carbonaceous fragments. SANDSTONE: brown to light grey medium to coarse grained carbonaceous sandstone or grit. Often weathered at basement contact. CARBONACEOUS MUDSTONE: grey to dark grey silty carbonaceous mudstone, containing abundant carbonaceous fragments with some thin carbonaceous beds (30-100 mm). SIDERITIC HARDBANDS: red brown to grey silty siderite band 50 mm to 300 mm thick often containing disseminated pyrite. SANDSTONE: orange to brown, fine grained silty quartz sandstone. Moderately to weakly cemented. Beds up to 2m thick.
Adelaidean	Weathered basement Fractured basement	CARBONACEOUS SANDSTONE: blue grey to green silty calcareous shales and siltstone. Thinly bedded (30-100 mm). DOLOMITIC LIMESTONE: red and grey dolomitic limestone beds up to 10 m thick containing oolites and stromatolites in some places.

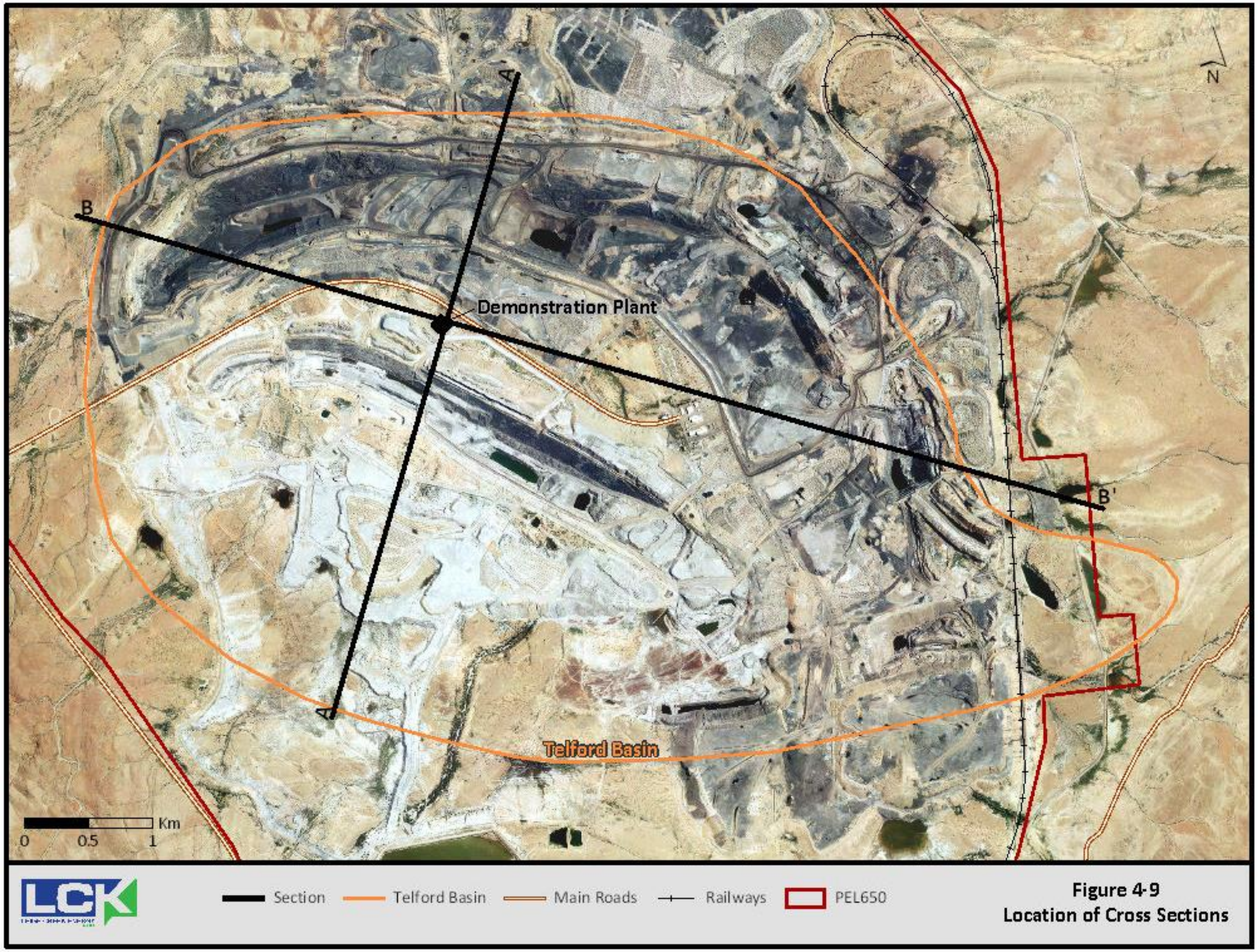


Figure 4-9
Location of Cross Sections

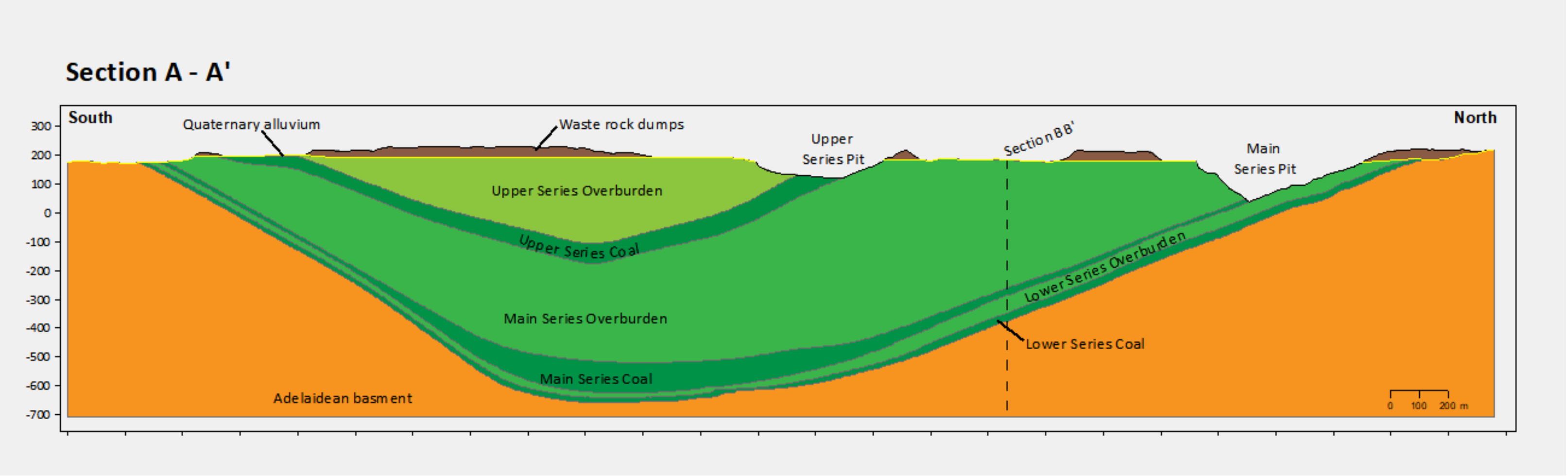


Figure 4-10: Schematic south-north cross section of the Telford Basin

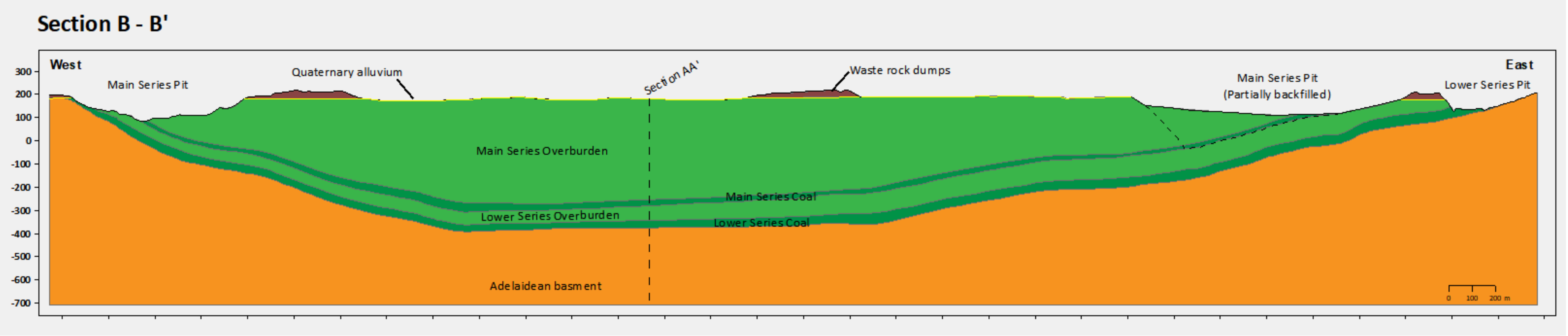


Figure 4-11: Schematic west-east cross section of the Telford Basin

4.6.3 Demonstration Site Geology

At the demonstration plant site, the Telford Gravels are approximately 12 m thick and overlie the Main Series Overburden (i.e. the Upper Series is not present). Below the Main Series Overburden, the top of the Main Series Coal is inferred to be at a depth of 540 m. The target coal seam for the demonstration plant is 12 m thick and is underlain by about 8 m of interbedded coal and mudstone. This combined 20 m thick sequence of coal and mudstone are referred to as the Main Series Coal. The Lower Series Overburden lies below the Main Series Coal.

The rock layers in the Main Series Overburden, Main Series Coal, and Lower Series Overburden all dip to the south at approximately 25 degrees.

Figure 4-12 shows the stratigraphy at the demonstration plant site (based on stratigraphy in the Playford-5 well).

Geological structures in the Telford Basin include bedding planes, fractures, and faults. Faults are known to displace the Main Series Coal and persist (extend) above and below the Main Series Coal seam for many tens of metres. Faulting extending from the Adelaidean basement into the Coal Measures and within Lower Series are also known. Orientation of faults is the result of folding and compression of strata as the basin subsided. Typically, the faults are steeply dipping toward the basin margins for hundreds of metres parallel to the long axis of the basin.

At the demonstration plant site, the Main Series Coal target comprises a 12 m thick coal seam with a dip of about 25 degrees, generally to the south. Seismic reflection survey data and drilling was completed in 2016 and indicates that natural fractures which occur within the Main Series Overburden are comprised of tight, closed joints. Geotechnical logging of the drill core indicated no evidence of weak material or gouge filled joints, and no faulting was evident.

Geotechnical observations of sections of the Main Series Pit highwall (180 m of exposed Main Series Overburden) did not identify weak seams or gouge filled joints. Exposed sections of the high wall to the north of the demonstration plant location indicate the Main Series Overburden is laterally and vertically consistent in rock type and geological structures (Plate 4-5).

Plate 4-5: Main Series Pit high wall from the north west showing consistency of strata in the exposed Main Series Overburden.

Seismic reflection surveys along dip and strike directions were undertaken around the demonstration plant area to determine the continuity of coal strata and the nature and distribution of faults. Interpretation of these seismic sections and existing conventional exploration boreholes indicates that the demonstration plant gasifier will be in an area that is at least 100 m from faults (that are inferred to pass at a steep dip angle through the coal) and where the target coal seam is laterally consistent along strike.

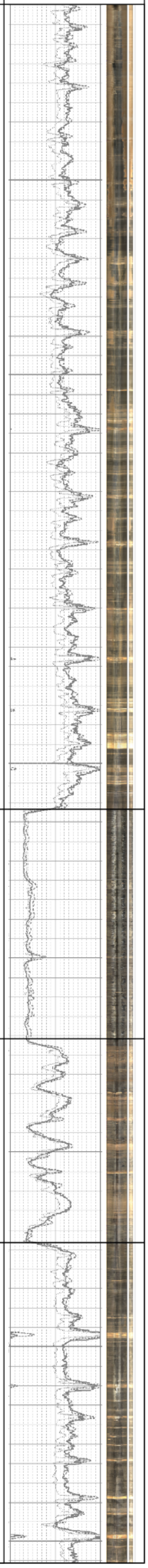
Geological Unit	Lithological Description	Inferred Depth	Representative Density and Optical Logs
Main Series Overburden (MO)	Carbonaceous mudstone with interbedded siderite bands (”hardbars” which appear as light coloured bands in the optical log and corresponding peaks on the density log)	540 m	
Main Series Coal (MC)	Coal (target coal seam for the Demonstration Plant gasifier)	552 m	
	Interbedded coal and mudstone	560 m	
Lower Series Overburden (LO)	Carbonaceous mudstone with interbedded siderite bands (”hardbars” which appear as light coloured bands in the optical log and corresponding peaks on the density log)		

Figure 4-12: Geological type section for the demonstration plant location

Figure 4-13 and Figure 4-14 show a cross-section through the demonstration plant site that shows the geology and indicative faults.

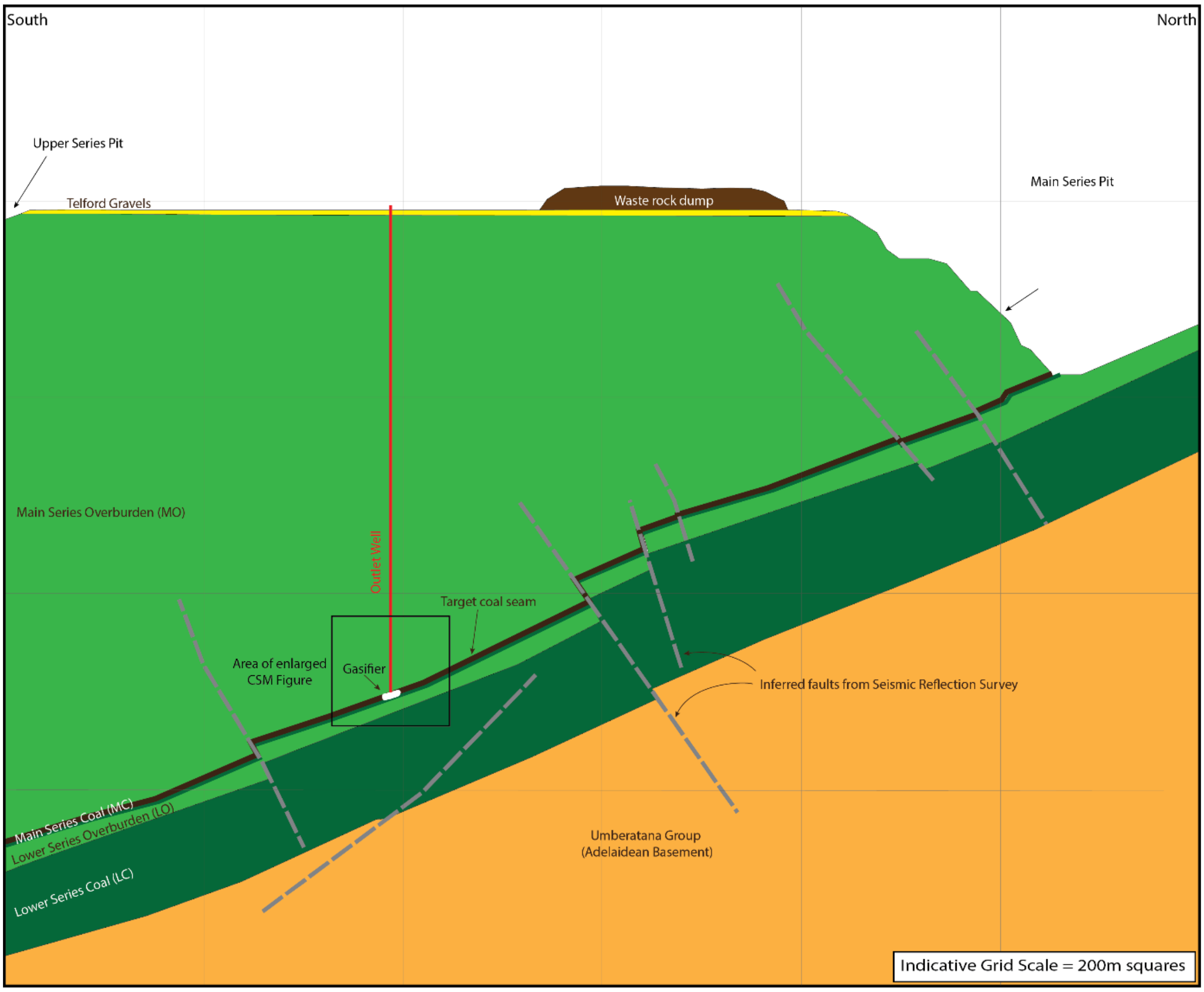


Figure 4-13: Cross-section through demonstration plant site showing location of inferred faults

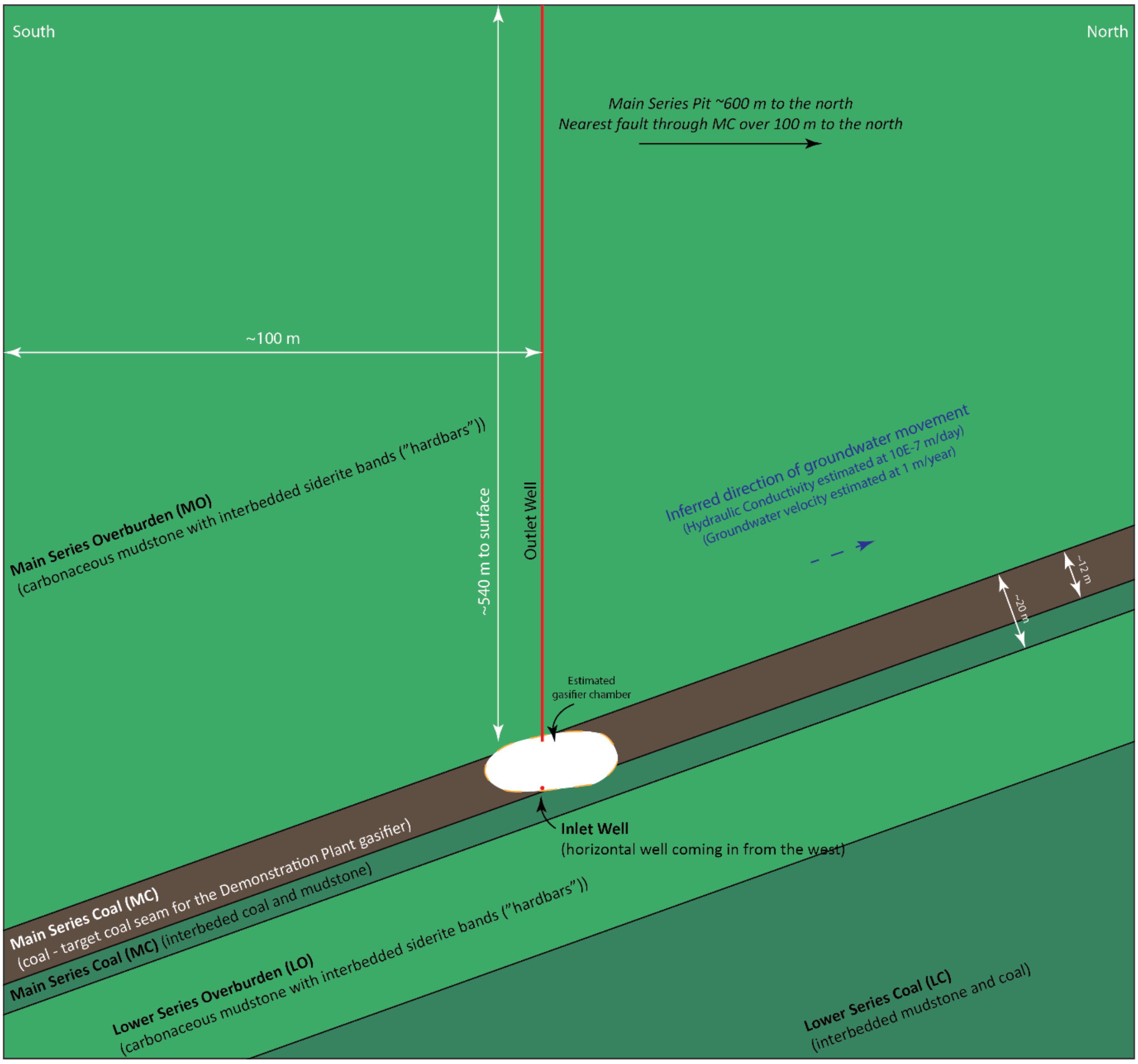


Figure 4-14: Detailed cross section through demonstration plant gasifier

4.6.4 Geotechnical Considerations

The geotechnical suitability of the demonstration plant site is important in both the technical success of an ISG operation in producing syngas and in the management of environmental impacts. The geotechnical issues for ISG are nearly identical to those encountered with underground coal mines, and many of the same geotechnical design procedures apply (Camp and White 2015).

Assessment of geotechnical suitability of the site has been undertaken both at a broad scale in the site evaluation process (refer to Section 3.3) and at a detailed technical level as outlined in the geotechnical assessment in Appendix B.

The key geotechnical considerations (addressed in Appendix B) are:

- siting of the gasifier relative to existing geological structures that could provide a migration pathway for gas or fluids
- potential for excessive thermal rock spalling that could affect ISG reactions within the gasifier
- potential for uncontrolled/runaway structural failure of the gasifier roof causing ground subsidence

- potential for new fracturing or reactivation of existing fracturing of the surrounding rock as a result of operation of the gasifier, forming new migration pathways for gas or fluids, or providing a connection to existing geological structures.

These considerations are summarised briefly below. Further detail is provided in Appendix B, and these issues are also discussed in the environmental risk assessment contained in Section 5.

Siting of the gasifier: As noted in Section 4.6.3, a combination of interpretation of seismic reflection survey data and existing conventional exploration boreholes indicates that the demonstration plant gasifier will be in an area that is at least 100 m from faults (that are inferred to pass at a steep dip angle through the coal) and where the target coal seam is laterally consistent along strike. If a preferential fluid pathway were to develop between the gasifier and a fault, it is considered unlikely, based on water pressure testing completed, that there would be migration of fluids to the surface or other groundwater systems. This is due to the limited vertical continuity of these faults and inherent low permeability of the strata. In addition, there are no known aquifers present that could be impacted, as discussed in Section 4.7.

Thermal rock spalling: The high organic content of the coal and surrounding carbonaceous mudstones mean they will be heat insulators and, other than the gasification reactions themselves at the edge of the chamber, will not conduct heat far into the surrounding formation. As such heat effects will not propagate significantly away from the chamber. The likely extent of spalling of the overburden from thermal effects is currently unquantified. It will be investigated further using data collected prior to and during operation of the demonstration plant. Thermal spalling of the overburden may affect the performance of the gasifier but it is not considered an environmental risk.

Uncontrolled structural failure and subsidence: Preliminary estimates of the likely progression and propagation of caving of the roof, in addition to fracturing and deformation of the rock strata within the overburden above the gasifier, have been made using methods developed for the coal mining industry. These suggest that for a 30 m (wide) gasifier chamber, the overall height of the combined collapsed and fractured zones would be likely to extend to a height above the coal seam in the order of 60 - 75 m. This is the maximum predicted extent of rock alteration due to cave-in filling the chamber after gasifier decommissioning, with the overlying layers remaining intact due to filling of the void by way of bulking of the rock mass. Based on these estimates, ground surface subsidence is not expected.

The geotechnical assessment also reviewed the work undertaken by Golder (1985) which modelled cave-in and subsidence at the surface for a notional commercial scale ISG gasifier in the Leigh Creek Coalfield. This hypothetical gasifier was operated for 20 years at an average depth of 350 m (in a 14 m thick coal seam) and was 500 m wide. The Golder assessment led to the conclusion that subsidence at the surface was likely for the large-scale gasifier that was modelled. However, the LCK demonstration gasifier is over 150 m deeper and is significantly smaller (30 m wide compared to 500 m wide). Equivalent calculations to those undertaken by Golder indicate that it is unlikely to result in any effects at the surface.

Fracturing forming pathways for gas or fluids: An increase in permeability above the coal seam is expected to be constrained within the 60 - 75 m fracture zone above the gasifier. The Main Series Overburden beyond the fracture zone is expected to remain undisturbed and maintain its low permeability. The creation of pathways for gas or groundwater to migrate from the chamber to the ground surface is unlikely, based on formation integrity testing which indicated that the initiation, propagation and closure pressures for defects to be created or affected by the proposed gasifier are well in excess of the proposed operating pressure of the gasifier.

The geotechnical assessment (Appendix B) indicates that the geomechanical risk is considered to be low.

4.6.5 Natural Seismic Activity

Much of the naturally occurring seismic activity in South Australia is concentrated along the Flinders Ranges between Gladstone and Hawker (Sutton 1968). Natural seismic events are relatively common, predominantly occurring under the uplifted regions of the state due to compressional stress. The adjacent large flat-lying sedimentary basins tend to experience relatively few earthquakes (Gibson and Sandiford 2013). Most earthquakes occur at depths between 2 km and 20 km (Gibson and Sandiford 2013). Figure 4-15 shows the historical distribution of earthquakes in the region.

Earthquake hazard mapping (Figure 4-16) shows that the Leigh Creek area has a similar earthquake hazard to Adelaide. Peak ground acceleration in the Leigh Creek area with an annual exceedance probability of 1 in 500, is 0.06 to 0.07g. For comparison purposes, the 1988 Tennant Creek earthquake (which had a magnitude of 6.6) and the 1968 Meckering earthquake (which had a magnitude of 6.9) recorded ground accelerations of 0.147g and 0.12g respectively (Durbride *et al.* 2012).

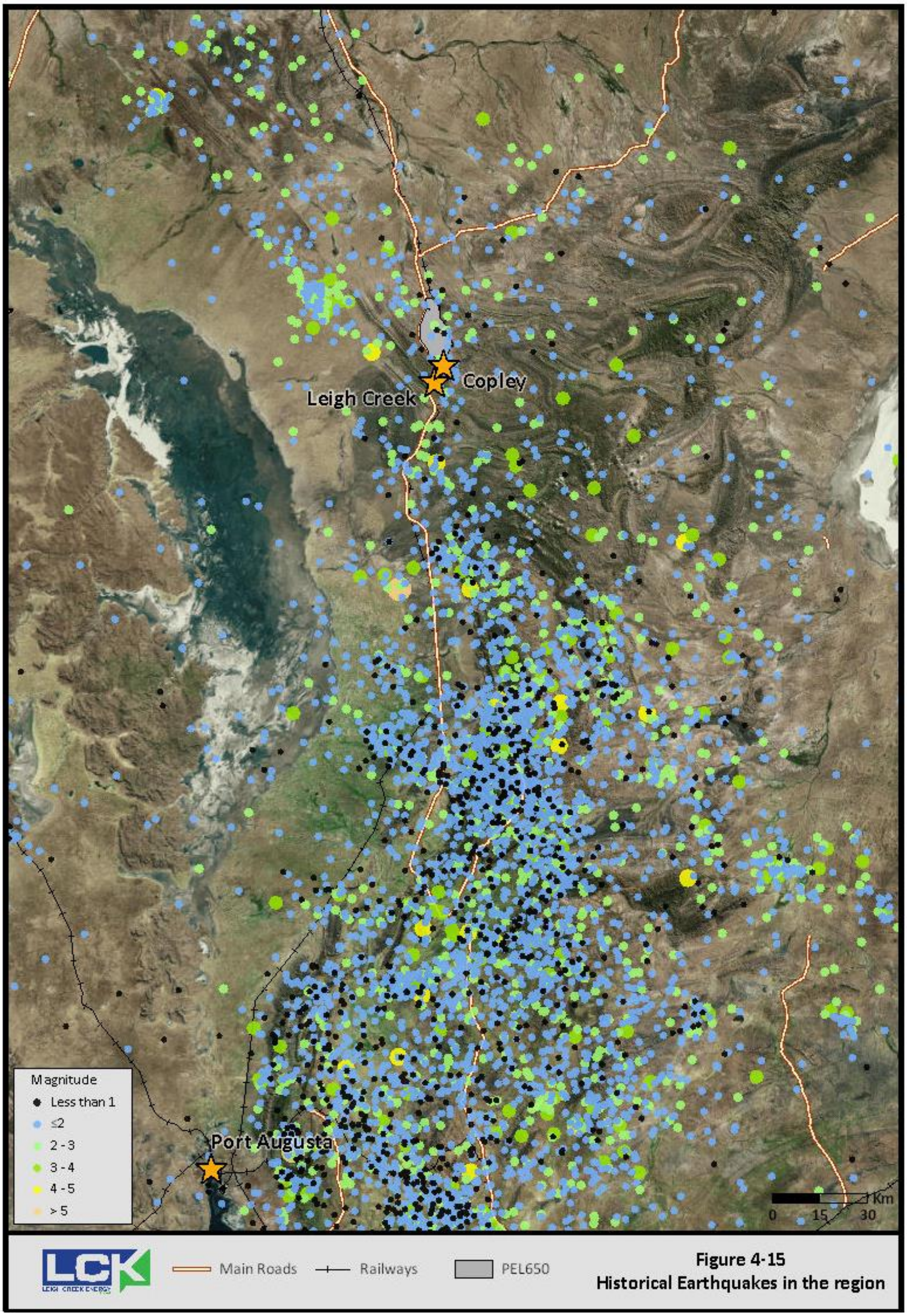


Figure 4-15
Historical Earthquakes in the region

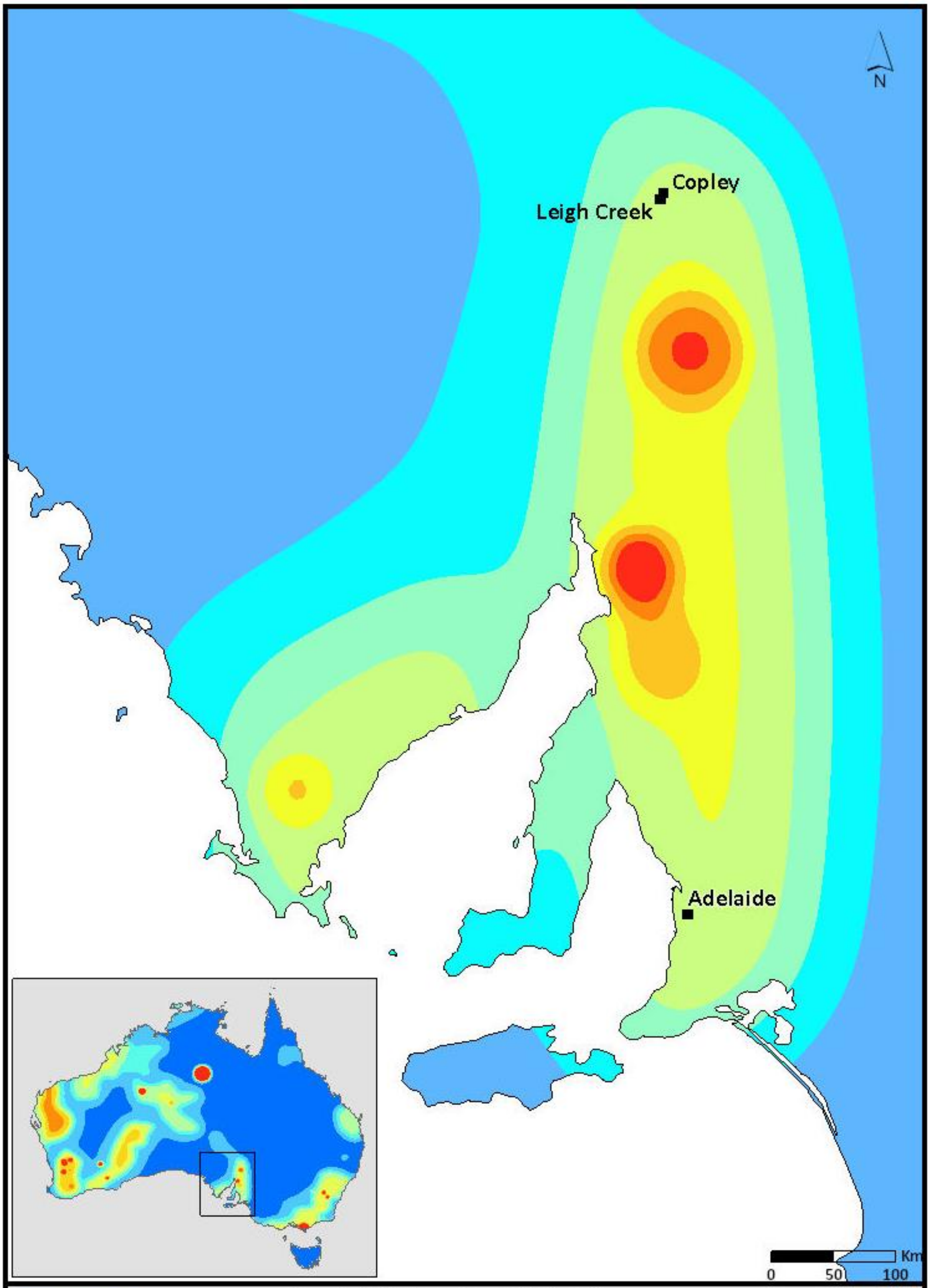


Figure 4-16
Earthquake Hazard map

4.7 Hydrogeology

This section presents an overview of the hydrogeology of the Telford Basin and surrounds, based on existing information and hydrogeological data generated for the Leigh Creek Coalfield, and drilling and hydrogeological investigations undertaken by Leigh Creek Energy. Further detail is provided in the hydrogeological report contained in Appendix A.

4.7.1 Groundwater, Aquifers, Aquitards and Water Quality

All water found below the ground surface is considered groundwater. Where the rock becomes saturated, this depth is referred to as the water table.

The ability for groundwater to move through rock media is controlled by the porosity of the rock (volume of void space within the rock media) and the permeability (the connectivity of the voids to allow movement of water).

The void space within the rock media can be the spaces between sedimentary grains (in sedimentary rocks) which is referred to as 'primary', or the space developed when joints or faults open up (fractured rocks) or where the rock media has been dissolved (e.g. in limestone), which is referred to as 'secondary'. The measure of the rate at which a rock can transmit water is termed the "hydraulic conductivity" of the rock, which is sometimes referred to as the "permeability" of the rock.

The depth at which rock becomes saturated (the water table) may be different to the depth (or height) water may rise to in a well (or bore) when the point of measurement of the groundwater pressure is deep. This is the 'artesian' nature of a groundwater system, where as in the Great Artesian Basin, there is enough groundwater pressure to push water out of the well, when the surrounding rock may be dry to a depth of 50 m or more. In a groundwater system where there is not enough pressure to push water out of the well above ground level, but there is enough pressure to cause water in the well to rise above the depth at which groundwater is intersected by the well, this is referred to as being 'sub-artesian'.

When many points of measurement of groundwater head pressure are used to draw a surface, this is referred to as the 'potentiometric surface' of that groundwater system. The shape of this surface may vary at different rates than the water table surface due to changes that cause different pressures to act on the groundwater system.

4.7.1.1 Aquifers

Aquifers are geologic materials with high hydraulic conductivity that are able to receive, store and transmit groundwater in quantities sufficient for use as a water supply. The aquifer materials are typically sands and gravels, limestones, and fractures in hard rock materials.

4.7.1.2 Aquitards

Aquitards are geologic materials with low hydraulic conductivity that are able to receive and store groundwater, but cannot transmit the groundwater in quantities sufficient for use as a water supply. The aquifer materials are typically clays, silts and unfractured hard rock materials.

4.7.1.3 Water Quality

The terms aquifer and aquitard relate to the potential yield (amount of water) that can be pumped from a well for some desired use. A critical factor in what any given water can be used for is its quality, typically measured in terms of the concentration of Total Dissolved Solids (TDS) measured in mg/L or parts per million. In the field this is often assessed in the context of the electrical conductivity of the water, with higher the TDS giving higher electrical conductivity. In Australia, the suitable uses for water based on the TDS content is summarised in the following table.

Table 4-5: Water quality categories

Category*	Salinity (mg/L)* (Total Dissolved Solids)	Typical use**
Fresh	0 to 1,000	Limit of palatable Drinking Water Typical limit for Flowers, Fruit and Veg
Fresh to brackish	1,000 to 3,000	Limit for Pigs^ and Poultry^ Typical limit for Crops and Pastures
Brackish	3,000 to 5,000	Limit for Dairy Cattle^ – 4,000 Limit for Beef Cattle^ and Couch Grass
Saline	5,000 to 35,000	Limit for Horses^ – 6,000 Limit for Kikuyu Grass – 8,000 Limit for Sheep^ – 13,000
Hyper-saline	35,000 and above	Limited Mining/Industrial uses

^ Maximum to maintain condition only, not support healthy growth

*Source: EPA (2017) http://www.epa.sa.gov.au/environmental_info/water_quality/threats/salinity

**Source: DWLBC (2017) http://nitschkegroup.com/wp-content/uploads/2017/02/Groundwater-Salinity-Chart.pdf

4.7.2 Regional Hydrogeology

The Telford Basin is a small sedimentary basin which is contained within rocks of the Adelaidean basement. The Leigh Creek Coalfield occupies the entire footprint of the Telford Basin, with the demonstration plant site located in the Coalfield between the Upper Series Pit and Main Series Pit and related waste rock dumps.

The Great Artesian Basin is, at its closest, approximately 50 km to the north and has no connection with groundwater in the Telford Basin (see Figure 4-17).

Natural springs in the region include the Aroona, Top Well and Myrtle Springs. These springs are outside the Telford Basin, eight to twelve kilometres from the site, at higher elevation than the demonstration plant site and are not hydraulically connected to the Telford Basin. As such there is no potential for the groundwater discharged at these springs to be connected to the demonstration plant site.

4.7.3 Hydrogeology of the Telford Basin

The Telford Basin is approximately 8 km by 5 km and is up to 1,000 m deep. It is a small sedimentary basin which is contained within the rocks of the Adelaidean basement.

The location of the Telford Basin within the Adelaidean fractured rock basement indicates that the groundwater at this site is sourced from local rainfall runoff and infiltration and not connected to other regional groundwater systems such as the Great Artesian Basin.

Figure 4-17
Regional Hydrogeology

It is considered unlikely that the Telford Basin sequence plays a significant role in the regional groundwater flow patterns, because the Leigh Creek Coal Measures where they sit on the basement have a very low hydraulic conductivity and form a very thick aquitard. The Telford Basin is a barrier to groundwater flow, and it is anticipated that historically the majority of the regional groundwater would have flowed around and beneath the Leigh Creek Coal Measures, rather than through it. Some relatively small volumes of surface water may recharge into subcropping Upper Series Overburden strata, the only aquifers in the Leigh Creek Coal Measures. These strata intersect the Upper Series Pit and have been depressurised and significantly dewatered to maintain stability of the pit walls.

All other formations in the Telford Coal Measures are aquitards with low permeability to virtually impermeable.

The influence of the Leigh Creek Coal Measures on regional groundwater flow patterns may have changed since the creation of the open cut pits. The open cut pits expose rocks to a depth of up to 250 m, facilitating increased rates of evaporation from the groundwater system. This would likely encourage any movement of groundwater, however small, through the Coal Measures toward the open pits. When considered in the context of the modified surface drainage, the Telford Basin could now be considered a terminal basin with almost all groundwater and runoff within the modified landscape now moving to the pits where it will evaporate.

4.7.3.1 Telford Gravels

The Telford Gravels are a variably silicified, sedimentary perched water table groundwater system. There is no available information on the groundwater properties of this shallow sequence to determine groundwater flow processes. It is likely that this system would receive opportunistic infiltration recharge when rainfall events generate surface flow conditions. However, with the modification of the landscape over the Telford Basin by operation of the Coalfield it is likely any remaining groundwater in the Telford Gravels is localised and discontinuous due to the mine pits and limited runoff.

4.7.3.2 Demonstration Plant Site Hydrogeology

There are no aquifers at or within 500 m of the demonstration plant site. Groundwater in the carbonaceous mudstone and coal sequences appear to be one continuous, low permeability saturated zone with a potentiometric surface approximately 50 m below ground level.

Monitoring wells have been installed and screened separately in, above, and below the target coal seam in the Main Series Coal, Main Series Overburden and Lower Series Overburden. Salinity and chemistry data indicate that groundwater from each of these wells is related. These strata are all considered aquitards due to their low permeability. The salinity of the groundwater is saline.

No open geological structures, i.e. fractures or faults with the potential to transmit water, were identified within proximity to the site. Closed fractures were identified in drill core. Faults intersecting the target coal seam inferred by seismic reflection surveys and exploration drill holes were identified more than 100 m from the site. These faults do not penetrate the full sequence of strata, terminating in the carbonaceous mudstone above the coal, and are likely closed based on observations of this same strata exposed in the Main Series Pit.

4.7.3.3 Hydraulic Properties

The geological units of significance at the demonstration plant site are the:

- target coal seam – 12 m thick coal seam in the Main Series Coal
- coal seam roof – 530 m of carbonaceous mudstone of the Main Series Overburden
- coal seam floor – 8 m of interbedded coal and mudstone of the Main Series Coal and carbonaceous mudstones of the Lower Series Overburden.

The rate of groundwater recovery in the groundwater monitoring wells installed has been used to calculate the hydraulic conductivity of these units. All three are in the order of 10^{-7} m/day, which is classed as practically impermeable.

4.7.3.4 Groundwater Movement

Groundwater in, above, and below the target coal seam at the demonstration plant is understood to be moving very slowly to the north toward the Main Series Pit. The rate of natural groundwater movement through the area of the site is expected to be in the range of 1 m per year to 1 m per 100 years, based on observed groundwater gradients and hydraulic conductivities that have been determined in baseline investigations.

If this groundwater from the demonstration plant gasifier were to ultimately encounter the Main Series Pit (about 600 m to the north of the site) it could take more than 600 years.

A schematic of baseline hydrogeology of the demonstration plant is shown in Figure 4-18.

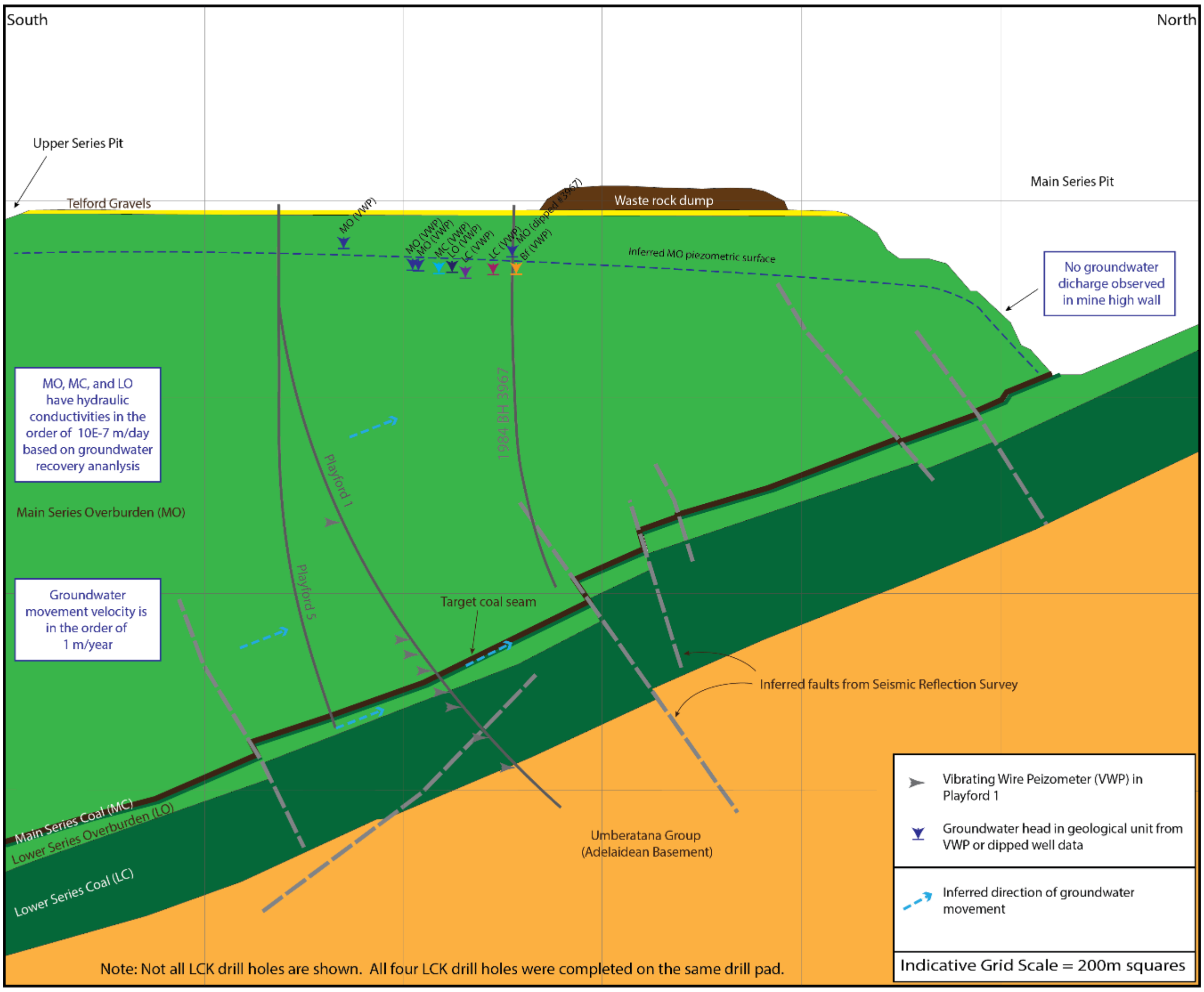


Figure 4-18: Baseline hydrogeology at the demonstration plant site

4.7.4 Conceptual Site Model

A conceptual hydrogeological model for the demonstration plant site has been developed to inform the impact assessment in Section 5.1. This model encompasses current conditions and conditions during and after operation of the demonstration plant, and is discussed further below (see Figure 4-19 to Figure 4-22).

4.7.4.1 Pre Demonstration Plant Conditions

The demonstration plant gasifier chamber will be located within low to very low hydraulic conductivity coal and bounded above and below by similarly very low hydraulic conductivity mudstones. The available measured groundwater pressure data support the conceptualisation that groundwater movement is along strata northward towards the mining pit.

Numerical modelling was undertaken to help understand groundwater movement. Using a groundwater gradient from instrumentation installed in groundwater monitoring wells and a conservative hydraulic conductivity of approximately 10^{-3} m/d (to allow for more permeable zones), the steady-state groundwater movement rate is likely to be less than 1 m per year. If hydraulic conductivity of 10^{-7} m/d, as determined in baseline investigations, is used, the rate of groundwater movement reduces to millimetres per year. Potential flow pathways through structural defects are not considered to be relevant as investigations to date have not identified any open structures.

This range in groundwater movement rates means that groundwater moving through the location of the demonstration plant gasifier would take between 600 and 60,000 years to reach the Main Series Pit. The absence of groundwater seeping from the Main Series Pit high wall suggests such low rates of movement mean the groundwater migrating toward the exposed face of the wall evaporates before it can discharge.

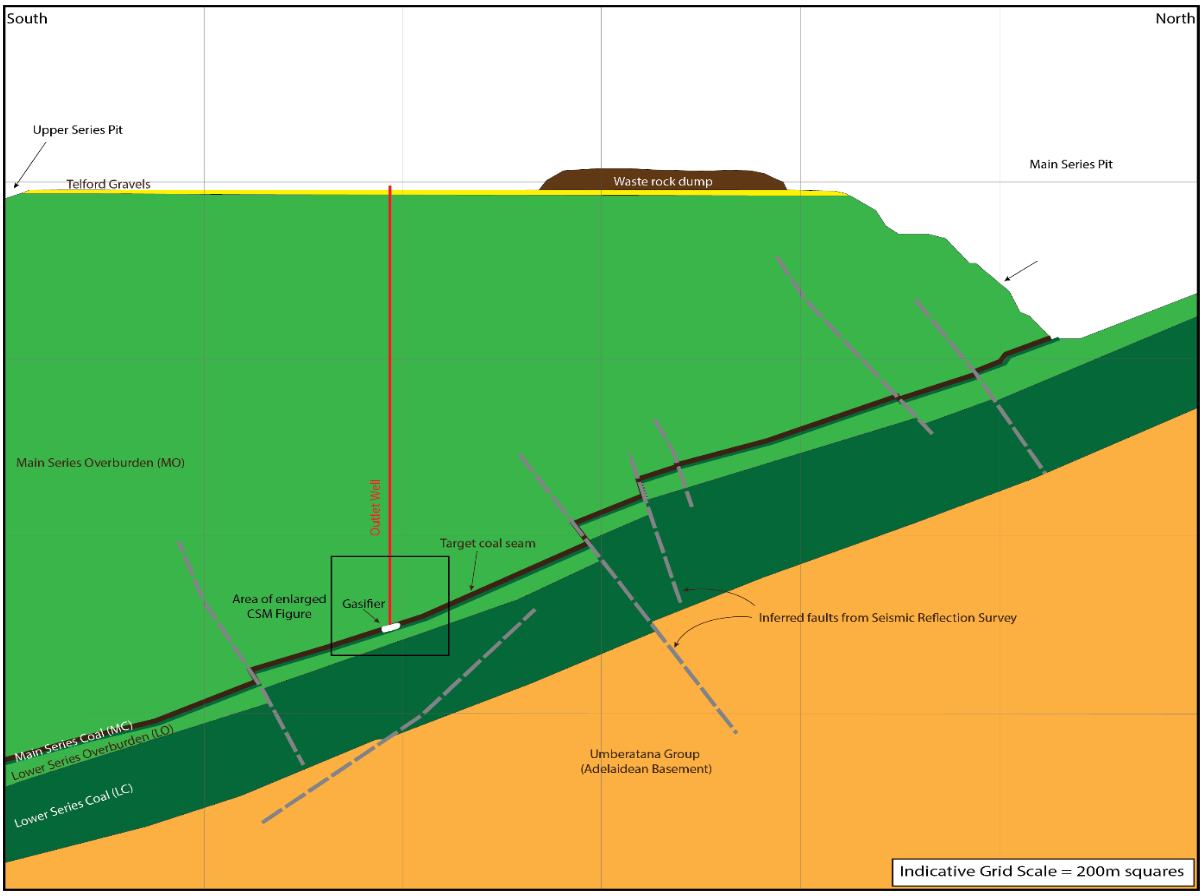


Figure 4-19: Cross section showing location of Conceptual Site Model for conditions before, during and after operation of the demonstration plant

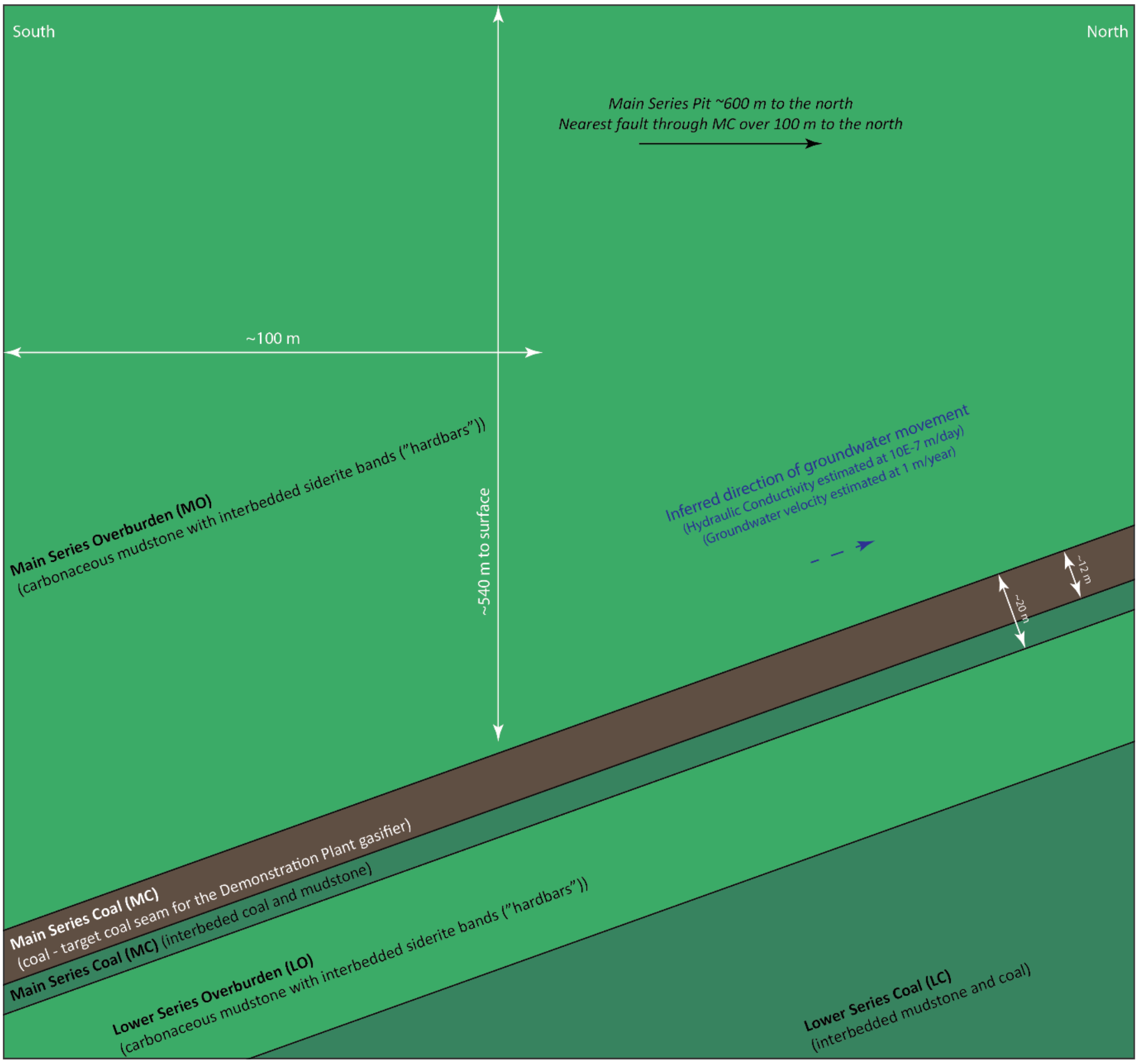


Figure 4-20: Cross section showing Conceptual Site Model for existing pre-demonstration conditions

4.7.4.2 During Demonstration Plant Operation

The demonstration plant chamber will develop as the coal is consumed and it is anticipated to be approximately 30 by 30 m laterally and approximately 15 m in height. This chamber will remain within the low to very low hydraulic conductivity mudstones above and below and will be surrounded by unchanged coal laterally.

The gasification process will consume the pore water in the coal. As all the in situ groundwater will be consumed, the gasification process will create a low-pressure environment in the gasifier and an inward groundwater pressure gradient (shown in Figure 4-21). However, due to the low to very low hydraulic conductivity, the rate of groundwater movement is very low. Combined with the limited period of operation of the gasifier, the radius of influence of the gasifier on surrounding groundwater is expected to be limited. It also means the potential for any fluids from the gasifier to enter the surrounding rock will be similarly limited.

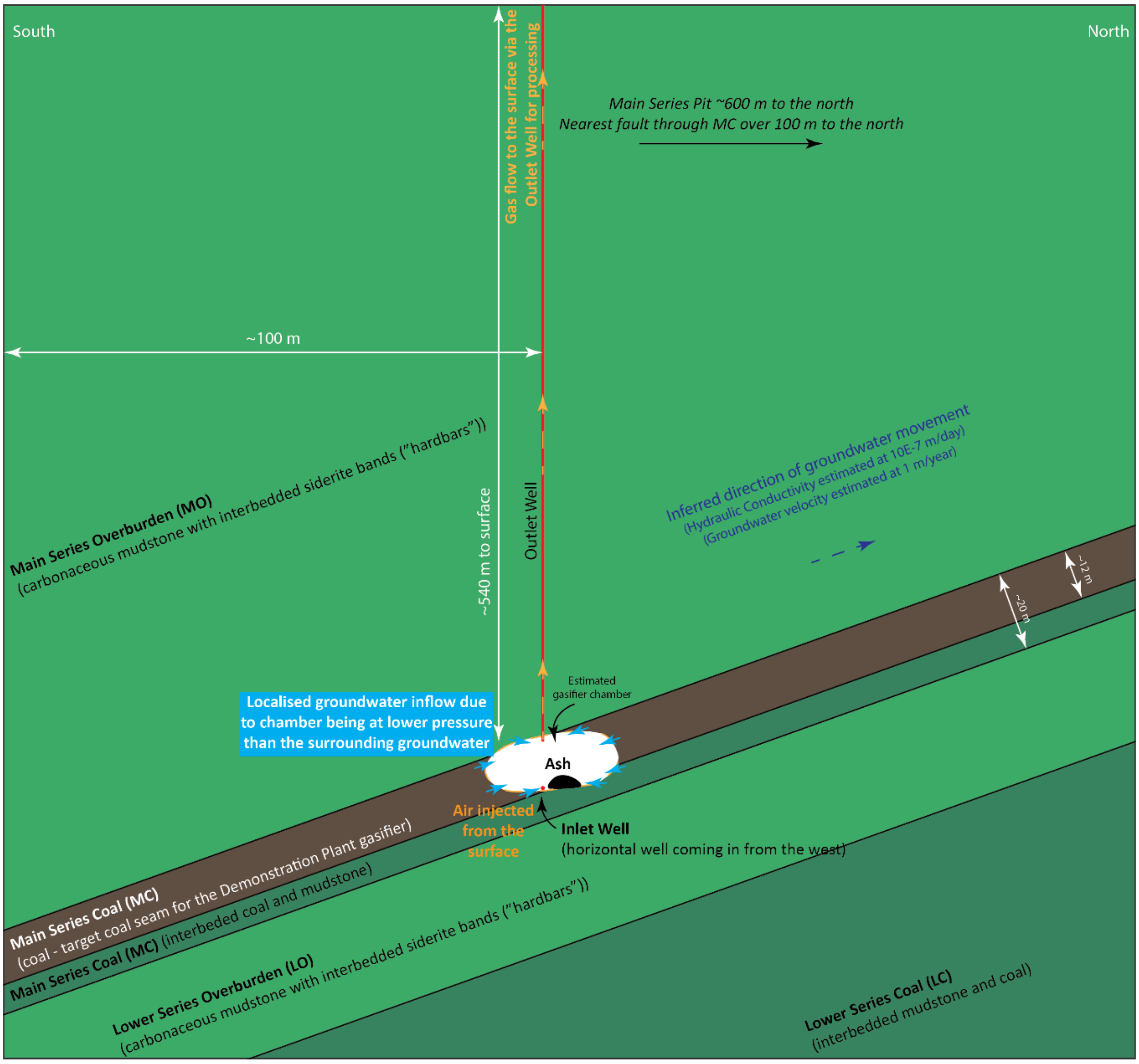


Figure 4-21: Cross section showing Conceptual Site Model of demonstration plant during operation

4.7.4.3 Post Demonstration Plant Operation

As the gasifier chamber is decommissioned (see Sections 3.1.5 and 3.9), the majority (if not all) volatile and soluble COPC will be removed via the outlet well, leaving the chamber largely empty except for the ash and other residue left after gasification. This process is not anticipated to leave any residual water within the chamber as the expected temperatures within the chamber will convert any added water into steam that will be exhausted from the chamber during the shut-down process.

It is thus expected that the chamber will be fluid free. Assuming a chamber volume of approximately 13,500 m^3 (e.g. 30 m x 30 m x 15 m), once the chamber temperature is low enough not to vaporise any moisture, it may take years or decades to refill. Over this time, the hydraulic gradient around the chamber will be inward.

Once the chamber has refilled (see Figure 4-22), there will still be a significant time lag while the groundwater heads revert to pre-operational conditions in the aquitard around the chamber. It is only when the groundwater pressures revert to pre-operational values that groundwater movement similar to ambient conditions in the vicinity of the chamber is expected. This is likely to be in the timescale of years to decades. For further discussion of the chamber after decommissioning see Section 5.2.2.6.

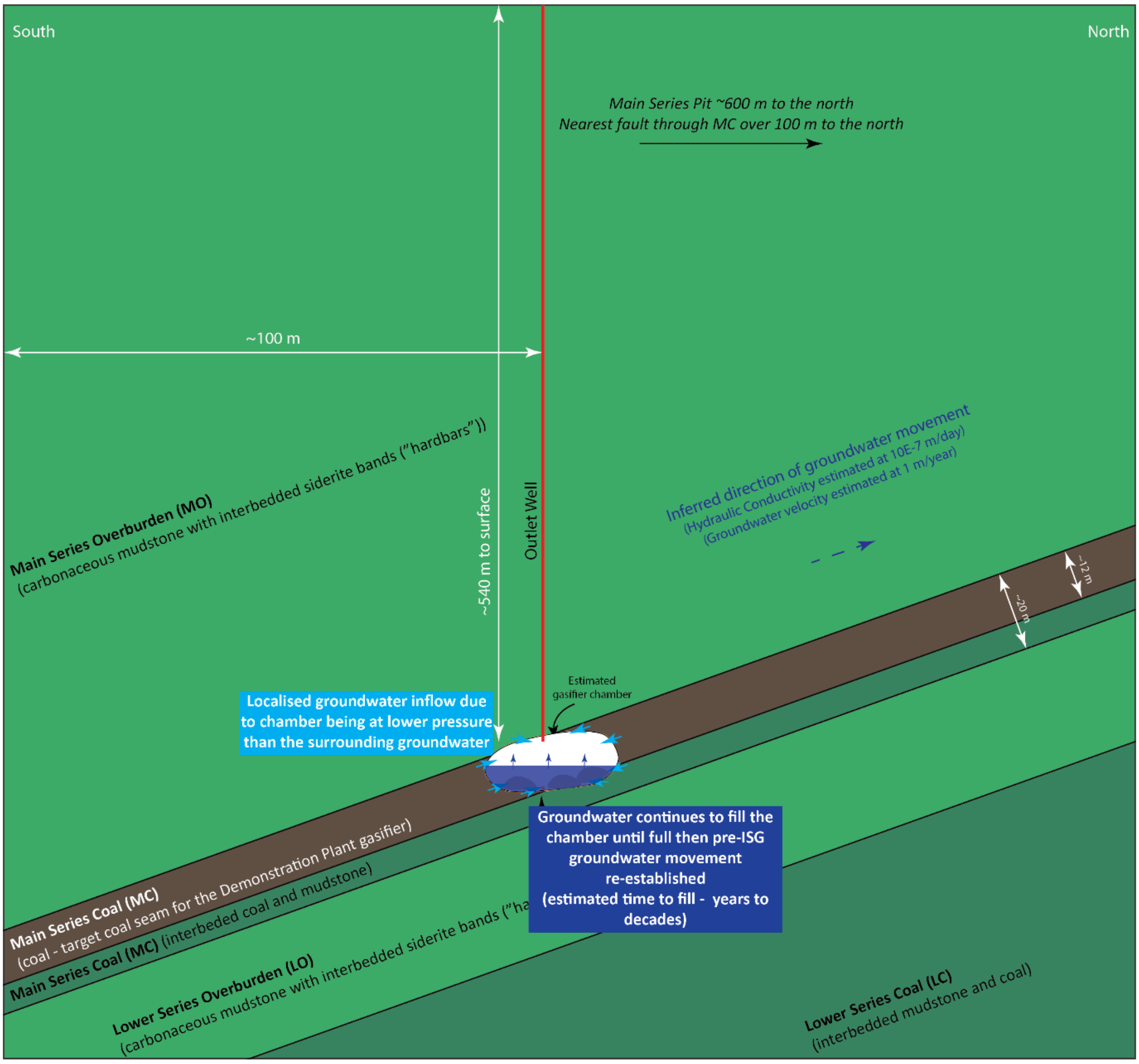


Figure 4-22: Cross section showing Conceptual Site Model of demonstration plant after decommissioning

4.7.5 Groundwater Quality

Samples were collected from three groundwater wells with production intervals (screens) installed within the Main Series Overburden, Main Series Coal and Lower Series Overburden horizons. The observed chemical characteristics of groundwater samples collected from these horizons is summarised below and presented in Table 4-6.

- Groundwater from all three wells was brackish to saline with the total dissolved solids (TDS) ranging between 4,600mg/L to 9,200 mg/L. Groundwater salinity was slightly higher in the well targeting the Main Series Overburden horizon (8,710 - 9,160 mg/L) compared with the wells targeting the Main Series Coal and Lower Series Overburden horizons (6,470 mg/L and 4,650 - 6,630 mg/L respectively). However, it was considered that there may still be some fresh water present within the groundwater wells as a result of the flushing of the well screens following installation.
- Groundwater from the Main Series Coal horizon is characterised by higher concentrations of petroleum hydrocarbons (C_{16}-C_{34} fractions) compared to groundwater collected from the Main Series Overburden and Lower Series Overburden horizons.
- BTEX and petroleum hydrocarbons (C_6 to C_9 fractions) were reported at higher concentrations in samples collected from the groundwater well targeting the Main Series Overburden horizon compared to samples collected from the Main Series Coal and Lower Series Overburden horizons. This may be due to the presence of oily inclusions within the Main Series Overburden material reported in historical reports.
- No discernible differences in heavy metal concentrations were noted between groundwater samples from each of the three horizons. The key metals reported in groundwater samples included boron (B) and zinc (Zn) (which was also noted in core samples).
- Phenolic compounds were detected slightly above the laboratory limits of reporting (LOR) from samples collected from the groundwater wells targeting the Main Series Overburden and Main Series Coal horizon. The reported PAH results were below the LOR in all samples tested.

As noted previously, the Main Series Coal and Main Series Overburden are aquitards and groundwater cannot be extracted at a rate that makes these units suitable for use as a water supply. Comparison of the groundwater quality against water quality guidelines (ANZECC 2000) indicated that the groundwater (even if it was able to be extracted) would not be suitable for livestock (cattle) water supply, drinking water supply, long-term irrigation or aquaculture, exceeds the trigger levels for protection of freshwater aquatic ecosystems and exceeds the guidelines for recreational purposes. These exceedances of guidelines and trigger levels included:

- Recreational Water Quality and Aesthetics (ANZECC 2000): manganese 0.17 mg/L (trigger value 0.1 mg/L), benzene 0.018 mg/L (trigger value 0.01 mg/L), pH 12.2 (trigger value <6.5 and >8.5).
- Long Term Irrigation (ANZECC 2000): Total Nitrogen 98.2 to 131 mg/L (trigger value 5 mg/L)
- Freshwater aquatic ecosystems (ANZECC 2000): boron 0.4 mg/L (trigger value 0.37 mg/L), zinc 0.012 mg/L (trigger value 0.008 mg/L).
- Aesthetics NHMRC (2011) (as amended Oct 2017): ethylbenzene 0.006 mg/L (trigger value 0.003 mg/L).
- Health NHMRC (2011) (as amended Oct 2017): >C10-C16 0.32 mg/L (trigger value 0.09 mg/L), >C16-C34 290 mg/L (trigger value of 0.09 mg/L), benzene 0.04 to 0.018 mg/L (trigger value 0.001 mg/L).
- Livestock: TDS values 4650 to 9160 mg/L (above the threshold for beef cattle where loss of production and decline in health would be expected (>5000 mg/L)).

Table 4-6: Baseline concentration ranges in groundwater samples (mg/L)

	MO monitoring well	MC monitoring well	LO monitoring well
pH	7.53 - 7.69	12.2*	8.0 - 11.2
Total dissolved solids	8,710 - 9,160	6,470*	4,650 - 6,630
Nutrients			
Total Nitrogen	98.2 - 116	n/a**	77.2-131
Hydrocarbons			
C_6-C_{10}	<0.02 - 0.02	0.02 - 0.03	<0.02
>C_{10}-C_{16}	0.11 - 0.12	<0.1 - 0.32	<0.1
>C_{16}-C_{34}	<100	<100 - 290	<100
Benzene	0.004 - 0.018	0.004 - 0.007	0.004 - 0.006
Ethylbenzene	<0.002 - 0.006	<0.002	<0.002
Toluene	0.003 - 0.008	<0.002	<0.002
Xylene	<0.002	<0.002	<0.002
Metals			
Arsenic	<0.001	<0.001	<0.001
Boron	0.28 – 0.37	0.22	0.34 – 0.40
Chromium	<0.001	<0.001	<0.001
Copper	<0.001	<0.001	<0.001
Lead	<0.001	0.001	<0.001
Manganese	0.16 - 0.17	n/a	0.08 - 0.09
Mercury	<0.0001	<0.0001	<0.0001
Nickel	0.001-0.002	<0.001	<0.001
Thorium	<1	<1	<1
Uranium	<1	<1	<1
Zinc	<0.005 - 0.001	0.012	<0.005-0.005

*One sample collected only

**Not tested

4.7.5.1 Baseline Chemistry of Rock Strata

Chemistry of the rock strata present in and around the target coal seam has the potential to influence groundwater chemistry and the transport of COPC from the gasifier chamber.

Drill core samples were collected from rock strata in, above, and below the target coal seam. Samples were analysed for a range of chemicals (Table 4-7) and the following was determined:

- The coal is characterised by higher concentrations of total hydrocarbon (C_{15}-C_{28}) fractions, the presence of PAHs and lower concentrations of metals compared to samples above and below
- Concentrations of nitrogen (mainly TKN) were reported in samples collected from all three horizons
- Key metals reported at higher concentrations (compared to other metals tested) in samples collected from above and below the coal (predominantly mudstone) included barium (Ba), cobalt (Co), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), and zinc (Zn).

Table 4-7: Baseline concentration ranges in drill core samples (mg/kg)

Analyte	MO drill core	MC drill core	LO drill core
Nutrients			
Total Nitrogen	800 - 2,980	190 - 3,000	580 - 2,240
Hydrocarbons			
C_6-C_{10}	<10 - 21	<10	<10 - 13
>C_{10}-C_{16}	<50	<50 - 90	<50
>C_{16}-C_{34}	<100 - 190	130 - 630	<100 - 180
Benzene	<0.2 - 0.3	0.3 - 1.0	<0.2 - 0.2
Ethylbenzene	<0.5 - 1.2	<0.5	<0.5 - 0.6
Toluene	<0.5	<0.5	<0.5
Xylene	<0.5	<0.5	<0.5
Metals			
Arsenic	<5 - 7	<5	8 - 9
Barium	130 - 1,110	10 - 50	70 - 150
Chromium	15 - 31	3 - 25	8 - 14
Cobalt	9 - 17	<2 - 2	6 - 22
Copper	35 - 52	<5 - 21	35 - 42
Lead	12 - 30	<5 - 19	21 - 26
Manganese	31 - 814	<5 - 32	<5 - 10
Mercury	<0.1 – 0.4	<0.1	<0.1 – 0.1
Nickel	20 - 32	<2 - 8	6 - 32
Thorium	17.4 - 22.8	2.1 - 5.5	15.1 - 16.5
Uranium	2.1 - 4.6	0.1 - 1.4	1.1 - 2.9
Vanadium	24 - 36	<5 - 57	18 - 19
Zinc	78 - 153	<5 - 62	113 - 170
Polycyclic Aromatic Hydrocarbons (PAH)			
PAHs (Sum of total)	<0.5	3.1 - 29	<0.5
Dioxins			
Octa-Dioxin	n/a	17.8 pg/g	n/a

Note: pg/g = parts per billion

4.7.6 Groundwater Beneficial Uses and Sensitive Receptors

The review of potential sensitive groundwater receptors and beneficial uses in the region indicated the following:

- No beneficial uses have been identified within the existing coal mine footprint. The mine has ceased operations and groundwater is not believed to be extracted for any activities associated with the mine closure.
- Groundwater is used from wells outside the mine footprint and outside the Telford Basin (see Figure 4-23) for stock water. Groundwater wells to the west (Myrtle Springs Station), east (Leigh Creek Station), and south (Copley area) are at higher elevations than the Coalfield and are likely to be extracting groundwater from shallow water table groundwater systems. Such groundwater will be moving toward the Telford Basin and therefore will not be affected by any ISG activities.

The Telford Basin is now understood to be a terminal groundwater basin, due to the presence of the mine pits and related modifications to the landscape preventing external runoff from entering the mine site. Consequently, there will be no groundwater discharge outside the Telford Basin from the area of the demonstration plant.

4.7.7 Groundwater Dependent Ecosystems

There are no groundwater dependent ecosystems at or near the demonstration plant site. As discussed in Section 4.9.3, there are several areas of vegetation in and adjacent to the PEL that are expected to be reliant on groundwater as well as surface water inflows, and would be classified as groundwater dependent ecosystems. None of these areas of vegetation have any hydrogeological connectivity to the geological units present at the demonstration plant site.

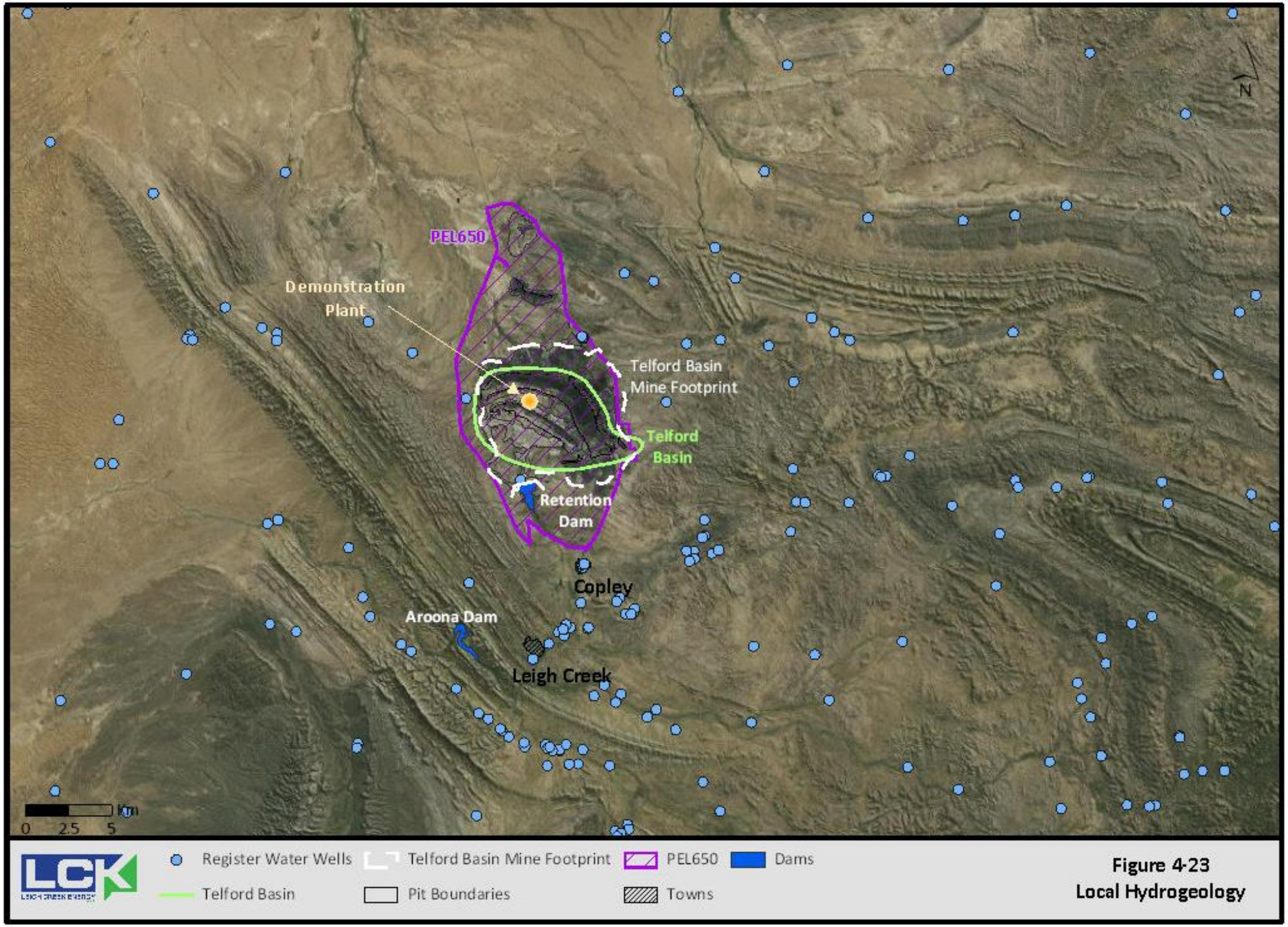


Figure 4-23
Local Hydrogeology

4.8 Surface Water

PEL 650 lies in the catchment of Leigh Creek, which is on the southern edge of the Lake Eyre Basin and drains north-west towards Lake Eyre. The major surface water features in the region are Lake Torrens, located approximately 55 km to the west, and Lake Frome which is located approximately 110 km east of PEL 650, on the eastern side of the Gammon Ranges.

Leigh Creek is the main surface water system in PEL 650. It enters the PEL on the southern boundary, north of Copley and exits the PEL near Lobe C of the Leigh Creek Coalfield at the PEL's north-western boundary.

Ridge lines located to the west and east of PEL 650 direct runoff via numerous small drainage lines towards the gently undulating plain where the PEL is located. Under natural (pre-mining) conditions, surface water would have moved generally northwards through PEL 650 from south to north-west, discharging to the Leigh Creek floodplain where it crosses the current Outback Highway.

Figure 4-24 shows the regional surface water features.

Modifications to drainage patterns by mining operations have resulted in much of the flow of Leigh Creek and its tributaries being retained on the southern, eastern and western boundaries of Lobe B. The Retention Dam captures the majority of flow in Leigh Creek, and two earthen walls have been constructed on the eastern and western margins of the coalfield to intercept flows towards the pits from the eastern and western ranges. A gap in the western wall allows water overflowing from the Retention Dam to flow closer to the coalfield, however its progress is impeded by the presence of mine spoil dumps and it does not reach the former channel of Leigh Creek within the coalfield downstream of the Retention Dam, or reach the Upper Series or Main Series pits (see Figure 4-25).

Surface water within Lobe B is inferred to remain predominantly within the Telford Basin, given the likelihood of mine pits acting as groundwater depressions and the reduced surface water runoff contributions from the ranges due to interception by the earthen walls. Transport downstream of Lobe B is confined to surface water overflow around the north-eastern and north-western margins of the site (outside the earthen walls) and via limited flow in the shallow water table aquifer, primarily in the floodplain sediments from recharge north of the Main Series Pit. As discussed in Section 4.7, the Main Series and Upper Series pits act as groundwater sinks and would capture any shallow groundwater from south of the Main Series Pit in Lobe B.

There are artificial water storages across the site, including the Retention Dam, dams formed by the eastern and western earthen walls, the two quarries located east of the Retention Dam, the mine pits and numerous constructed surface depressions where water pools after rain. Water in the Retention Dam, the quarries and the Lobe C, Lobe D and Lower Series pits is permanent.

Aroona Dam and its catchment, which supplies water to the town of Leigh Creek, is outside PEL 650 and outside the Leigh Creek catchment. Aroona Dam and its feeding creeks, Emu and Windy Creeks, are part of the Lake Torrens catchment draining to the west.

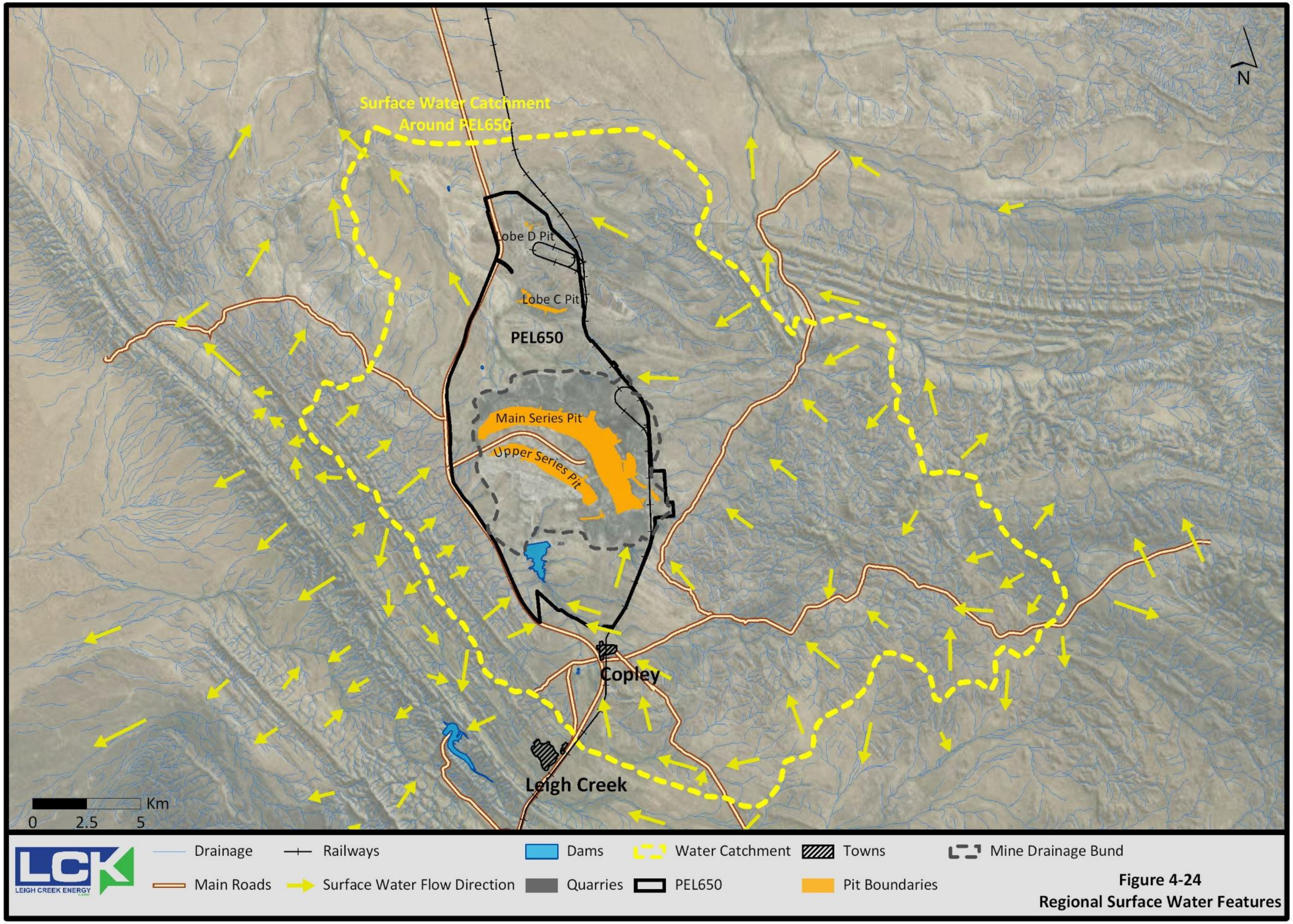


Figure 4-24
Regional Surface Water Features

PEL650

Aerial Image 18 Oct 2010

Figure 4-25
Lobe B Flooding

4.8.1 Demonstration Plant Site

The demonstration plant is located within Lobe B of the Leigh Creek Coalfield and surface water at the site is effectively isolated from the surrounding area by the adjacent Main Series and Upper Series pits and associated stockpiles. The site drains in a generally northerly direction via overland flow and collects in shallow depressions along the main road along the north of the demonstration plant area.

The site is bounded by haul roads to the west, east and south and the main road into the Coalfield to the north. Mine workers have indicated that during heavy rain the runoff is contained by the surrounding roads and can inundate the area.

4.9 Flora and Fauna

4.9.1 Vegetation

Vegetation in the vicinity of PEL 650 is typified by open eucalypt woodland or tall shrubland on larger creeks and drainage lines, open chenopod shrublands on floodouts and plains, and low woodlands, shrublands and grasslands on stony hills and ridges.

Vegetation types that are mapped as present in the vicinity of the PEL in DEWNR vegetation mapping (NatureMaps 2016) are listed in Table 4-8. The bulk of the mine site (including the demonstration plant site) is not mapped as native vegetation.

Table 4-8: Vegetation mapped in the vicinity of PEL 650

Veg. Code	Description
FR0002	*Tecticornia* sp. low open shrubland
FR0003	*Eucalyptus camaldulensis* ssp. +/- *Callitris glaucophylla* mid woodland
FR0004	*Acacia victoriae* ssp. tall open shrubland
FR0005	*Nitraria billardierei*, *Rhagodia spinescens*, *Maireana pyramidata* +/- *Atriplex nummularia* ssp. *nummularia* low shrubland
FR0008	*Atriplex vesicaria* ssp., *Maireana astrotricha*, *Maireana pyramidata* +/- *Maireana sedifolia* +/- *Ptilotus obovatus* var. *obovatus* low shrubland

The vegetation in the vicinity of the demonstration plant site has been highly disturbed and is dominated by species that can tolerate disturbance or are readily able to recolonise in disturbed areas. There are no vegetation types of conservation significance present.

Vegetation is predominantly a low, open to very open chenopod shrubland dominated by Black Bluebush (*Maireana pyramidata*) and Saltbush (*Atriplex* spp.) with occasional larger shrubs including Native Myrtle (*Myoporum montanum*), Plumbush (*Santalum lanceolatum*) and Elegant Wattle (*Acacia victoriae*).

Vegetation is generally very sparse, and bare ground dominates. Vegetation density is highest in areas where water accumulates and regeneration has been enhanced, such as previously graded tracks and drains. Larger, dense shrubs of Native Myrtle, Saltbush and Nitrebush (*Nitraria billardierei*) are often present in such areas.

Other plant species present include Copperburrs (*Sclerolaena* spp.), Spiny Saltbush (*Rhagodia spinescens*), Inland Shrubby Groundsel (*Senecio lanibracteus*), Lemon-grass (*Cymbopogon ambiguus*), Low Bluebush (*Maireana astrotricha*), Apple-bush (*Pterocaulon sphacelatum*) and Malvastrum (*Malvastrum americanum*). Plant species recorded during an inspection in May 2016 are listed in Appendix C.

4.9.2 Fauna

The disturbed nature of the site and vegetation present provide limited habitat value for native fauna.

Common fauna that would naturally occur in the region and are able to tolerate some level of disturbance are expected to be present at or use the site, in low numbers. This could include frogs (tadpoles were noted in a small excavated dam during drilling in July 2016, however very poor water quality during the site inspection in May 2016 precluded their presence at that time); possibly several species of lizards, snakes and small mammals; and birds that can utilise open shrubland habitats. Habitat for terrestrial vertebrates that are smaller and less mobile is generally compromised as a result of previous disturbance at the site.

Emus were observed on site during the site inspection and evidence of kangaroos, cattle and foxes was noted.

The degraded habitat present at the site is unlikely to provide habitat that is important to the survival of any species on any scale (local, regional, state or national).

4.9.3 Groundwater Dependent Ecosystems

There are several areas of vegetation in and adjacent to the PEL that are expected to be reliant on groundwater as well as surface water inflows, and would be classified as groundwater dependent ecosystems. These are associated with the channels of Leigh Creek and its tributaries and are generally outside the earthen walls bounding Lobe B, including several areas where hydrological modifications (such as blocking of creek lines that would have entered the mine site) have increased surface water ponding and water table recharge. The two excavated quarries that are approximately 4 km south of the demonstration plant site are understood to be expressions of the water table aquifer (AECOM 2016), and support a derived groundwater dependent ecosystem, with fauna present including fish and waterbirds.

There are no groundwater dependent ecosystems at or near the demonstration plant site and none of the groundwater dependent ecosystems in the broader area have any hydrogeological connection to the demonstration plant site or the strata underlying it (refer to Section 4.7.7).

4.9.4 Listed Threatened Species and Ecological Communities

A search of the EPBC Act and DEWNR flora and fauna databases has identified a number of rare or threatened flora and fauna species as being present or likely to occur in the general area of the PEL (DEE 2016a; DEWNR 2016a). Information on these species is provided in Appendix C.

No species of conservation significance were recorded during the inspection undertaken in the general area of the demonstration plant site in May 2016. Species of conservation significance are considered unlikely to occur, given the habitats present and the highly disturbed nature of the site[12].

There are no nationally listed threatened ecological communities known to be present in the area and none are present at or near the site.

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[12] The site inspection was carried out in late autumn following generally dry conditions, although there had been some significant rainfall approximately two months prior and one week prior to the inspection. Due to the timing and preceding conditions, there may be annual or ephemeral species present at the site, or migratory species that use the site, that were not evident at the time of the inspection. However, given the highly disturbed nature of both the site and the vegetation community present, it is considered unlikely that any species of conservation significance would occur.

A number of State-listed threatened ecological communities have been identified as conservation priorities within the Stony Plains and Flinders Lofty Block bioregions, including Coolibah and River Red Gum woodland on drainage lines and floodplains, Old-man Saltbush on floodplains, Queensland Bluebush shrubland on cracking clay depressions and Bullock Bush tall shrubland (DEH 2009). None of these communities are present at or near the site.

4.9.5 Weeds and Pest Animals

No declared plants or weeds of high significance have been noted at the site. Wards weed (*Carrichtera annua*) is present in low numbers. Malvastrum (*Malvastrum americanum*) which is introduced to Australia but considered naturalised, is also present.

Pest animals in the region that could potentially occur on site include cats, goats, foxes, rabbits and wild dogs. The area is inside (south of) the Dog Fence where wild dogs / dingoes are a declared pest under the Natural Resources Management Act, and numbers are generally low. Goats are widespread in the Flinders Ranges but are typically more common in hills and rockier areas. European Carp (*Cyprinus carpio*) was known to be present in the Leigh Creek Retention Dam following its illegal introduction (Ehmann 2009) however surveys in 2012 did not locate any carp following eradication work undertaken in previous decades (FPP 2017).

4.10 Air Quality

Air quality in the broader region is expected to be typical of a remote rural environment and influenced by a range of activities such as:

- dust from stock and vehicle movements or high winds
- vehicle and equipment exhaust fumes.

Air quality in the vicinity of the Leigh Creek Coalfield is also likely to be influenced by:

- dust generation from spoil dumps and mining / rehabilitation activities
- particulates, vapour and combustion emissions from spontaneous combustion of mine spoil dumps. The pits are surrounded by mine spoil dumps which are known to spontaneously combust releasing particulates and sulphurous and phenolic odours.

The closest residences are at Copley which is located approximately 8.5 km south of the demonstration plant site and approximately 1 km south of the southern boundary of PEL 650.

The occurrence of odours at Copley (e.g. the smell of rotten eggs) has been informally raised by several stakeholders in mid to late 2016 (before any activities with the potential to release odour had been undertaken by Leigh Creek Energy).

A preliminary background odour assessment was carried out in June 2017 (Pacific Environment 2017a). This detected odour from the coalfield (a smoky character consistent with fugitive emissions from spontaneous combustion) at a distance of approximately 5 km. Odour was also recorded in Copley from the caravan park wastewater irrigation area. Winds were not blowing towards Copley at the time of the site visit for field odour observations, which meant that there was no opportunity to observe odour from the coalfield at Copley. However, it is understood that odour from the coalfield is occasionally present in Copley and that coalfield odour has been observed as far south as Leigh Creek

4.11 Noise

The existing noise environment in the region is typical of sparsely populated regional and pastoral areas, with generally low levels of background noise dominated by natural sources (e.g. wind, animals and insects) and intermittent background noise from traffic on the nearby Outback Highway. Mining activities, including blasting, would have influenced the noise environment in proximity to the mine prior to closure. Ongoing mine closure activities by Flinders Power are expected to generate intermittent noise (e.g. from heavy machinery operation), with locations and noise levels dependent on the activities being undertaken.

The region is extremely sparsely populated and there are no residences or other sensitive receptors within the PEL. The closest residences are at Copley which is located approximately 8.5 km south of the demonstration plant site and approximately 1 km south of the southern boundary of PEL 650.

4.12 Land Use

4.12.1 Land Owners

The demonstration plant site and PEL 650 are located in the Leigh Creek Coalfield, which is constituted by a number of different titles.

A list of all land owners for the demonstration plant site (as defined by the Petroleum and Geothermal Energy Act) is provided in Table 4-9. The demonstration plant site is located on Crown Lease 1545/20 (Section 324).

Table 4-9: Land Owners for the Demonstration Plant Site

Name	Land Owner
Leigh Creek Coalfield	Perpetual Crown Lease CL 1067/36 Section S320 Transferred to Flinders Power Pty Ltd 23/04/1999 Perpetual Crown Lease CL 1234/37 Section S319 Transferred to Flinders Power Pty Ltd 23/04/1999 Perpetual Crown Lease CL 1545/20 Sections S321, S324, S418, S485, S486 and S489 Transferred to Flinders Power Pty Ltd 23/04/1999 CL 6163/703 Section Q3003 Transferred to Generation Lessor Corporation (State Government) 19/06/2003
PEL 650	Leigh Creek Operations Pty Ltd

4.12.2 Land Use

The major land uses in the region are mining, pastoralism, conservation and tourism.

The closest population centres to PEL 650 are Copley (1 km south of the PEL and 8.5 km south of the demonstration plant site), Leigh Creek (5 km south of the PEL and 12 km south of the demonstration plant site) and Lyndhurst (12 km north of the PEL and 21 km north of the demonstration plant site). Beltana is located 30 km to the south of the PEL and Neppabunna is located 51 km to the east (see Figure 4-26).

4.12.2.1 Mining

Mining has been undertaken in the project region since the 1850's. There are a number of Mining Leases (MLs) in the region surrounding PEL 650, the closest of which (the Mountain of Light Copper Mine) is located approximately 3 km south of PEL 650. Commodities produced in the region include copper, marble, gold and magnesite. Several Mining Exploration Licences (ELs) are also in place in the region primarily west, south and east of PEL 650, covering exploration for magnesite, gold, silver, copper, lead, zinc, base metals and marble. There are numerous abandoned mines in the broader region from which minerals such a copper, radium and uranium were extracted (Northern Flinders Ranges SCB 2004).

The primary land use in PEL 650 was open cut coal mining which commenced in Leigh Creek in the 1940s. The Leigh Creek open cut mine was originally established under a Crown Agreement issued by the South Australian Government to the Electricity Trust of South Australia (ETSA) in an effort to secure the State's electricity supply. After the *Mining Act 1971* came into effect to regulate mining in the state, the Leigh Creek area continued to be reserved from its provisions rather than operating under a conventional Mining Lease issued under the Mining Act (AECOM 2016).

The Leigh Creek Coalfield was most recently operated by Alinta Energy. Mining ceased in November 2015 after it became increasingly uneconomic. Mine closure activities are currently being undertaken within PEL 650 by Flinders Power, as discussed in Section 4.1.

4.12.2.2 Pastoralism

Pastoralism, in the form of livestock grazing (cattle and sheep) on native pastures, has a long history in the region, beginning in the 1850s and continues to be the most extensive regional land use.

Pastoral leases in the region around PEL 650 are listed in Table 4-10 and shown in Figure 4-26.

Table 4-10: Pastoral leases in the region of PEL 650

Pastoral lease	Distance from PEL 650 (station boundary)
Myrtle Springs (Vinya Aboriginal Corporation)	Adjacent (west)
Leigh Creek (Adnyamathanha Land Council Inc)	Adjacent (east)
Farina	6 km north
North Moolooloo	6 km south-east
Burr Well	7 km east
Beltana	15 km west
Puttapa	10 km south
Mount Lyndhurst	12 km north

4.12.2.3 Conservation

The Vulkathunha - Gammon Range National Park (50 km east of PEL 650) and Ikara-Flinders Ranges National Park (81 km south of PEL 650) are the largest protected areas in the region. The parks are co-managed by the Department of Environment, Water and Natural Resources and the Adnyamathanha traditional owners. The Adnyamathanha people also manage the 58,000 ha Nantawarrina Indigenous Protected Area, which adjoins the southern boundary of the Vulkathuna – Gammon Ranges National Park.

Lake Torrens National Park is located 48 km west of PEL 650 and protects Lake Torrens, a large ephemeral salt lake. Lake Torrens is listed in the Directory of Important Wetlands as 'Inland Saline

Lake' together with Lake Frome and Lake Callabonna (DEE 2016b). This series of inland lakes together form a complex of relatively pristine playa and ephemeral wetlands providing habitat for large wader (bird) populations when in flood.

Ediacara Conservation Reserve is located 35 km south-west of PEL 650 and was established to protect an internationally significant fossil assemblage and places of Aboriginal and non-Aboriginal cultural heritage.

Aroona Sanctuary, which encompasses Aroona Dam and areas around the Leigh Creek township and was gazetted as a sanctuary under the National Parks and Wildlife Act in 1995, is approximately 3 km south of the PEL and 10 km south of the demonstration plant location.

Warraweena, a former pastoral station which is operated as a private conservation reserve, is located approximately 25 km south-east of PEL 650.

There are no protected areas within PEL 650.

Conservation reserves in the area are shown in Figure 4-26.

4.12.2.4 Tourism

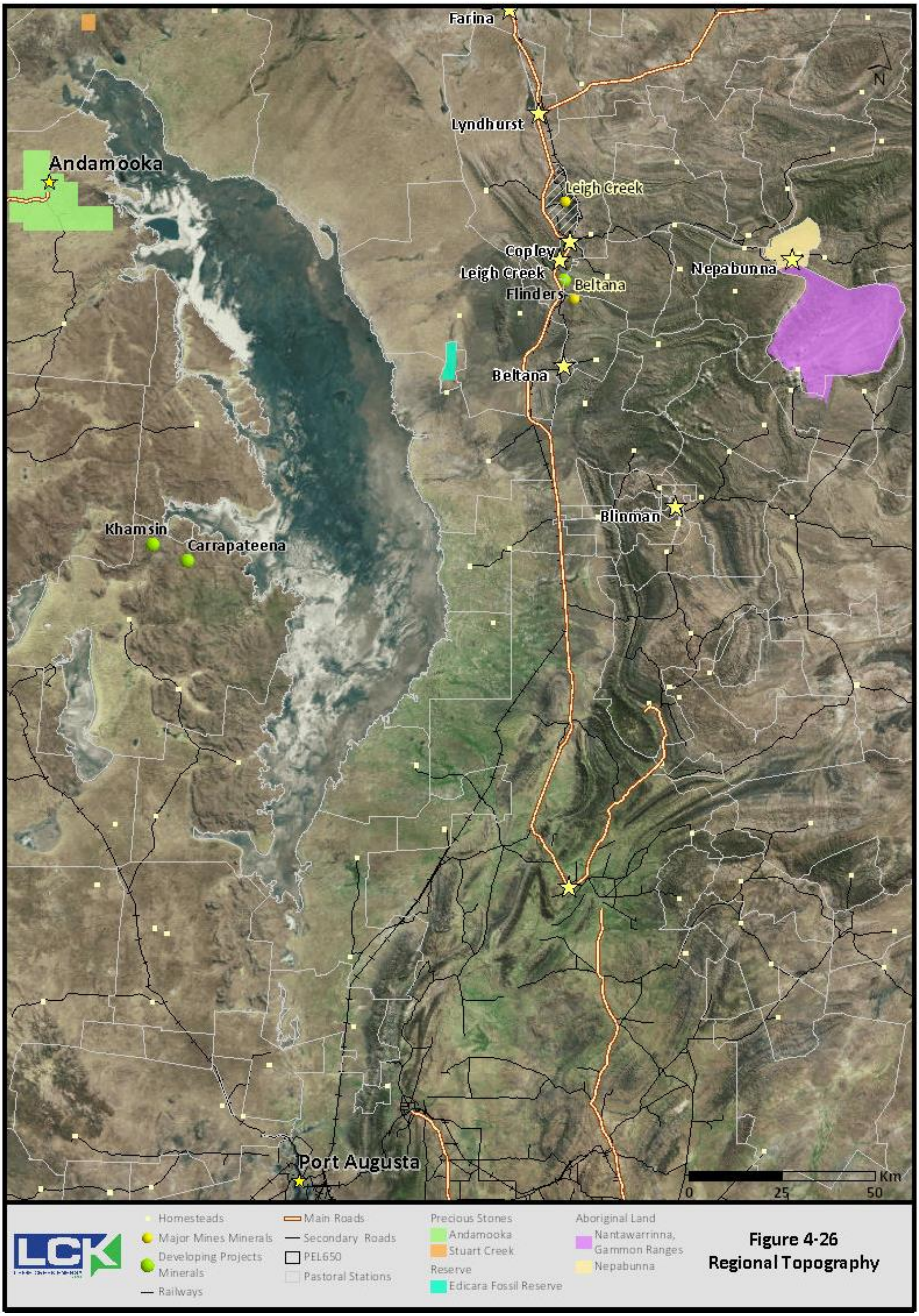
Tourism in the region is mainly focussed on 'outback' and 'wilderness' experiences, particularly associated with the national parks located in the Flinders Ranges. Tours of the region are offered by tour operators and provide a range of activities including coach tours, personalised 4WD tours, camel trekking, horse riding, bushwalking, town tours and scenic flights. Many pastoral stations in the region also offer accommodation and activities such as self-drive 4WD tours for tourists (Northern Flinders Ranges SCB 2004).

The community at Nepabunna offers visitors to the region accommodation and tours to locations such as painting and carving sites, ochre pits, and local gorges which would otherwise be inaccessible without a local Adnyamathanha guide (Nepabunna Community Inc 2016). Iga Warta, located approximately 5 km west of Nepabunna, is an Aboriginal cultural tourism centre which offers a unique opportunity for visitors to experience Adnyamathanha, Aboriginal culture, living, sharing and learning in an Aboriginal community setting (Iga Warta 2016).

The most regular visitation to the Leigh Creek area is by self-drive, independent and RV (recreational vehicle) travellers, with caravan and camping enjoyed by 35% of domestic and 55% of international tourists to the area (DSD 2016). Leigh Creek Township is utilised as a base for day trips to destinations such as Beltana, Copley, Lyndhurst and Farina.

The Outback Highway (the Hawker-Lyndhurst Road) which passes the township of Leigh Creek and the Leigh Creek Coalfield, is utilised by tourists travelling to and from outback South Australia, Queensland and the Northern Territory via the Oodnadatta, Birdsville and Strzelecki Tracks.

The South Australian Government is focusing on developing further tourism opportunities for the area following the closure of the Leigh Creek Coalfield and the transition of Leigh Creek Township from a 'closed' community solely dedicated to the operation of the coalfield, to an open independent regional service centre (DSD 2016).


Farina
Lyndhurst
Andamooka
Leigh Creek
Copley
Leigh Creek
Beltana
Flinders
Nepabunna
Beltana
Blinman
Khamsin
Carrapateena
Port Augusta
Km
0
25
50
N
Homesteads
Major Mines Minerals
Developing Projects Minerals
Railways
Main Roads
Secondary Roads
PEL650
Pastoral Stations
Precious Stones
Andamooka
Stuart Creek
Reserve
Edicara Fossil Reserve
Aboriginal Land
Nantawarrinna, Gammon Ranges
Nepabunna
Figure 4-26
Regional Topography

4.12.3 Native Title

PEL 650 lies within the boundaries of the Adnyamathanha No 1 Native Title determination. The State of South Australia has granted PEL 650 on the basis that native title within the land is extinguished. Irrespective of the incidents of tenure history, LCK recognise and respect the Adnyamathanha as the traditional owners of the region and therefore as key stakeholders. LCK has entered into a heritage protection agreement with the Adnyamathanha Traditional Lands Association (ATLA) and is consulting with ATLA relative to proposed activities within PEL 650.

There are a number of Indigenous Land Use Agreements currently agreed between the South Australian Government and the Adnyamathanha Native Title claimants in the broader region covering issues including mineral exploration and co-management of national parks.

4.13 Socio-economic

The region is located in the Unincorporated area (i.e. out of councils area) of South Australia. Jurisdiction for the area falls under the responsibility of the Outback Communities Authority (OCA) which has legislative responsibility to provide administration and management support for outback communities.

The main population centre in the region is Leigh Creek Township, built in 1982 by the State Government to support the State-owned electricity company. The township was leased to Alinta Energy and operated as a ‘closed’ town until the closure of the Leigh Creek Coalfield in 2016. Flinders Power will continue to manage the town until January 2017 when it is expected that the Outback Communities Authority will take over operational management of the township (OCA 2016).

At its peak the population of the Leigh Creek Township was in excess of 1000 people (OCA 2016), but by 2011 the resident population had fallen to 505 (ABS 2016). Following announcement of the coalfield closure, the population has continued to decrease incrementally with data indicating 220 residents in the town in April 2016, comprised of residual families, contractors, government employees and business employees (DSD 2016).

The town of Copley, located 6 km north of Leigh Creek township, had a population of 103 in 2011, 45% of whom were Aboriginal and Torres Strait Islanders (ABS 2016).

The township of Leigh Creek is an important regional service centre providing essential services including water supply, an airport, a school, a hospital, emergency services, a supermarket, a post office and shops. Almost all government employees in the region are accommodated in Leigh Creek. Leisure services are also provided with the town having a tavern, swimming complex, a caravan park, community buildings and parks. Leigh Creek is expected to continue to provide essential services for about 700 people in the township and surrounding region (DSD 2016).

The Outback Highway (the Hawker-Lyndhurst Road) which passes the township of Leigh Creek and the Leigh Creek Coalfield is the main transport and tourism access road in the region.

The Stirling North-Telford Railway was constructed to transport coal from the Leigh Creek Coalfield to the Port Augusta power stations. Following closure of the coalfield, the railway remains operational despite no further coal trains being operated. The railway is currently leased to Flinders Power and is due to be returned to the government in an operating condition in July 2017 (Flinders Power 2016).

ElectraNet’s Davenport to Leigh Creek 132 kV high-voltage transmission line and sub-station which supply power to Leigh Creek Township and the coalfield are located south-west and west of PEL 650.

Aroona Dam provides the water supply to Leigh Creek and surrounding townships and pastoral stations. It is located west of the Leigh Creek township and is approximately 5 km south-west of the PEL boundary and 12 km south-west of the demonstration plant site. A reverse osmosis plant located between the Leigh Creek township and airport provides backup water supply from three local borefields (Windy Creek, Emu Creek and Emu Creek South) (Collins Anderson 2007).

5 Environmental Impact Assessment

This section discusses potential and perceived environmental impacts related to the proposed demonstration plant.

Sections 5.1 to 5.10 provide a detailed discussion of the components of the environment that are potentially impacted by the proposed activities. A key focus of the discussion is the potential for impact to groundwater, which is discussed in Section 5.2.

The discussion is supported by an environmental risk assessment. The risk assessment is summarised in Table 5-4 (in Section 5.11), which outlines the potential hazards, the potential consequences and their likelihood, the management measures that will be applied and the resulting level of risk.

Reference is made to the results of the risk assessment where relevant throughout the discussion.

5.1 Cultural Heritage

Potential impacts to cultural heritage arise mainly from:

- earthworks associated with construction and rehabilitation
- activity outside designated / approved areas.

The demonstration plant is located in existing disturbed areas within the Leigh Creek Coalfield. The site and its surrounds have been subject to extensive, heavy disturbance from previous coal mining activities and consequently any cultural heritage values and sensitivity have been significantly reduced.

Work Area Clearances with the Adnyamathanha Traditional Lands Association have been carried out for the demonstration plant site. Demonstration plant activities will be undertaken within the area cleared by the Work Area Clearance. Signage and fencing (where required) will be installed to delineate approved areas and any restricted areas. If sites of cultural heritage significance are present in the vicinity they will be flagged and / or fenced off where necessary to prevent disturbance. In addition, procedures are in place to deal with the incidental discovery of cultural heritage material.

5.1.1 Risk Assessment

The level of risk to cultural heritage in relation to earthworks during construction and rehabilitation activities has been assessed as low, due to the remote likelihood of this occurring at the site after a Work Area Clearance has been carried out. The level of risk for impact to cultural heritage caused by activity outside designated areas, although unlikely, has the potential for a major consequence, leading to a medium level of risk (see Table 5-4).

5.2 Groundwater

Potential (and perceived) impacts to groundwater from demonstration plant activities arise mainly from the following hazards:

- Loss of containment due to loss of well integrity
- Migration of COPC away from the gasifier
- Spills or leaks of fuel, chemicals or produced fluids
- Groundwater drawdown from consumption in the gasifier.

In general, the risk to groundwater posed by the demonstration plant is relatively low as there are no aquifers present at or near the site, the gasifier is surrounded by very low permeability aquitards, groundwater in these aquitards is saline, and there are no groundwater receptors present in the Telford Basin and no credible pathways to groundwater receptors. This is discussed further in the following sections.

5.2.1 Loss of containment due to loss of well integrity

A loss of well integrity could result in the leakage of gas and other COPC to shallower geological units or possibly to the surface. The risk is reduced to as low as reasonably practical by well design and construction and managed through operational monitoring and maintenance. In particular:

- Well design and construction provides the mechanical integrity that reduces this risk to as low as possible. Wells (including monitoring wells near the gasifier) are designed to withstand the pressure, temperature, operational stresses and loads that will occur (see Section 3.2).
- The operating envelope of the wells is within the experience of the manufacturers producing the wellhead and downhole equipment to be used. Whilst the temperatures expected at the outlet and observation wells during operation are high, they are still within the range of temperatures for which standard design solutions are available and these standard design solutions are being used in the wellheads.
- The wellheads are designed with two isolating valves to each flow path and with a back-pressure valve profile so that an extra pressure containing barrier can be installed if these valves need to be replaced.
- All high pressure equipment and all well integrity barriers are pressure tested to ensure well integrity (including the well and well head).
- All leak seal areas on the inlet, outlet and observation wells have multiple seals and the pressure testing includes the void spaces between the seals.
- Cement bond logs or ultrasonic logs are run to confirm the integrity of cement that fills the space between the casing and the well bore and prevents migration.

If a well integrity failure occurred, it could result in syngas and COPC being released to the strata adjacent to the well, or moving up the outside of the well to shallower depths. A major well integrity failure could lead to uncontrolled flows to the surface (and possibly fire or explosion, which are discussed further in Section 5.9.3). If a major well integrity failure occurred, injection of air into the gasifier would be shut off and action taken to control the well where required (e.g. using specialist intervention equipment). ISG reactions in the gasifier chamber would rapidly cease following removal of the oxidant supply, and emissions would be expected to attenuate rapidly and cease within a period of days.

The potential impacts of a well integrity failure on aquifers or groundwater users are heavily mitigated by the hydrogeological setting of the demonstration plant. None of the geological units at the site are considered aquifers and there are no groundwater users within or near the footprint of the demonstration plant. Although the Telford Gravels at the surface is a potential water table aquifer, it is discontinuous (and has been effectively dewatered at the site) due to mining operations and the presence of the adjacent pits. All other units intersected by the wells and below the gasifier (the Main Series Overburden, Main Series Coal and Upper Series Overburden) are aquitards with very low permeability.

If a well integrity failure did occur, gas and other COPC released from the well would encounter groundwater held in the aquitard units. However, any impacts would remain relatively localised and minor due to the low permeability, very low rate of groundwater movement, natural occurrence of many of the COPC in the coals and overburden and the adsorption characteristics of these units.

A well integrity failure that resulted in gas and COPC reaching the surface could impact soils at the site (as discussed in Section 5.3.3). However, as surface water that infiltrates the Telford Gravels does not drain away from the vicinity of the site (and ultimately drains to the adjacent pits) this would not result in impact to any aquifers or surface water off-site.

There are consequently no credible pathways that would result in impact to aquifers or groundwater users from a well integrity failure.

Risk Assessment

The level of risk has been assessed as low for potential casing or cement failure, however the higher consequence rating associated with the risk that a major cement / casing failure could lead to fire or explosion leads to a medium level of risk for this event (see Table 5-4).

5.2.2 Migration of COPC away from gasifier

There are number of mechanisms that could potentially lead to migration of COPC away from an ISG gasifier. At the demonstration plant site, the potential mechanisms can be summarised as:

- gasifier pressure exceeding surrounding groundwater pressure, causing migration in groundwater away from gasifier
- direct escape from the gasifier through drill holes or transmissive faults
- gasifier chamber growth intersecting a potential migration pathway
- increase in permeability of the gasifier's surroundings by mechanical stress changes and fracturing (including significant gasifier chamber collapse)
- migration of COPC from the gasifier chamber after decommissioning.

The likelihood of these mechanisms (if they occurred) resulting in impact to aquifers or groundwater users is very low due to the geological setting of the demonstration plant site, as well as the absence of aquifers or groundwater users.

The following sections discuss each of these mechanisms in detail, with reference to the discussion of escape scenarios and pathways provided by Camp and White (2015) where relevant.

5.2.2.1 Gasifier pressure exceeding surrounding groundwater pressure

The demonstration plant will be operated to keep pressure in the gasifier chamber below surrounding groundwater pressure at the top of the gasifier chamber, in order to avoid outward pressure gradients. Outward pressure gradients could potentially drive flow of COPC away from the gasifier (either as a gas or dissolved in groundwater or as a non-aqueous phase liquid).

Possible events that could result in gasifier pressure exceeding surrounding groundwater pressure (based on Camp and White 2015) include:

- pressure in the gasifier chamber becoming higher than intended due to causes such as plugging of the outlet well or the in-seam gas exit channel faster than controls (such as reducing the inlet flow rate) can compensate, equipment failure (e.g. gauges, valves/controllers), injection (too fast), outflow (too slow), software failure, operator error, design flaws reducing the ability to control to the specified pressure (particularly in multiple gasifier ISG designs)
- temporal fluctuations in gasifier chamber gas pressure become greater than expected
- groundwater pressure in the surroundings is lower than thought
- the gasifier chamber or connected gas-filled fractures extend vertically upwards higher than thought.

These events can largely be avoided or mitigated by careful design and operation of the gasifier (including the use of safety factors[13] to allow for uncertainties and the integration of multiple preventative controls and mitigation strategies as discussed in Section 3.4.3) and monitoring of the gasifier and surrounding groundwater pressure. Demonstration plant design and operation will be undertaken to avoid these events occurring as far as practicable, and will take into account the relevant design and mitigation measures outlined in Camp and White (2015).

If the gasifier pressure was to exceed the surrounding groundwater pressure, the potential for COPC to migrate away from the gasifier is extremely limited due to the low permeability of the coal and surrounding strata, the resulting very slow groundwater movement (see Section 4.7.4), and high adsorption properties of the surrounding coal and carbonaceous mudstone (which would further retard movement of COPC). In particular:

- the gasifier is overlain by 530 m of carbonaceous mudstone overburden which is a low permeability aquitard
- the Main Series Coal is approximately 12 m thick and is also a low permeability aquitard similar to the Main Series Overburden
- the Lower Series Overburden consists of low permeability interbedded coal and mudstone in the order of 100 m and is considered an aquitard.
- there are no known existing drill holes through the coal within 100 m of the gasifier
- the monitoring wells installed for the demonstration plant are the closest subsurface infrastructure (the closest monitoring well will be approximately 10 m distant). The closest well is cased and cemented and engineered to withstand gasifier chamber pressures and temperatures
- there are no transmissive faults in close proximity to the gasifier.

If COPC did enter the surrounding rock, the conceptual site model (Section 4.7.4) indicates that groundwater movement after demonstration plant operation would be towards the gasifier chamber for years or decades. After this, groundwater movement would be towards the Main Series Pit, however it is expected to take hundreds to thousands of years for groundwater from the vicinity of the gasifier to reach the pit.

In addition, the absence of aquifers or groundwater users at or near the site means that there is no credible likelihood of impact to aquifers or groundwater users.

<u>Risk Assessment</u>

The level of risk has been assessed as low for this mechanism (see Table 5-4).

5.2.2.2 Direct escape from the gasifier through drill holes or transmissive faults

The gasifier is located at a site where existing drill holes and transmissive faults are not documented to be present. No seismic profiling is available at this location, however the selection of the proposed gasifier location has been considered using available (historic) exploratory holes,

[13] A safe gasifier operating pressure is determined by considering initial groundwater or “confining” pressure; the change in confining pressure over time; potential growth of the gasifier over time and any connected opening or joint above the gasifier; and a factor of safety to ensure that the gasifier pressure does not exceed the confining pressure. These elements will be monitored constantly throughout the operation of the gasifier and the gasifier pressure adjusted if required. Based on an initial confining pressure of 490 m of water, the gasifier releasing stress up to 75 m above the gasifier, and a 10% factor of safety, the maximum safe operating pressure is 373.5m of water or 37.35 bar. LCK plans to operate the gasifier at a variety of pressures to test the efficiency of the gasification processes. The gasifier will not be operated at a pressure above 36 bar to ensure the safe operating pressure is not reached.

wireline logging and predictive interpretation of the geological structures in the area. The closest available (historic) drill hole is located over 100 m from the proposed gasifier. Geological investigations have confirmed the absence of significant faulting within the proposed gasifier buffer zone: a 100 m radius about the proposed gasifier. Formation integrity testing, to determine pressures at which fracturing may initiate and propagate, has been completed and interpretation of these data suggest new or existing features are unlikely to be created/affected as the proposed operating pressure of the gasifier is substantially lower than any pressure required to affect the rock mass. To date, no feature displaying permeability in excess of the surrounding formation, has been identified.

Risk Assessment

The level of risk has been assessed as low for escape via this mechanism (see Table 5-4).

5.2.2.3 Other potential migration mechanisms during normally pressured operations

Several other mechanisms have been described where outward flow of gas and COPC could theoretically occur despite the inward water pressure gradients and inward flow of groundwater that occur during normal operations (Camp and White 2015, Couch 2009). These include:

- formation of gas-saturated shoulders in the upper part of the coal seam surrounding the gasifier chamber
- fingering of gas upwards against the pressure gradient due to buoyancy-induced instability
- thermally or density (salinity) driven upward flow of groundwater.

These mechanisms do not pose a credible risk at the demonstration plant site, because the low permeability of the coal and overburden at the site effectively prevents them occurring.

5.2.2.4 Gasifier chamber growth intersecting potential migration pathway

Migration of COPC away from the gasifier could potentially occur if the gasifier chamber grows further than expected and intersects a permeable pathway. This could potentially occur via:

- vertical growth of gasifier chamber or its fractures into a high permeability stratum
- lateral gasifier chamber growth intersecting a permeable pathway.

The geomechanical investigations into gasifier chamber growth and the lack of permeable strata or permeable pathways near the gasifier chamber indicate that the likelihood of this occurring is very low, as discussed further below.

Gasifier growth is limited by the in-coal distance between the inlet and outlet wells. Gasifier growth can be controlled by oxidant injection rate/pressure and outlet well flow/pressure. The oxidant supply can be shut off if required to control or halt the ISG process and halt chamber growth.

Geomechanical estimates indicate that the if the gasifier chamber is up to approximately 30 m across and up to 15 m high the potential fractured zone could extend up to 60 - 75 m above the level of the roof of the coal seam (see Appendix B). On this basis it is currently estimated over 400 m of Main Series Overburden (low permeability aquitard) will remain in place to provide a hydraulic seal above the demonstration stage gasifier.

The effect of heat and / or partial combustion on the roof rock of the gasifier chamber is currently under evaluation. Additional roof collapse as a result of temperatures generated by the gasifier could potentially reduce the success of gasification but could not feasibly result in chamber growth through 400 m of overburden.

In addition, there are no permeable pathways in close proximity to the gasifier chamber that would plausibly be intersected even if excessive chamber growth occurred, as discussed in Section 5.2.2.1. In particular, there are thick aquitards (with low permeability) above and below the gasifier chamber and growth of the chamber or fractures to the surface (over 500 m) is not plausible.

There are no discontinuities, drill holes or transmissive faults in close proximity that could be intersected by the chamber, as discussed in Section 5.2.2.1. The monitoring wells installed for the demonstration plant are the closest subsurface infrastructure (the closest proposed monitoring well is approximately 10 m distant) and this well is designed and constructed to withstand gasifier chamber pressures and temperatures.

There are also no aquifers present that could be impacted, as discussed in Section 5.2.2.1.

Risk Assessment

The level of risk has been assessed as low (see Table 5-4)

5.2.2.5 Increase in permeability of surroundings by mechanical stress changes and fracturing (including significant gasifier chamber collapse)

Stress changes due to the creation of the gasifier chamber can alter the permeability of the surrounding strata. This can potentially include creation of new fractures (or reactivation of existing fractures), delamination of bedding planes, reactivation of faults or large scale changes if significant gasifier chamber collapse occurs.

The gasifier chamber is small-scale and deep. As discussed above, geomechanical investigations indicate that the gasifier chamber is expected to be up to approximately 30 m across and up to 15 m high with a potential fractured zone extending up to 60 - 75 m above the level of the roof of the coal seam (see Appendix B). Any increase in permeability above the coal seam is expected to be constrained within this fracture zone above the gasifier. The Main Series Overburden beyond the fracture zone is expected to remain undisturbed and maintain its low permeability. It is currently estimated that up to 400 m of Main Series Overburden (low permeability aquitard) will remain in place to provide a hydraulic seal above the demonstration stage gasifier.

As there are no overlying aquifers that could be impacted, and overlying strata are aquitards with only very slow movement of groundwater (towards the Main Series Pit), any changes in permeability of surrounding strata that did occur would not impact aquifers or groundwater uses.

Risk Assessment

The level of risk has been assessed as low (see Table 5-4).

5.2.2.6 Migration of COPC from gasifier chamber after decommissioning

The presence of COPC in the gasifier chamber after gasification ceases presents a potential source that could affect groundwater. The nature of the source and potential movement of COPC are discussed further below.

Source conditions

After decommissioning, the gasifier chamber will be fluid free, as discussed in Section 4.7.4, but it will partially be filled with condensed tars and mineral ashes which will create a source of chemicals which could potentially be mobilised into groundwater. Organic compounds (e.g. monocyclic and polycyclic hydrocarbons) that are decomposed in the reaction zone whilst gasification continues would be formed and then retained within this zone post-gasification.

At demonstration plant decommissioning there will also be a zone of devolatilised coal around the periphery of the gasification chamber. This is due to the retained heat in the coal and may still be adequate to produce organic chemicals after oxygen ceases to reach the coalface. This could result in increased concentrations of some organic and inorganic chemicals in groundwater in the chamber. The concentrations of inorganic chemicals (such as calcium, magnesium, iron, lead and others) which are present in the coal and whose solubility is a function of pH, temperature and carbon dioxide concentration would also increase significantly.

Until the chamber completely fills with groundwater and pressures re-equilibrate with the surrounding aquitards, the potential for any such chemicals to move out of the chamber is insignificant due to the inward hydraulic gradient. If these chemicals persist after the groundwater equilibrates, any organic compounds that enter groundwater in the chamber would be removed to some degree from the solution by sorption (i.e. organics will adsorb quite strongly onto substrates with high organic carbon content) as they move into the surrounding rocks (coal and carbonaceous mudstone).

Phenols and low molecular weight aromatic compounds will persist in solution, but less soluble and heavier molecular weight compounds are likely to be fully removed by sorption. The primary organic chemicals of concern which may reside in groundwater for long periods of time include some phenolic species, BTEX and naphthalene.

Inorganic compounds would primarily be associated with leaching from the ash left in the gasification chamber. The ash typically contains leachable calcium, aluminium, sulphate, hydroxide, barium, magnesium, boron, bromide and several other heavy metals. These chemicals could leach from the ash in concentrations higher than those found in the natural groundwater (baseline conditions).

Post gasification monitoring of groundwater quality at a number of in situ gasification trials indicates that over time the concentrations of organic and inorganic chemicals (such as heavy metals (cadmium, iron, lead and zinc), PAHs and phenols reduce naturally as a result of sorption and precipitation (Ahern and Frazier 1982).

Groundwater Movement

In general, the potential for COPC to migrate away from the gasifier is extremely limited due to the low permeability, slow groundwater movement and high sorption properties of the surrounding coal and carbonaceous mudstone.

The conceptual site model (Section 4.7.4 and Figure 5-1) indicates that groundwater movement after demonstration plant operation would be towards the gasifier chamber for years or decades. After this, groundwater movement would be towards the Main Series Pit, however it is expected to take hundreds to thousands of years for groundwater from the vicinity of the gasifier to reach the pit. Significant degradation and adsorption of any COPC in the migrating groundwater would occur over this period.

Concentrations of COPC in the chamber would reduce naturally as a result of sorption and precipitation. The anticipated time period where COPC are present and available for migration is estimated to be significantly smaller than the time period for the chamber to fill and provide groundwater movement away from the chamber.

Once the temperature reduces to allow for safe entry, groundwater monitoring of the chamber for COPC will be undertaken using the observation well. Regular sampling of the groundwater monitoring wells around the demonstration plant site will continue during the decommissioning and closure period to investigate the presence of COPC and confirm the expected low level of risk.

There are no aquifers in the area of operation and no pathways to aquifers from the gasifier chamber. The absence of aquifers or groundwater users at or near the site means that the likelihood of impact to aquifers or groundwater users occurring is negligible.

Risk Assessment

The level of risk has been assessed as low (see Table 5-4).

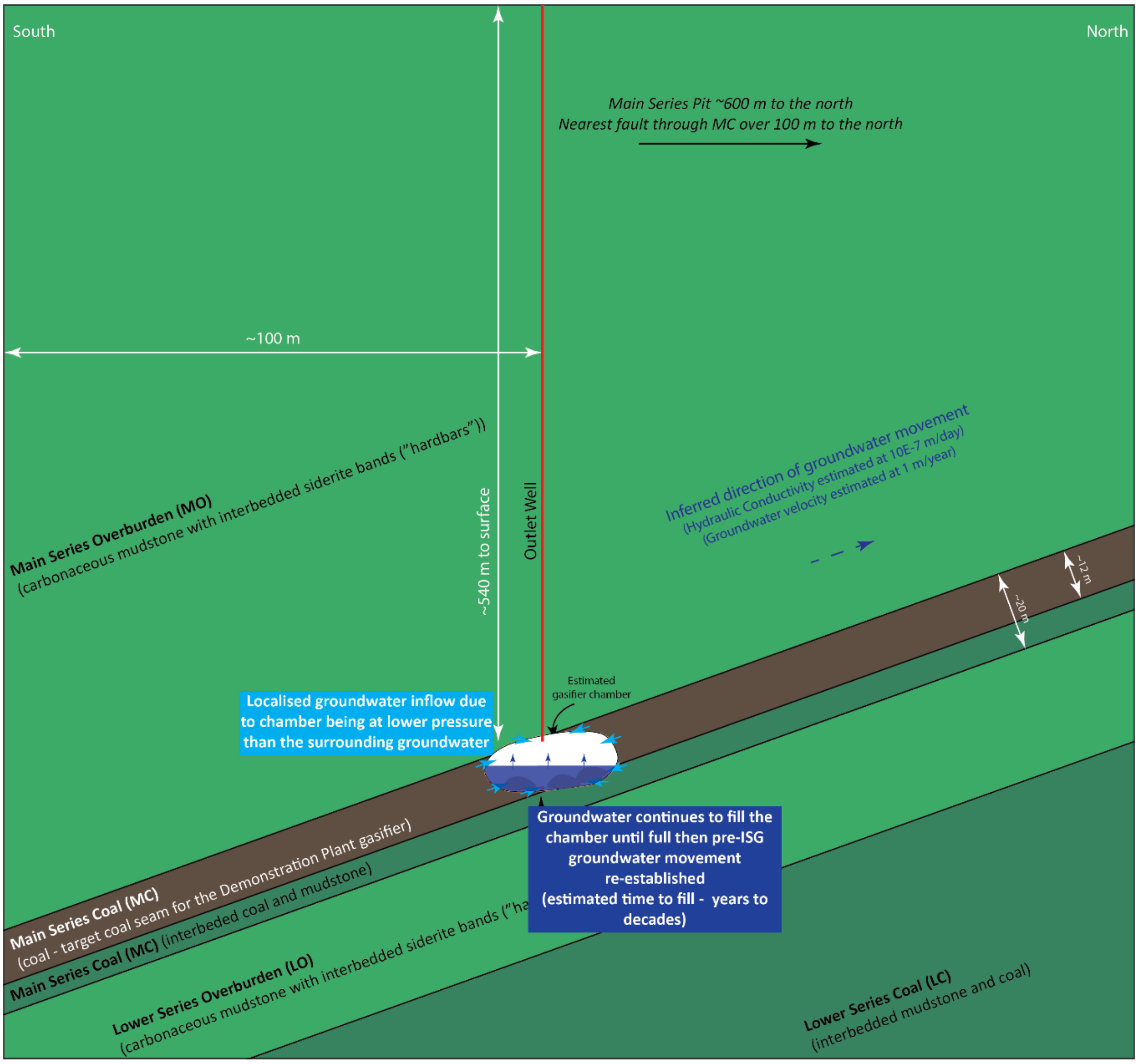


Figure 5-1: Conceptual Site Model for the demonstration plant gasifier at decommissioning

5.2.3 Spills or leaks of fuel or chemicals or produced fluids

Spills or leaks of fuel or chemicals or produced fluids have the potential to result in localised contamination of any unconfined water table aquifer, if present.

At the demonstration plant site, the shallow water table aquifer in the Telford Gravels has been dewatered by historic mining activities. Although the Telford Gravels may contain discontinuous perched water seasonally, the presence of the adjacent Main Series and Upper Series pits is expected to effectively keep this potential aquifer dewatered. Measures discussed in Sections 5.3.2 and 5.3.3 will be implemented to prevent spills or leaks, or mitigate their impact if they do occur. If spills did infiltrate into the Telford Gravels, the presence of the pits would prevent spilt material being transported to areas where shallow groundwater is present.

Risk assessment

The level of risk has been assessed as low (see Table 5-4).

5.2.4 Groundwater drawdown from consumption in the gasifier

The potential for drawdown of aquifers as a result of consumption of groundwater in the gasifier is identified in the literature (e.g. Camp and White 2015) as a potential impact for ISG projects.

This does not present a credible risk for this project because there are no aquifers present that could potentially be impacted. The Main Series Coal and all adjacent strata are aquitards with very low permeability, so they would provide little water to the gasifier and widespread drawdown would not occur. Any impacts to groundwater pressure in these aquitards would be localised to the immediate vicinity of the gasifier chamber.

5.3 Soils

Potential impacts to soils arise mainly from:

- earthworks associated with construction and rehabilitation
- spills or leaks associated with storage and handling of fuel and chemicals
- spills or leaks of produced fluids
- storage, handling and disposal of waste.

5.3.1 Earthworks

Earthworks and site construction activities have the potential for localised impacts to soil through inversion, compaction or increased erosion.

The site is relatively flat, and has been subject to heavy disturbance related to previous coal mining activities.

Disturbance to soils will be localised and restricted to defined areas. Topsoil will be stockpiled prior to construction activities, for use in rehabilitation. Following the completion of activities at the site, it will be rehabilitated in accordance with industry standard criteria (e.g. SAPEX 2013, PIRSA 2009) to ensure that visual impact is minimised, revegetation of indigenous species occurs and that sites are left in a clean, tidy and safe condition.

Given the disturbed nature of the site, the impacts resulting from the project will not be significant.

5.3.2 Spills or leaks of fuel or chemicals

Improper storage and handling of fuel or chemicals has the potential to result in localised contamination of soil. In order to minimise this risk, fuel and chemicals on site are stored and handled in accordance with relevant standards and guidelines. Fuel and chemicals will be stored in designated areas with appropriate secondary containment as required (e.g. lined, bunded areas or on self-bunded pallets). Any spills will be immediately cleaned up and any contaminated material removed off-site for appropriate treatment or disposal. If larger scale spills that cannot be immediately contained and cleaned up occurred, they would be assessed consistent with the requirements of the NEPM[14] and, where required, remediated in accordance with relevant guidelines (e.g. EPA guidelines).

5.3.3 Spills or leaks of produced fluids

Spills or leaks of produced fluids have the potential to result in localised contamination of soils.

Produced water is likely to contain hydrocarbons and other COPC from the ISG process. As noted above in Section 5.2.3, it is likely that there is no continuous unconfined water table aquifer present at the site and no sensitive receptors or sensitive land uses present. The rate of infiltration of COPC would be limited by the low rainfall, high evaporation and relatively low permeability of the clayey surface soil present at the site.

Consequently, should a leak of produced fluids occur (e.g. from piping or equipment), it would be expected to have a localised impact. Immediate containment and clean-up of spills would be implemented to minimise the impact. As noted in Section 5.3.2, larger scale spills that cannot be immediately contained and cleaned up would be assessed consistent with the requirements of the NEPM and, where required, remediated in accordance with relevant guidelines (e.g. EPA guidelines). Design and installation of piping and equipment in accordance with appropriate standards, integrity testing of piping and equipment, operation in accordance with design criteria and relevant standards, and ongoing monitoring all minimise the risk of spills or leaks.

Similarly, if material was released from a loss of well integrity or explosion or fire, impacts would be localised and contained within the immediate vicinity of the demonstration plant or the Upper Series Pit. Management measures outlined in Section 5.2.1 and 5.9.3 will be implemented to minimise the likelihood of this occurring.

5.3.4 Waste management

Inappropriately managed waste has the potential to result in localised disturbance or contamination of soil. Storage of waste and transport to licensed disposal or recycling facilities will be undertaken in accordance with relevant legislation and guidelines. Waste generation will be minimised where practicable, waste will be stored securely and appropriately licensed waste contractors will be used for waste transport.

5.3.5 Risk Assessment

The level of risk has been assessed as low for these potential hazards (see Table 5-4).

5.4 Surface Water

Potential impacts to surface water arise mainly from:

- earthworks associated with construction and rehabilitation (e.g. disturbance to natural drainage patterns, increased erosion / sedimentation)
- spills or leaks associated with storage and handling of fuel and chemicals
- spills or leaks of produced fluids
- storage, handling and disposal of waste
- water use for project activities.

As discussed in the subsections below, the potential for impact to surface water is generally low, due to the highly modified nature of the site.

[14] *National Environment Protection (Assessment of Site Contamination) Measure (1999)* amended in 2013

5.4.1 Earthworks

Earthworks have the potential to alter natural drainage patterns or result in increased sedimentation of surface water features.

Due to the highly modified nature of the site, its location within the Leigh Creek Coalfield and the internal nature of drainage within the mine, the potential for impact is very low. Minor and localised impacts will occur as a result of site earthworks, however these will only affect areas in in the vicinity of the site where drainage is already heavily modified and isolated from natural drainage features. The site will ultimately be rehabilitated to restore existing surface profiles and drainage patterns.

A marginal increase in sedimentation may occur, however this is not significant given the existing high sediment loads from adjacent stockpiles, highly disturbed nature of the site and absence of flow off the mine site or to natural surface water features.

5.4.2 Spills or leaks of fuel or chemicals or produced fluids

The principal risk to surface water typically results from the potential transport off-site of material from spills or leaks.

Due to the modified nature of the site and the isolation from drainage lines or significant surface water features, any impacts from spills or leaks would be relatively minor and localised even if material was transported off the immediate spill site. Any material transported off the demonstration plant site would be confined to disturbed areas in the immediate vicinity and impacts outside the mine site are not plausible.

The measures discussed above in Section 5.3 will be implemented to ensure safe storage and handling of fuel and chemicals. Spill containment and clean-up equipment would be present on site and any spills immediately cleaned up.

Similarly, if gas or produced fluids were released from a loss of well integrity or explosion or fire, impacts would be localised and contained within the immediate vicinity of the demonstration plant. Management measures outlined in Section 5.2.1 and 5.9.3 will be implemented to minimise the likelihood of this occurring.

Potential migration of COPC from the gasifier to surface water is not considered a credible impact due to the absence of pathways through the 500 m of aquitard above the gasifier (see Section 5.2.2). In addition, the demonstration plant site is isolated from any natural catchments (including the Aroona dam catchment) and this, coupled with the lack of surface water drainage features at the site, means there are no pathways for impact to surface water values in the area.

5.4.3 Waste management

Measures to ensure secure storage and handling of waste will be implemented as outlined in Section 5.3 above.

5.4.4 Water use for project activities

The main risks related to surface water from the use of water for project activities include the potential depletion of surface water supplies, potential adverse impact on surface water users, and potential impact on surface water dependent ecosystems.

The water supply will be obtained from artificial water storages constructed for mine-site use which have minimal environmental value. Water supply sources will be reviewed to ensure that their use does not impact adversely on environmental values or existing users.

Water extraction volumes will be monitored to ensure there are minimal impacts to surface water supplies.

5.4.5 Risk Assessment

The level of risk has been assessed as low for these potential hazards (see Table 5-4).

5.5 Flora and Fauna

Potential impacts to flora and fauna arise mainly from:

- earthworks associated with construction and rehabilitation
- spills or leaks associated with storage and handling of fuel and chemicals
- spills or leaks of gas or produced fluids
- activity outside designated / approved areas
- presence of personnel, lighting, general site activity and road use
- storage, handling and disposal of waste.

5.5.1 Earthworks

Earthworks and site construction activities have the potential for localised impacts to native vegetation and wildlife habitats and to disturb or injure fauna.

The site is located in an area where vegetation has been highly disturbed and no vegetation of conservation significance is present. The sites will ultimately be rehabilitated in accordance with standard regulatory criteria, as discussed in Section 3.9 and 5.3.1. Impacts to vegetation and wildlife habitats will not be significant or long term.

Any direct impacts to fauna will be short term and localised. As the activities will impact degraded habitat, which forms an extremely small proportion of available habitat in the region, the activities are not likely to have any significant impact on fauna populations.

Earthworks and movement of vehicles and machinery can also result in the introduction or spread of weeds. Standard measures will be implemented to minimise this risk (e.g. vehicles and equipment will be cleaned (and washed down where necessary) before commencing work at site or after operating in an area of known weed infestation). If project activities result in the introduction or increased densities of pest plants, a weed control plan will be developed and implemented in consultation with the land manager and the relevant NRM officer where appropriate.

5.5.2 Spills or leaks of fuel, chemicals or produced fluids

Spills of fuel, chemicals or produced fluids have the potential to damage native vegetation. As discussed in Section 5.3, this risk will be minimised by appropriate storage, handling and spill response and design and installation, operation, testing and monitoring of piping and equipment in accordance with relevant standards and guidelines. As noted above, vegetation and habitats present in the vicinity of the site have been highly disturbed and no vegetation of conservation significance is present, which limits the potential for impact. There is no likelihood that a spill or leak could impact vegetation that is undisturbed, has high environmental value or is of conservation significance.

Similarly, if gas or produced fluids were released from a loss of well integrity, impacts would be localised and contained within the immediate vicinity of the demonstration plant or the Upper Series Pit. Well integrity management measures outlined in Section 5.2.1 will be implemented to minimise the likelihood of this occurring.

Access to fuel and chemicals and produced fluids presents a potential hazard for wildlife. Access to chemicals and fuel will be prevented by storing and handling them appropriately in designated areas and implementing immediate containment and clean-up if any spills occur. Emus and kangaroos are occasionally present on site and stock-proof fencing will be erected around the site to restrict access.

Migration of COPC to groundwater dependent ecosystems or surface water dependent ecosystems is not a plausible risk due to the absence of pathways (see Sections 5.2.2 and 5.4.2).

5.5.3 Activity outside designated / approved areas

Activities outside designated / approved areas have the potential to impact vegetation and fauna. All activities will be confined to designated areas, with signage and fencing (where required) installed to delineate approved areas and any restricted areas. The disturbed nature of vegetation and habitats adjacent to the site means that any impact from activities outside designated / approved areas would be of very limited consequence.

5.5.4 Presence of personnel, lighting and general site activity and road use

The presence of personnel, lighting and general activity on site have the potential to impact vegetation and fauna. Use of roads and tracks could also result in injury or death of small numbers of fauna. Impacts will be relatively localised and are not expected to have any significant impact on fauna populations, particularly given the disturbed nature of vegetation and habitats present.

5.5.5 Waste management

Measures to ensure secure storage and handling of waste will be implemented as outlined in Section 3.11.3. Covered bins will be used to prevent native fauna and pest animals accessing or spreading waste.

5.5.6 Risk Assessment

The level of risk has been assessed as low for these potential hazards (see Table 5-4).

5.6 Air Quality

Potential impacts to air quality arise mainly from:

- dust generation from earthworks and site activities
- combustion emissions (e.g. thermal oxidiser, diesel generators and compressors)
- syngas release (e.g. non-routine venting, purging, leaks)
- explosion or fire.

Potential impacts associated with air emissions include reduction in local air quality and generation of greenhouse gases and an increase in odour.

5.6.1 Dust generation

Earthworks and the use of unsealed roads have the potential to generate dust.

Earthworks for construction and rehabilitation will be limited in scale and short term. Dust emissions are likely to be less than those from previous mining operations and ongoing rehabilitation operations and there are no sensitive receptors near the site (the nearest sensitive receiver is approximately 8.5 km from the demonstration plant site). Consequently, dust impacts are unlikely to be significant. Dust control measures (e.g. water spraying) will be implemented if required.

Vehicle access will be predominantly via sealed public roads and the main mine access road, with short sections of unsealed tracks only present at the site itself. Vehicle speeds will be restricted at the site and dust control measures (e.g. water spraying) will be implemented if required.

5.6.2 Combustion emissions

Combustion emissions from operation of the thermal oxidiser and other fuel-burning equipment such as compressors and generators have the potential to reduce local air quality and result in the generation of greenhouse gases.

Combustion emissions from operation of the thermal oxidiser and compressors and generators have been modelled to investigate potential air quality impacts (Pacific Environment 2017). The emissions modelled included nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur trioxide (SO_3), hydrogen sulphide (H_2S) and particulates (PM_{10}) from the thermal oxidiser, and NO_2, CO, sulphur dioxide (SO_2) and PM_{10} from the compressors and generators. A summary of the modelling methods and results is provided in Appendix D.

The modelling indicated that surrounding air quality from combustion emissions remained within relevant air quality criteria.

Predicted maximum ground level concentrations were below the ambient air quality criteria established in the Environment Protection (Air Quality) Policy (the Air EPP) at all sensitive receptors and all locations outside PEL 650.

In close proximity to the demonstration plant (within PEL 650 and the mine site), the modelling predicted minor exceedances of Air EPP criteria for NO_2, however the predicted maximum levels are within Safe Work Australia exposure standards, which are more relevant than the Air EPP criteria in these locations. The modelling also included very conservative assumptions for conversion ratios of nitrogen oxides (NO_x) to NO_2, and is likely to overestimate likely maximum levels, particularly in the area close to the source. Maximum levels of H_2S were also predicted to be above Air EPP odour criteria at some locations within PEL 650 and the mine site, indicating that odour would be detectable inside PEL 650 under some conditions.

Air quality measurements will be undertaken during operation of the demonstration plant to confirm the level of impact and collect data that will be used to inform any future commercial-scale development.

5.6.2.1 Greenhouse Gas Emissions

The demonstration plant will emit greenhouse gases during the period of operation, principally carbon dioxide as a result of syngas and diesel combustion. Plant operation will be short term, and will gather data that will be used to characterise emissions and develop greenhouse gas management strategies for any future commercial-scale development. Greenhouse gas emissions will be reported where necessary, in accordance with the requirements of the National Greenhouse and Energy Reporting Act.

5.6.2.2 Summary

In summary, the modelling indicates that combustion emissions will not adversely impact air quality at any receptors or areas accessible to the public.

5.6.3 Syngas release from non-routine venting

Venting of syngas from the demonstration plant during non-routine operating conditions has the potential to have short-term impacts on air quality and odour.

The demonstration plant includes a vent stack which is designed to be used (where required) to prevent over-pressurisation of the gasifier and to protect surface equipment from process excursions beyond their design limits.

During standard operations, all syngas from the demonstration plant will flow directly to the thermal oxidiser for destruction.

Flow of syngas will only be directed to the vent stack during initiation of the gasifier and under some non-routine operating conditions, such as detection of high oxygen concentrations, process trips (e.g. high pressure or temperature), if the thermal oxidiser is out of service or activation of emergency shutdown.

Venting during gasifier initiation is required to let oxygen levels in the syngas drop below levels where a potentially explosive mixture could be present in the surface equipment. It is expected to occur for less than 60 minutes, and based on previous experience may take approximately 20 minutes.

Venting under other circumstances such as detection of high oxygen concentrations, process trips (e.g. high pressure or temperature) or the thermal oxidiser being out of service is expected to be infrequent, and these circumstances (and associated venting) may not actually occur. Venting in these circumstances would be expected to occur for approximately 30-60 minutes. Venting for minor maintenance during commissioning of the thermal oxidiser, if required, would typically be for less than 60 minutes. Longer periods would be required for major maintenance (e.g. 6-12 hours to replace the fan or diesel pump using spares that will be held on site), however (as noted in Section 3.8.1) the thermal oxidiser is a high reliability system and is expected to operate for the duration of the demonstration without requiring any major maintenance.

A full emergency shutdown of the demonstration plant could result in venting for approximately 48 hours, with flows reducing progressively over this period.

5.6.3.1 Modelling

Air quality modelling has been undertaken to assess the potential air quality impacts from venting during non-routine operating conditions (Pacific Environment 2017). The modelling was a conservative screening assessment which modelled various flow rates, but each with continuous emissions (see modelling summary in Appendix D).

The assumption of continuous emissions for this non-continuous process provides a conservative assessment of worst case impacts, as it ensures the worst case emissions will co-occur with the worst case meteorological conditions for dispersion.

Three main scenarios were modelled to cover the range of possible operating conditions for the vent:

- vessel purge venting (venting of small amounts of gas to remove oxygen-rich gas mixtures from vessels or pipework at startup or following maintenance)
- low flow venting (venting of moderate flows for up to several hours)
- high pressure/flow venting (venting of high flows e.g. in an emergency shutdown).

The modelling results indicated that for all venting scenarios, even with continuous emissions, predicted maximum ground level concentrations for all criteria except odour were below the maximum values established in the Air EPP at all sensitive receptors and all locations outside PEL 650.

This means that venting is not predicted to result in a health risk in Copley or any other receptor locations, regardless of the time of day or weather conditions during venting or the length of time that venting occurs.

The modelling predicted that for high and low flow venting scenarios, levels of hydrogen sulphide (H_2S)[15] could potentially exceed Air EPP odour criteria at receptor locations, depending on weather conditions and wind direction. Predicted maximum H_2S concentrations at receptors are less than 4% of the Air EPP health-based criteria, so do not represent a health risk. However, odour would be detectable at receptors if venting occurred under certain conditions.

Sensitivity analysis indicated that if non-routine venting occurred, and if it occurred at the worst time of day for impacts, there is less than a 1 in 10 chance that odour would then be detectable at Copley.

The modelling predicted that vessel purge-venting is unlikely to result in odour at any sensitive receptor.

The model also predicted that the high and low flow venting scenarios could result in exceedance of Air EPP ambient air quality criteria for carbon monoxide (CO) within PEL 650 in close proximity to the demonstration plant, however the predicted maximum levels are within Safe Work Australia exposure standards, which are more relevant than the Air EPP criteria in these locations.

Odour is known to occur in the area from the mine and other sources (see Section 4.10). A pilot gas ignition system is also planned to be incorporated into the vent design, which would enable the syngas to be combusted in the event that the thermal oxidiser is not available and would significantly reduce the potential for odour impacts. If the thermal oxidiser was to be unavailable for a prolonged period, flow rates would be reduced and an assessment undertaken to decide whether the gasifier operation should continue, as discussed in Section 3.8.1.

Air quality and odour measurements will be undertaken during operation of the demonstration plant to confirm the level of impact and collect data that will be used to inform any future commercial-scale development.

5.6.3.2 Summary

Venting is not predicted to result in any health risks to the public. Venting may result in odour at receptors if it occurred when wind conditions favoured dispersion towards that receptor, however this is likely to be infrequent and would be short term.

5.6.4 Leaks of syngas

Leaks from wells, piping or equipment have the potential to result in localised emissions.

Leaks from piping and equipment will be minimised by pressure testing prior to use to ensure integrity. Due to the depth of the wells and geology of the overlying strata, fugitive gas emissions from migration through overlying strata to surface is not considered a plausible pathway (see Section 5.2.2). Migration along well bores is a potential source of fugitive emissions and this is mitigated by well design and construction methods, in particular design for temperatures and pressures that will be experienced, the installation of cemented casing strings, assessment of the

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[15] Hydrogen sulphide (H_2S) is a naturally occurring colourless gas which is produced during breakdown of organic materials. It can be released from swamps, sewers, volcanic gases and is produced in the human body in low concentrations.
At low concentrations hydrogen sulphide is not toxic but has a characteristic rotten egg smell.
In South Australia the Air EPP odour criteria for H_2S is very low (at the limit of human detection) and is 0.15 µg/m^3 (3 min average). In other states the odour criteria is higher (in NSW it is 2.9 µg/m^3 (1 hr average) and in QLD is 7.5 µg/m^3 (30 min average)). These interstate criteria are comparable to the worst-case levels at receptors predicted by the modelling (which range from 2.7 to 17.9 µg/m^3).
Hydrogen Sulphide can be toxic at high concentrations. The health based ambient air quality criteria in SA is 510 µg/m^3. The Safe Work Australia exposure standard is 14,000 µg/m^3 (8 hr average).
Note: Modelling results in Appendix D are reported in mg/m^3 (1 mg/m^3=1000 µg/m^3)

cement quality with logging tools and monitoring of wells during operations. Remedial work can be undertaken if well integrity issues are detected, or wells can be plugged if they cannot be remediated. Historical drill holes in areas surrounding the demonstration plant have been identified and avoided by the plant location (see Section 5.2.2.6).

If a major well integrity failure occurred, resulting in uncontrolled escape of gas to the surface, injection of air into the gasifier would be shut off and action taken to control the well where required (e.g. using specialist intervention equipment). ISG reactions in the gasifier chamber would rapidly cease following removal of the oxidant supply, and emissions would be expected to attenuate rapidly and cease within a period of days. The impact to air quality would be relatively short term and localised and not dissimilar to impacts from venting (discussed above) or spontaneous combustion events that currently occur in some stockpiles at the site.

5.6.5 Explosion or fire

An explosion or fire generated at the surface would have a short term impact on air quality. Impacts would be expected to be relatively localised, and unlikely to result in significant impacts to sensitive receptors (e.g. at Copley or Leigh Creek) given the separation distances and based on the results of the emissions and venting modelling. Fire would be unlikely to persist for a long period or spread far from the site given the relatively low amount of combustible material at the site and the low fuel loads provided by the native vegetation present.

5.6.6 Risk Assessment

The level of risk has been assessed low in relation to dust, combustion emissions and leaks of syngas. The level of risk associated with explosion or fire, although unlikely, has been assessed as medium due to the higher rating assigned for potential consequences. The potential release of syngas through non-routine venting has also been assessed as medium; although the consequences of this hazard are at most minor, it is possible that this level of consequence could occur (see Table 5-4).

5.7 Noise

Potential impacts associate with noise emissions include:

- disturbance to local community
- disturbance to wildlife.

Noise emissions generated at the site during the proposed operations will be localised and short term and are not likely to have a significant impact on any sensitive receptors. There are no residences nearby, with the closest house approximately 8.5 km from the site. Noise levels from site activities would not be significant at such separation distances, as a result of noise attenuation with distance, and potential noise levels are further reduced by the screening provided by the stockpiles surrounding the project site.

Noise from the cold vent is rated to <93 dB(A) at the base of the vent stack and <85 dB(A) at 20 m away from the stack.

Noise levels are unlikely to be higher than those associated with previous mining operations or ongoing rehabilitation activities at the site.

Equipment will be operated and maintained in accordance with specifications in order to minimise noise emissions.

Limited numbers of wildlife are present and site noise will not have a significant impact.

5.7.1 Risk Assessment

The level of risk associated with noise emissions has been assessed as low (see Table 5-4).

5.8 Land Use

The proposed activities are not likely to have any significant impact on land uses (e.g. mining / mine rehabilitation, pastoralism, conservation or tourism) or landholders within the region. The site is located within an area where there are no mining or rehabilitation works planned, and operations are being undertaken in consultation with Flinders Power to ensure there is minimal impact from demonstration plant operations.

The site is not visible from the adjacent Outback Highway. It is distant from public roads or pastoral stations (see Figure 4-26) and separated from them by the mine stockpiles and mine boundary. Consequently it will have little to no impact on pastoral activities or visual amenity. There are no conservation reserves in close proximity. The site will ultimately be rehabilitated, as discussed in Section 5.3.1.

The Civil Aviation Safety Authority (CASA) will be notified if required regarding operation of the thermal oxidiser and the location of the thermal plume.

5.8.1 Risk Assessment

There were no credible potential environmental impacts to land use identified by the risk assessment (see Table 5-4).

5.9 Public Safety and Risk

The key areas where potential or perceived impacts to public safety and risk could arise are:

- unauthorised access resulting in exposure to site hazards during operations
- use of roads and movement of vehicles and machinery
- explosion or fire
- seismicity.

5.9.1 Unauthorised access

The demonstration plant is located within the Leigh Creek Coalfield, where public access is prohibited. The site is approximately 3 km inside the mine site boundary and 3.7 km from the adjacent Outback Highway. In addition to security at the mine site entrance, measures such as signage and fencing will be in place to warn of the hazards at the site and restrict access into the site. Access to the demonstration plant site by other third parties (e.g. Flinders Power personnel) is also strictly controlled and infrastructure such as the cold vent has been located sufficiently distant from mine access roads (and with suitable exclusion zones) to achieve safety of Flinders Power personnel. Potentially hazardous areas will be securely fenced with warning signs in place. The demonstration plant will be attended by an operator during operation, enabling any unauthorised access to be detected or deterred.

5.9.2 Use of roads

The existing road network is already heavily used by the transport, mining, oil and gas and pastoral industries and the incremental change as a result of the demonstration plant is not likely to be significant. Measures to mitigate the risks to the public will be in place including signage near the site entrance, speed restrictions and education programs.

As noted in Section 5.3.4, transport of waste to licensed disposal or recycling facilities will be undertaken in accordance with relevant legislation and guidelines.

5.9.3 Explosion or fire

A fire or explosion at the surface can pose a danger to personnel, contractors, third parties (e.g. Flinders Power personnel) and possibly the public. The activities will be carried out at a site which is distant from public roads and where public access is prohibited. Access to the demonstration plant site by other third parties (e.g. Flinders Power employees) is also strictly controlled. All piping and equipment will be designed and constructed in accordance with relevant standards; safety, testing, maintenance and inspection procedures will be implemented; and appropriate emergency / spill response procedures for explosion or fire will be established. Appropriate fire-fighting equipment will be maintained at or in close proximity to the site. The approach to design, commissioning, operation and decommissioning of the demonstration plant will utilise best practice systems to ensure that risks are appropriately identified and managed.

An uncontrolled underground ‘fire’ within the gasifier chamber (which is an extremely unlikely scenario) would be managed by shutting off the air supply and flooding the chamber with water. This would deprive the fire from oxygen and thereby extinguish the fire.

Subsidence could also result in explosion or fire if it damages surface infrastructure. Significant subsidence at the surface is not predicted by geotechnical investigations. The gasifier is at significant depth with up to 400 m of Main Series Overburden estimated to be remaining in place above the gasifier and the potentially fractured zone (see Appendix B). Surface infrastructure associated with the gasifier is designed to accommodate deformations associated with tilt and strain and is not susceptible to subsidence. Consequently, explosion or fire resulting from subsidence is not likely to occur.

5.9.4 Seismicity

There are two perceived risk pathways for seismicity to impact on public health and safety:

- induced seismicity as a result of project activities
- natural earthquake activity compromising the integrity of the demonstration plant (which could potentially lead to leaks / releases or a fire / explosion).

5.9.4.1 Induced seismicity

Earthquakes can be triggered by human activities, including filling of large water reservoirs, mining, and activities involving pumping fluids into and out of the rock formations, such as required in hydrocarbon, geothermal energy and some water resource activities (Gibson and Sandiford 2013). These types of earthquakes are called induced. Microseismic events can be generated by hydraulic fracturing of rock formations.

There are two broad mechanisms for triggered earthquake activity: changing the stress within the crust or reducing the strength of faults (Gibson and Sandiford 2013). Stress in the crust can be increased by loading (e.g. a large dam and water reservoir) or by unloading (e.g. a very large open-cut mine such as the Kalgoorlie Super Pit, or by releasing a large volume of water from a reservoir). The most common way to trigger earthquakes is to increase the ground water pore pressure, decreasing the stress at which failure will occur on faults.

The demonstration plant operation does not involve hydraulic fracturing. There may be a need to inject additional water to supplement the natural groundwater to assist in the gasification process, however this is unlikely to increase groundwater pore pressures.

The gasifier chamber will be at a depth of over 500 m. Rocks at this depth tend to be weaker than those at greater depth, and can support a lower stress, or strain energy density (Gibson and

Sandiford 2013). This limits the magnitude of potential earthquakes that can occur at that depth, and limits the chance of inducing a larger earthquake at depth (Gibson and Sandiford 2013).

Due to the relatively small scale and limited duration of the operation and the depth of the gasifier chamber, it is not anticipated that any notable seismic events that could impact public safety, will be triggered by potential dynamic stress changes associated with activities undertaken at the demonstration plant.

It is concluded that the site activities are unlikely to generate seismic events and on that basis the risks are considered to be low.

5.9.4.2 Natural earthquake activity

The demonstration plant is located in a region which has a background seismic hazard similar to the Adelaide region (see Section 4.6.5). The peak ground acceleration for the 1 in 500 annual exceedance probability earthquake is 0.06 to 0.07g.

Modern wells used in the oil and gas industry are designed to withstand seismic deformations (Foxall and Friedmann (undated)). The steel casings proposed for the demonstration plant have been designed to be flexible and able to deform and not rupture from disruptions relating to seismic waves. It is of note that several major earthquakes (including magnitude 6.8) have occurred in the southern California area with relatively few problems experienced by oil wells.

An earthquake of sufficient magnitude to cause damage to the demonstration plant and subsurface infrastructure is very unlikely to occur during the operation of the plant.

The possibility of earthquake damage has been incorporated into the risk assessment for the hazards that could potentially result - explosion or fire (Section 5.9.3) and loss of well integrity (Section 5.2.1).

5.9.5 Risk Assessment

The level of risk has been assessed as medium for these potential hazards due to the higher consequence ratings assigned when considering the safety of the public (see Table 5-4).

5.10 Economic Impact

The demonstration plant project is very unlikely to result in adverse economic impact on stakeholders. The activities will be relatively short term and the site is located within an area where there are no mining or rehabilitation works planned. Operations are being undertaken in consultation with Flinders Power to ensure there is minimal impact from demonstration plant operations. The coal seam that the demonstration plant project is accessing is deep and uneconomic to mine and the amount of coal that will be gasified represents a very small fraction of the coal resource present at the site. As discussed in Section 5.8, there will be no impact to other land uses within the area.

The demonstration plant project has a number of potential benefits. These include:

- increased understanding of the cultural heritage aspects of the region (in collaboration with the traditional owners)
- direct economic benefits to the Leigh Creek and Copley townships resulting from supply of fuel, food, accommodation and other services during the demonstration plant project
- direct economic benefit via payments to local construction companies
- employment opportunities for local personnel during various phases of the project
- increased understanding of the water, air, fauna and flora of the region.

If the project leads to further ISG development at the Leigh Creek Coalfield, including the construction of a commercial operation, the potential benefits include:

Cultural:

- increased understanding of the cultural heritage aspects of the region (in collaboration with the traditional owners)
- development of cultural awareness training

Economic:

- direct benefits to the traditional owners in production payments
- direct benefits Leigh Creek and Copley townships resulting from supply of fuel, food, accommodation and other services
- development of new business opportunities
- payment of royalties to the State

Social:

- creation of employment opportunities, training and education for new staff
- supply of power to state electricity grid
- potential supply of syngas derivatives including methane, ammonia and fertiliser
- ongoing need for town amenities including school, police and health services
- investment in social infrastructure and services

Environmental:

- benefits in the provision of significant environmental benefit (SEB) payments
- ongoing rehabilitation and monitoring of previous coal mining activities
- increased understanding of the water, air, fauna and flora of the region.

5.11 Environmental Risk Assessment Summary

As discussed above, Leigh Creek Energy has undertaken an environmental risk assessment of the proposed ISG demonstration plant activities in PEL 650. This section summarises the process and results of the assessment.

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

The risk assessment process involves:

- identifying the potential hazards or threats posed by the project
- categorising the potential consequences and their likelihood of occurring
- using a risk matrix to characterise the level of risk.

The level of risk for the proposed demonstration plant has been assessed based on the assumption that management measures that are discussed in this EIR will be in place. The risk assessment was prepared by JBS&G and Leigh Creek Energy, based on knowledge of the existing environment, understanding of proposed operations and previous experience of Leigh Creek Energy personnel with similar operations.

The risk assessment process was based on the procedures outlined in Australian and New Zealand Standard AS/NZS ISO 31000:2009 (*Risk Management*) and HB 203:2012 (*Managing environment-related risk*).

5.11.1 Environmental Risk Assessment Definitions and Risk Matrix

The risk assessment uses the risk matrix and definitions for consequences and likelihood that are outlined below. These are consistent with the risk matrix and consequence and likelihood definitions that have been previously used for assessment of similar projects in South Australia (e.g. Beach 2012, Strike 2014).

Definition of Consequences

To describe the severity, scale and duration of potential impacts, the five categories of consequence listed in Table 5-1 are used. The columns in the table that are directly related to impact to the environment have been used to assess consequence levels in the risk assessment; those that are not directly related to impact to the environment (e.g. reputation) are used as guidance only for the purposes of this EIR.

Table 5-1: Consequence definition

		Health and Safety	Natural Environment	Reputation Community / Media	Financial A$
Critical	**5**	Fatality of employees, contractors, or the public	Critical ecological or cultural impact and/or regulatory intervention	Critical impact on business reputation /or international media exposure	Financial loss in Excess of $20 Million
Major	**4**	Extensive injury or Hospitalisation of employees, contractors, or the public	Significant ecological or cultural impact and/or regulatory intervention	Significant impact on business reputation and/or national media exposure	Financial loss $2 Million to $20 Million
Moderate	**3**	Medical treatment of employees, contractors, or the public	Significant local environmental impact and/or regulatory intervention	Moderate to small impact on business reputation	Financial loss from $0.5 Million to $2 Million
Minor	**2**	First-aid treatment of an employee, contractor, or a member of the public	Minor local environmental impact and/or regulatory notification is required	Some impact on business reputation	Financial loss from $0 to $0.5 Million
Negligible	**1**	Minimal impact to any issue	Minimal impact to any issue	Minimal impact to any issue	Minimal impact to any issue

Definition of Likelihood

The likelihood of potential environmental consequences occurring is defined using the five categories shown in Table 5-2. The likelihood refers to the probability of the particular consequences eventuating, rather than the probability of the hazard or event itself occurring.

Table 5-2: Likelihood of the consequences selected occurring

A	**Almost Certain**	Is expected to occur in most circumstances
B	**Likely**	Will probably occur in most circumstances
C	**Possible**	Possible that it might occur at some time
D	**Unlikely**	Unlikely, but could occur at some time
E	**Remote**	Highly unlikely, may occur in exceptional circumstances

<u>Characterisation of Risk</u>

The risk associated with each hazard was characterised as low, medium or high, using the matrix shown in Table 5-3.

Table 5-3: Environmental risk matrix

RISK MATRIX			Consequence				
			Negligible	Minor	Moderate	Major	Critical
			1	2	3	4	5
Likelihood	Almost Certain	A	M	M	H	H	H
	Likely	B	M	M	M	H	H
	Possible	C	L	M	M	H	H
	Unlikely	D	L	L	M	M	H
	Remote	E	L	L	L	M	M

High Risk - Immediate Action Required. **Medium Risk** - Management Attention Needed

Low Risk - Managed by Standard Operating Procedures

5.11.2 Environmental Risk Assessment Summary Table

A summary of the level of environmental risk for the proposed demonstration plant is provided in Table 5-4 below. As noted previously, the level of risk has been assessed based on the assumption that the management measures outlined in this EIR will be in place.

Table 5-4: Environmental risk assessment for ISG demonstration plant in PEL 650

Risk Event / Hazard		Potential Environmental Impacts	Key Management Measures	Comments	Consequence	Likelihood	Residual Risk
Loss of containment underground							
Loss of well integrity resulting in loss of containment	Casing leak leading to escape of gas and other COPC from well to shallower units and possibly escape of gas to surface	Contamination of groundwater Contamination of soil and surface water Emissions to the atmosphere / reduction in local air quality Danger to health and safety of the public	Steel casing string(s) and cement isolate well contents from surrounding strata and groundwater. Casing and wellhead designed to meet pressure, temperature, operational stresses and loads that will occur. Premium casing, connections and high temperature cement used for inlet and outlet wells as recommended in independent third party review of thermal design. Observation well designed to same standard as inlet and outlet wells. Monitoring well in close proximity also designed and constructed to the same standard. New casing and wellhead installed. Cement bond logs run to confirm quality of cement. Installation of tubing string in inlet and outlet well. Active cooling of outlet well via tubing string. Ongoing well integrity monitoring. Monitoring undertaken for leaks / fugitive emissions at wells Access to site restricted during operations. Signage and site access control measures in place to warn of hazards and restrict access to the site. Emergency response plan (scenario based) in place and drills conducted. Site will be attended by operators 24/7 during plant operation. Note: Drilling is managed under existing Drilling SEO (Sapex 2013).	No aquifers at the site. No groundwater users within or near the footprint of the demonstration plant. No credible pathways resulting in impact to aquifers or groundwater users. No significant surface water features. Site is distant from air emissions receptors. Site is inside the fenced mine boundary and over 4 km from the public road. Restricted access inside the mine boundary and to the site.	Minor	Unlikely	Low
	Cement failure at depth leading to escape of gas and other COPC from gasifier to shallower units				Minor	Unlikely	Low
	Major cement / casing failure leading to uncontrolled flows to surface and possibly explosion				Major	Unlikely	Medium
Gasifier pressure exceeds surrounding groundwater pressure causing migration of COPC in groundwater away from gasifier and reaching surface or near surface environments		Contamination reaching the surface or impacting shallow groundwater or soil vapour	Gasifier operated automatically via a control system to keep pressure below surrounding groundwater pressure at top of gasifier chamber (including a safety factor) to avoid outwards pressure gradients and flows. Real-time monitoring of pressure, temperature and flow both at the inlet and outlet wells and sub-surface temperature monitoring of the casing strings. Overpressure protection installed on observation well to cold vent in the unlikely event outlet well or production facilities are unavailable. Monitoring for gas and COPC undertaken in monitoring wells installed around gasifier and at selected surface locations. Abnormal and Emergency Operations Plan developed (scenario based) to detail actions required for each event (e.g. reduced pressure, increase sampling frequency). Location and status of existing drill holes identified and avoided by site location. Geotechnical investigations (drilling, seismic) undertaken to confirm absence of significant faulting. All wells installed for the project designed and constructed to maintain integrity under operating conditions i.e. they do not represent a pathway for migration of COPC (see well integrity discussion above).	Potential pathways for migration of COPC from the gasifier to the surface are unlikely because: - The gasifier is overlain by 530 m of carbonaceous mudstone overburden which is a low permeability aquitard containing occasional/irregular closed structural defects. - Coal seam is approximately 12 m thick and is also low permeability aquitard similar to the overburden. - The underlying Lower Series Overburden consists of low permeability interbedded coal and mudstone and is considered an aquitard. - There are no known existing drill holes through the coal within 100 m of the gasifier. The potential for COPC to migrate away from the gasifier is extremely limited due to low permeability, slow groundwater movement and high adsorption properties of the surrounding coal and carbonaceous mudstone. There are no aquifers in the area of operation. The 12 m of clays and gravel at surface may contain discontinuous perched water seasonally	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures	Comments	Consequence	Likelihood	Residual Risk
Direct escape of COPC from the gasifier through drill holes or transmissive faults	Contamination reaching the surface or impacting shallow groundwater or soil vapour Reduction in local air quality and exposure to site users	Location and status of existing drill holes identified and avoided by site location. Geotechnical investigations (drilling, seismic) undertaken to confirm absence of significant faulting. All wells installed for the project designed and constructed to maintain integrity under operating conditions i.e. they do not represent a pathway for migration of COPC (see well integrity discussion above). Monitoring undertaken for leaks / fugitive emissions at wells and drill holes and at selected surface locations. Access to site restricted during operations. Signage and site access control measures in place to warn of hazards and restrict access to the site. Site will be attended 24/7 by operators during plant operation.	There are no known transmissive faults or drill holes in close proximity to the gasifier to allow direct escape from the gasifier chamber.	Minor	Unlikely	Low
Gasifier chamber growth intersecting potential pathway leading to migration of COPC: - vertical growth of gasifier chamber or its fractures into high permeability stratum - lateral gasifier chamber growth intersecting permeable pathway	Contamination reaching the surface or impacting shallow groundwater or soil vapour	Geomechanical investigations / modelling undertaken to determine potential gasifier chamber growth. Conservative geotechnical design used for demonstration plant to avoid excessive gasifier chamber growth Gasifier growth is limited by in-coal distance between inlet and outlet wells. Real-time monitoring of pressure, temperature and flow both at the inlet and outlet wells. Syngas chemistry used to detect behaviour of gasifier chamber (e.g. spalling/collapse). Oxidant injection rate/pressure and outlet well pressure /flow used to control gasifier pressure. Oxidant supply shut off if required to control / halt ISG process and chamber growth. Well integrity management as above. Closest groundwater monitoring well will be constructed as a thermal completion well. Location and status of existing drill holes identified and avoided by site location. Geotechnical investigations (drilling, seismic) undertaken to confirm absence of significant faulting. Monitoring for gas and COPC undertaken in monitoring wells installed around gasifier and at selected surface locations.	There are no permeable pathways in proximity to the gasifier chamber that could be intersected if excessive gasifier chamber growth occurred (see discussion above under 'Gasifier pressure exceeds surrounding groundwater pressure'). There are no aquifers in the area of operation. Geomechanical investigations indicate gasifier chamber expected to be up to approx. 30 m across and up to 15 m high with the fractured zone extending up to 60 - 75 m above the level of the roof of the coal seam. Currently estimated that up to 400 m of Main Series Overburden (low permeability aquitard) will remain in place to provide a hydraulic seal above the demonstration stage gasifier. Effect of heat and / or partial combustion on the roof rock of the gasifier chamber is currently under evaluation. Additional roof collapse as a result of temperatures generated by the gasifier could potentially reduce the success of gasification but could not feasibly result in chamber growth through 400 m of overburden.	Minor	Unlikely	Low
Increase in permeability of surroundings by mechanical stress changes and fracturing (including significant gasifier chamber collapse) leading to migration of COPC	Contamination reaching the surface or impacting shallow groundwater or soil vapour	Risk mitigated through site selection - deeper target coal seam and thick overburden with high structural integrity. Geomechanical investigations / modelling undertaken to determine gasifier chamber stability and likely extent of any fractured or collapse zones. Conservative geotechnical design used for demonstration plant to avoid unwanted gasifier chamber collapse. Syngas chemistry used to detect behaviour of gasifier chamber (e.g. spalling/collapse).	Geomechanical investigations indicate fractured zone could extend up to 60 - 75 m above the level of the roof of the coal seam. Currently estimated that up to 400 m of Main Series Overburden rock will remain in place to provide a hydraulic seal above the gasifier. Potential impacts (increased permeability) expected to be constrained with the zone of subsidence in the Main Series Overburden. Beyond the zone of subsidence it is expected to remain in an undisturbed and hydraulically tight condition. There are no aquifers in the area of operation. Modelling will be undertaken to better define the extent of the subsidence when geotechnical parameters at the gasifier are confirmed following drilling.	Minor	Unlikely	Low
Migration of COPC from gasifier chamber after decommissioning / rehabilitation	Contamination reaching the surface or impacting shallow groundwater	Decommissioning plan will minimise generation of COPC and protect well integrity by:	There are no aquifers in the area of operation and no pathways to aquifers or surface water.	Negligible	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures	Comments	Consequence	Likelihood	Residual Risk
		- Removing oxidant supply. - Active cooling of cavity through water injection to move though pyrolysis as quickly as practical without excessive thermal cycling of well. - Using active cooling to steam the cavity of COPC. Well integrity monitoring. Monitoring of gasifier chamber and monitoring wells and at selected surface locations.	The potential for COPC to migrate away from the gasifier is extremely limited due to low permeability, slow groundwater movement and high adsorption properties of the surrounding coal and carbonaceous mudstone. Groundwater flow will be towards gasifier chamber until pressures equilibrate (which may take years). Groundwater movement away from the gasifier after this, if it occurs, will be very slow due to low hydraulic gradient and low permeability. Concentrations of COPC in the chamber would reduce naturally as a result of sorption and precipitation. Anticipated time period where COPC are present and available for migration is estimated to be significantly smaller than the time period for the chamber to fill and provide groundwater movement away from the chamber. Groundwater movement after the chamber fills and pressures equilibrate would be towards the Main Series pit and may take 600 years or more to reach it. Significant degradation and adsorption would occur over this period.			
Surface activities						
Earthworks associated with construction and rehabilitation	Damage to cultural heritage sites	All new disturbance contained within areas subject to cultural heritage clearance. Areas of sensitivity (e.g. cultural heritage exclusion areas, if present) flagged and / or fenced off where necessary to prevent disturbance.	Work Area Clearances with the Adnyamathanha Traditional Lands Association have been undertaken for the site.	Moderate	Remote	Low
	Impacts to soil (e.g. erosion, inversion)	Activities confined to defined site. Area of new disturbance restricted to the minimum necessary. Topsoil stockpiled (where present) during site construction for use in restoration. Areas where there is potential for (or signs of) soil erosion or sedimentation occurring will be stabilised and control measures reinstated. Training and induction for all personnel to educate them on the importance of remaining within designated / approved areas. Disturbed areas reinstated once they are no longer required e.g. by backfilling excavations, restoring natural contours, ripping areas of compacted soil and respreading topsoil and stockpiled vegetation.	Significantly modified landform, relatively level ground.	Negligible	Unlikely	Low
	Disturbance to existing drainage patterns Sedimentation of surface waters	Site layout and construction designed to minimise adverse impacts to existing drainage patterns and secondary impacts mine site operations. Adequate drainage of site and surrounds maintained, in consultation with Flinders Power. Overland flows diverted around site where required.	Drainage patterns highly modified. Key issue is not impacting mine operations (e.g. inundation of main access road, rehabilitation activities). Drainage is internal to this part of mine site – surface water does not move off-site. Existing sediment levels high from stockpiles and existing disturbed ground.	Negligible	Unlikely	Low
	Damage to intact native vegetation and habitat Impact to threatened species	All disturbance contained within defined area and restricted to the minimum necessary. Areas of significant vegetation or habitat (if present) avoided where possible.	Site inspection indicates no significant vegetation present. Vegetation that will be cleared is previously disturbed and of low significance. Threatened species presence or reliance on site highly unlikely.	Minor	Unlikely	Low
	Disturbance to wildlife	Fencing installed where necessary to prevent access by large native fauna species. Excavations managed to minimise hazard to fauna (e.g. excavated areas left open for as little time as possible and regularly inspected for trapped fauna).	The mine site is not stocked, and very limited wildlife present – degraded site within mine.	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures	Comments	Consequence	Likelihood	Residual Risk
	Introduction and spread of weeds or pathogens	Earth moving equipment cleaned and inspected before commencing work at site or after operating in areas of known weed infestations. Imported material (e.g. gravel or road base) sourced from areas considered to be weed /disease free. If project activities result in the introduction or increased densities of pest plants, a weed control plan will be developed and implemented in consultation with the relevant NRM officer and the land manager.	No significant weed species detected on site.	Minor	Unlikely	Low
	Generation of dust affecting sensitive receptors	Dust suppression measures implemented where required.	Dust levels consistent with or less than previous mine operations and current rehabilitation operations. Receptors are not in close proximity (over 8 km).	Negligible	Unlikely	Low
Explosion or fire (surface activities)	Contamination of soil and surface water Reduction in air quality Burning of vegetation and habitat Injury to or loss of native fauna Damage to infrastructure Danger to health and safety of the public	Demonstration plant facilities designed, constructed, operated and maintained in accordance with relevant standards and best practice (e.g. AS1940, ASME B16.5, AS3000, AS3008, AS3788, ASME B31.3, AS4100, AS4343, AS/NZ ISO 31000, AS60079, API STD 520 – Part 1, API STD 521, API RP520 – Part 2, AS1210). Use of vent when high oxygen levels are present to prevent potentially explosive mixtures in surface equipment. Safety, testing, maintenance and inspection procedures are implemented. Risk assessments applied at design and during operation where appropriate to identify threats and controls to mitigate risks. Recognised risk management processes will be implemented in design through to decommissioning. Risk controls will include site selection, process design, process control, critical alarms, safety instrumented systems, pressure relief systems, physical protection, plant emergency response and community emergency response. Establishment of appropriate emergency / spill response procedures for explosion or fire. Appropriate fire-fighting equipment on site. Erection of signage and, where required, fencing to delineate restricted / hazardous areas. Safe work permits be obtained to ensure only individuals with proper clearance can conduct works. Designated no smoking site. Appropriate firebreaks are maintained.	Spread of bushfire very unlikely - fuel load and extent of flammable vegetation at site very low. Receptors are not in close proximity (over 8 km).	Major	Unlikely	Medium
Uncontrolled underground fire	Contamination of groundwater Damage to subsurface infrastructure	Demonstration plant facilities designed, constructed, operated and maintained in accordance with relevant standards and best practice (e.g. AS1940, ASME B16.5, AS3000, AS3008, AS3788, ASME B31.3, AS4100, AS4343, AS/NZ ISO 31000, AS60079, API STD 520 – Part 1, API STD 521, API RP520 – Part 2, AS1210). Risk assessments applied at design and during operation where appropriate to identify threats and controls to mitigate risks. Recognised risk management processes will be implemented in design through to decommissioning. Risk controls will include site selection, process design, process control, critical alarms, safety instrumented systems, pressure relief systems, physical protection, plant emergency response and community emergency response. Establishment of appropriate emergency procedures for subsurface fire (e.g. air supply shut off and water injection into chamber increased if necessary). Refer to risk events under *Loss of containment underground* above for potential impacts to groundwater if loss of containment occurs.	Combustion at over 500 m depth is not self-sustaining and would cease without the injection of oxidant.	Major	Remote	Medium
Subsidence	Damage to surface and subsurface infrastructure	The gasifier is situated within a remote and undeveloped area within an existing mining lease and critical surface / subsurface infrastructure is not present at the site. Mitigated through site selection - deeper target coal seam.	Significant subsidence at the surface is not predicted. Gasifier is at significant depth with up to 400 m of Main Series Overburden estimated to be remaining in place above the gasifier. Preliminary estimates of the height of the fractured zone indicates the fractured	Negligible	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures	Comments	Consequence	Likelihood	Residual Risk
		Surface infrastructure associated with the gasifier designed to accommodate deformations associated with tilt and strain and is not susceptible to subsidence. Well designed to maintain integrity under potential operating conditions. (Refer to previous discussion on well integrity).	zone could potentially extend up to 60 - 75 m above the level of the roof of the coal seam.			
Leak of gas at surface (e.g. from piping or plant)	Reduction in site air quality and exposure to site users	Demonstration plant facilities designed, constructed, operated and maintained in accordance with relevant standards and best practice (e.g. AS1940, ASME B16.5, AS3000, AS3008, AS3788, ASME B31.3, AS4100, AS4343, AS/NZ ISO 31000, AS60079, API STD 520 – Part 1, API STD 521, API RP520 – Part 2, AS1210). Safety, testing, maintenance and inspection procedures are implemented as per the site management plan. Recognised risk management processes will be implemented in design through to decommissioning. Risk controls will include site selection, process design, process control, critical alarms, safety instrumented systems, pressure relief systems, physical protection, plant emergency response and community emergency response.		Minor	Unlikely	Low
Leak or spill of produced fluids at surface (e.g. from piping or plant)	Contamination of soil, surface water and shallow groundwater Damage to native vegetation Access to contaminants by wildlife	Tanks used for onsite storage of fluids produced during operation. 24/7 operational presence on site including regular plant inspections. Establishment of appropriate emergency / spill response procedures. Erection of signage and, where required, fencing to delineate restricted / hazardous areas. Safe work permits be obtained to ensure only individuals with proper clearance can conduct works. Safety equipment on site appropriate to the anticipated gas composition such as breathing apparatus and personal gas detectors.	No environmentally sensitive features at site. No aquifers in the area of operation. No surface water runoff to natural features.	Minor	Unlikely	Low
Spill or leaks associated with fuel or chemical storage, handling and transport	Contamination of soil, surface water and shallow groundwater Damage to native vegetation Access to contaminants by wildlife	Implementation of appropriate chemical and fuel storage and handling procedures, in accordance with Safety Data Sheets and relevant standards and guidelines, including AS 1940, EPA *guidelines 080/16 Bunding and Spill Management* and the Australian Dangerous Goods Code. Appropriate spill capture methods implemented in refuelling areas (e.g. use of drip trays or liners). Emergency/spill response procedures in place and appropriate spill response equipment is available on site. Personnel have received training in the use of spill response equipment. Spills or leaks are immediately reported and clean-up actions initiated. Fencing of contaminated areas if threat is posed to wildlife. Any contaminated soil treated in-situ or removed for treatment / disposal at an EPA approved facility. Any areas of contamination are assessed and managed in accordance with the principles of the National Environment Protection Measure for the Assessment of Site Contamination, in consultation with DPC and EPA where appropriate.	No environmentally sensitive features at site. No aquifers in the area of operation. No surface water runoff to natural features.	Minor	Unlikely	Low
Water supply / use	Depletion of surface water supplies Drawdown of aquifers with beneficial uses and values Adverse impact on surface water or groundwater users Impact on surface water or groundwater dependent ecosystems	Water supply obtained from artificial water storages constructed for mine-site use with minimal environmental value. Water supply sources reviewed to ensure that their use does not impact adversely on environmental values or existing users. Water supply wells (if used) reviewed to ensure that their use does not impact adversely on existing users of groundwater or groundwater dependent ecosystems. Existing water wells (if used) accessed in consultation with well owners. Monitoring of water extraction volumes.	Injection water planned to be sourced via the existing mine industrial catchment (same water used to water roads currently) with potable water used for cementing of wells.	Minor	Unlikely	Low
Presence of personnel, general site activity	Disruption to mining / rehabilitation activities Disturbance to wildlife	Liaison with Flinders Power regarding notification / management of works, traffic and site issues High standard of 'housekeeping' maintained.	Site selection avoids main areas of mine / rehabilitation activity and is not visible from public roads or tourist sites. Significantly modified site with relatively low habitat values.	Minor	Unlikely	Low

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures	Comments	Consequence	Likelihood	Residual Risk
Activity by LCK outside designated / approved areas	Disturbance to cultural heritage sites	Training and induction for all personnel includes the importance of remaining within designated / approved areas. Activities confined to designated / approved areas. Approved work areas and restricted areas clearly delineated on site. All new disturbance contained within areas subject to cultural heritage clearance. Areas of sensitivity (e.g. significant vegetation or cultural heritage exclusion areas, if present) flagged and / or fenced off where necessary to prevent disturbance.	No areas of sensitivity have been identified near the site. Adjacent environment is significantly modified and not highly sensitive to further disturbance	Major	Unlikely	Medium
	Damage to native vegetation and habitat			Minor	Unlikely	Low
Combustion emissions (e.g. thermal oxidiser, diesel generators and compressors)	Reduction in local air quality Generation of greenhouse gas emissions	Thermal oxidiser specification and operation to achieve high destruction efficiency of gas stream and includes diesel firing to ensure this is maintained under low calorific syngas conditions. Modelling undertaken to confirm emissions from thermal oxidiser meet EPA criteria for maximum ground level concentrations outside site / PEL 650. All fuel burning equipment operated and maintained in accordance with design parameters and manufacturer specifications. Monitoring of emissions and air quality undertaken. Demonstration plant operation kept to minimum length of time necessary to establish resource and production parameters. Greenhouse gas emissions recorded and reported in accordance with NGER requirements where applicable.	Modelling indicates no exceedances of EPA air quality criteria away from the immediate vicinity of the demonstration plant site, outside PEL 650 or at sensitive receptors. Operations are short term.	Minor	Unlikely	Low
Syngas release (e.g. non-routine venting, purging)	Reduction in local air quality Generation of odours Exposure to site users	Outlet well flow directed to thermal oxidiser under normal operating conditions. Non-routine venting only carried during start-up or under abnormal or emergency situations. Planned venting (e.g. at initiation) not undertaken when winds are in the direction of closest receptors (e.g. Copley) as far as practicable. Plant operated to minimise gas releases from vent. Cold vent ignited (with supplementary fuel (LPG) to allow low calorific value syngas to be combusted) to minimise odour potential if extended period of venting is likely. Personal gas detection / monitoring to warn if dangerous levels of gas occur Erection of signage and, where required, fencing to delineate restricted / hazardous areas. Equipment and piping designed, constructed and pressure tested in accordance with relevant standards and guidelines. Greenhouse gas emissions recorded and reported in accordance with NGER requirements where appropriate. Management measures implemented for venting (e.g. exclusion zones downwind, notification of Flinders Power where appropriate) to minimise any hazard to personnel on the site. Liaison with local community regarding operations. DPC notified regarding venting operations.	Worst-case scenarios modelled (continuous venting emissions) indicate: - no exceedances of EPA air quality criteria for CO or H_2S health-based criteria away from the immediate vicinity of the demonstration plant site, outside PEL 650 or at sensitive receptors. - venting would result in H_2S above EPA odour criteria at sensitive receptors under some wind conditions (e.g. less than 10% of venting events would result in odour at Copley). Existing odours on the site from previous mining operations and spontaneous combustion of waste stockpiles and other odour sources in Copley (e.g. wastewater irrigation). Operations are short term and venting would be very infrequent and short duration.	Minor	Possible	Medium
Noise emissions	Disturbance to local community Disturbance to wildlife	Liaison with local community regarding operations. Plant and equipment operated and maintained in accordance with design parameters and manufacturer specifications. Screening provided by the stockpiles surrounding the project site. Venting activities will be minimised.	Existing noise from current operations and heavy vehicle traffic on the highway. Noise emissions during operations will be localised and short term. No nearby residences, with the closest approximately 8.5 km from the site. Topography shields Copley and Leigh Creek. Limited numbers of wildlife are present.	Negligible	Unlikely	Low
Unauthorised third party access	Danger to health and safety of the public	Access to site restricted during operations. Signage and fencing in place to warn of site hazards and restrict access to the site. Site will be attended by operators during plant operation.	Site is inside the fenced mine boundary and over 3 km from the public road. Access inside the mine boundary is restricted.	Major	Unlikely	Medium

Risk Event / Hazard	Potential Environmental Impacts	Key Management Measures	Comments	Consequence	Likelihood	Residual Risk
Storage, handling and disposal of waste	Localised contamination of soil and surface water Damage to vegetation and habitat Attraction of scavenging animals (native / pest species) and access to contaminants by wildlife Litter / loss of visual amenity	Waste generation minimised (e.g. by compliance with EPA's Waste Hierarchy model (avoid, reduce, reuse, recycle, recover, treat, dispose)). High standards of 'housekeeping' implemented. Waste removed off-site and disposed of at an EPA licensed waste handling facility. Secure systems used for storage and transport of waste (e.g. covered bins in designated area for waste collection and storage prior to transport). Hazardous wastes handled in accordance with relevant legislation and standards. Licensed contractors used for waste transport. Liquid waste (e.g. water and condensate from the ISG process) will be stored in appropriate tanks and disposed in the thermal oxidiser or transported off site to an EPA licensed facility. All wastewater (sewage) is disposed in accordance with the South Australian *Public Health (Wastewater) Regulations 2013* or to the satisfaction of the Department of Health.	Site is inside the fenced mine boundary and over 3 km from the public road. Access inside the mine boundary is restricted. Low numbers of wildlife	Minor	Unlikely	Low
Use of roads; movement of heavy machinery and vehicles	Injury or death of stock or fauna Disturbance to local community	Compliance with relevant speed limits and restrictions. Driver behaviour and vehicle speed limits included in compulsory induction. Appropriately licensed and competent contractors will be used. All required authorisations (e.g. DPTI, police) obtained where required for significant activities (e.g. movement of large items of equipment) on public roads. Emergency services and potentially affected landholders / local community will be informed of significant activities (e.g. movement of large items of equipment) on public roads.	Site access uses sealed mine access road and public roads which carry significant heavy traffic. Minor increase for demonstration plant will not be significant.	Minor	Unlikely	Low
	Increased road hazard / disturbance to local road users			Moderate	Possible	Medium

6 Environmental Management Framework

6.1 Environmental Management System

LCK has designed an Environmental Management System based on the principles of *ISO 14001: Environmental Management Systems*. LCK's Environmental Management System therefore comprises the following components, as described by ISO 14001:

- Environmental Policy
- Planning
- Implementation and Operation
- Checking
- Management Review.

Environmental Policy

LCK acknowledges that excellence in environmental management is essential to the success of the LCK. Therefore, LCK's Environmental Policy is a statement of the company's intent to achieve environmental compliance and ensures all environmental activities are consistent with LCK's objectives. The policy is a statement of commitment from management and reflects the values of the LCK Board. The policy is reviewed every year by the Board for its appropriateness and to ensure it is up to date with current legislation. The policy is signed and dated by the Chief Executive Officer after every review.

The policy is communicated to people working for or on behalf of LCK through inductions, and is displayed by the entrance to the LCK offices. The policy is made available to the public on the LCK website www.lcke.com.au.

Environmental Objectives

Environmental objectives for the proposed activities have been developed in the accompanying SEO (LCK 2017). These objectives have been designed to provide a clear guide for the management of environmental issues.

Responsibilities

Environmental management and compliance will be the responsibility of all personnel with overall responsibility for environmental compliance lying with Leigh Creek Energy. The indicative organisation roles and responsibilities for personnel overseeing environmental management are detailed in Table 6-1. All contractors and individuals will also be responsible and accountable through their conditions of employment or contract. The training of all personnel will ensure that each individual is aware of their environmental responsibility.

Table 6-1: Indicative roles and responsibilities

Role	Accountabilities
Chief Executive Officer	Ensure that resources are made available so that all accountabilities below are actioned by the relevant people
Environmental Approvals and Compliance Manager	Implement environmental policy Implement programs for achieving set objectives and targets Monitoring and measurement of environmental performance Overall responsibility for system implementation
Operations Manager	Communicate EMS responsibilities to site employees
Training Coordinator	Ensure that all employees, contractors and visitors have undertaken EMS induction and training
EHS Officer	Day to day implementation of EIR/SEO, monitoring activities during construction, monitoring and audits during operation, environmental internal reporting and incident investigation
Employees, contractors and visitors	Adhere to policies and procedures at all times

Environmental Management Plan

All Leigh Creek Energy employees and contractors are responsible for ensuring compliance with the Leigh Creek Energy Environmental Management Plan (EMP) for the ISG Demonstration Plant Project and with associated environmental legislation. Leigh Creek Energy conducts periodic environmental reviews to assess the appropriateness of the EMP to meeting Leigh Creek Energy's policy, legislative requirements and environmental objective commitments and whether the EMP has been properly implemented and maintained.

Job Safety Analysis (Permit to Work)

Job Safety Analysis (JSA) is a process used to identify hazards associated with a job, by assessing the risks and implementing control measures to ensure the job can be conducted in a safe manner. Leigh Creek Energy conducts JSAs for tasks where a work procedure does not exist, where the task has not previously been conducted by the personnel assigned to the task, or where additional hazards are present.

Induction and Training

Prior to the start of field operations all field personnel are required to undertake an environmental induction to ensure they understand their role in protecting the environment. This induction is part of a general induction process which also includes safety procedures. Site specific environmental requirements will be documented in the work program or work instruction. A record of induction and attendees will be maintained.

6.2 Emergency Response and Contingency Planning

Emergency response plans (ERPs) will be developed to guide actions to be taken to minimise the impacts of accidents and incidents. ERPs will be reviewed and updated on a regular basis to incorporate new information arising from any incidents, near misses and hazards and emergency response simulation training sessions. These plans will also include the facilitation of fire danger season restrictions and requirements.

Emergency response drills will also be undertaken at regular intervals to ensure that personnel are familiar with the plans and the types of emergencies to which it applies, and that there will be a rapid and effective response in the event of a real emergency occurring.

6.3 Environmental Monitoring and Audits

Ongoing monitoring and auditing of the demonstration plant activities will be undertaken to determine whether significant environmental risks are being managed, minimised and where reasonably possible, eliminated.

Monitoring programs will be designed to assess:

- compliance with regulatory requirements (particularly the SEO)
- integrity of bunding and containment systems
- site contamination
- site revegetation following completion and any restoration

Further detail on proposed monitoring for the demonstration plant is provided in Section 3.10.

6.4 Incident Management, Recording and Corrective Actions

LCK and its contractors have a system in place to record environmental incidents, near misses and hazards, track the implementation and close out of corrective actions, and allow analysis of such incidents to identify areas requiring improvement. The system also provides a mechanism for recording 'reportable' incidents, as defined under the *Petroleum and Geothermal Energy Act 2000* and associated regulations.

6.5 Reporting

Internal and external reporting procedures will be implemented to ensure that environmental issues and / or incidents are appropriately responded to. A key component of the internal reporting will be contractors' progress and incident reports to LCK.

External reporting (e.g. incidents, annual reports) will be carried out in accordance with *Petroleum and Geothermal Energy Act 2000* requirements and the SEO. Annual reports are available for public viewing on the DPC website.

7 Consultation

LCK is committed to the principles of stakeholder engagement as outlined by the International Association of Public Participation (IAP2). LCK recognises its stakeholders as any individual, group of individuals, organisation or entity with an interest in its activities.

LCK is committed to respectful and transparent communications, and aims to:

- have informed discussions and proactively work with stakeholders
- engage openly and honestly with stakeholders
- identify and address issues or opportunities raised by stakeholders
- build long term relationships of trust with stakeholders.

LCK aims to continue to engage stakeholders for the lifecycle of the project to ensure that all potential concerns are identified and appropriately addressed. Stakeholder correspondence is registered and documented to ensure that issues are appropriately addressed.

LCK has been undertaking a program of consultation with directly affected parties and other stakeholders, as outlined below. Issues raised to date have been integrated into this report where relevant.

To meet these commitments LCK has employed a dedicated Stakeholder Relations team with experience in mining and petroleum projects throughout South Australia.

7.1 Stakeholder Consultation

Stakeholders in the Leigh Creek region include the Adnyamathanha Traditional Lands Association (ATLA), the local communities of Copley, Leigh Creek, Nepabunna, Iga Warta and Hawker, Flinders Power, regulatory agencies, industry groups and environmental organisations.

LCK has held meetings with relevant stakeholders to present a description of the project and discuss potential environmental impacts and mitigation strategies. A number of meet and greet activities were held in Copley and Hawker in June 2017 with no attendees from these communities. A community meeting with the Copley community in August 2017 was initially well attended with 23 attendees however the meeting was shortened when a large proportion of attendees left after expressing opposition to the project. A letter to the LCK Directors was also presented as a formal notice of opposition from a number of Copley residents.

LCK has had regular engagement with ATLA through attendance at their monthly Board meetings during which time project updates are given and cultural heritage is recognised. A number of specialised workshops have been held with ATLA where project overview presentations and updates have been given, with particular attention given to proposed the demonstration works plan.

As noted above, there were no attendees from Copley and Hawker at either of the meet and greet community engagement activities in June 2017. While this was the case for these activities, efforts have been made to familiarise LCK personnel with business operators in both towns and to date, enjoys a positive relationship with business entities within the towns.

In early November 2017, LCK provided draft copies of the EIR and SEO to a large group of stakeholders including ATLA, the communities of Copley and Leigh Creek, Flinders Power, Conservation Council SA, Wilderness Society, Nature Foundation SA, Outback Communities Authority, South Australian Arid Lands Natural Resources Management (NRM) Board and other interested parties.

During November, LCK also held another Open Day at the Copley Bakery, briefed the Leigh Creek Community Progress Association at their AGM and General Meeting, and presented to the South Australian Arid Lands NRM Board. The Open Day at the Copley Bakery was attended by two people, and further feedback was received by a third stakeholder over email.

LCK also participates in the Leigh Creek Energy Internal Government Agency Reference Group which meets regularly to discuss technical progress and stakeholder relations updates. These meetings occur between LCK, the Environment Protection Authority (EPA), Department of Environment, Water and Natural Resources (DEWNR) and DPC’s Energy Resources and Minerals Divisions.

Table 7-1 identifies the key stakeholders engaged with since the commencement of the project and highlights the activities undertaken with each stakeholder.

Table 7-1: Summary of stakeholder consultation

Stakeholder Category	Stakeholder	Activity
Traditional Owners	ATLA	Monthly board meetings attendance Specialised project workshops Work Area Clearances
Community	Copley	Workshops Community meet and greets
	Leigh Creek	Meetings with business owners: Foodland Newsagent/Post Office Service Station Leigh Creek Outback Resort Doctor Leigh Creek Area School SAPOL SAAS Health Services
	Hawker	Community meet and greets
	Parachilna	Meetings
Progress Associations	Beltana	Presentation
	Leigh Creek	Presentation
	Copley	Presentation
	Lyndhurst	Presentation
Landholders	Flinders Power	Meetings
Pastoralists	Beltana and Puttapa Pastoral Lease	Meeting
	Leigh Creek Pastoral Lease	Meeting
	Myrtle Springs Pastoral Lease	Meeting
	North Moolooloo Pastoral Lease	Meeting
	Nilpena Pastoral Lease	Meeting
	Farina Pastoral Lease	Meeting
	Angepena Pastoral Lease	Meeting
	Depot Springs Pastoral Lease	Meeting
	Maynards Well Pastoral Lease	Meeting

Stakeholder Category	Stakeholder	Activity
	Leigh Creek Pastoral Lease	Meeting
	Mt Serle Pastoral Lease	Meeting
Regional Councils	Outback Communities Authority	Meetings with CEO Presentations
	Nepabunna Council	Meetings with CEO Presentations
	Port Augusta Council	Meetings with CEO Presentations
	Flinders Ranges Council	Meetings with CEO Presentations
	Whyalla Council	Meetings with CEO Presentations
Government Departments and Bodies	Department of Premier and Cabinet – Energy Resources Division	Meetings
	Department of Premier and Cabinet – Minerals Division	Meetings
	Environment Protection Authority	Meetings
	Department of Environment and Natural Resources	Meetings
	Natural Resources Management (NRM) Board	Meetings and presentations
	SA Arid Lands Board	Meetings and presentations
	Pastoral Board	Meetings and presentations
	Department of Health and Ageing	Meetings
	Regional Development Australia Far North	Meetings and presentations
	Regional Development Australia Far North	Meetings and presentations
	Regional Development Australia Whyalla and Eyre Peninsula	Meetings and presentations
	Regional Development Australia Mid North	Meeting
	Upper Spencer Gulf and Outback TaskForce	Meetings and presentations
Other	Conservation Council SA	Meeting
	Wilderness Society	Meeting
	Nature Foundation SA	Meetings

7.2 Stakeholder Feedback

LCK submitted draft copies of the EIR and SEO to the regulator (DPC) for an adequacy assessment against the requirements of the legislation. DPC requested that further information be provided, including geotechnical information to support that the proposed location of the PCD meets all the conditions recommended by the Independent Scientific Panel report as outlined previously in Table 3-2. In collecting this information LCK drilled additional geological holes and consequently, the geotechnical and hydrogeological reports attached to this EIR and the relevant sections in the EIR have been amended to provide further details in those areas.

Table 7-2 identifies the key stakeholder issues raised, and indicates the sections of the EIR which relate to these issues. It has been amended to include further comments that arose from the November consultation sessions in Copley and Leigh Creek, as well as questions received from other stakeholders via email.

Table 7-2: Responses to stakeholder questions

Comment	Where covered in EIR	Summary of Response
What is the difference between ISG vs UCG?	Section 3.1	The processes are the same. ISG (in situ gasification) is the term used in South Australian legislation. UCG (underground coal gasification) is used in Queensland legislation.
Is it fracking?	n/a	No, fracking (hydraulic fracturing) is not used
Is fracking the same as ISG?	n/a	No, fracking (hydraulic fracturing) involves injection of water and additives under pressure into the rock formation to open gas flow pathways The demonstration will direct drill a pathway from well to well
Will it affect surface water?	Section 4.8, 5.4	No, small scale, short duration trial. No natural surface water features present at the site.
How will you manage groundwater quality?	Section 5.2	The gasifier chamber contents will be contained by keeping chamber pressure below surrounding groundwater pressure. This is done by control of chamber pressure from air supply flow and by monitoring the well pressures. There are no aquifers present. Although the rocks contain water, they are considered to be aquitards and the water cannot move easily or be extracted for water supply by wells at the surface.
Why is there so little water?	Section 4.7	'Tight' rock formations hold water but it does not move easily
Could you have missed the groundwater?	Section 4.7	Other groundwater sources are not expected as the basin geology is uniform and well documented
Which wells do groundwater monitoring?	Section 3.10	Deep groundwater monitoring wells (approx. 500m) Shallow groundwater monitoring wells (approx. 80m) Water table wells (approx. 10m)
How deep are drillholes?	Section 3.10	As above
What is a (gasifier) chamber?	Section 3.1	The void left behind when solid coal converts to syngas
Is the coal burning?	Section 3.1	No, burning coal will form carbon dioxide and heat Coal undergoes a chemical reaction started with heat

Comment	Where covered in EIR	Summary of Response
Does the coal burn outside the chamber?	Section 3.1	Coal will only convert to syngas inside the chamber
How much gas will be produced during the trial?	Section 3.8	Approx. volume of syngas is 10,000m^3 per hour
What do you want the gas for?	Section 1	Syngas can be used as fuel for a power station or converted to methane for cooking, heating etc
How do you measure success of the trial?	n/a	High quality syngas that can be easily used for power generation, that is managed safely and with minimal environmental impact
What happens if the trial is successful?	n/a	A successful trial would provide information to design a commercial facility
Is it hot underground?	Section 4.7	Normal groundwater temperatures reach up to 50°C
Are there any waste products?	Section 3.11.3	All demonstration plant products will be destroyed by incineration (by the Thermal Oxidiser), including syngas, water and solids
Where does the waste go?	Section 3.11.3	All domestic waste will be taken to the Leigh Creek landfill. Any non-domestic waste will be taken offsite to EPA licensed landfill
What are the employment opportunities?	Section 5.10	Short term contracts for the demonstration will be managed by WorkPac
Will there be smoke?	Section 5.6	There will be no smoke from the operations
What is the rotten egg smell?	Section 4.10, 5.6.3	Hydrogen sulphide smell comes from coal in the waste dumps, and also comes from town sewage treatment systems
Will you make more smells?	Section 5.10	There is not expected to be any odour from day to day activities Non-routine venting (e.g. emergency activities) may cause a short term odour
What about earthquakes?	Section 5.9	Plant and wells have been designed to meet petroleum industry engineering standards
Is LCK a rebranded Marathon Resources?	Section 1.1	No, LCK acquired Marathon in a reverse takeover with none of Marathon's projects or liabilities
Do you just stick big pipes down the ground?	Section 3.2	Wells are drilled and constructed with steel casing which is concreted in place to meet petroleum industry standards
How is the groundwater protected?	Section 3.2	Groundwater is protected through the design and construction of wells to petroleum industry standard with steel casing which is concreted in place. As noted above there are no aquifers present.
Do you pull the pipes (casing) out of the ground once complete?	Section 3.9	Steel and concrete casing are left in the ground and each well is decommissioned as per the requirements of the regulator
Would an earthquake damage the casing underground once demonstration is complete?	Section 5.9	Wells and plant have been designed to meet petroleum industry standards including risk of earthquakes.
What goes down the inlet well?	Section 3.8.1	Air and water are pumped through the inlet well
Where does the water come from?	Section 3.11.1	Water will be provided by multiple sources including reclaimed mine pit water as well as from available third party suppliers (such as SA Water or others).

Comment	Where covered in EIR	Summary of Response
What ignites (starts the process) the coal?	Section 3.7	A heating element known as an initiation tool is placed down the inlet well and uses a high temperature chemical reaction to begin the gasification process
Are there chemicals in the waste water?	Section 3.11.3	All waste water contains some chemicals which will be sent to the thermal oxidiser for destruction
Will animals drink the water in the recycled water tanks?	Section 3.11.3	No, the tanks are covered
Will any rain fill the recycled water tanks up and will they overflow?	Section 3.11.3	No, the tanks are covered
Why is there liquid remaining in the gas?	Section 3.1.1	All gas products contain some water (condensate) which is removed and sent to the thermal oxidiser for destruction
Where will the gas go?	Section 3.8.1	During the demonstration period, gas will be destroyed through the thermal oxidiser.
What about greenhouse gas emissions?	Section 5.6.2	The demonstration plant operation will be short term, and will gather data that will be used to characterise emissions and develop greenhouse gas management strategies for any potential future commercial-scale development.
Where are the weather monitoring stations going to be?	Section 3.10	Two weather stations have been installed on PEL 650. One at the demonstration site, and one at the highest point of PEL 650 (approx. 4-5km north of the town of Copley).
How did you decide to put a weather monitoring station in that location?	Section 3.10	One near the demonstration site for data relevant to the plant and one at the highest point at the site to collect background data
Does the Telford Basin groundwater system connect to the town of Copley or Leigh Creek?	Section 4.1 and 4.7 Appendix A	No, the Telford Basin is a standalone basin sitting on and surrounded by very old basement rocks.
How close is the nearest fault (to the gasifier chamber once initiated) and should it be any cause for concern?	Section 4.6.4	A 100 m exclusion zone for all geological structures has been incorporated into the design of the gasifier. The Geotechnical Report shows that no geological structures occur within this zone.
How come you are doing this trial / demonstration at Leigh Creek?	Section 1	The remaining resource at the Leigh Creek Coalfield is deep and no longer economic to mine using conventional methods. ISG technology is able to access the deep coal via a system of linked wells. Leigh Creek was chosen specifically using a series of environmental and technical criteria.
Why did you need to drill extra holes?	Section 7.2	Additional information was requested by the regulator to provide additional geotechnical information, in particular that no geological structures exist within a 100m exclusion zone of the gasifier.
How can the community ask questions or give feedback on the project?	Section 7.3	There is a dedicated Community Feedback Portal which can be accessed at http://lcke.c3register.com/. Community members can track the progress of their request through this portal. In addition to that, there is also a community@lcke.com.au email address where questions can be sent to direct. The Stakeholder Relations Team are also happy to meet with locals to discuss the project at length. Please email the Community email address to organise a meeting.

7.3 Online Community Portal

LCK has introduced a targeted online community portal via the LCK website for interested stakeholders. Community members can easily login and share their experiences of the project, leave feedback, and locate or request information. The portal offers enhanced two-way communication where community users can track the progress of any requests they make and add reminders so that their questions are answered in a timely manner.

The site has been designed for ease of use and will be monitored by a dedicated Stakeholder Relations Coordinator. The Community Portal can be accessed through the LCK website's 'Contact us' section (www.lcke.com.au/contact) and directly through http://lcke.c3register.com/.

In addition, a suite of educational materials about the company and the project are being developed for use in community engagement activities and more will be developed as questions are asked through the Community Portal and ongoing community meetings.

7.4 Formal Public Consultation

The EIR and Draft SEO were submitted to DPC for assessment on 20th December 2017. After an assessment against the Petroleum and Geothermal Energy Act and Regulations, DPC invited public comment on the EIR and Draft SEO. Copies of the EIR and Draft SEO were made available for members of the public and other regulatory agencies to review and submit comment to DPC by 28th February 2018.

LCK received a total of 94 written submissions subsequent to the formal public consultation undertaken by DPC for the EIR and Draft SEO. Of these submissions, 32 were in support of the proposed project and 62 were opposed to the proposed project.

Each submission has been numbered and reviewed, and questions, concerns, comments or suggestions about the proposed project have been categorised into topics for response. A summary of the submissions and the topics raised, together with the number of each submission which raised these topics, and the detailed responses from LCK have been tabulated and are presented in Appendix E. As many respondents raised issues common to other submissions, not all submissions have been addressed individually.

Where relevant, the responses clarify, or provide a reference to, information already contained in the EIR.

The scope of the consultation on the EIR and SEO is the assessment of the potential environmental impacts of the construction, operation and decommissioning of a small-scale ISG demonstration plant located in PEL 650. Some submissions provided comments which did not relate to the project; were specifically addressed to government, rather than to LCK; referred to communications between respondents and the Regulator / other government agencies; or related to the possible commercial scale ISG project. These submissions are outside the scope of consultation on the EIR and SEO and have not been addressed in this summary. Submissions directed to the government have been deferred to the government to address as appropriate.

This section provides LCK's response to the main topics raised in the submissions. Detailed responses to the issues raised are contained in Appendix E.

7.4.1 Summary of Main Topics Raised in Responses

7.4.1.1 General opposition

A number of submissions were received stating general opposition to the proposed project without providing a specific reason or question, such as "*I write to submit my view against the underground coal gasification trial project at Leigh Creek*".

LCK acknowledges these submissions and, as outlined in Section 7, will continue to provide opportunities for engagement and communications for all stakeholders. LCK notes that in situ gasification, either by exploration or production, is regulated by the PGE Act and Regulations, and will develop the project within this legislative framework.

Environmental objectives for the proposed activities have been developed in the accompanying SEO (LCK 2017). These objectives have been designed to provide a clear guide for the management of environmental issues.

7.4.1.2 General support

A number of submissions were received stating their support for the proposed project for the following reasons:

- site selection
- site location
- regional benefits for other resource projects
- thorough environmental impact assessment
- employment opportunities for Leigh Creek
- economic benefits of commercial project
- energy security
- continued use of an existing resource.

7.4.1.3 Aboriginal heritage

A submission was received from the Adnyamathanha Traditional Lands Association (ATLA) in relation to the proposed demonstration project.

In their submission ATLA states opposition to the project on a number of grounds including protection of Aboriginal heritage, native title issues, environmental impacts, and application of the Petroleum and Geothermal Energy Act to ISG.

LCK acknowledges the significance of the Leigh Creek area in the context of the Yurlu Ngukandanha *mura*, and the disturbance to the *mura* from historical coal mining operations. LCK is committed to conducting its operations in accordance with the requirements of the *Aboriginal Heritage Act 1988* and will continue to engage with ATLA to build a co-operative and mutually beneficial relationship with the Traditional Owners of the region.

Native title matters in relation to the PEL are issues to be addressed between ATLA and the South Australian Government and are outside the scope of this EIR. These comments have been deferred to the government.

The submission raised concern regarding potential for environmental impacts from movement of COPCs through sub-surfaces during and after the operational and decommissioning phases, resulting in impacts to water sources. The assessment of the risks relating to migration of COPC away from the gasifier is discussed in Section 5.2.2 and provided in Table 5.4. As noted in this assessment, the potential for COPC to migrate away from the gasifier is extremely limited due to the low permeability, slow groundwater movement and high sorption properties of the surrounding coal and carbonaceous mudstone, and there are no aquifers in the area of operation and no pathways to aquifers from the gasifier chamber. Consequently, the level of risk has been assessed as low.

7.4.1.4 UCG projects in other jurisdictions

A significant number of submissions raised issues relating to environmental impacts caused by a number of UCG trials undertaken in Queensland, particularly in relation to impacts to groundwater. Comments were also provided regarding the Queensland Government decision in 2017 to no longer permit UCG projects in Queensland. A small number of comments also raised the issue of 'fracking'. One submission commented on the status of UCG in Scotland.

Section 3.12 notes that the LCK demonstration plant project will apply learnings from previous ISG projects to ensure that environmental risks are identified and appropriately managed, and that the project does not result in significant adverse impacts. As noted in Section 3.12, the project will follow the recommendations of the Independent Scientific Panel (Moran *et al.* 2013) and other recently published information (e.g. Hyder 2012, Camp and White 2015, Camp 2017). All publicly available results and reports of recent pilot projects in Queensland (including the successfully operated and decommissioned Carbon Energy project) have also been reviewed by LCK personnel, and learnings have been incorporated into the design of this project.

As noted in Section 3.12, factors that have been raised as issues in some of the Queensland trials (e.g. shallow depth of coals, sensitive land use and presence of aquifers with beneficial uses) do not occur at the Leigh Creek site and techniques that have been raised as potentially problematic in some Queensland pilots, such as hydraulic fracturing of the coals will not be used for this project.

As noted in Section 3.1.5, the Carbon Energy pilot in Queensland did meet the recommended requirements of the Independent Scientific Panel, and demonstrated safe and effective decommissioning of the pilot panel (Garrett 2016).

7.4.1.5 Reliance on fossil fuels and renewable energy

A number of submissions opposed the proposed project because of the respondent's desire for a reduced reliance on fossil fuels and increased reliance on renewable energy.

As stated in Section 3.13, developing suitable strategies for management of greenhouse gases, particularly carbon dioxide, will be an important element in planning for any future commercial-scale ISG development.

A key outcome from the demonstration plant is an understanding of the composition of the gases produced, their volumes, temperature, pressure and flowrates. The information developed on carbon dioxide production will allow LCK to identify the most appropriate mitigation strategies and carbon dioxide capture technology for any future development.

7.4.1.6 Environmental impacts

A number of submissions were received expressing environmental impact concerns, including potential impacts to groundwater quality, biodiversity / ecosystems, soil and geological integrity.

As outlined in Section 5.2, the risk to groundwater posed by the demonstration plant is low as the gasifier is surrounded by very low permeability aquitards, there are no groundwater receptors present in the Telford Basin and no credible pathways to groundwater receptors.

LCK has committed to a number of measures in the EIR and SEO to manage and mitigate risk of the environmental impacts identified in submissions. These measures are detailed in Appendix E and include:

- management philosophy

- site selection
- learnings from previous projects
- independent environmental assessments
- construction design
- construction testing
- operational control
- 'clean cavern' approach to closure and rehabilitation of the gasifier
- monitoring.

In implementing these measures to mitigate and manage risk, LCK are committed to reducing risks to as low as reasonably practicable.

7.4.1.7 Experimental technology and process

A number of submissions were received that commented on issues seen as arising from the 'experimental' nature of in situ gasification technology. These comments are detailed in Appendix E.

As noted in Section 3.12, approximately one hundred experimental, pilot and demonstration ISG operations have been undertaken globally in the last eighty years. These have shown the process to be technically feasible, and over this time the technology and understanding of the process has continually improved.

The environmental risk assessment for the proposed demonstration plant is summarised in Table 5-4 (in Section 5.11). It indicates that the level of risk of the proposed project is manageable and relatively low for the key areas of concern identified by stakeholders (cultural heritage, air quality, groundwater, surface water and ground stability). No high or unacceptable risks have been identified for the proposed demonstration plant. LCK will implement engineering design in accordance with relevant standards, risk assessment and management procedures and environmental management systems to ensure that all risks are appropriately managed and compliance with regulatory requirements is achieved.

7.4.1.8 Adequacy of the Statement of Environmental Objectives (SEO)

Comments were received in relation to the adequacy of a number of objectives in the SEO. Detailed responses to these comments are set out in Appendix E. SEO Objectives addressed include:

- SEO Objective 3 - *No loss of gasification products to the surface or subsurface environment via pre-existing drill holes and/or transmissive geological features*.
- SEO Objective 4 - *Well integrity is maintained to prevent loss of gasification products to the surface or subsurface environment*.
- SEO Objective 5 - *No gasifier induced subsidence measured at the surface*
- SEO Objective 9 - *Avoid the introduction or spread of weeds, plant pathogens or pests (including feral animals).*
- SEO Objective 10 - *Air pollution and greenhouse gas emissions reduced to as low as reasonably practical.*

7.4.1.9 Closure and rehabilitation liabilities

Several submissions stated concerns around financial security for potential ongoing liability and remediation.

As a licensee under the Petroleum and Geothermal Energy Act, LCK is required by section 75 to have adequate technical and financial resources to ensure compliance with environmental obligations (including the rehabilitation of land adversely affected by regulated activities carried out under the licence).

7.4.1.10 Other issues

A range of other issues were raised in individual submissions and have been addressed in detail in Appendix E. These include:

- adequacy of groundwater assessment and connectivity of aquifers
- integrity of well casing
- seismic and tidal impact on project
- decommissioning success
- location of the demonstration plant and PEL 650 in relation to the town of Copley
- information on additional investigations
- fauna entrapments
- public and community reporting
- water allocation
- independent hydrologist / aquifer pollution
- air pollution baseline study and monitoring
- impact of self-combusting coal fires
- use of compressed air and query of other chemical use
- waste generation by the process and treatment
- impact to land prices and compensation
- ISG process and difference to fracking.

Questions directed to the government and concerns raised in a small number of submissions relating to the South Australian regulatory framework, LCK corporate history and the commercial plant were considered outside the scope of the EIR and SEO. These submissions have been noted by LCK and recorded in Appendix E.

7.5 Government Agency Submissions

As part of the formal consultation process, copies of the EIR and SEO were provided by DPC to the following South Australian government agencies:

- Safework SA
- Department of Health and Ageing (DHA)
- Environment Protection Authority (EPA)
- Aboriginal Affairs and Reconciliation (AAR)
- Department of Environment, Water and Natural Resources (DEWNR)
- Department of Planning, Transport and Infrastructure (DPTI)
- Primary Industries and Regions South Australia (PIRSA)
- Outback Communities Authority (OCA).

The feedback and questions raised by these agencies, and the responses provided by LCK, have been incorporated into Appendix F. No comments were received from DPTI, PIRSA and OCA.

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9 Abbreviations and Glossary

ADG Code	Australian Dangerous Goods Code. The Australian Dangerous Goods Code sets out the requirements for transporting dangerous goods by road or rail.
Adelaide Geosyncline	A major central South Australian geological province that extends from the northern parts of the Flinders Ranges to Kangaroo Island, and includes the Mount Lofty Ranges. The sedimentary rocks were primarily deposited in the Neoproterozoic era. Lithology includes siltstone, shale and limestone.
aquifer	Geologic materials with high hydraulic conductivity that are able to receive, store and transmit groundwater in quantities sufficient for use as a water supply.
aquitard	Geologic materials with low hydraulic conductivity that are able to receive and store groundwater, but cannot transmit the groundwater in quantities sufficient for use as a water supply.
AS 1940	Australian Standard. AS 1940: *Storage and Handling of Flammable and Combustible Liquids.*
ASX	Australian Securities Exchange. Prior to December 2006 it was known as the Australian Stock Exchange.
ATLA	Adnyamathanha Traditional Lands Association
BOM	Bureau of Meteorology.
BTEX	Refers to the chemicals Benzene, Toluene, Ethylbenzene and Xylene.
CASA	Civil Aviation Safety Authority
casing	Large diameter steel pipes that are screwed together to form a casing string, which is run into a core hole or well and cemented in place.
casing shoe	The bottom of the casing string, usually bull-nose shaped device which helps guide the casing string past any ledges or obstructions when being installed.
casing string	A long section of connected oilfield pipe that is lowered into a well bore and cemented into place.
cement bond log	The output from an acoustic tool that is lowered down an oil or gas well to evaluate the integrity of the bond of the cement to the casing and formation.
contamination	Contamination means the condition of land or water where any chemical substance or waste has been added as a direct or indirect result of human activity at above background level and represents, or potentially represents, an adverse health or environmental impact.
COPC	Chemical(s) of potential concern. Chemicals with the potential (depending on background levels, where they are located and potential receptors) to have adverse impacts on human health or the environment.
coiled tubing	A continuous length of steel tubing that can be spooled on a reel for transport, then deployed into a well for the placement of fluids or manipulation of tools during workover and well-intervention operations.
dB(A)	A-weighted decibels.
DEE	Department of Environment and Energy.
DEH	Department of Environment and Heritage (SA) (now DEWNR).
DEWNR	Department of Environment, Water and Natural Resources (SA).
DPC	Department of Premier and Cabinet.
DSD	Department of State Development.
directional drilling	The intentional deviation of a well during drilling from the path it would naturally take, often used in petroleum drilling to place the well in contact with the most productive reservoir rock.
EL	Exploration licence (mining).

EIR	Environmental Impact Report.
EMP	Environmental Management Plan.
endothermic	A process or reaction that absorbs energy (usually heat) from its surroundings.
EPA	Environment Protection Authority (SA).
EPBC	*Environment Protection and Biodiversity Conservation Act 1999* (Cth).
ephemeral	Existing for only a short time, often dependent upon climatic influences.
ETSA	Electricity Trust of South Australia
EWS	Engineering and Water Supply Department
exothermic	A process or reaction that releases energy (usually heat) to its surroundings.
flaring	The burning of unwanted gas through a pipe (called a flare).
formation	The term for the primary unit in stratigraphy consisting of a succession of strata useful for mapping or description, which possesses certain distinctive lithologic and other features.
gasification	Process that converts coal into gas, principally carbon dioxide, hydrogen and carbon monoxide.
gasifier chamber	The void that is formed underground in the coal seam following consumption of coal in the ISG process.
GSEL	Gas storage exploration licence.
HAZCON	Hazard Construction.
HAZOP	Hazard and Operability.
hydraulic head	Measurement of groundwater pressure above a height datum, expressed in units of length.
IBRA	Interim Biogeographic Regionalisation for Australia.
IESC	Independent Expert Scientific Committee (on Coal Seam Gas and Large Coal Mining Development).
initiation tool	A tool which produces heat and is used to initiate the gasification reactions in the coal.
in situ	In position.
injection point	The location underground where oxidant is introduced into the gasifier.
inlet well	The well that is used to inject oxidant into the gasifier.
ISG	In situ gasification. In situ (underground) conversion of coal into an energy-rich product gas.
Independent Scientific Panel	Independent Scientific Panel for Underground Coal Gasification, established in Queensland in 2013 to review and report on outcomes of UCG trial activities in Queensland.
Jurassic	Relating to the period of geological time approximately 205 to 141 million years ago.
kVA	Kilovolt-amps.
LCEP	Leigh Creek Energy Project.
LCK	Leigh Creek Energy Ltd
LOPA	Layers of Protection Analysis.
mechanical collapse	Larger-scale failure of walls of the gasifier chamber due to stresses created by gasifier chamber creation and pore pressure changes.
Mesozoic	Relating to the era of geological time including Triassic, Jurassic and Cretaceous ages, approximately 250-65 million years ago.
Neoproterozoic	Relating to the era of geological time 1000-545 million years ago, which precedes the Palaeozoic era.
NEPM	*National Environment Protection (Assessment of Site Contamination) Measure (1999)* amended in 2013

OCA	Outback Communities Authority.
organic condensables	Organic (carbon containing) compounds that can be condensed (to form a liquid).
outlet well	The well that is used to bring the target liquid or gas to the surface.
outward pressure gradient	A situation where pressure is higher on the inside than the outside.
overburden	Rock or soil overlying a mineral deposit which would need to be removed for the deposit to be mined.
oxidant	A chemical substance that oxidises another substance.
oxidation	The process by which an element or compound undergoes a chemical reaction involving the removal of electrons; often involves reaction with oxygen to form an oxide.
PAH	Polycyclic Aromatic Hydrocarbon.
PCB	Polychlorinated Biphenyl.
PEL	Petroleum Exploration Licence.
PELA	Petroleum Exploration Licence Application.
produced water	In conventional oil and gas, refers to water from an underground formation that is brought to the surface during petroleum exploration and production. In the ISG process, produced water is used to refer to any water that flows to the surface through the outlet well. For the demonstration plant, this water is predominantly water that has been injected from the surface.
pyrolysis	The breaking of large organic molecules into smaller parts due to heat. Occurs when coal is heated in the absence of oxygen.
Quaternary	Relating to the period of time approximately 1.8 million years ago to the present.
reactive transport	Process where fluids are undergoing chemical reactions and transport (i.e. movement).
receptor	A person, animal, plant, ecosystem, property or water with the potential to be adversely affected or impacted by an activity
rock decomposition	Physical disintegration of the rock due to thermal decomposition of its minerals.
SAAL NRM Board	South Australian Arid Lands Natural Resources Management Board.
SEO	Statement of Environmental Objectives.
SID	Safety in Design.
siderite	A mineral composed iron carbonate
sideritic	Of, containing or related to or containing siderite
SIL	Safety Integrity Level.
Sm^3/hr	Standard cubic metres per hour. Flow rate of gas measured at 1 atmosphere pressure and 0°C
subsidence	Downwards movement or settlement of the ground surface.
syngas	Synthesis gas. The product of gasification, composed mainly of carbon dioxide, hydrogen, carbon monoxide, methane, nitrogen, steam and gaseous hydrocarbons.
thermal oxidiser	A process unit for air pollution control to remove hazardous gases from industrial air streams by destroying them using high temperature.
thermal spallation	Small-scale erosion of rock due to induced thermal stress.
Triassic	Relating to the period of geological time approximately 251 to 205 million years ago.
UCG	Underground coal gasification. UCG is equivalent to ISG.
venting	The release of gas, usually through a vertical pipe called a vent or vent stack.
vertical chamber growth	Growth of the gasifier chamber into the surrounding rock formation due to spalling, rock decomposition or mechanical collapse.

Appendix A: Hydrogeological Conceptual Site Model

Leigh Creek Energy

HYDROGEOLOGICAL CONCEPTUAL SITE MODEL

ISG DEMONSTRATION PLANT

December 2017

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Table of Contents

List of Tables

List of Figures

Appendices

1 Executive Summary

Leigh Creek Energy Limited (LCK) is proposing to construct and operate an In-Situ Gasification (ISG) Demonstration Plant at Leigh Creek Coalfield in South Australia. This work will be undertaken under Petroleum Exploration Licence 650 (PEL 650) covering the Leigh Creek Coalfield. The results from this Demonstration Plant will be used to inform the economic opportunities and technical design of a potential commercial ISG facility at Leigh Creek.

This report provides a Conceptual Site Model for the hydrogeology and baseline chemistry of groundwater for the ISG Demonstration Plant gasifier.

The ISG process converts coal from its solid state into a gaseous form, resulting in the generation of synthesis gas (syngas) containing methane, hydrogen and other valuable components. The syngas can be either used to produce electricity directly or further refined into a variety of products including synthetic methane and ammonia.

Ash, metals and other chemicals present within the coal that are not converted to syngas remain in the chamber formed during the ISG conversion process. The chamber, also called the gasifier, contains the ISG reactions and retains all the solid products from this process. To operate the ISG safely, the gasification operating pressures are maintained below the ambient pressure acting on the coal. The ambient is controlled by the depth to the coal, and the height (and therefore weight) of groundwater above the coal. By maintaining operating pressures below the ambient pressure, natural groundwater movement during gasification will always be towards and into the chamber.

The target ISG coal resource is contained with a geological basin structure called the Telford Basin. This resource is a deeper continuation of the coal seams previously mined from the open pit coal mines currently undergoing rehabilitation by Flinders Power Partnership.

The siting of the Demonstration Plant within PEL 650 has been carefully thought out, as is based on several key factors:

- Main Series Coal seam depth, thickness and quality;
- Absence of open structure (existing drill holes, geological fractures and faults) that could provide pathways for gas or groundwater to move from the ISG chamber;
- Geological strata with low hydraulic conductivity surrounding the ISG chamber to minimise the movement of groundwater and gas from the chamber;
- The absence of groundwater aquifers;
- The accessibility of the area for Demonstration Plant construction and operation; and
- To minimise disturbance to existing and surrounding landowners.

The selected site is located between two (now disused) open pit coal mines and related waste rock dumps. The site is located at natural ground level disturbed by previous mining related activities. At the site, the coal and related rock strata dip to the south at an angle of about 25 degrees. The strata include carbonaceous mudstones (up to 540 m thick) overlying the 12 m thick target coal seam, which in turn overlies an 8 m thick sequence of interbedded coal and mudstone. Below this there is approximately 100 m of carbonaceous mudstone.

The gasification will develop a chamber in the form of a horizontal tear drop or pear shape with the thick end at the Inlet Well and the tapered (thin) end 30 m away at the Outlet Well. The drill hole for installing the Inlet Well will intersect the bottom of the drill hole for the Outlet Well and provide the initial connection for the ISG reactions after initiation. At its widest the chamber could be in the order of 30 m and 12 m high. It is expected the shape will be somewhat irregular depending coal seam characteristics such as natural ash distribution and small scale structural imperfections in the coal seam.

The Telford Basin exists within the hard, folded and fractured rocks that form its geological basement. These basement rocks were laid down over 700 million years ago, and buried deeply and deformed after that time. After these basement rocks were exposed at the surface and eroded, many layers of plants, mud, silt, and some sand were deposited over the top between 240 and 190 million years ago in low-lying areas.

Since this time the area was again buried and deformed, and eroded leaving small disconnected basins like the Telford Basin containing coal and related sedimentary rocks. Before mining occurred, the landscape was relatively flat, with a surface layer made up of gravels, sand and clays which laid down in the valleys and plains over the last 150,000 years that covered much of the basin and surrounding areas. The Telford Basin is about 7.7 km long, 4.7 km wide and up to about 800 m deep.

The Telford Basin is located within the surface water catchment of Leigh Creek, forming the southernmost margin of the Lake Eyre catchment, an arid catchment with no permanent natural surface water. Nearby Aroona Dam, and the shallow groundwater well fields in Emu Creek and Windy Creek are in the separate and unrelated Lake Torrens catchment. The Great Artesian Basin, a groundwater basin, is separated from the Telford Basin by approximately 100 km (at their closest) by a continuation of the basement geology.

Information on the Telford Basin groundwater systems is mostly sourced from monitoring associated with mining activities. It is understood localised groundwater investigations supporting the management of mine pit (geotechnical) stability were undertaken by mine operators. These identified aquifers that intersected the mine’s Upper Series Pit, approximately 500 m south of the Demonstration Plant site at their closest. It is understood that these aquifers contained saline groundwater and were depressurised and significantly dewatered during mine operations. All other strata in the Telford Basin are considered aquitards, i.e. saturated but with no potential for groundwater extraction and minimal natural groundwater movement. Any such natural groundwater movement in these aquitards is expected to be toward the existing mine pits. The coal mine was the only user of groundwater within the Telford Basin and this was part of formation dewatering to maintain pit wall stability.

With open pit coal mining the Telford Basin landscape was significantly modified with earth bunds and waste rock dumps preventing natural drainage from the surround catchment entering or leaving the basin’s footprint. Any runoff in and around the Demonstration Plant site will be captured in nearby existing surface storage or the former mine pits and will not leave the former mine area.

Exploration drill holes drilled by LCK and completed as groundwater monitoring wells have identified the site geology and groundwater occurrence for the Demonstration Plant gasifier. The site consists of a 12 m thick surficial layer of alluvial clays, sands, and gravels overlying approximately 540 m of repetitive carbonaceous mudstone then a 12 m coal seam (the target coal seam for the

Demonstration Plan gasifier), 8 m of interbedded coal and mudstone and then another repetitive sequence of carbonaceous mudstones up to 100 m thick. The entirety of this carbonaceous mudstone and coal sequence consists of beds dipping to the south at an angle of approximately 25^{o}.

There are no aquifers at or within 500 m of the Demonstration Plant site. Groundwater in the carbonaceous mudstone and coal sequences appear to be one continuous low permeability water-bearing zone with a potentiometric surface approximately 50 m below ground level. The completed monitoring wells are screened separately in, above, and below the target coal seam. Salinity and chemistry data indicates groundwater from each of these wells is related. The rate of natural groundwater movement through the area of the future gasifier is expected to be in the range of 1 m per year to 1 m per century. If this groundwater were to ultimately encounter the Main Series mine Pit (about 600 m to the north of the site) it could take more than 600 years. As such, changes to groundwater outside the Telford Basin as a consequence of the Demonstration Plant gasifier is considered extremely unlikely.

No open geological structures, i.e. fractures or faults with the potential to transmit water, were identified within proximity to the site. Closed fractures were identified in drill core. Faults intersecting the target coal seam inferred by seismic reflection surveys were identified more than 100 m from the site. These faults do not penetrate the full sequence of strata, terminating in the carbonaceous mudstone above the coal, and are likely to be closed based on observations of this same strata exposed in the Main Series Pit.

ISG has the potential to concentrate Chemicals of Potential Concern (COPCs) that exist naturally in the coal (metals and other organic and inorganic chemical compounds) and produce others (volatile and soluble hydrocarbons, ammonia, sulphides, etc.) that also can occur naturally in this geological environment. Rock core and groundwater samples were tested to identify the baseline (natural) chemistry in the area of the Demonstration Plant gasifier, i.e. in, above and below the target coal seam before any ISG is undertaken. Operation of the gasifier at pressures less than the natural groundwater pressure in the surrounding rocks will mean movement of groundwater, if any, will be towards the chamber. All volatile COPCs will be removed via the Outlet Well during operation and on decommissioning. Any concentration of COPCs remaining in the chamber will likely be insoluble (and therefore immobile in groundwater) or contained by the inward pressure gradient as it fills with groundwater.

It is estimated that the chamber may take years to decades to fill with groundwater and restore ambient groundwater movement conditions. The groundwater at the proposed Demonstration Plant gasification site is tightly bound by the sediments and not likely to move away from this site in the foreseeable future. As the proposed Demonstration Plant gasifier is small scale, located deep within the geologic profile of the Telford Basin and of short-term duration, it is considered a low risk.

It is anticipated that the residual ash and chemical by-products remaining in the chamber will chemically stabilise and likely become inert within one year of cessation of gasification. Groundwater seeping in from the surrounding rock will, it is estimated, take between two and twenty years to fill the chamber and reach equilibrium with the surrounding strata. Once the chamber is full, groundwater movement conditions similar to pre-ISG or baseline will re-establish. By this time COPCs remaining in the chamber will mostly be made up of naturally occurring chemicals and compounds from the converted coal, and migration of COPCs out of the chamber is unlikely.

2 Introduction

Leigh Creek Energy Ltd (LCK) is the owner and proposed operator of the Leigh Creek Energy Project (LCEP), located at Leigh Creek in South Australia, 550 km north of Adelaide. The project is located within Petroleum Exploration Licence 650 (PEL 650), which overlies the Leigh Creek Coalfield, and will develop deep coal resources that are unable to be accessed by open-cut mining.

LCK plans to produce energy from coal using a process known as in-situ gasification (ISG). The ISG process converts coal from its solid state into a gaseous form, resulting in the generation of synthesis gas (syngas) containing methane, hydrogen and other valuable components. The syngas can be either used to produce electricity directly or further refined into a variety of products including synthetic methane and ammonia.

The LCEP aims to produce commercial quantities of pipeline quality gas (methane), fertiliser and electricity using ISG.

As the initial stage of the project, an ISG demonstration plant is proposed to be constructed to obtain design information for a possible commercial facility. The demonstration plant will involve establishment of a single gasifier chamber and above-ground infrastructure to produce syngas for a short period (approximately 2 to 3 months), so that the syngas composition and performance of the process can be confirmed. Environmental data will also be collected during operation of the demonstration plant to support any commercial plant approvals process. Syngas produced by the demonstration plant will be combusted following analysis.

The location of the LCEP and proposed Demonstration Plant is shown in Figure 2.1.

The Demonstration Plant will involve establishment of an underground gasifier at a depth of approximately 540 m in the Main Series Coal at the Leigh Creek Coalfield, and operation of the gasifier and associated above-ground equipment for period of approximately 2 to 3 months. Gas produced will be analysed and then incinerated in a thermal oxidiser.

The purpose of the demonstration plant is to collect data on the in situ gasification performance of the Main Series Coal. Information collected will include:

- syngas composition, flow rates, temperature and pressures;
- coal gasification performance and gasifier physical properties;
- gasifier optimisation properties pressure, flow rate and reactants;
- condensate and organic liquid phase volumes, properties and constituents;
- environmental data; and
- additional relevant data for the subsequent design of a possible commercial facility.

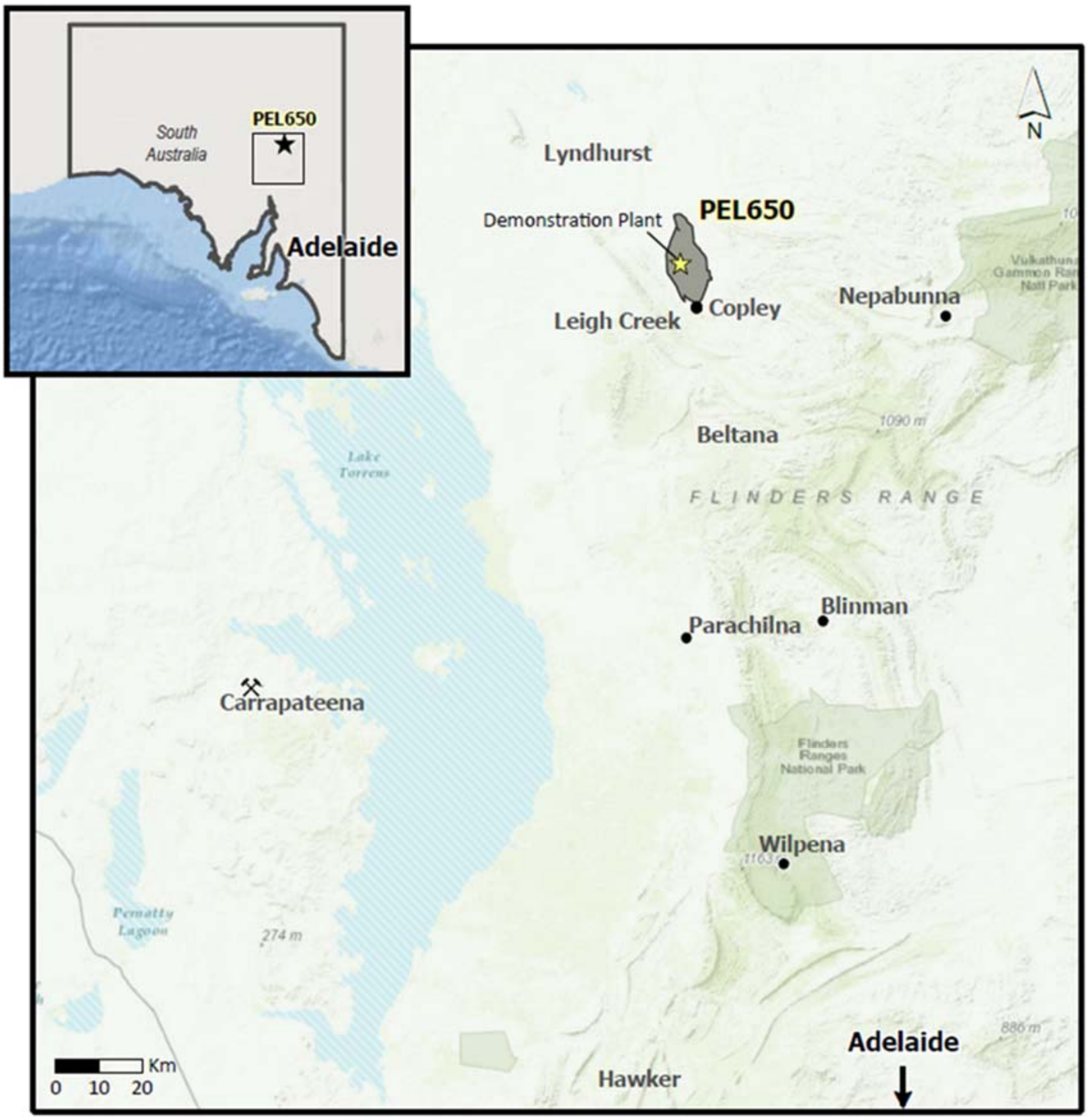

FIGURE 2.1 LOCATION OF PEL 650 AND ISG DEMONSTRATION PLANT

Overview of ISG Process

In situ gasification (ISG) is a technique in which solid coal underground is converted in situ ('in position') into a gaseous product known as synthesis gas (syngas). Syngas is composed mainly of carbon dioxide, hydrogen, carbon monoxide, methane, nitrogen, steam and gaseous hydrocarbons. It can be used for a variety of downstream applications, such as power generation, or as a feedstock for recognised chemical products like methanol, ammonia, fertilizers, synthetic natural gas and liquid fuels. ISG enables the development of deep coal resources where open-cut mining is not feasible or is uneconomic.

ISG is also known as underground coal gasification (UCG), however the terms 'in situ gasification' or 'ISG' are used throughout this report for consistency.

In the simplest ISG configuration, two wells are drilled into a coal seam, one for the inlet and the other for the outlet (refer Figure 2.2). A combination of horizontal and vertical wells is often used to create a linked system. An oxidant (air for the Demonstration Plant but it could be one or a combination of air, oxygen and steam) is introduced through the inlet well and a conventional initiation device is used to start the ISG reactions in the coal seam. As the coal is consumed, a series of reactions convert the solid fuel into syngas, which is then extracted through the outlet well. The underground void in the coal seam that forms where the gasification takes place is referred to as the gasifier chamber). The gasification reactions typically occur at temperatures of between 900°C and 1200°C but may reach up to 1500°C (Moran et al. 2013).

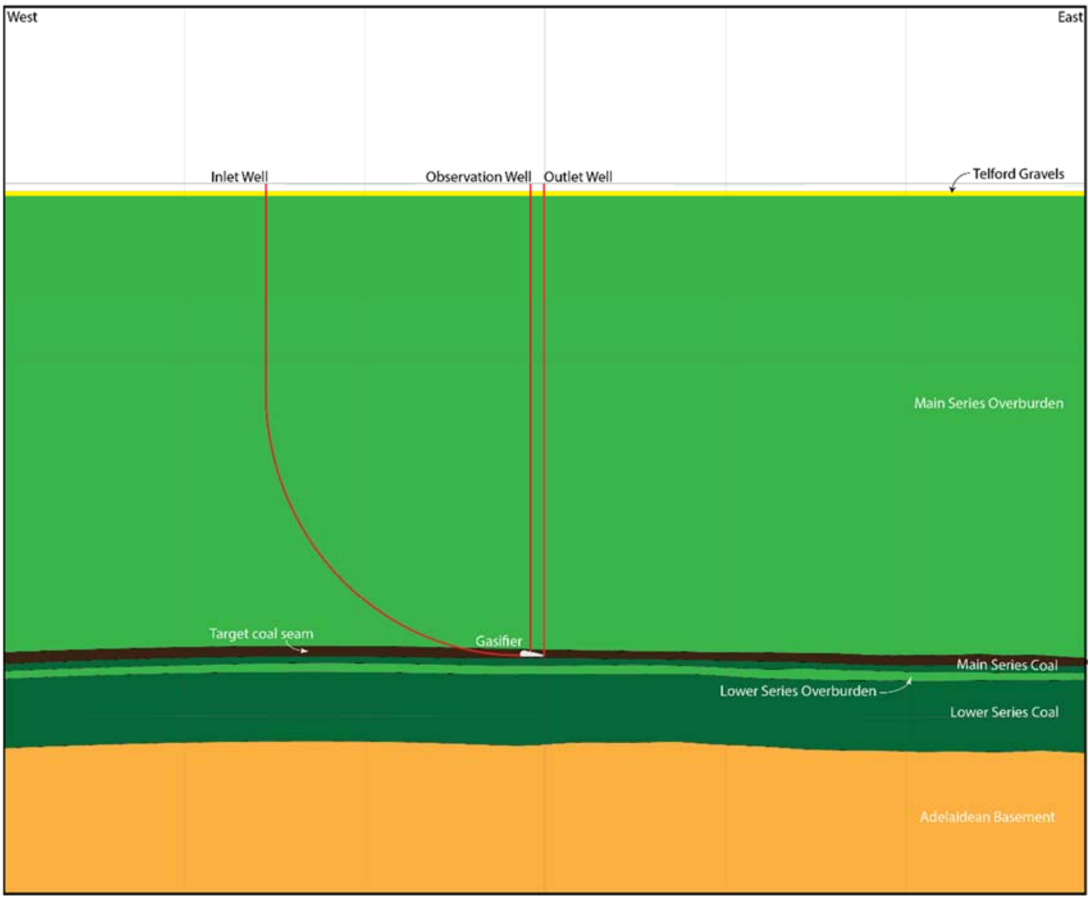

FIGURE 2.2 SCHEMATIC OF DEMONSTRATION PLANT GASIFIER

The ISG process is controlled by using the inlet and outlet wells to manipulate the flow of oxidant and the pressure in the gasifier chamber. The pressure in the gasifier chamber is kept below the surrounding groundwater pressure to avoid an outward pressure gradient that could result in movement of water and COPCs away from the gasifier chamber. The process can be stopped by shutting off the oxidant supply from the inlet well.

The ISG process produces a variety of COPCs such as BTEX compounds (benzene, toluene, ethylbenzene, xylene), phenols and aromatics, some of which will remain in the gasifier chamber after shutdown, depending on factors such as operation and optimisation of the ISG process and gasifier shutdown procedures (Camp and White 2015). During decommissioning of the gasifier, steam (via water injection) is typically generated in the gasifier chamber to remove these chemicals from the chamber via the gas flow out of the outlet well as the chamber cools.

2.1 Report Objectives

This report describes the hydrogeological conceptual site model of the proposed ISG Demonstration Plant gasifier location and its suitability of ISG using the groundwater related elements of the Hazard Screening Checklist contained in Camp and White (2015). This conceptual model includes characterising the rock strata and groundwater chemistry in, above, and below the target coal seam.

2.2 Scope of Work

The scope of work for this assessment included:

- Review of reports and data relating to the geology and groundwater of the Leigh Creek Coalfield available in the public domain and provided by LCK;
- Review of geological and groundwater data provided to LCK by Flinders Power Partnership;
- Review of data collected by LCK during the completion of four exploration drill holes (completed as three groundwater monitoring wells and one piezometer well) completed at a site similar to (i.e. depth, dip, and thickness of the target coal seam) approximately 500 m along geological strike from the intended ISG Demonstration Plant; and
- Collection and analysis of groundwater data and samples from the LCK installed groundwater monitoring wells.

Data from these sources was used to develop the conceptual site mode for the Demonstration Plant gasifier.

Figure 2.3 illustrate the location of the LCK drill holes relative to the Coalfield works and the ISG Demonstration Plant location.

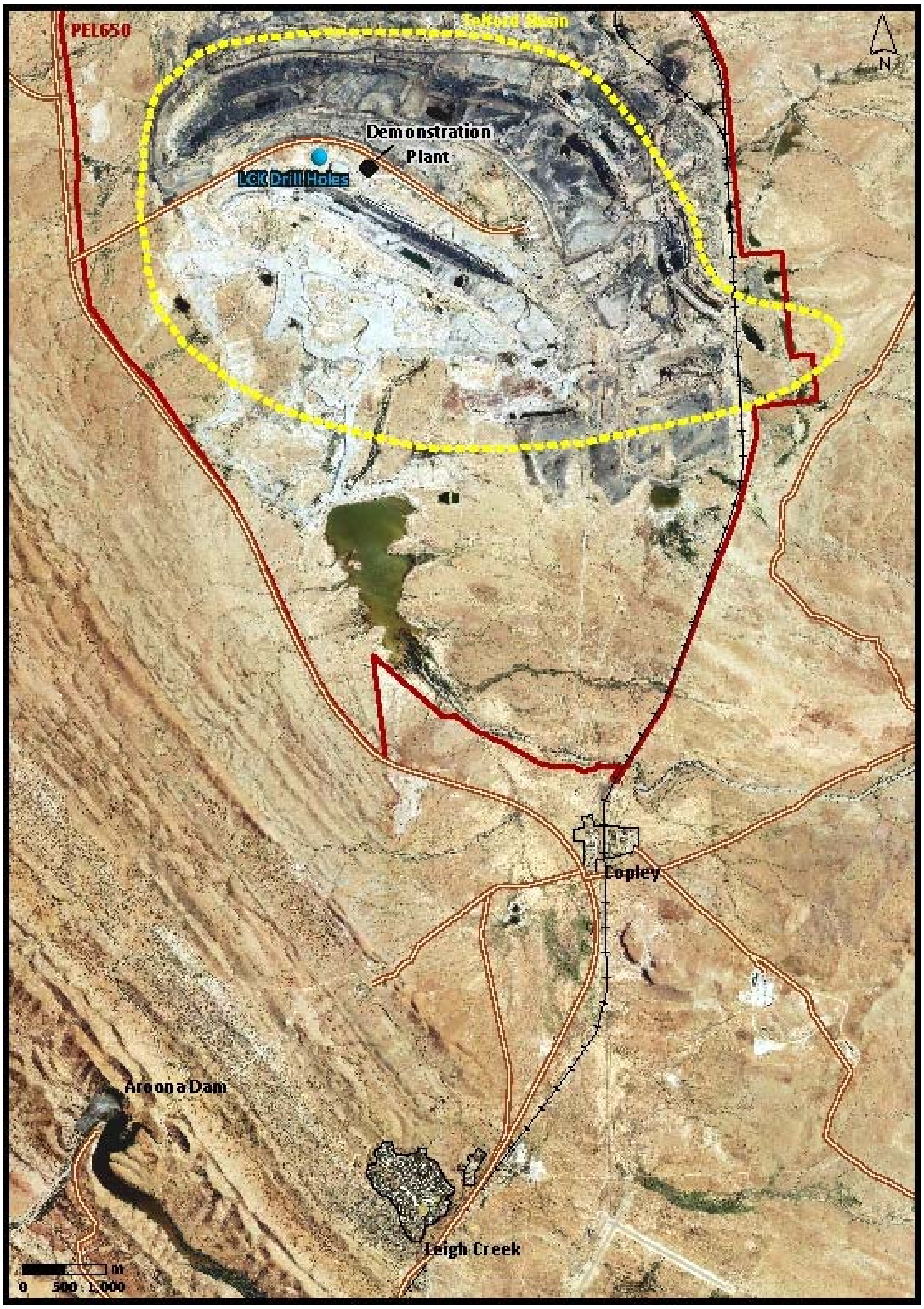

FIGURE 2.3 LOCATION OF THE LCK DRILL HOLES RELATIVE TO THE COALFIELD WORKS AND THE ISG DEMONSTRATION PLANT LOCATION

2.3 Groundwater, Aquifers, Aquitards, and Water Quality

All water found below the ground surface is considered groundwater. Where the rock becomes saturated, this depth is referred to as the water table. The ability for groundwater to move through rock media is controlled by the porosity of the rock (volume of void space within the rock media) and the permeability (the connectivity of the voids to allow movement of water). The void space within the rock media can be the spaces between sedimentary grains (in sedimentary rocks) which is referred to ‘primary’, or as the space developed when joints or faults open up (fractured rocks) or where the rock media has been dissolved (karstic) as in limestone, which is referred to as ‘secondary’. The measure of the rate at which a rock can transmit water is termed the “hydraulic conductivity” of the rock, which is sometimes referred to as the “permeability” of the rock

The depth at which rock becomes saturated (referred to as the water table) may be different to the depth (or height) water may rise to in a well (or bore) when the point of measurement of the groundwater pressure is deep. This is the ‘artesian’ nature of a groundwater system, where (as in the Great Artesian Basin) there is enough groundwater pressure to push water out of the well, when the surrounding rock may be dry to a depth of 50 m or more. In a groundwater system where there is not enough pressure to push water out of the well above ground level, but there is enough pressure to cause water in the well to rise above the depth at which groundwater as intersected by the well, this well is referred to as being ‘sub-artesian’. When many points of measurement of groundwater head pressure are used to draw a surface, this is referred to as the ‘potentiometric surface’ of that groundwater system. The shape of this surface may vary at different rates than the water table surface due to changes that cause different pressures to act on the groundwater system.

Aquifer

Geologic materials with high hydraulic conductivity that are able to receive, store and transmit groundwater in quantities sufficient for use as a water supply. Aquifer materials are typically sands and gravels, limestones, and fractures in hard rock materials.

Aquitard

Geologic materials with low hydraulic conductivity that are able to receive and store groundwater, but cannot transmit the groundwater in quantities sufficient for use as a water supply. Aquitard materials are typically clays, silts and unfractured hard rock materials.

Water Quality and Beneficial Uses

The terms aquifer and aquitard relate to the potential yield (amount of water) that can be pumped from a well for some desired use. However a critical factor in what any given water can be used for is its quality, typically discussed as ‘salinity’ or ‘salt content’, and is measured in terms of the concentration of Total Dissolved Solids (TDS) and reported in mg/L or parts per million. In the field the electrical conductivity (EC) of the water is used to indicate the salinity. The higher the electrical conductivity the higher the TDS (or salinity) of the water.

The Environment Protection (Water Quality) Policy 2015 indicates that groundwater with a salinity exceeding 3,000 mg/L is only considered suitable for livestock watering purposes.

The suitable uses for water based on the TDS content is summarised in Table 2.1.

TABLE 2.1: COMMON SALINITY TERMS AND COMPARISION BETWEEN ED AND TDS

Category*	Electrical Conductivity (EC)* (µS/cm @ 25°C)	Total Dissolved Solids (TDS)** (mg/L or ppm)	Typical Use^^ (mg/L)
Fresh	Up to 1,820	Up to 1,000	Limit of palatable Drinking Water Typical limit for Flowers, Fruit and Veg.
Fresh to Brackish	1,820 to 5,300	1,000 to 3,000	Limit for Pigs^ and Poultry^ Typical limit for Crops and Pastures
Brackish	5,300 to 8,715	3,000 to 5,000	Limit for Dairy Cattle^ – 4,000 Limit for Beef Cattle^ and Couch Grass
Saline	8,715 to 55,330	5,000 to 35,000	Limit for Horses^ – 6,000 Limit for Kikuyu Grass – 8,000 Limit for Sheep^ – 13,000
Hyper-saline	Over 55,330	Over 35,000	Limited Mining/Industrial uses

* Source: http://www.chemiasoft.com/chemd/TDS: commonly a factor of 0.64 is used to convert EC to TDS.

** Source: http://www.epa.sa.gov.au/environmental_info/water_quality/threats/salinity.

^ Maximum to maintain condition only, not support healthy growth.

^^ Source – DWLBC Groundwater Group Fact Sheet "Groundwater Salinity".

This level of groundwater salinity is not suitable to maintain healthy growth of majority livestock species and Table 2.1 indicates the general salinity limits to maintain animal condition only with the exception of sheep which can tolerate waters with the salinity up to 13,000 mg/L (refer Salinity of Groundwater in SA, Fact Sheet 32 of the former DWLBC). Similarly groundwater salinity exceeding 3,000 mg/L is too saline for irrigation of most economic crops apart from the more tolerant couch and kikuyu grasses. Saline groundwater would be suitable for industrial and mining use but the well yields are generally not be sufficient to supply such purposes.

3 Background Information

3.1 Regional Geology

The geology of the Leigh Creek Coal Measures and surrounds is previously described in Parkin (1953)[1] , Johns (1970)[2] , and Springbett (1995)[3] and is shown in Figure 3.1. The Mesozoic (Late Triassic to Early Jurassic) Telford Basin is hosted within the complexly folded Neoproterozoic Adelaidean metasediments of the Adelaide Geosyncline, and is overlain by a semi-continuous covering of Quaternary gravels, clays and sands. The extend and schematic cross sections of the Telford Basin are shown in Figure 3.2, Figure 3.3 and Figure 3.4.

3.1.1 Adelaidean Basement - Neoproterozoic

The Telford Basin overlies the Umberatana Group sequence of Tapley Hill Formation, Balcanoona Formation and the Amberoona Formation. The Umberatana Group is estimated to be approximately 700 million years old and lies midway through the mapped sequences of the Adelaide Geosyncline.

The Tapley Hill Formation is the main geological unit in contact with the Telford Basin sediments. This formation is typically an indurated grey to black, dolomitic and pyritic siltstone; grading upwards to calcareous, thinly laminated, locally cross-bedded dolomite; a grey, flaggy to massive limestone; intra-formational conglomerate and greywacke.

The Balcanoona Formation conformably overlies the Tapley Hill Formation and has a relatively narrow surface expression. This formation is typically a pale grey dolomite and dolomite marble; stromatolitic limestone with edgewise conglomerate interbeds; and minor shale.

The Aberoona Formation unconformably overlies the Balcanoona Formation and also has a relatively narrow surface expression. This formation is typically a basal calcareous lag or breccia; a monotonous succession of laminated non-calcareous dark green or dark grey siltstone; some purple and grey slate; minor dolostone, sandstone, limestone and dolomite.

The sequence was buried at great depth, folded and faulted, and then the upper surface weathered and eroded.

3.1.2 Leigh Creek Coal Measures – Triassic/Jurassic Age

The Leigh Creek Coal Measures occur within five separate basins, of these the Telford Basin is the largest (refer Figure 2.2). The Leigh Creek Coal Measures is largely a Triassic age (estimated age from 250 to 200 million years ago) dark grey carbonaceous mudstone with distinct interstratified brown coal seam horizons, occasional hard sideritic bands, rare thin fine-grained sandstone lenses and a minor and intermittent basal conglomerate. In the Telford Basin this sequence contains the Lower, Main and Upper Series coal deposits.

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[1] Parkin 1953. The Leigh Creek Coalfield, South Australia. GSSA Bulletin 31
[2] Johns RK 1970. The Leigh Creek Coal Measures. Mineral Resources Review SA 132: 145-154
[3] Springbett GM, Kremor AG and Brennan SH 1995. Leigh Creek Coalfield; in Geology of Australian Coal Basins GSA Coal Geology Group; Special Publication 1: 513-524

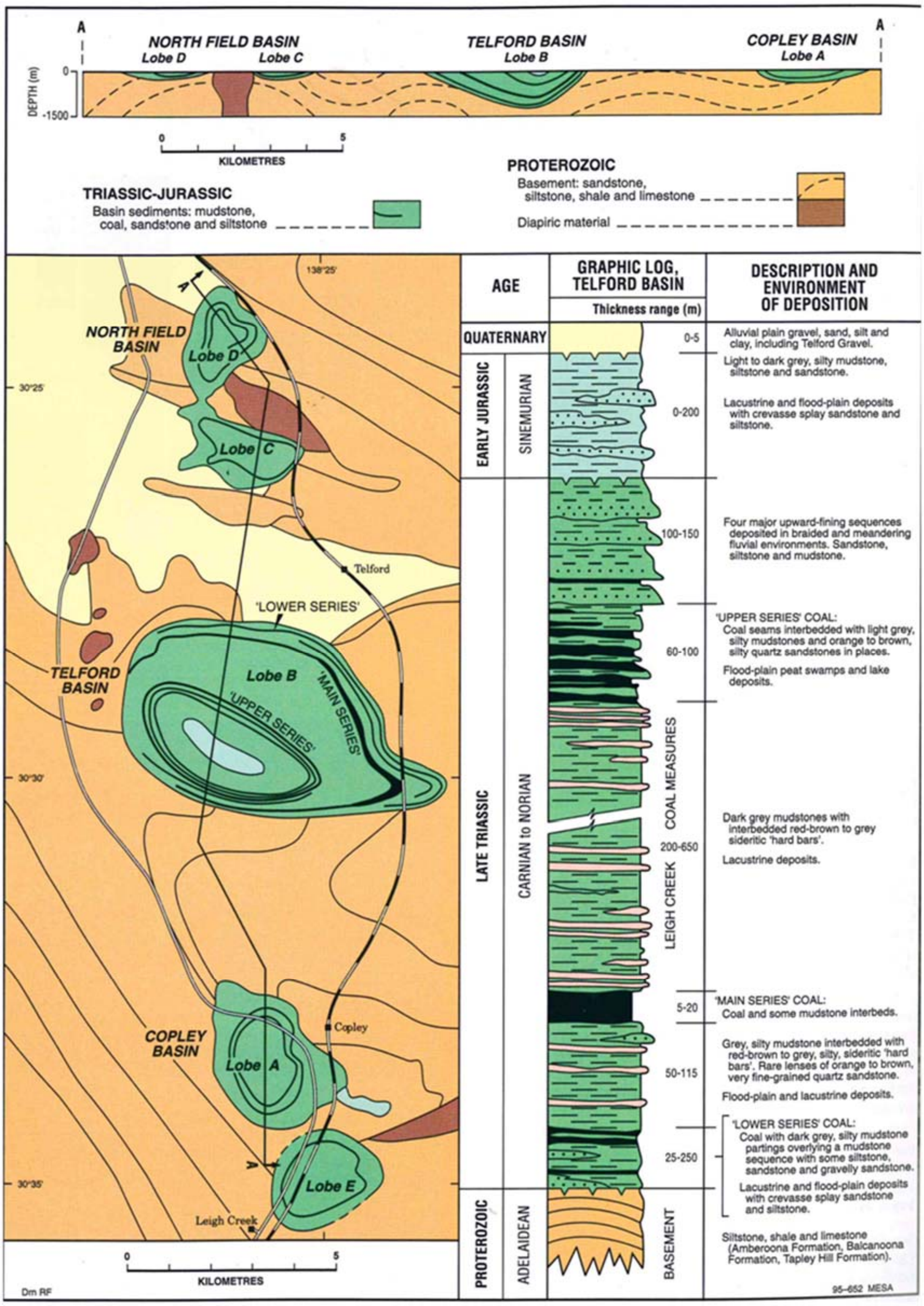

FIGURE 3.1 TELFORD BASIN GEOLOGIC SEQUENCE (FROM THE GEOLOGY OF SOUTH AUSTRALIA: THE PHANEROZOIC. GSSA BUL 54)

FIGURE 3.2 THE EXTENT OF THE TELFORD BASIN AND LOCATION OF CROSS SECTIONS

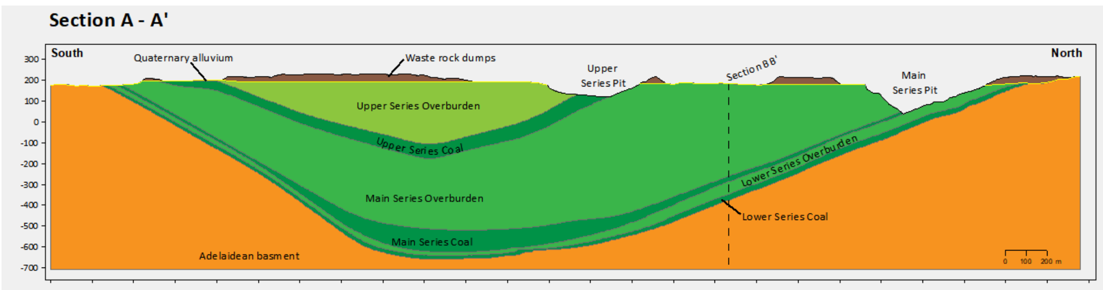

FIGURE 3.3 TELFORD BASIN CROSS SECTION A-A’

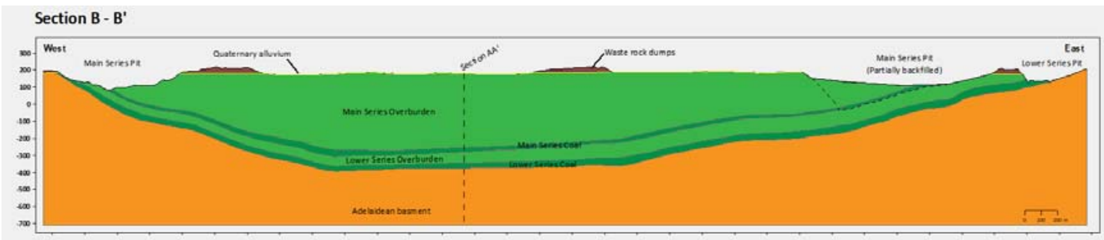

FIGURE 3.4 TELFORD BASIN CROSS SECTION B-B’

Above the Upper Series coal is a series of upward fining lacustrine depositional sequences grading from fine sandstones to mudstones. Unconformably overlaying this is a Lower Jurassic age (estimated age from 200 to 174 million years ago) grey siltstone, with fine grained, poorly consolidated sand and gypsum layers.

After deposition, the Triassic and Jurassic sequence and the underlying Basement sequence has been subject to deformation and erosion, resulting in a bowl-shaped syncline. The surface expression of the coal deposits, where present, form three concentric rings (refer Figure 3.5). Faulting occasionally offsets the coal seams near the contact with the basement.

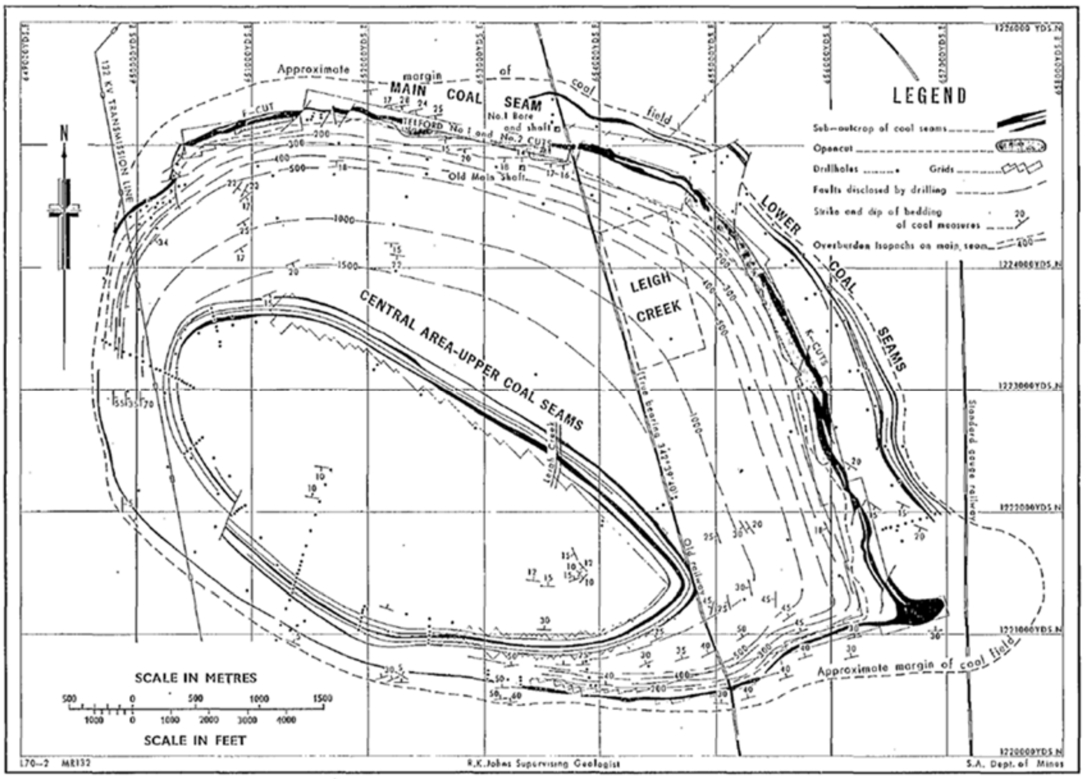

FIGURE 3.5 SURFACE GEOLOGICAL PLAN OF THE TELFORD BASIN (FROM GSSA MINERAL RESOURCES REVIEW 132)

3.1.3 Telford Gravels – Quaternary Age and Younger

Unconformably overlying the Adelaidean Basement and Telford Basin is a Quaternary sequence that includes the Telford Gravel, Arrowie Formation and the Pooraka Formation (estimated age from 125,000 years). More recently alluvium deposits (estimated age from 11,000 years) outline the drainage features across the site. Collectively this report refers these formations as the Telford Gravels.

The Telford Gravel Formation consists of polymict gravel which is well rounded and includes boulders which is typical of alluvial fan deposits. The Arrowie Formation is typically a red-brown clay containing sub-angular, lime-coated gravel (possibly includes gravels of other ages). Overlying this is the Pooraka Formation, which is typically an unconsolidated red-brown poorly-sorted clayey sand; gravel; conglomerate; breccia; as a colluvial sheet wash, alluvial fan and residual lag. This formation forms extensive, coalesced, low-angle fans, high-angle talus cones and scree slopes.

3.1.4 Interaction between the Telford Basin and the adjacent Coal-Bearing Basins

The Jurassic/Triassic sediments in the Telford Basin are separated from the other four Jurassic/Triassic basins (i.e.Copley Basin (Lobe A), Lobe E, and Lobe C and D (North Field Basin)) by the fractured rocks of the Adelaidean Basement, as shown in the cross-section at the top of Figure 3.1.

The Telford Basin is separated from the Copley Basin by distance, topography, and geology. The Copley and Telford Basins are separated by a broad low ridge of Adelaidean Basement rocks about 4 km wide. The base of this ridge to the south is marked by the channel of Leigh Creek immediately at the northern end of the main road through Copley township. Leigh Creek cuts through this ridge approximately 2 km to the northwest of the township where it flows through a narrow valley before entering the coalfield Retention Dam. All surface drainage in the Copley township area ultimately flows to the northwest through this Leigh Creek valley to the Retention Dam. There are potential groundwater aquifers in the Copley Basin but these are not connected to or affected by groundwater in the Telford Basin due to their geological, spatial, and topographic separation.

The small changes in groundwater pressure or any groundwater migration from the gasifier that occurs in the Telford Basin will not be measurable in any of the other coal-bearing basins (Copley Basin, Lobe E, and the North Field Basins).

3.2 Topography and Drainage

A review of the local topography and surface drainage system of this region indicates the surface water drains to the north and east of the site. The Leigh Creek catchment which drains through the Telford Basin extends to the west by approximately 5 km, extends to the south by approximately 15 km and to the east by approximately 21 km. The Telford Basin and the proposed Demonstration Plant site is located within the Lake Eyre Catchment, which is a different catchment to the one in which the Aroona Dam and its sources are located (refer Figure 3.6). Aroona Dam and its main sources (Emu and Windy Creeks) are in the Lake Torrens Catchment.

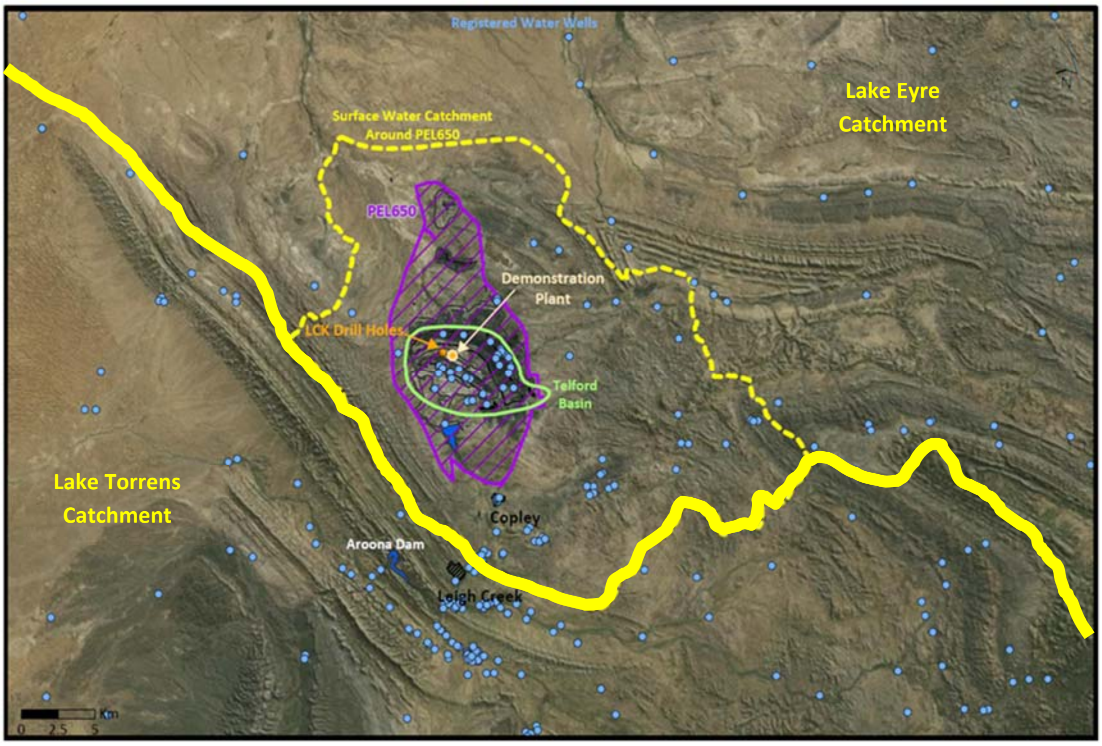

FIGURE 3.6 LOCATION OF THE PROPOSED DEMONSTRATION PLANT IN RELATION TO THE SURFACE DRAINAGE SYSTEMS.

Historic drainage system mapping (refer Figure 3.7) indicates a lack of definition of drainage lines within the central portion of the Telford Basin. Also, the mapping shows that a man-made drain was constructed to connect drainage lines from south to north (see “drain” annotations on Figure 3.7. This suggests that, where the definition of drainage lines becomes indistinct, the surface water may have ponded on the surface and perhaps recharged the underlying Jurassic sequence. This suggests that the Telford Basin may have acted as a sink for incident rainfall and low volume surface water flows out of the surrounding catchment, which in turn suggests that the historic groundwater processes was dominated by local recharge.

The surface footprint of the Telford Basin is almost identical to that of the most recently active working area of the Leigh Creek Coalfield. This footprint was modified to prevent almost all runoff from the surrounding catchment entering the Coalfield through construction of the Retention Dam across Leigh Creek immediately south and earth bunds and waste rock dumps around the remainder of the basin to prevent flooding of the open pit mines.

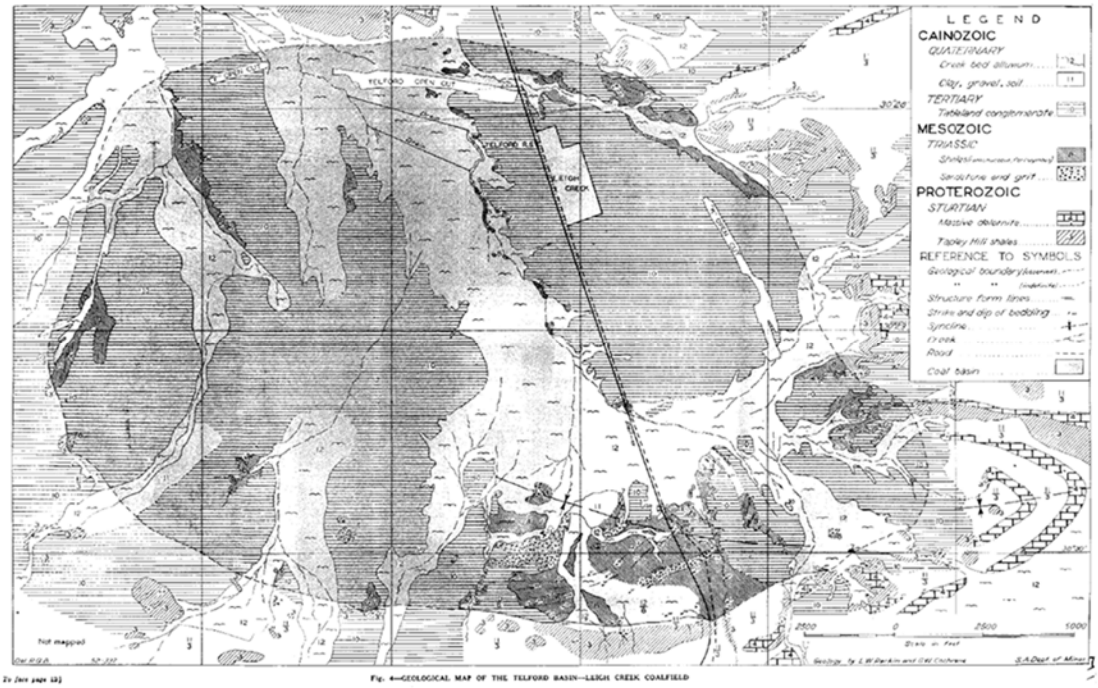

FIGURE 3.7 GEOLOGY AND DRAINAGE OF THE TELFORD BASIN; FROM PARKIN LW 1953 GSSA BULLETIN 31

3.3 Regional Groundwater

3.3.1 Adelaidean Basement

The Adelaidean Basement is a fractured rock groundwater system. Most of the groundwater flow occurs through joints and faults, and little through the rock matrix itself. There is limited drill hole information available to determine groundwater hydraulic properties or flow processes. It is likely that the regional groundwater flow direction will follow the regional topographic gradient – a north westerly direction but locally subject to topographic control. Groundwater flow paths are likely to be controlled by the prevailing structural defect orientations and will be of varying lengths and/or compartmentalised.

Historically, recharge to the fractured rock systems is likely to be infiltration through surface fracture systems when surface flow occurs. The general brackish salinity suggests that the recharge is a small percentage of the incident rainfall. Current recharge to these systems is likely to be infiltration through the fracture systems when surface flow occurs and potentially point-source recharge at the various surface water retention areas when located over near-surface basement exposure.

Analysis of the groundwater data contained within the Department of Environment, Water and Natural Resources "Water Connect" database (www.waterconnect.sa.gov.au) suggests a groundwater salinity for the Adelaidean Basement ranges from approximately 2,200 to 19,000 mg/L TDS in areas adjacent to the Telford Basin. The higher groundwater salinities have been observed in wells completed in the basement beneath the Telford Basin. Well yield ranges from <0.5 to approximately 10 L/sec. In general, well yields are low and the rates and volumes of groundwater movement through the basement fractured rock aquifers are considered small.

Historic and current groundwater discharge processes are poorly understood. Noted springs in the region are the Aroona, Top Well and Myrtle Springs. These are eight to twelve kilometres distance. All these appear to be at higher hydraulic pressure head heights than the Telford Basin so are not sourced from groundwater in the Telford Basin (discussed in Section 3.3.2).

3.3.2 Leigh Creek Coal Measures and Telford Basin

The location of the Telford Basin within the Adelaide Geosyncline fractured rock province suggests that the groundwater at this site is sourced from local rainfall runoff and infiltration and not connected to other regional groundwater systems such as the Great Artesian Basin.

It is considered unlikely that the Telford Basin sequence plays a significant role in the regional groundwater flow patterns, because the Leigh Creek Coal Measures where they sit on the basement have a very low hydraulic conductivity and form a very thick aquitard. It is a barrier to groundwater flow, and it is anticipated that historically the majority of the regional groundwater would have flowed around and beneath the Leigh Creek Coal Measures, rather than through it. Some relatively small volumes of surface water recharge to, and evaporative discharge from, the Leigh Creek Coal Measures are expected to have occurred, but these volumes are anticipated to be only a small percentage of the regional groundwater flow volumes.

The influence of the Leigh Creek Coal Measures on regional groundwater flow patterns may have changed since the creation of the open cut pits. The open cut pits expose rocks to a depth of up to 250 m, facilitating increased rates of evaporation from the groundwater system. This would likely encourage any movement of groundwater, however small, through the Coal Measures toward the open pits. When considered in the context of the modified surface drainage the Telford Basin could now be considered a terminal basin with almost all groundwater and runoff within the modified landscape now moving to the pits where it will evaporate.

Groundwater pressures and levels in the Telford Basin and the Adelaidean Basement may fluctuate with infiltration of precipitation, barometric pressure changes, earth tides caused by the moon, and seismic events. Historic coal mining has created significant changes in groundwater pressures and levels within the Telford Basin. The pressure changes caused by the gasifier operation will be much smaller than the changes caused by historic mining, and may be smaller than the pressure responses caused by the ongoing mine rehabilitation program. Barometric and earth tide fluctuations are cyclic, and their effect is relatively small. Seismic events may cause rapid responses but generally will have no lasting effect on groundwater pressures or levels.

3.3.3 Telford Gravels

The Telford Gravel is a variably silicified sedimentary rock groundwater system, where groundwater water movement is through the sediment matrix where it is not silicified, and appears to be perched on top of the silicified horizons. There is no available information on the groundwater properties of this shallow sequence to determine groundwater flow processes. It is likely that this system would receive infiltration recharge when rainfall events generate surface flow conditions. However with the modification of the landscape over the Telford Basin by operation of the Coalfield it is likely any remaining groundwater system in the Telford Gravels is significantly localised and discontinuous. Any groundwater movement direction will likely follow the local regional topographic gradient – towards the open mine pits or other surface depressions.

4 ISG Demonstration Plant Gasifier Groundwater Investigation

4.1 Drilling and Well Completions

LCKs first exploratory drill holes on PEL 650 were within the Leigh Creek Coalfield at a location geologically representative of the Demonstration Plant site. The objective of these drill holes was to collect geological and groundwater data to enable preparation of the conceptual site model for the demonstration gasifier site. Table 4.1 summarises the completion details for these drill holes.

TABLE 4.1: LCK MONITORING WELL DRILLING SUMMARY.

PEL Name	LCK Designation	Date Completed	Total Depth (m)	Completion	Well Screen Interval	Target Formation
Playford 1	P1	18.07.2016	695	Piezometer (grouted VWPs)	n/a	Main Series Overburden (MO), Main Series Coal (MC), Lower Series Overburden (LO), Lower Series Coal (LC), Adelaidean Basement ("Basement")
Playford 5	P1M1	17.11.2016	570	Groundwater Monitoring Well	486 to 498	Main Series Overburden **(above the gasifier)**
Playford 4	P1M2	25.06.2017	539	Groundwater Monitoring Well	533.5 to 539.5	Main Series Coal **(target coal seam)**
Playford 6	P1M3	12.06.2017	571	Groundwater Monitoring Well	552 to 558	Main Series Coal and Lower Series Overburden **(under the gasifier)**

Figure 4.1 shows the layout of the investigation drilling undertaken to-date. Information from existing wells 3967 (shown on Figure 4.1), 3964, and 3965 were included in the development of this conceptual site model. These wells were installed as part of an ETSA investigation into ISG in the 1980s.

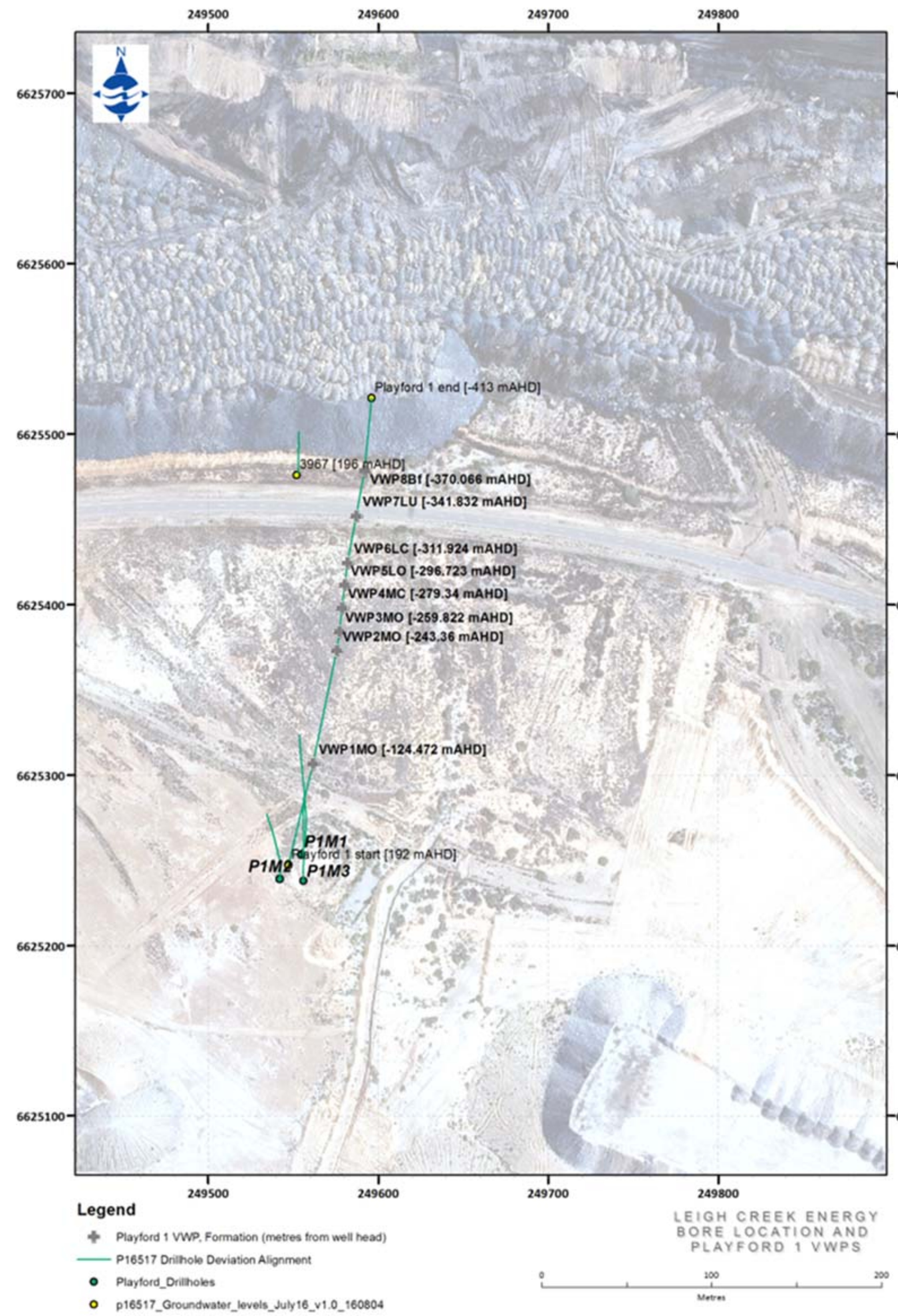

FIGURE 4.1 HORIZONTAL DISTRIBUTION OF VIBRATING WIRE PIEZOMETERS MONITORING POINTS AT THE PLAYFORD 1 DRILL SITE.

4.2 Inferred Geology of the Demonstration Plant Gasifier and Relative Positions of Well Screens

Figure 4.2 illustrates the inferred geology at the Demonstration Plant site and where the well screens in P1M1, P1M2, and P1M3 are positioned relative to the target coal seam.

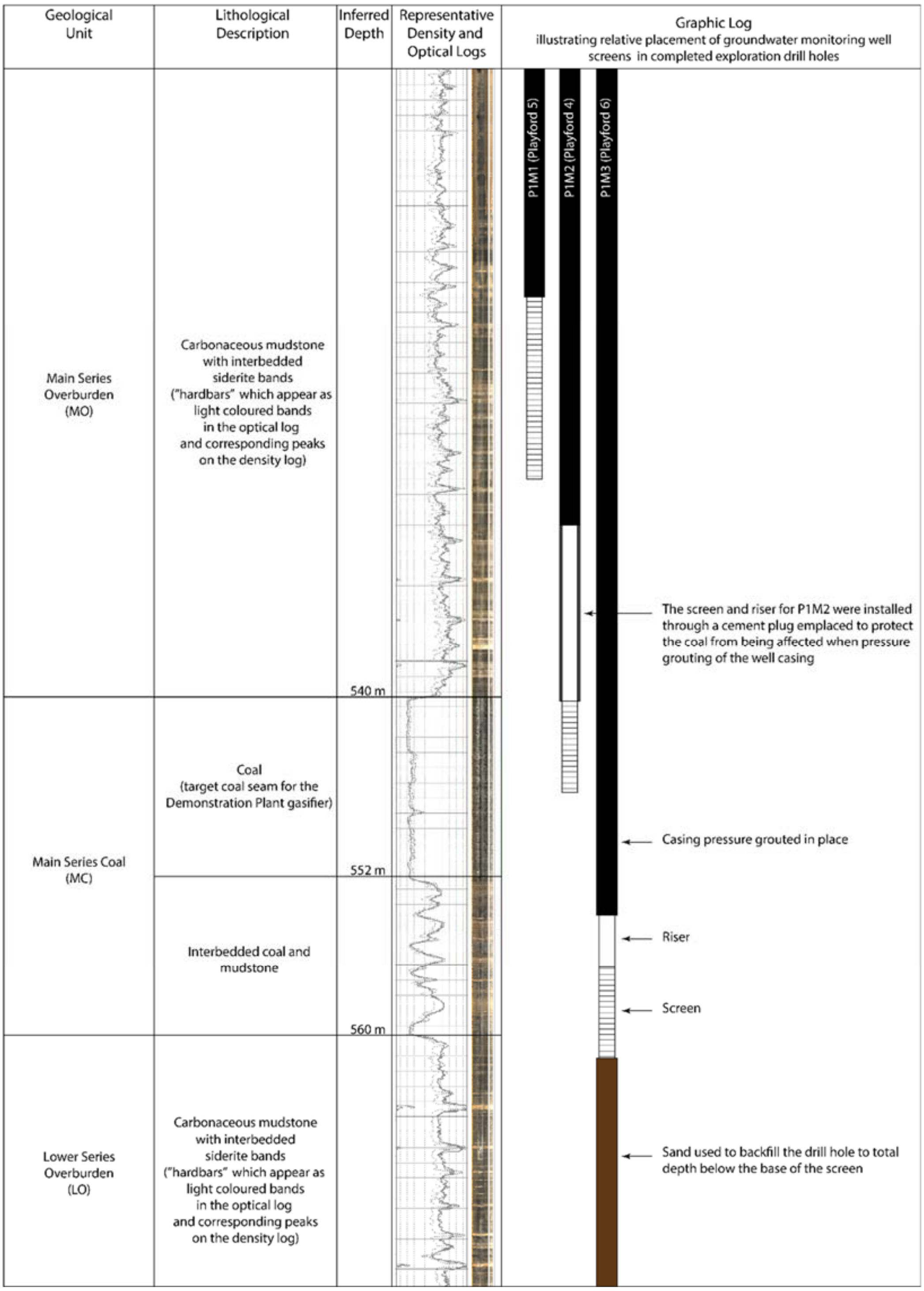

FIGURE 4.2 TYPE GEOLOGY FOR THE DEMONSTRATION PLANT GASIFIER

4.3 Seismic Reflection Surveys

Seismic reflection surveys completed in 1978 and 2016 were also used to interpret the vertical and lateral geological characteristics at the Demonstration Plant site. Figure 4.3 provides the seismic survey results through the LCK drill site with inferred strata and structures.

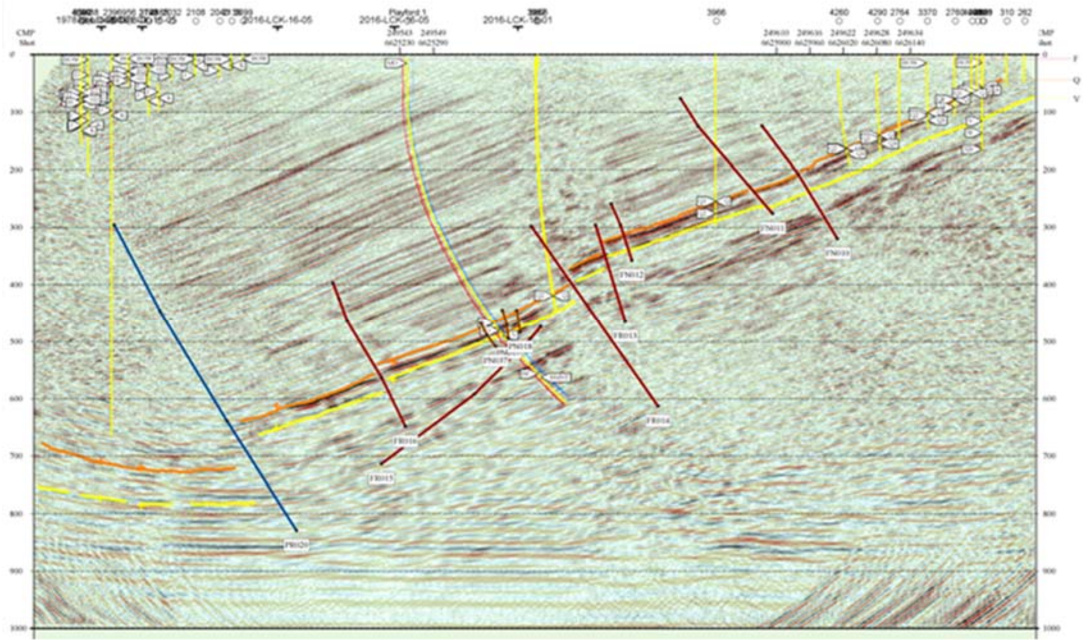

FIGURE 4.3 INTERPRETED SEISMIC REFLECTION SURVEY THROUGH THE LCK DRILL SITE.

4.4 Formation Hydraulic Conductivity

Three groundwater monitoring wells were constructed to investigate the hydrogeological characteristics for the Demonstration Plant gasifier, i.e. strata in, above, and below the target coal seam. Due to the low permeability nature of the strata, groundwater recovery after well development is the primary method being used to quantify their hydraulic properties. The observed recovery of groundwater levels in P1M1, P1M2 and P1M3 have well yields of less than 10 litres per day.

In November 2016 the water from P1M1 was removed, and in June 2017 groundwater in all three wells was removed using a swabbing technique. The recovery of the water level in these wells was monitored by electronic dataloggers. Figure 4.4 shows the recovery traces for each of the observation wells to late July 2017. The rates of recovery suggest that the time required for these wells to fully recover may be between 18 to 36 months (shown by the dashed lines indicating assumed recovery). The recovery timing assumes, in part, that the groundwater level observed in the long-established observation well 3967 (open to the MO interval) represents the fully recovered status of groundwater local to this area.

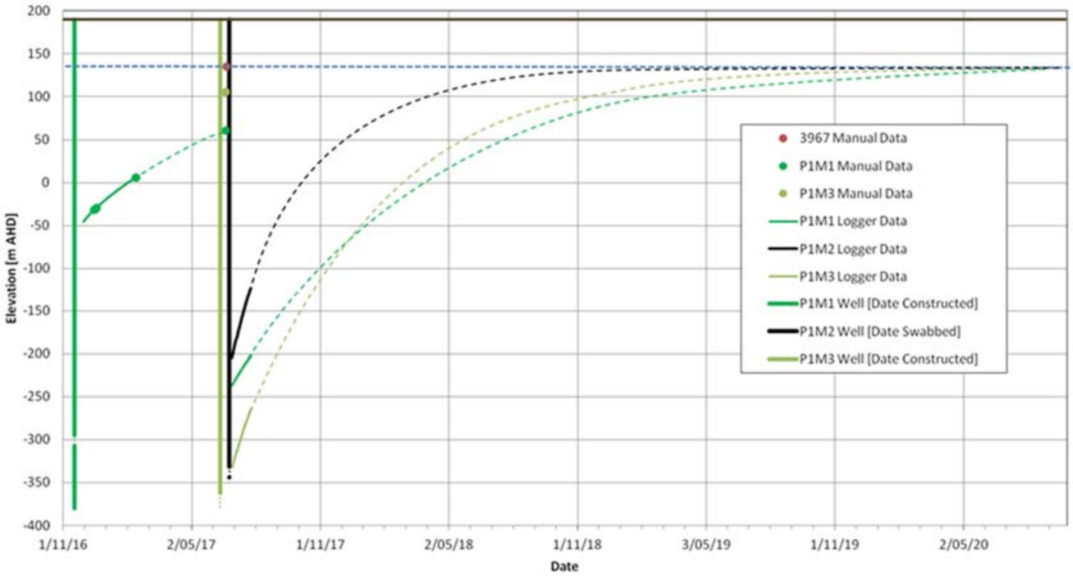

FIGURE 4.4 GROUNDWATER RECOVERY HYDROGRAPHS FOR P1M1, P1M2 AND P1M3

Investigations to-date indicate that the hydraulic conductivity of the carbonaceous mudstones above, in the target coal seam, and interbedded coal and mudstone below is very low. Very short-term tests conducted at the time of drilling P1M1 using a form of falling head test on isolated sections of the drill hole suggested an hydraulic conductivity of around 10^{-3} m/d. Hydraulic conductivities calculated from analysis of well recovery data from each of the observation wells after mid-June 2017 (refer Table 4.2) are much lower than the tests conducted at the time of drilling P1M1, at around 10^{-7} m/d. Sensitivity analysis of the results, by fixing the Storage Coefficient (shown as S in Table 4.2) in all three analyses to a single value which is typical of confined aquifers, demonstrates that the results are not materially affected by the S value adopted.

The well recovery data is anticipated to provide the more reliable estimates of hydraulic conductivity, however the possibility that the hydraulic conductivities are of the order of 10^{-3} m/d is considered as this provide a conservative assessments of potential groundwater behaviour. The range measured (i.e. between 10^{-3} and 10^{-7} m/d) represent low to virtually impermeable aquitards, with no evidence of any increase in hydraulic conductivity from faults or fractures.

TABLE 4.2: ANALYSIS OF WELL RECOVERY DATA INTERPRETED USING COOPER-BREDEHOEFT-PAPADOPOLOUS SLUG TEST METHOD IN AQUATESTPRO©

Well	Unconstrained S			Constrained S at $5x10^{-4}$		
	T (m2/d)	k (m/d)	S (-)	T (m/d)	k (m/d)	S (-)
P1M1 (MO)	3.0×10^{-05}	1.1×10^{-06}	1.1×10^{-05}	2.7×10^{-05}	9.7×10^{-07}	5.0×10^{-04}
P1M2 (MC)	1.1×10^{-05}	5.9×10^{-07}	5.0×10^{-04}	1.1×10^{-05}	5.9×10^{-07}	5.0×10^{-04}
P1M3 (LO)	1.2×10^{-05}	1.5×10^{-06}	1.3×10^{-02}	2.9×10^{-05}	3.7×10^{-06}	5.0×10^{-04}

4.5 Groundwater Heads

The historic coal mining practices have altered the groundwater flow regime compared to what occurred under pre-development conditions. The current groundwater pressure surface appears to have developed depressions centred on the deeper portions of the Upper Series and Main Series pits. Dewatering wells on the high wall of the Upper Series pit served to keep the Upper Series Pit dry and it appears that evapotranspiration and minor pit-sump dewatering were adequate to keep the Main Series Pit dry. Significant rainfall events resulted in the need to divert water captured within both sumps and low-lying areas within each pit.

Investigations undertaken for this project include the installation of vibrating wire piezometers (VWPs) in the MO, MC, LO, LC, and Basement. The resultant construction, due to deviation during drilling, resulted in a non-vertical alignment of VWPs with drill-hole deviation generally trending northward. Figure 4.1 indicates the horizontal deviation of each of the VWPs relative to the surface location for each of the monitoring wells.

Figure 4.5 shows the groundwater pressure trends in each of the VWPs installed at the LCK drill pad. The VWPs in P1 (shown as VWP1-depth and sequence designation) show a very consistent pattern of slowly decreasing pressure trends. The pressures are plotted in cross-section in Figure 4.6. The two VWPs installed in P1M2 show similar slow trends after a period of equilibrating after installation. At this stage, the groundwater pressures shown here are interpreted to be indicative rather than diagnostic results, but over time will be useful as they settle and represent groundwater pressure.

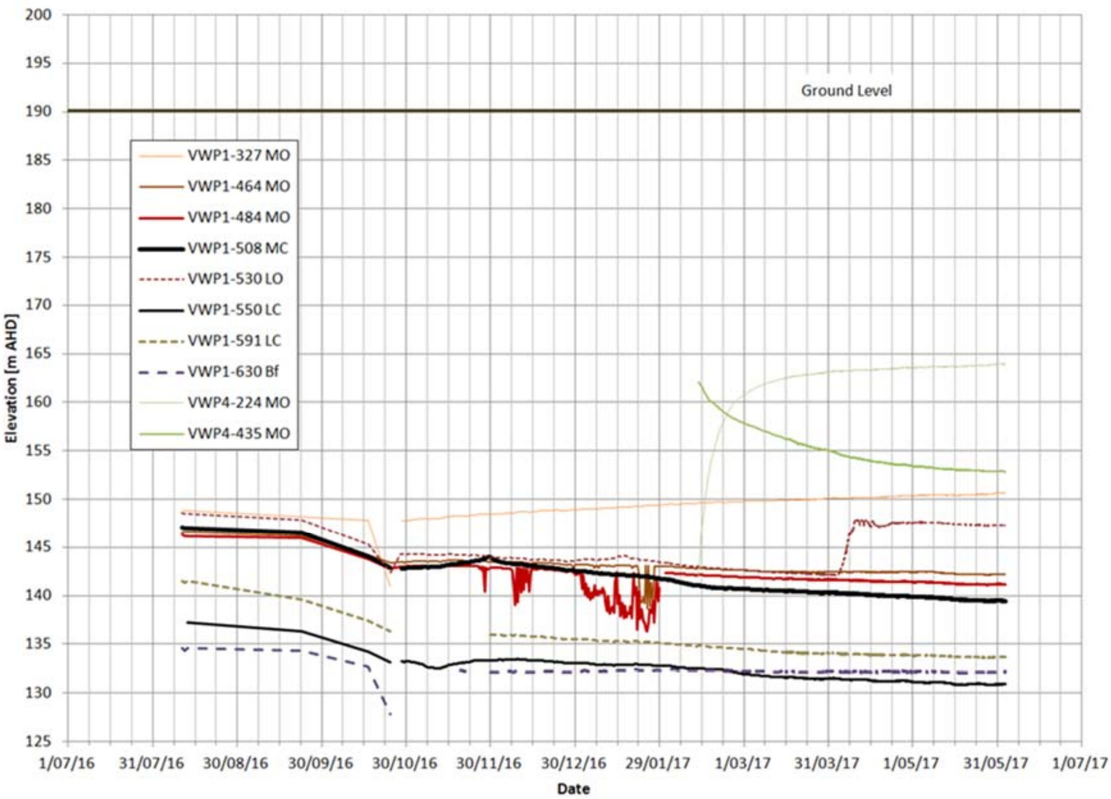

FIGURE 4.5 GROUNDWATER HEAD PRESSURE HYDROGRAPHS FROM INSTALLED VIBRATING WIRE PIEZOMETERS

The groundwater pressure trend observed for the Basement appears to be steady over time. This suggests that the Adelaide Basement may be hydrogeologically disconnected from the Leigh Creek Coal Measures in the region of the proposed Demonstration Plant site.

The lateral separation of the VWP configuration in P1 and P1M2 has enabled an assessment of groundwater head pressure gradient to be undertaken. By projecting the location of the VWPs onto a common axial plane, the groundwater pressure gradients show a groundwater gradient declining northward towards the Main Series pit (refer Figure 4.6). This is possibly confirmed by the water level obtained from bore 3967, although the salinity profile in this bore needs to be measured before an accurate pressure at the monitoring depth can be calculated.

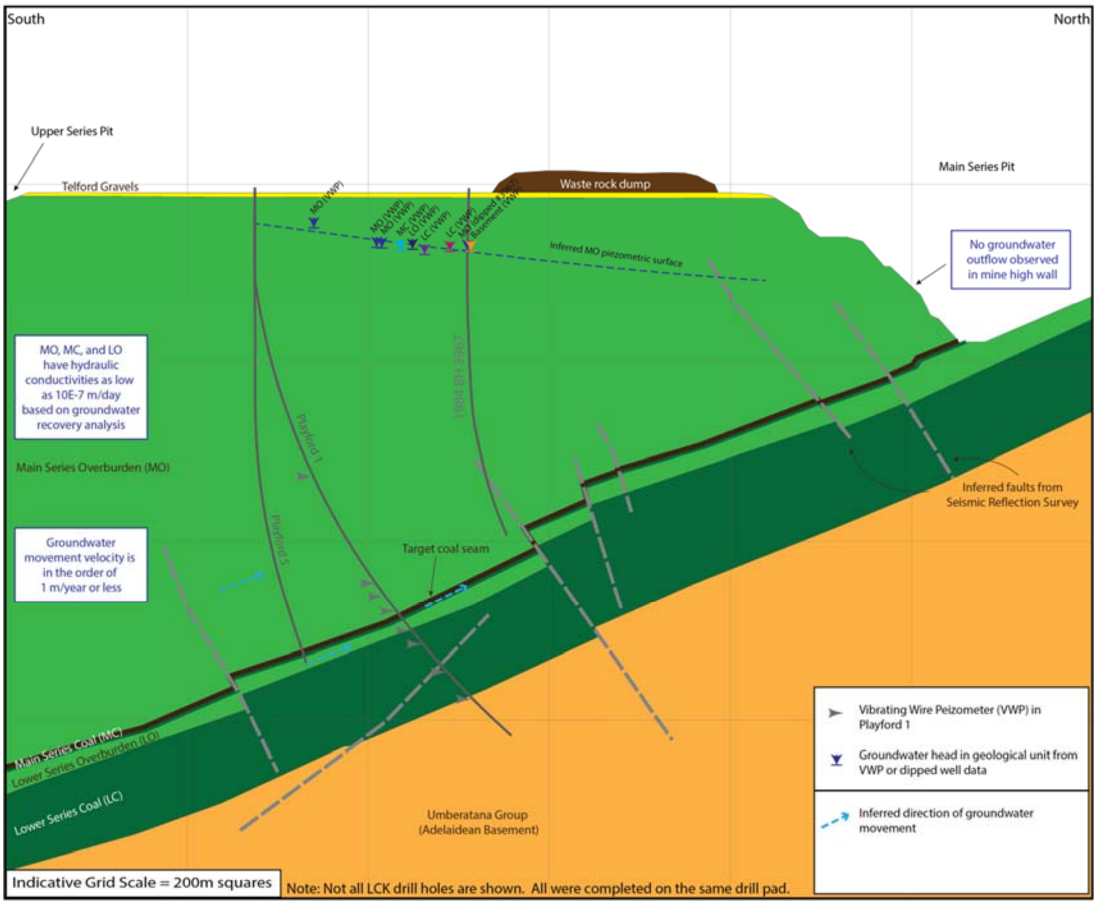

FIGURE 4.6 SCHEMATIC CROSS SECTION OF THE BASELINE GROUNDWATER PRESSURE GRADIENT FOR THE DEMONSTRATION PLANT (NOTE: "10E-7" IS THE SAME AS "1 X 10^{-7}")

Initial interpretation of the groundwater head pressure gradient suggests groundwater movement in, above, and below the target coal seam is very slow in a northward direction.

4.6 Groundwater Salinities

The salinity of groundwater observed in well 3967, open to the MO, ranged from 3900 to 4600 mg/L TDS from the depth of 55 m (just below the standing groundwater depth) to 106 m depth. Monitoring wells P1M1, P1M2 and P1M3 were regularly sampled in July and August. Results received to-date indicate that groundwater salinity for the MO, MC and LO is in the range of

4,600 to 9,200 mg/L TDS. Although the groundwater sampled from the MO, MC and LO wells may still be influenced by fresh water introduced during well screen flushing, it is considered that these results closely represent ambient groundwater chemistry. Additional sampling will be undertaken to assess this further.

4.7 Groundwater Sampling Major Ions

Groundwater samples from P1M1, P1M2, and P1M3 were analysed for major cations (Ca, Mg, Na and K) and anions (HCO3, CO3, SO4 and Cl). Figure 4.7 presents these analyses in graphical form. The chemical signature of groundwater in P1M2 (July 2017) and in P1M3 (August) is not consistent with the chemical signatures of groundwater from P1M1 and P1M3 from other rounds. P1M2 has only one set of results due to difficulties collecting samples in the screened interval. The nature and variations in chemistry in samples from P1M2 and P1M3 suggest some ongoing interaction between the well casing grout (cement) and groundwater. These wells are the last to be completed before groundwater sampling commenced.

Taking into account potential interference from the well grout, it appears the chemical signatures for groundwater in, above, and below the target coal seam are similar and the groundwater may have originated from the same water-bearing source.

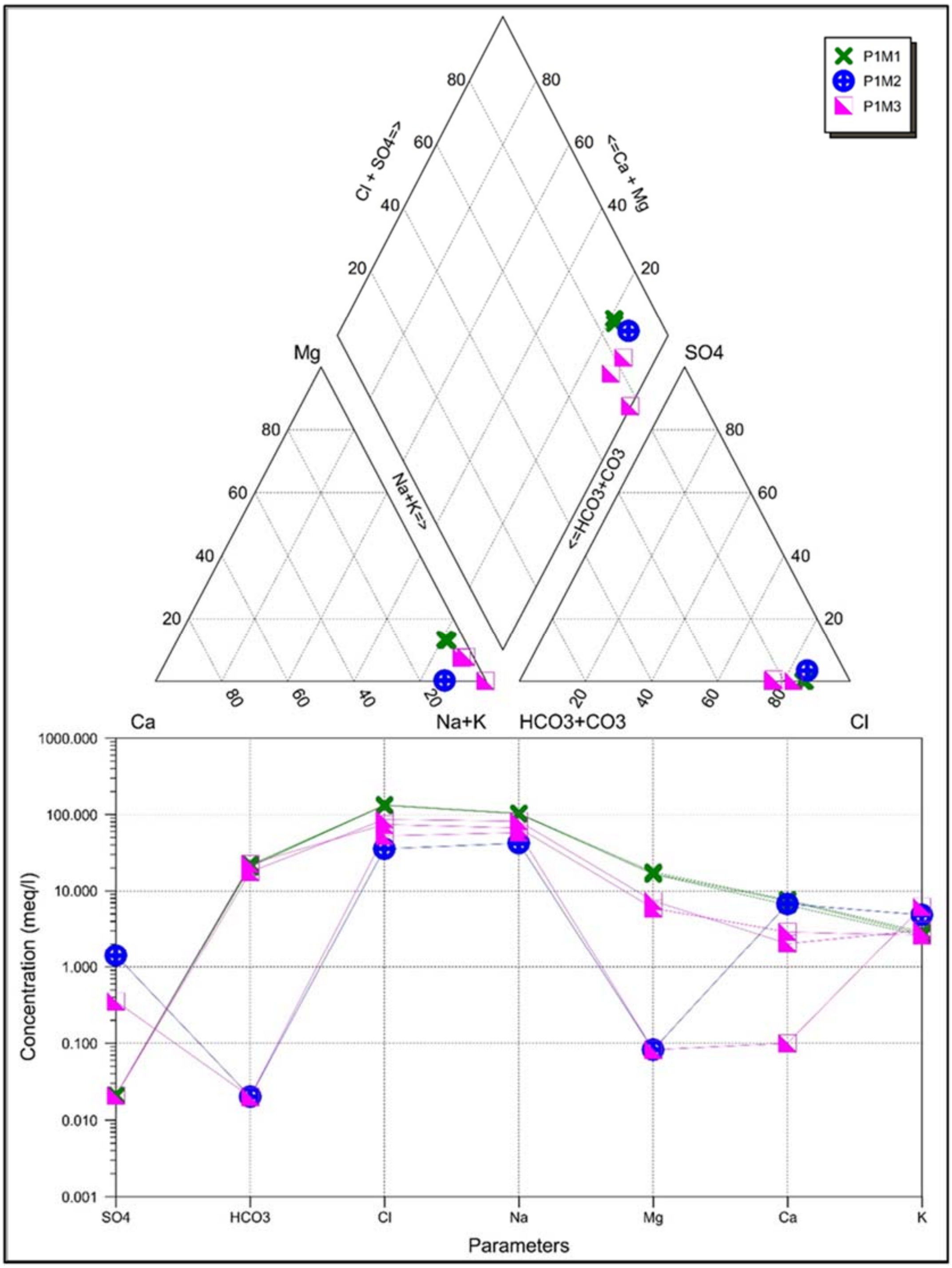

FIGURE 4.7 PIPER & SCHOELLER PLOTS

4.8 Groundwater Chemistry Investigations and Results

The natural chemistry of the Telford Coal Measures (and any coal related geology) includes many of the chemicals potentially created and destroyed in the ISG chamber. As such, understanding the nature and extent of this natural chemistry is important to assess the future effects of ISG on the surrounding environment and aid in design of the ISG Demonstration Plant operation.

4.8.1 Chemicals of Potential Concern (COPCs)

During ISG operations, there is the potential for a number of chemicals to be generated by pyrolysis and other reactions. Some chemicals may be fully consumed by generation of syngas, but there may also be a number of by-products and residual chemicals depending on natural composition of coal.

The gas phase products would be expected to be almost completely removed during the ISG via the outlet well(s). However, as the gasification chamber enlarges it is likely to be partially filled with the tar, solid char, ash and potentially residual gases. Groundwater that fills the chamber after Demonstration Plant operation ceases will come in contact with the residual materials in the chamber. These may dissolve into groundwater and, once the chamber fills with water and comes into equilibrium with groundwater in the surrounding rock strata, may move with groundwater from the chamber.

Once groundwater leaves the chamber, any chemicals it has dissolved will be subject to natural attenuation mechanisms as it moves through the rock. The practically impermeable nature of the coal will mean any such movement will be very slow in the direction of the Main Series Pit, while the dissolved chemicals will be subject to adsorption (on organic matter within the coal and carbon rich mudstone), dispersion, diffusion, and, potentially, biological degradation.

A number of publications have been reviewed to determine the list of COPCs which may be generated and concentrated within the ISG chamber and potentially become mobile in the groundwater:

- Underground Coal Gasification: An Overview of Groundwater Contamination Hazards and Mitigation Strategies, by. Camp and White, dated March 2015.
- Independent Scientific Panel Report on Underground Coal Gasification Pilot Trials, by Queensland Independent Scientific Panel for Underground Coal Gasification (ISP), dated June 2013.
- Underground coal gasification, by Gordon R Couch of IEA Clean Coal Centre, dated July 2009.

The review identified a number of chemicals which have been adopted to form a baseline set for comparison purposes and these are summarised in Table 4.3.

TABLE 4.3: CHEMICALS OF POTENTIAL CONCERN

Name	Description
Organic Compounds	Hydrocarbons ranging from "light oils' to "heavy tars". Typical chemical groups are phenol, polycyclic aromatic hydrocarbon (PAHs) and light/volatile petroleum hydrocarbons such as benzene, toluene, ethylbenzene, xylenes and naphthalene (BTEXN).
Inorganic compounds	Nutrients, metals, radioactive metals, cyanides, halides, major ions as well as total inorganic carbon and others.
Dioxins	Dioxins is a group of chemicals which may be formed as a result of combustion of organic matter in the presence of chlorine and metals.

4.8.2 Baseline Chemistry

Naturally occurring concentrations of COPCs in rock and groundwater has been obtained during completion and subsequent monitoring of P1M1, P1M2, and P1M3. The baseline chemistry was assessed through a variety of techniques on rock and groundwater samples to provide an indication of the natural chemistry of rocks and groundwater in, above and below the target coal seam at the Demonstration Plant site.

The baseline investigation locations are listed in Table 4.4. The baseline sampling results are discussed in sections below.

TABLE 4.4: BASELINE SAMPLING LOCATIONS

Sample Location Name	Description
P1M1-ENV-GW	Playford 5 – rock core samples collected during drilling P1M1 – groundwater monitoring well screened in carbonaceous mudstone (MO) above the target coal seam
P1M2-ENV-GW	P1M2 – groundwater monitoring well screened in the target coal seam (MC)
P1M3-ENV-GW	P1M3 – groundwater monitoring well installed below the target coal seam in interbedded coal and mudstone (MC and LO)

Drill Core Sampling Scope and Methodology

Rock core samples were collected from Playford 5/P1M1 to characterise the:

- Main Series Overburden;
- Main Series Coal; and
- Lower Series Overburden.

All samples collected were transported to ALS Laboratory Group (ALS) which is accredited by the National Association of Testing Authorities (NATA) and the analyses conducted are within their NATA accreditation. Summary tables presenting the rock core sampling results are attached in Appendix A.

The concentrations of key COPCs are summarised in Table 4.5, and presented as a range of reported concentrations for each material type (i.e. MO, MC and LO).

Dioxins and Furans

Dioxins and furans can be formed during combustion of organic matter (e.g. coal, kerogen/oil shale, etc.). It is known that coal and carbonaceous shale is prone to spontaneous combustion where exposed in the open pits and waste rock dumps. This indicates there is the potential for these compounds to occur naturally at depth as a result of spontaneous combustion, or other natural combustion processes, over the geological history of the basin. These compounds are practically insoluble and remain in the rock/soil and are unlikely to occur in groundwater at measurable concentrations.

Analysis of rock core samples was completed to test for the presence of these compounds. A summary of the reported dioxin and furan results from the Main Series coal is presented in Table 4.6.

TABLE 4.5: BASELINE CONCENTRATION RANGES IN DRILL CORE SAMPLES (mg/kg)

Analyte	P1M1 [MO Core]	P1M1 [MC Core]	P1M1 [LO Core]
Nutrients and Inorganics			
Ammonia	70	50-360	50-60
Total Nitrogen	800 - 2,980	190 - 3,000	580 - 2,240
Cyanides	<1	<1	<1
Hydrocarbons			
C6-C10	<10 - 21	<10	<10 - 13
>C10-C16	<50	<50 - 90	<50
>C16-C34	<100 - 190	130 - 630	<100 - 180
>C34-C40	<100	<100 - 110	<100
Benzene	<0.2 - 0.3	0.3 - 1.0	<0.2 - 0.2
Ethylbenzene	<0.5 - 1.2	<0.5	<0.5 - 0.6
Toluene	<0.5	<0.5	<0.5
Total Xylene	<0.5	<0.5	<0.5
Total BTEX	<0.2-1.5	0.3 – 1.0	>0.2 – 0.8
Naphthalene	<0.5	0.6 – 1.0	<0.5
Metals			
Arsenic	<5 - 7	<5	8 - 9
Barium	130 - 1,110	10 - 50	70 - 150
Boron	<50	<50	<50
Cadmium	<1	<1	<1
Chromium	15 - 31	3 - 25	8 - 14
Cobalt	9 - 17	<2 - 2	6 - 22
Copper	35 - 52	<5 - 21	35 - 42
Lead	12 - 30	<5 - 19	21 - 26
Manganese	31 - 814	<5 - 32	<5 - 10
Mercury	<0.1 – 0.4	<0.1	<0.1-0.1
Nickel	20 - 32	<2 - 8	6 - 32
Thorium	17.4 - 22.8	2.1 - 5.5	15.1 - 16.5
Uranium	2.1 - 4.6	0.1 - 1.4	1.1 - 2.9
Vanadium	24 - 36	<5 - 57	18 - 19
Zinc	78 - 153	<5 - 62	113 - 170
Polycyclic Aromatic Hydrocarbons (PAH) and Phenols			
PAHs (Sum of total)	<0.5	3.1 - 29	<0.5
Phenols	<0.5	<0.5 - <1.1	<0.5

TABLE 4.6: DIOXINS AND FURANS

Group Name	Unit	Main Series Coal
Tetra-Dioxins	pg/g	<0.5
Penta-Dioxins	pg/g	<2.5
Hexa-Dioxins	pg/g	<2.5
Hepta-Dioxins	pg/g	<5.0
Octa-Dioxin	pg/g	**17.8**
Tetra-Furans	pg/g	<0.5
Penta-Furans	pg/g	<2.5
Hexa-Furans	pg/g	<2.5
Hepta-Furans	pg/g	<2.5
Octa-Furan	pg/g	<5.0

Note: pg/g = parts per trillion

Groundwater Sampling Rationale and Methodology

To characterise the baseline chemistry of the groundwater, three rounds of groundwater sampling were conducted through July and in August 2017 from the three groundwater monitoring wells P1M1, P1M2 and P1M3.

The samples from these wells were collected using the Snap Sampler groundwater sampling technique.

Groundwater Sampling Field Parameters

The results of selected field parameters measured during groundwater sampling are summarised in Table 4.7.

TABLE 4.7: FIELD MEASURED GROUNDWATER QUALITY PARAMETERS (MO, MC AND LO WELLS)

Well	Date Sampled	pH	Temperature* (ºC)	Electrical Conductivity (µS/cm)	TDS** (mg/L or ppm)
P1M1	3/07/2017	7.32	44.0	14,490	8,454
	26/07/2017	6.71		13,210	7,681
	14/08/2017	6.59		15,120	8,837
P1M2	4/07/2017	9.61	45.7	10,600	6,117
P1M3	5/07/2017	7.01	47.5	9,370	5,378
	25/07/2017	7.09		11,570	6,696
	15/08/2017	6.94		12,630	7,332

* Groundwater temperature measured in situ by VWPs.
**Note: converted from EC using http://www.chemiasoft.com/chemd/TDS

Groundwater within P1M2 is considered likely to still be influenced by the well construction phase as the high pH result is considered to indicate that the cementing undertaken in the construction of this well is still reacting with the groundwater entering the well. Representative field parameters from only one sampling round are included due to sampling equipment challenges preventing collection of full set of groundwater sampling containers for the screened interval of the well during 25 July 2017 and 16 August 2017 sampling events.

The field parameters measured at P1M1 and P1M3 show consistency over time between the sampling rounds and as such the groundwater sampled is likely to be representative of the formation groundwater at these wells.

Groundwater Sampling Analytical Results

The concentration ranges for key chemicals for each groundwater formation (i.e. MO, MC and LO) are summarised in Table 4.8. Full set of groundwater results for these wells are attached in Appendix B.

TABLE 4.8: BASELINE CONCENTRATION RANGES IN GROUNDWATER (mg/L)

Analyte	**P1M1 [MO]**	**P1M2 [MC]**	**P1M3 [LO]**
General			
pH	7.53 - 7.57	12.2*	8.0 – 11.2*
TDS	8,710 - 9,160	6,470	4,650 - 6,630
Inorganics and Nutrients			
Ammonia	94 - 101	-**	73.2 - 131
Bromide	7.74 – 8.20	1.98	4.64 - 5.59
Total Nitrogen	96.4 - 116	-**	77.2 - 131
Total Organic Carbon (TOC)	21 - 30	8	3 - 25
Hydrocarbons			
C6 – C10	0.03 – 0.05	0.03	<0.02
>C10-C16	0.11 - 0.12	0.32	<0.1
>C16-C34	<0.1	0.19 - 0.40	<0.1 - 0.1
>C34-C40	<0.1	<0.1	<0.1
Benzene	0.004 - 0.018	0.004 - 0.007	0.004 - 0.006
Ethylbenzene	0.005 - 0.006	<0.002	<0.002
0.03 – 0.05	0.003 -0.008	<0.002	<0.002
Total Xylene	<0.002	<0.002	<0.002
Total BTEX	0.007 - 0.032	0.004 - 0.007	0.004 - 0.006
Polycyclic Aromatic Hydrocarbons (PAH)			
Total PAHs	<0.0005	<0.0005	<0.0005
Phenolic Compounds			
2,4-dimethylphenol	0.003 - 0.0031	<0.001 - 0.0012	<0.001
3-&4-methylphenol	0.0037 - 0.004	0.0024 - 0.0025	<0.002
Phenol	0.0023 - 0.0028	0.0049 - 0.0055	<0.001
Metals			
Arsenic	<0.001	<0.001	<0.001
Boron	0.28 - 0.37	0.22	0.34 - 0.40
Cadmium	<0.0001	<0.0001	<0.0001
Chromium	<0.001	<0.001	<0.001
Copper	<0.001	<0.001	<0.001
Lead	<0.001	0.001	<0.001
Manganese	0.16 - 0.171	-**	0.08 - 0.095
Mercury	<0.0001	<0.0001	<0.0001
Nickel	<0.001 - 0.002	0.005	<0.001
Thorium	<0.001	<0.001	<0.001
Uranium	<0.001	<0.001	<0.001
Zinc	<0.005 - 0.01	0.012	<0.005 - 0.007

* groundwater pH is influenced by the cement plug;

** the volume of groundwater sample was not sufficient to fill sampling containers for these analytes as some Snap Sampler containers failed to close in-situ.

5 Demonstration Plant Gasifier Conceptual Site Model

5.1 Demonstration Plant Operation - Impact on Groundwater Behaviour

The Leigh Creek Coal Measures at the proposed ISG Demonstration Plant have very low permeability. This groundwater system is therefore considered to have very low hydraulic conductivity, and is considered an aquitard.

The following discussion describes the conceptual site model for groundwater conditions pre-ISG demonstration and how groundwater will respond during ISG operations working and after shut down. These scenarios are informed by numerical modelling used to assist with conceptualisation of groundwater movement patterns and quantification of groundwater movement rates.

5.1.1 Current Conditions – Pre-ISG

The Demonstration Plant gasifier chamber will be located within low to very low hydraulic conductivity coal and bounded above and below by similarly very low hydraulic conductivity mudstones. The available measured groundwater pressure data illustrated in Figure 4.6 support the conceptualisation that the groundwater movement direction is northward.

Local to the gasifier chamber the groundwater movement is assumed to be predominantly northward parallel with the strata as illustrated in Figure 5.1 With hydraulic conductivities of approximately 10^{-3} m/d, the steady-state groundwater movement rate is likely to be in the order of or less than 1 m per year. If the lower value for hydraulic conductivity (10^{-7} m/d) is used, the rate of groundwater movement reduces toward millimetres per year. Potential movement pathways through structural defects are not considered important as investigations to-date have not identified any open structures.

This range in groundwater movement rates means groundwater moving through the location of the Demonstration Plant gasifier would take between 600 and 60,000 years to reach the Main Series Pit. The absence of groundwater seeping from the Main Series Pit high wall suggests such low rates of movement mean the groundwater migrating toward the exposed face of the wall evaporates before it can discharge.

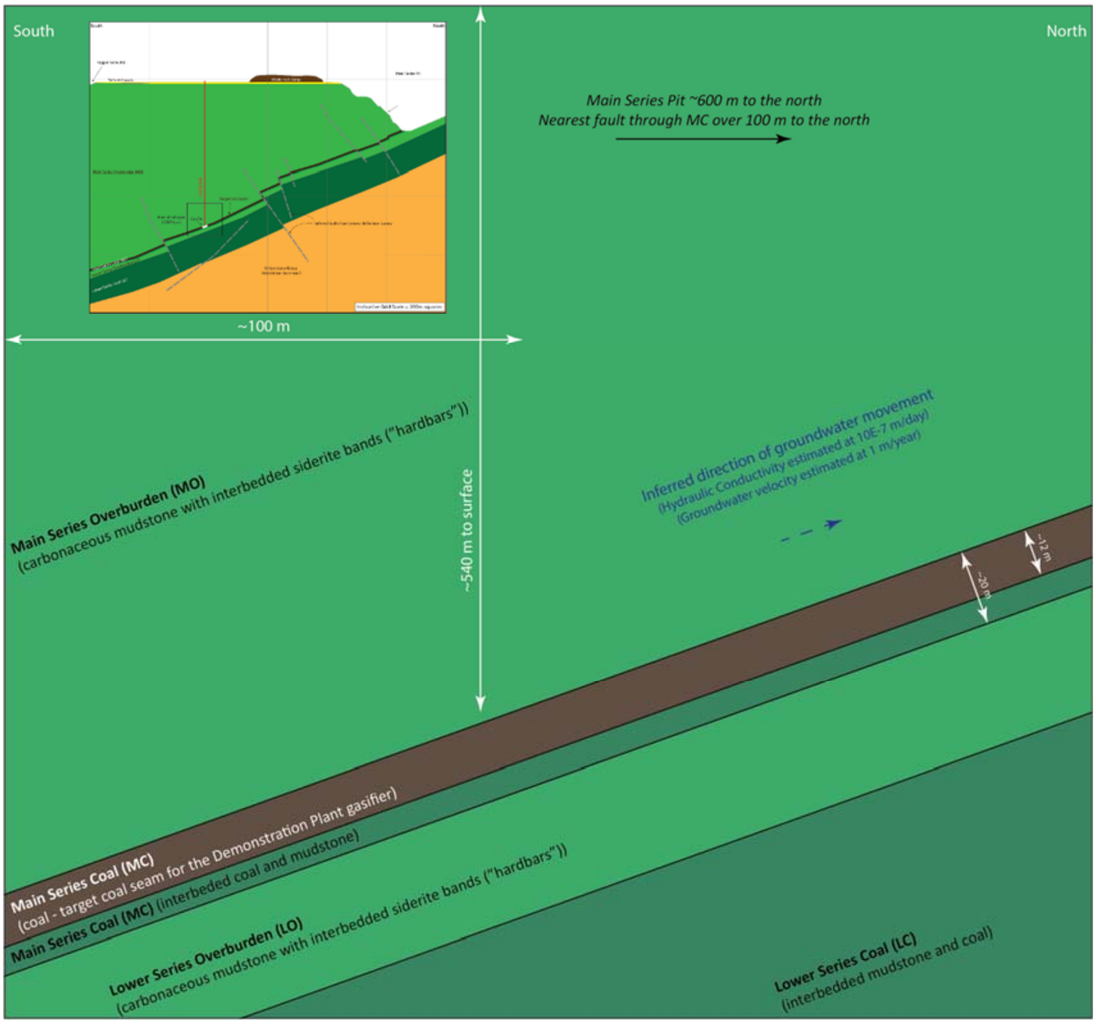

FIGURE 5.1 SCHEMATIC CROSS SECTION OF THE CURRENT CONDITIONS FOR THE DEMONSTRATION PLANT

5.1.2 During Demonstration Plant Operation

The Demonstration Plant chamber will develop as the coal is consumed and it is anticipated to be approximately 30 by 30 m laterally and approximately 15 m in height as illustrated in Figure 5.2. This chamber will remain within the low to very low hydraulic conductivity mudstones above and below and by unchanged coal laterally.

The gasification process will consume the pore water in the coal. As all the in-situ groundwater will be consumed, the gasification process will create a low-pressure environment in the gasifier and an inward groundwater pressure gradient. However, due to the low to very low hydraulic conductivity, the rate of groundwater movement is very low. Combined with the limited period of operation of the gasifier, the radius of influence of the gasifier on surrounding groundwater is expected to be limited. It also means the potential for any fluids from the gasifier to enter the surrounding rock will be similarly limited.

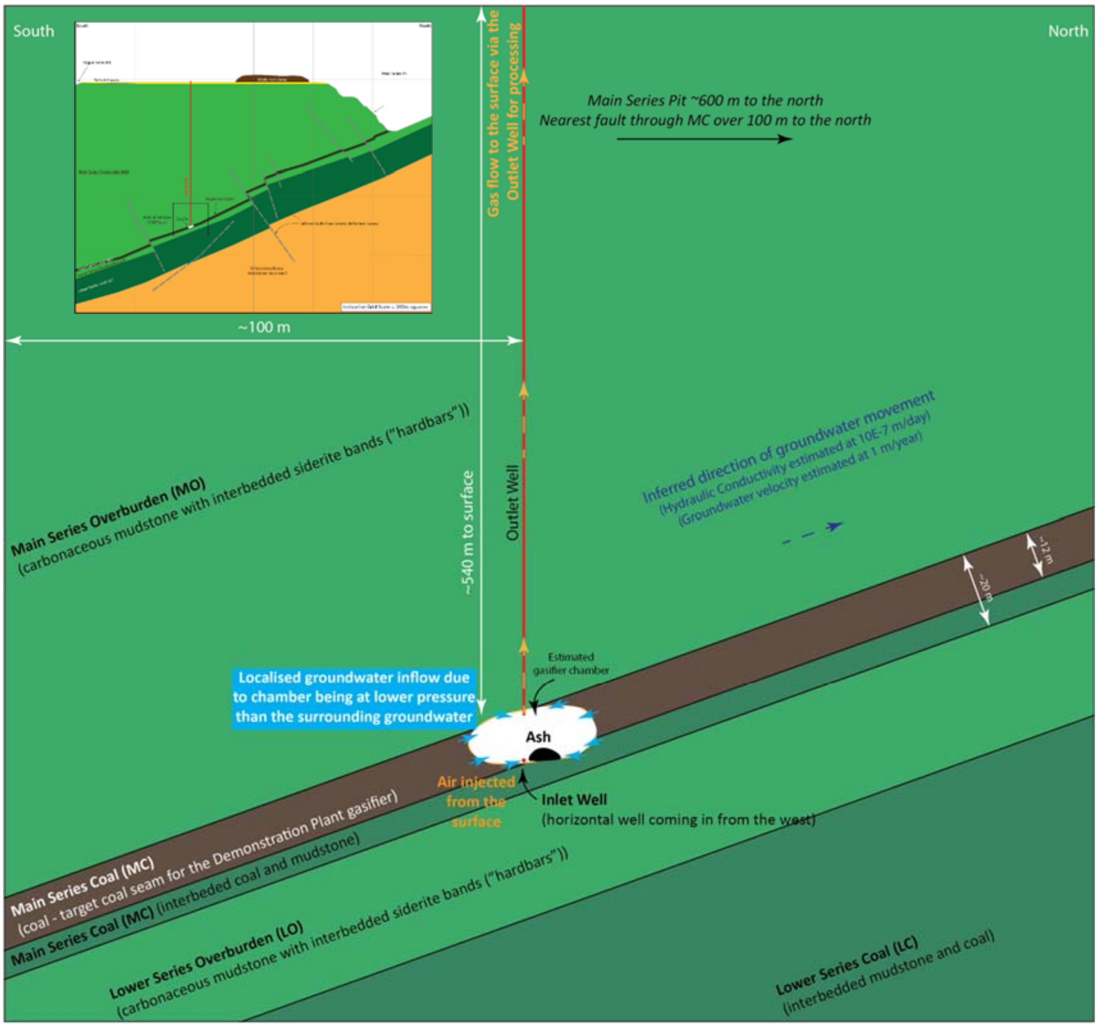

FIGURE 5.2 SCHEMATIC CROSS SECTION OF THE DEMONSTRATION PLANT DURING OPERATION

5.1.3 Post Demonstration Plant Operation - Hydrogeology

The Demonstration Plant chamber, once operation has ceased, will be decommissioned and the majority of, if not all, volatile and soluble COPCs will be removed via the Outlet Well leaving the chamber largely empty except for the ash and other residue left after gasification, as illustrated in Figure 5.2. This process is not anticipated to leave any residual water within the chamber as the expected temperatures within the chamber will convert any added water into steam that will be exhausted from the chamber during the shut-down process.

It is thus expected that the chamber will be fluid free. Assuming a chamber volume of approximately 13,500 m^3 [e.g. 30 m x 30 m x 15 m], once the chamber temperature is low enough not to vaporise any moisture, the groundwater from surrounding strata will start seeping into the chamber which may take years or decades as illustrated in Figure 5.3. Over this time the hydraulic gradient around the chamber will be inward. The calculated volume used here is considered an overestimate as the chamber will likely be a rounded chamber and not rectangular.

Once the chamber has refilled, there will still be a significant time lag while the groundwater heads revert to pre-operational conditions in the aquitard around the chamber. It is only when the groundwater pressures revert to pre-operational values that groundwater movement similar to ambient conditions in the vicinity of the chamber is expected. This is likely to be in the timescale of years to decades in addition to the time required to fill the chamber.

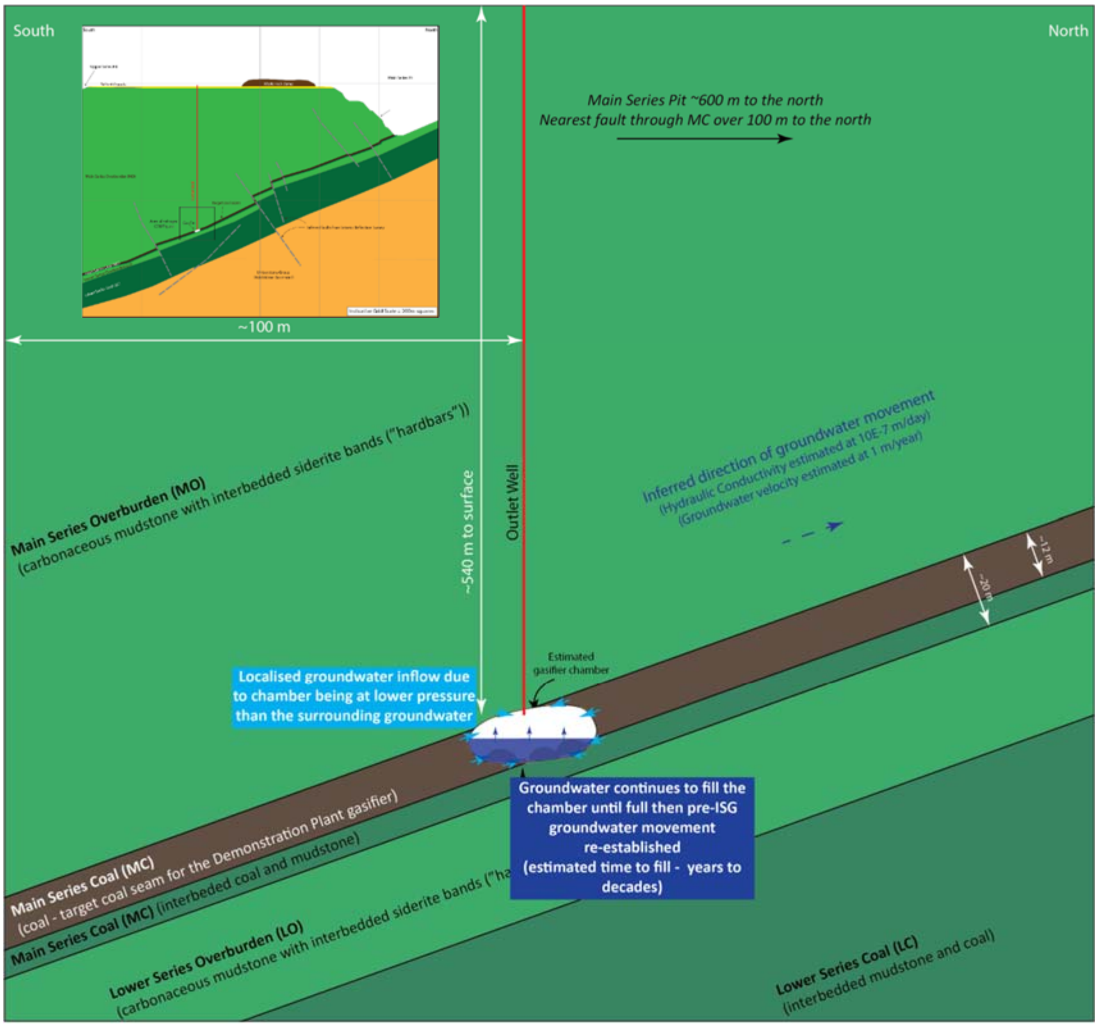

FIGURE 5.3 SCHEMATIC CROSS SECTION OF THE DEMONSTRATION PLANT POST OPERATION

5.1.4 Post Demonstration Plant Operation –Groundwater Chemistry and Chemical Indicators

After the gasification is complete, the void created will be fluid free, as indicated above but it will partially be filled with condensed tars and mineral ashes which will create a source (indirectly produced chemicals) of chemicals which could be mobilised into groundwater. Organic compounds (monocyclic and polycyclic hydrocarbons, etc) that are decomposed in the reaction zone whilst gasification continues, would be formed and then retained within this zone post gasification.

At Demonstration Plant shut down, there will be a zone of devolatilised coal around the periphery of the gasification chamber. This is due to the retained heat in the coal and may still be adequate to produce organic chemicals after oxygen ceases to reach the coalface. This could result in increased concentrations of some organic and inorganic chemicals in groundwater in the chamber. The concentrations of inorganic chemicals (such as calcium, magnesium, iron, lead and others) which are present in the coal and whose solubility is a function of pH, temperature and carbon dioxide concentration would also increase significantly.

Until the chamber completely fills with groundwater and pressures re-equilibrate with the surrounding aquitards the potential for any such chemicals to move out of the chamber is insignificant due to the inward hydraulic gradient, which will be maintained for decades. If these chemicals persist after groundwater equilibrates, any organic compounds that enter groundwater in the chamber would be removed to some degree from the solution by sorption (i.e. organics will adsorb quite strongly onto substrates with high organic carbon content) as they move into the surrounding rocks (coal and carbonaceous mudstone).

Phenols and low molecular weight aromatic compounds will persist in solution, but less soluble and heavier molecular weight compounds are likely to be fully removed by sorption. The primary organic chemicals of concern which may reside in groundwater for long period of time include some phenolic species, BTEX and naphthalene.

Inorganic compounds would primarily be associated with leaching from the ash left in the gasification chamber. The ash typically contains leachable calcium, aluminium, sulphate, hydroxide, barium, magnesium, boron, bromide and several other heavy metals. These chemicals could leach from the ash in concentrations higher than those found in the natural groundwater (baseline conditions).

Post gasification monitoring of groundwater quality at a number of in-situ gasification trials indicates that over time the concentrations of organic and inorganic chemicals (such as heavy metals (cadmium, iron, lead and zinc), PAHs and phenols) reduce naturally as a result of sorption and precipitation (refer 'Water Quality Changes at Underground Coal Gasification Sites - A Literature Review', by J.J. Ahern and J.A. Frazier of Water Resources Research Institute from University of Wyoming, US, dated February 1982).

6 Preliminary Assessment of Risks

6.1 Risk Assessment

As discussed in Section 3.3.4 of this report, no realistic beneficial uses for the groundwater at the proposed Demonstration Plant have been identified due to the high groundwater salinity and low well yield, and due to the very low hydraulic conductivity observed at the gasification site.

The anticipated time period whereby COPCs are present and available for migration is estimated to be significantly smaller relative to the time period estimated for the chamber to fill and then provide groundwater movement away from the chamber to transport COPCs to the surrounding environment (refer Figure 6.1)

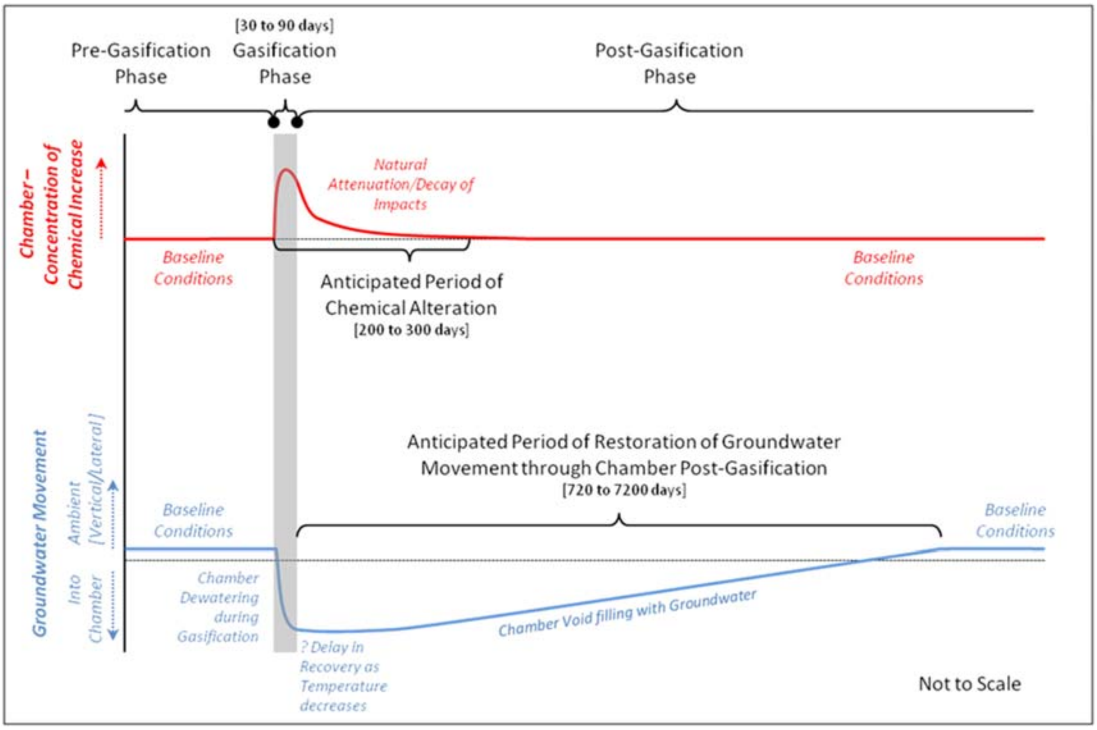

FIGURE 6.1 STYLISED TIMELINE OF IMPACTS FROM GASIFICATION

As such, groundwater potentially impacted as a result of in situ gasification is not likely to pose an unacceptable risk to people or the environment. Measurable groundwater pressure responses to the in situ gasification are expected only in the vicinity of the gasifier within the Jurassic/Triassic sediments of the Telford Basin. No pressure response is expected in the basement or in the other Jurassic/Triassic Basins (e.g. Lobe E, the Copley Basin or the North Field Basins). Any changes in groundwater chemistry will lag behind the changes in groundwater pressure. Any change to the groundwater chemistry is likely to remain limited within the immediate vicinity of the Demonstration Plant site. Any groundwater movement would be towards the Main Series pit and it is estimated it would take more than 100 years for groundwater to reach the pit from the Demonstration Plant site.

6.2 Recommendations for Monitoring Program

As groundwater movement through formations around the gasifier is likely to be very slow (a few millimetres to a few metres per year), it is unlikely that any detection of COPC from a gasifier loss of containment will be made using a groundwater quality monitoring program. Since groundwater pressure changes can be transmitted through the formation much faster than groundwater flow and chemical movement, it is recommended that real time monitoring of the gasifier be undertaken using vibrating wire piezometers (VWPs) to measure the pressure around, above and below the gasifier.

Pressure monitoring identifying a pressure gradient from the gasifier into the surrounding formation should therefore be used as a lead indicator of a potential loss of containment.

It is also recommended that an operational groundwater monitoring well be installed down hydraulic gradient as close as practical to, but not intersecting, the gasifier. In the event of a potential loss of containment, water quality in this well can be used to assess the rate and magnitude of any potential COPC release to the formation. This well should not be used as a compliance well, but rather as an indicator well as it would be located within the operational zone of influence.

Water quality monitoring of the operational monitoring well should therefore be used as a lead indicator of a potential loss of containment.

Secondary to the pressure monitoring network and the operational monitoring well, it is recommended that a number of sentinel groundwater monitoring wells be installed at a distance of approximately 50m from the gasifier to detect any change in COPCs relative to background in the event of a potential loss of containment before they move beyond the 100m operational zone. Detection of COPCs in groundwater monitoring wells via water quality sampling will be used to confirm and quantify the rate of movement of COPCs away from the gasifier and inform appropriate remedial actions to contain and manage effects of the loss of containment.

Further details such as analytical parameters, frequency, quality control etc should be developed as part of a Groundwater Monitoring Plan for the operation of the demonstration plant.

7 Evaluation of Demonstration Plant Site

The following tables provide an evaluation of the demonstration plant site with the preferred attributes from the ISG Hazard Screening Checklist Categories for Groundwater (Camp and White 2015).

4. Hydrology and Geochemistry

4.1	***The stratigraphic column contains drinking water and/or protected aquifers.***
	There are no aquifers in the stratigraphic column for the Demonstration Plant. Groundwater is present in aquitards and is too saline for drinking water.
4.2	***Aquifers and coal formations are not separated by reliable, low-permeability seals.***
	There are no aquifers above the Demonstration Plant gasifier and the rock strata above, in, and below the target coal seam have very low hydraulic conductivity and are practically impermeable. All these strata are aquitards.
4.3	***There is significant regional groundwater flow through the formation and/or nearby strata***
	The Demonstration Plant is in an area of the Telford Basin where all strata are aquitards with open pit coal mines to the north and south. The groundwater system in the basin is now considered a terminal water basin due to surface and subsurface (open pit mines) landscape modifications and the arid climate, i.e. low rainfall and high evaporation rates.
4.4	***Coal and/or adjacent units have high permeability, in either the lateral or vertical direction.***
	Investigations to date indicate that the Main Series Coal horizon, including above and below strata within the Telford Basin, have low permeability aquitard characteristics. Estimates of horizontal hydraulic conductivity range from 10^{-3} to 10^{-7} m/day, which puts these formations into the very low hydraulic conductivity class. Vertical hydraulic conductivities would be in a similar order of magnitude.
4.5	***Coal and/or adjacent units contain permeable fractures and joints.***
	It is well documented that the Leigh Creek Coal Measures within the Telford Basin are commonly jointed or faulted, often causing some coal seam displacement near the contact with the underlying Adelaidean Basement. However, these faults generally do not protrude through the entire thickness of coal measures, nor create connections with the underlying bedrock. The investigations conducted to date suggests that the general characteristic of structural defects within the coal seam and adjacent mudstone portions of the Leigh Creek Coal Measures Formation is one of being annealed, limiting the enhancement of secondary permeability within these formations. Typically observed groundwater discharges (from the highwall exposures) are through unconformity formation boundaries (e.g. perched in the Telford Gravel) and occasionally permeable sedimentary layers (high in the Leigh Creek Coal Measures Formation sequence) rather than through structural defects.
4.6	***Coal and/or adjacent units contain non-sealing faults.***
	Refer to 4.5.
4.7	***Baseline hydrology (with temporal fluctuations) is unavailable.***
	Baseline hydrogeology (groundwater): Groundwater data was collected for the demonstration site. Rock and groundwater chemistry is known. There are minor temporal variations in groundwater pressure, and the groundwater occurs in low to practically impermeable aquitards. Baseline hydrology (surface water): The Leigh Creek Coalfield has been in operation for many decades, during which time the management of the surface water at the mine area has been active. The site is bunded around the circumference creating diversion of surface water flows away from the mine pit and active mine areas. This diversion, however, does not influence significantly the flows in local creek systems in and surrounding the mine area.

4.8	***Baseline water-quality (with temporal fluctuations) is unavailable.***
	Refer to 4.7. A baseline water quality sampling program has been implemented. Sampling results will be reported in due course.
4.9	***Adsorption properties are unavailable.***
	Adsorption potential of the groundwater saturated material in relation to metals and organic chemicals is likely to be significant (typical for very fine grained material rich in organic matter).

7. Operation and Monitoring Plan

7.6	***Water well density and sampling frequency is insufficient to detect water-quality degradation quickly.***
	A groundwater monitoring well network is being constructed to target the formations at the Demonstration Plant gasifier.
7.7	***Water-sampling regimen has weak quality controls.***
	A water monitoring program to meet regulatory requirements is being designed and will be implemented.

8. Closure and Reclamation Plan

8.1	***Drinking-water degradation could occur if cavity-flushing is incomplete or ineffective.***
	Refer to 4. There are no aquifers or is no evidence of groundwater of drinking water quality within the project area.
8.3	***Post-operation monitoring effort insufficient to measure long term water quality.***
	The post-operation monitoring regime will conform to agreed arrangements as per Licence conditions.

Appendix A : Summary Tables – Rock Core Results

					Inorganics													
					Ammonia as N	Chloride	Cyanide (Free)	Cyanide (WAD)	Cyanide Total	Fluoride	Total Inorganic Carbon	Kjeldahl Nitrogen Total	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total Oxidised)	Nitrogen (Total)	Reactive Phosphorus as P	Phosphorus
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					20	10	1	1	1	40	0.02	20	0.1	0.1	0.1	20	0.1	2
LocCode	Field ID	Sampled	Sample_Depth_Avg	Material_Code														
	P1M1_ENV_CR001	29/10/2016		MO	70	310	<1	<1	<1	430	1.07	2,980	0.2	<0.1	0.2	2,980	0.2	1,880
	P1M1_ENV_CR002	12/11/2016	500	MO	-	360	-	-	-	-	-	-	-	-	-	-	-	-
	P1M1_ENV_CR003	13/11/2016	512	MO	70	230	-	-	<1	-	0.11	800	<0.1	<0.1	<0.1	800	-	-
	P1M1_ENV_CR004	13/11/2016	512.97	MC	360	570	-	-	<1	-	5	470	<0.1	<0.1	<0.1	470	-	-
	P1M1_ENV_CR005	13/11/2016	515.95	MC	-	510	-	-	-	-	-	-	-	-	-	-	-	-
P1M1	P1M1_ENV_CR006	13/11/2016	518.97	MC	50	180	<1	<1	<1	<40	4.8	190	<0.1	<0.1	<0.1	190	<0.1	55
	P1M1_ENV_CR007	13/11/2016	521.5	MC	-	460	-	-	-	-	-	-	-	-	-	-	-	-
	P1M1_ENV_CR008	13/11/2016	525.74	MC	60	200	<1	<1	<1	-	1.5	3,000	<0.1	<0.1	<0.1	3,000	0.2	153
	P1M1_ENV_CR009	14/11/2016	531.45	MC	-	450	-	-	-	-	-	-	-	-	-	-	-	-
	P1M1_ENV_CR010	14/11/2016	540	LO	50	230	-	-	<1	-	-	2,240	0.1	<0.1	0.1	2,240	-	-
	PIMI_ENV_CR011	17/11/2016	554.26	LO	60	210	-	-	<1	-	-	580	1.4	<0.1	1.4	580	-	322

					Metals																
					Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium (III+VI)	Cobalt	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Thorium	Uranium	Vanadium	Zinc
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					5	10	1	50	1	2	2	5	5	5	0.1	2	5	0.1	0.1	5	5
LocCode	Field ID	Sampled	Sample_Depth_Avg	Material_Code																	
	P1M1_ENV_CR001	29/10/2016		MO	7	560	1	<50	<1	15	17	52	18	814	<0.1	32	<5	17.5	2.1	24	153
	P1M1_ENV_CR002	12/11/2016	500	MO	<5	1,110	2	<50	<1	31	9	35	24	56	<0.1	20	<5	17.4	4.6	28	100
	P1M1_ENV_CR003	13/11/2016	512	MO	7	130	<1	<50	<1	18	16	49	30	31	0.4	24	<5	22.8	3.7	36	78
	P1M1_ENV_CR004	13/11/2016	512.97	MC	<5	290	<1	<50	<1	<2	<2	<5	<5	5	<0.1	<2	<5	4.3	0.1	<5	<5
	P1M1_ENV_CR005	13/11/2016	515.95	MC	<5	10	<1	<50	<1	3	<2	<5	6	<5	0.2	<2	<5	2.1	0.5	<5	14
P1M1	P1M1_ENV_CR006	13/11/2016	518.97	MC	<5	40	<1	<50	<1	7	<2	21	<5	16	0.2	<2	<5	5.2	0.9	5	15
	P1M1_ENV_CR007	13/11/2016	521.5	MC	<5	50	<1	<50	<1	8	<2	<5	17	6	<0.1	<2	<5	3.7	0.7	13	<5
	P1M1_ENV_CR008	13/11/2016	525.74	MC	<5	40	<1	<50	<1	15	<2	8	19	6	0.1	3	<5	5.5	1.4	37	62
	P1M1_ENV_CR009	14/11/2016	531.45	MC	<5	20	<1	<50	<1	25	2	6	<5	32	<0.1	8	<5	3.2	0.9	57	39
	P1M1_ENV_CR010	14/11/2016	540	LO	8	150	1	<50	<1	14	6	35	26	<5	0.1	6	<5	15.1	1.1	18	170
	PIMI_ENV_CR011	17/11/2016	554.26	LO	9	70	<1	<50	<1	8	22	42	21	10	<0.1	32	<5	16.5	2.9	19	113

						Nitrogen			NEPM 2013 TRH Fractions						TPH									BTEX						
					Moisture	Nitrogen (Organic)	N-Nitrosodiphenyl & Diphenylamine	Inorganic Nitrogen as N	>C16-C34 (F3)	>C34-C40 (F4)	C6-C10 without BTEX (F1)	C6-C10 with BTEX (F1)	C10-C16 without Naphthalene (F2)	C10-C16 with Naphthalene (F2)	C10 - C14	C6 - C9	C15 - C28	C29-C36	+C10 - C36 (Sum of total)	C10 - C40 (Sum of total)	TPH C10-C14 Fraction after Silica Cleanup	TPH C15-C28 Fraction after Silica Cleanup	TPH C29-C36 Fraction after Silica Cleanup	Benzene	Ethylbenzene	Toluene	Total BTEX	Xylene (m & p)	Xylene (o)	Xylene Total
					%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					1	20	1	20	100	100	10	10	50	50	50	10	100	100	50	50	50	100	100	0.2	0.5	0.5	0.2	0.5	0.5	0.5
LocCode	Field ID	Sampled	Sample_Depth_Avg	Material_Code																										
	P1M1_ENV_CR001	29/10/2016		MO	7.3	2,910	<1	70	100	<100	19	21	<50	<50	<50	19	<100	<100	<50	100	<50	<100	<100	0.3	1.2	<0.5	1.5	<0.5	<0.5	<0.5
	P1M1_ENV_CR002	12/11/2016	500	MO	8.5	-	<1	-	190	<100	11	12	<50	<50	<50	12	160	<100	160	190	<50	130	<100	0.2	1.2	<0.5	1.4	<0.5	<0.5	<0.5
	P1M1_ENV_CR003	13/11/2016	512	MO	7.6	-	<1	-	120	<100	<10	<10	<50	<50	<50	<10	<100	<100	<50	120	<50	<100	<100	<0.2	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5
	P1M1_ENV_CR004	13/11/2016	512.97	MC	24.2	-	<1.1	-	240	<100	<10	<10	<50	<50	<50	<10	200	<100	200	240	<50	170	<100	0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5
	P1M1_ENV_CR005	13/11/2016	515.95	MC	20.9	-	-	-	370	<100	<10	<10	<50	<50	<50	<10	310	110	420	370	-	-	-	0.7	<0.5	<0.5	0.7	<0.5	<0.5	<0.5
P1M1	P1M1_ENV_CR006	13/11/2016	518.97	MC	17.5	140	<1	50	220	<100	<10	<10	<50	<50	<50	<10	180	<100	180	220	<50	150	<100	0.6	<0.5	<0.5	0.6	<0.5	<0.5	<0.5
	P1M1_ENV_CR007	13/11/2016	521.5	MC	23.6	-	-	-	340	<100	<10	<10	<50	<50	<50	<10	280	120	400	340	-	-	-	1	<0.5	<0.5	1	<0.5	<0.5	<0.5
	P1M1_ENV_CR008	13/11/2016	525.74	MC	10.5	-	<1.1	-	130	<100	<10	<10	<50	<50	<50	<10	<100	<100	<50	130	<50	<100	<100	0.3	<0.5	<0.5	0.3	<0.5	<0.5	<0.5
	P1M1_ENV_CR009	14/11/2016	531.45	MC	18.5	-	-	-	630	110	<10	<10	90	90	<50	<10	520	220	740	830	-	-	-	0.4	<0.5	<0.5	0.4	<0.5	<0.5	<0.5
	P1M1_ENV_CR010	14/11/2016	540	LO	8	-	<1	-	180	<100	12	13	<50	<50	<50	12	130	<100	130	180	<50	120	<100	0.2	0.6	<0.5	0.8	<0.5	<0.5	<0.5
	PIMI_ENV_CR011	17/11/2016	554.26	LO	7.3	-	-	-	<100	<100	<10	<10	<50	<50	<50	<10	<100	<100	<50	<50	-	-	-	<0.2	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5

					PAH/Phenols																		
					7,12-dimethylbenz(a)anthracene	Benzo[b+j]fluoranthene	Benzo(a)pyrene TEQ (LOR)	Benzo(a)pyrene TEQ (zero)	2,4-dimethylphenol	2-chloronaphthalene	2-methylnaphthalene	2-methylphenol	2-nitrophenol	3-&4-methylphenol	3-methylcholanthrene	4-chloro-3-methylphenol	Acenaphthene	Acenaphthylene	Acetophenone	Anthracene	Benz(a)anthracene	Benzo(a) pyrene	Benzo(a)pyrene TEQ (medium bound) *
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
LocCode	Field ID	Sampled	Sample_Depth_Avg	Material_Code																			
P1M1	P1M1_ENV_CR001	29/10/2016		MO	<0.5	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6
	P1M1_ENV_CR002	12/11/2016	500	MO	<0.5	-	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6
	P1M1_ENV_CR003	13/11/2016	512	MO	<0.5	-	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6
	P1M1_ENV_CR004	13/11/2016	512.97	MC	<1.1	-	1.2	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<0.5	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
	P1M1_ENV_CR005	13/11/2016	515.95	MC	-	<1.1	1.2	<0.7	<1.1	-	-	<1.1	<1.1	<2	-	<1.1	<1.1	<1.1	-	<1.1	<1.1	<1.1	<0.7
	P1M1_ENV_CR006	13/11/2016	518.97	MC	<1	-	1.4	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1
	P1M1_ENV_CR007	13/11/2016	521.5	MC	-	7	2.6	2.1	<0.5	-	-	<0.5	<0.5	<1	-	<0.5	0.8	<0.5	-	<0.5	1.6	0.9	2.3
	P1M1_ENV_CR008	13/11/2016	525.74	MC	<1.1	-	1.2	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<0.5	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
	P1M1_ENV_CR009	14/11/2016	531.45	MC	-	2.9	1.8	1.2	<0.5	-	-	<0.5	<0.5	<1	-	<0.5	0.8	<0.5	-	<0.5	1.3	0.7	1.5
	P1M1_ENV_CR010	14/11/2016	540	LO	<0.5	-	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6
	PIMI_ENV_CR011	17/11/2016	554.26	LO	-	<0.5	1.2	<0.5	<0.5	-	-	<0.5	<0.5	<1	-	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5	0.6

					PAH/Phenols (cont.)													Halogenated Phenols					
					Benzo(b)&(k)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	Naphthalene	PAHs (Sum of total)	Phenanthrene	Phenol	Pyrene	2,4,5-trichlorophenol	2,4,6-trichlorophenol	2,4-dichlorophenol	2,6-dichlorophenol	2-chlorophenol	Pentachlorophenol
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
EQL					1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1
LocCode	Field ID	Sampled	Sample_Depth_Avg	Material_Code																			
P1M1	P1M1_ENV_CR001	29/10/2016		MO	<1	<0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1
	P1M1_ENV_CR002	12/11/2016	500	MO	<1	<0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1
	P1M1_ENV_CR003	13/11/2016	512	MO	<1	<0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1
	P1M1_ENV_CR004	13/11/2016	512.97	MC	<2	<1.1	-	<1.1	<1.1	1.8	<1.1	<1.1	<1	3.1	<1.1	<1.1	1.3	<1.1	<1.1	<1.1	<1.1	<1.1	<1
	P1M1_ENV_CR005	13/11/2016	515.95	MC	-	<1.1	<1.1	<1.1	<1.1	7.5	<1.1	<1.1	<1	10.2	<1.1	<1.1	2.7	<1.1	<1.1	<1.1	<1.1	<1.1	<2
	P1M1_ENV_CR006	13/11/2016	518.97	MC	3	<1	-	<1	<1	4.3	<1	<1	<1	9.2	<1	<1	1.9	<1	<1	<1	<1	<1	<1
	P1M1_ENV_CR007	13/11/2016	521.5	MC	-	0.8	1.3	2	<0.5	8.7	<0.5	1.6	0.6	29	<0.5	<0.5	3.7	<0.5	<0.5	<0.5	<0.5	<0.5	<2
	P1M1_ENV_CR008	13/11/2016	525.74	MC	<2	<1.1	-	<1.1	<1.1	4.1	<1.1	<1.1	<1	5.7	<1.1	<1.1	1.6	<1.1	<1.1	<1.1	<1.1	<1.1	<1
	P1M1_ENV_CR009	14/11/2016	531.45	MC	-	<0.5	0.7	1.5	<0.5	10.4	<0.5	0.5	1	25.1	1.4	<0.5	3.9	<0.5	<0.5	<0.5	<0.5	<0.5	<2
	P1M1_ENV_CR010	14/11/2016	540	LO	<1	<0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1
	PIMI_ENV_CR011	17/11/2016	554.26	LO	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2

Appendix B : Summary Tables – Groundwater Results

			Inorganics																								
			Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (Carbonate as CaCO3)	Ammonia as N	Anions Total	Bromide	Cations Total	Chloride	Cyanide (Free)	Cyanide (WAD)	Cyanide Total	Thiocyanate	Fluoride	Iodide	Ionic Balance	Kjeldahl Nitrogen Total	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total Oxidised)	Nitrogen (Total)	Total Carbon	pH (Lab)	Phosphorus	Reactive Phosphorus as P
			µg/L	mg/L	mg/L	mg/L	µg/L	meq/L	µg/L	meq/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L	pH_Units	mg/L	mg/L
EQL			1000	1	1	1	10	0.01	10	0.01	1	0.004	0.004	0.004	0.1	0.1	0.01	0.01	0.1	0.01	0.01	0.01	100	1	0.01	0.01	0.01
LocCode	Field ID	Sample Date																									
P1M1	P1M1	5/07/2017	<1000	1030	1030	<1	101,000	152	7740	136	4650	-	-	-	<0.1	0.4	<0.5	5.38	116	<0.01	<0.01	<0.01	116,000	246	7.57	0.33	0.02
	P1M1-ENV-GW	26/07/2017	<1000	1060	1060	<1	94,000	155	7860	132	4730	<0.004	<0.004	<0.004	<0.1	0.1	<0.5	8.02	98.2	0.01	<0.01	0.01	98,200	281	7.53	0.23	<0.01
	P1M1-ENV-GW	14/08/2017	<1000	1100	1100	<1	94,900	154	8200	128	4700	<0.004	<0.004	<0.004	<0.1	0.2	1.4	9.23	96.4	0.02	<0.01	0.02	96,400	279	7.69	0.47	<0.01
P1M2	P1M2	4/07/2017	1,340,000	1570	<1	233	-	68.3	1980	53.8	1260	-	-	-	-	0.2	<0.1	11.9	-	-	-	-	-	12	12.2	-	<0.01
	P1M2-ENV-GW	25/07/2017	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1M3	P1M3	5/07/2017	<1000	1130	1130	<1	73,200	96.8	4640	83.7	2630	<0.004	<0.004	<0.004	<0.1	0.2	2.12	7.28	86.6	0.02	<0.01	0.02	86,600	241	8	0.19	<0.01
	P1M3-ENV-GW	25/07/2017	<1000	889	889	<1	77,000	104	5590	94.7	3060	<0.004	<0.004	<0.004	<0.1	0.2	<0.5	4.7	77.2	0.01	<0.01	0.01	77,200	261	8.22	0.17	<0.01
	P1M3-ENV-GW	15/08/2017	601,000	1380	<1	777	131,000	80.4	4900	64.2	1860	<0.004	<0.004	<0.004	<0.1	0.2	3.44	11.2	132	0.01	0.02	0.03	131,000	146	11.2	0.64	0.08

			Inorganics (cont.)									Metals														
			Sodium (Filtered)	Sulphate (Filtered)	Sulphide	TDS	Hardness as CaCO3 (Filtered)	Calcium (Filtered)	Magnesium (Filtered)	Potassium (Filtered)	TOC	Aluminium (Filtered)	Arsenic (Filtered)	Boron (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Iron (Filtered)	Lead (Filtered)	Manganese (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Selenium (Filtered)	Thorium (Filtered)	Uranium (Filtered)	Zinc (Filtered)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
EQL			1	1	0.1	1	1	1	1	1	1	0.01	0.001	0.05	1E-04	0.001	0.001	0.05	0.001	0.001	1E-04	0.001	0.01	1	1	0.005
LocCode	Field ID	Sample Date																								
P1M1	P1M1	5/07/2017	2350	<1	-	8970	1210	149	203	106	-	-	<0.001	0.37	<0.0001	<0.001	<0.001	-	<0.001	-	<0.0001	0.001	<0.01	-	-	0.009
	P1M1-ENV-GW	26/07/2017	2380	<1	0.6	9160	1260	153	214	113	30	0.01	<0.001	0.3	<0.0001	<0.001	<0.001	12.9	<0.001	0.171	<0.0001	<0.001	<0.01	<1	<1	<0.005
	P1M1-ENV-GW	14/08/2017	2360	1	0.3	8710	1160	132	202	101	21	<0.01	<0.001	0.28	<0.0001	<0.001	<0.001	13	<0.001	0.16	<0.0001	0.002	<0.01	<1	<1	0.01
P1M2	P1M2	4/07/2017	970	68	-	6470	337	135	<1	190	-	-	<0.001	0.22	<0.0001	<0.001	<0.001	-	0.001	-	<0.0001	0.005	<0.01	-	-	0.012
	P1M2-ENV-GW	25/07/2017	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P1M3	P1M3	5/07/2017	1540	1	-	5910	441	58	72	103	3	-	<0.001	0.4	<0.0001	<0.001	<0.001	-	<0.001	-	<0.0001	<0.001	<0.01	-	-	0.007
	P1M3-ENV-GW	25/07/2017	1890	<1	0.2	6630	473	41	90	120	25	<0.01	<0.001	0.38	<0.0001	<0.001	<0.001	7	<0.001	0.095	<0.0001	<0.001	<0.01	<1	<1	<0.005
	P1M3-ENV-GW	15/08/2017	1330	17	0.3	4650	<10	2	1	242	20	<0.01	<0.001	0.34	<0.0001	<0.001	<0.001	-	<0.001	0.08	<0.0001	<0.001	<0.01	<1	<1	<0.005

LocCode	Field ID	Sample Date	NEPM 2013 TRH Fractions											
			>C16-C34 (F3)	>C34-C40 (F4)	C6-C10 without BTEX (F1)	C6-C10 with BTEX (F1)	C10-C16 without Naphthalene (F2)	C10-C16 with Naphthalene (F2)	>C34 - C40 Fraction (SG)	>C10 - C16 Fraction (SG)	>C10 - C16 Fraction minus Naphthalene (F2) (SG)	>C10 - C40 Fraction (sum) (SG)	>C16 - C34 Fraction (SG)	C10 - C36 Fraction (sum) (SG)
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL			0.1	0.1	0.02	0.02	0.1	0.1	100	100	100	100	100	50
P1M1	P1M1	5/07/2017	<0.1	<0.1	<0.02	0.05	0.12	0.12	<100	<100	<100	<100	<100	50
P1M1	P1M1-ENV-GW	26/07/2017	<0.1	<0.1	<0.02	0.04	0.12	0.12	<100	<100	<100	<100	<100	<50
P1M1	P1M1-ENV-GW	14/08/2017	<0.1	<0.1	0.02	0.03	0.11	0.11	<100	<100	<100	<100	<100	<50
P1M2	P1M2	4/07/2017	0.4	<0.1	0.02	0.03	0.32	0.32	<100	<100	<100	290	290	340
P1M2	P1M2-ENV-GW	25/07/2017	0.19	<0.1	0.03	0.03	<0.1	<0.1	<100	<100	<100	<100	<100	<50
P1M3	P1M3	5/07/2017	0.1	<0.1	<0.02	<0.02	<0.1	<0.1	<100	<100	<100	<100	<100	<50
P1M3	P1M3-ENV-GW	25/07/2017	<0.1	<0.1	<0.02	<0.02	<0.1	<0.1	<100	<100	<100	<100	<100	<50
P1M3	P1M3-ENV-GW	15/08/2017	<0.1	<0.1	<0.02	<0.02	<0.1	<0.1	<100	<100	<100	<100	<100	<50

LocCode	Field ID	Sample Date	TPH									BTEX						
			+C10 - C36 (Sum of total)	C10 - C14	C6 - C9	C15 - C28	C29-C36	C10 - C40 (Sum of total)	TPH C10-C14 Fraction after Silica Cleanup	TPH C15-C28 Fraction after Silica Cleanup	TPH C29-C36 Fraction after Silica Cleanup	Benzene	Ethylbenzene	Toluene	Total BTEX	Xylene (m & p)	Xylene (o)	Xylene Total
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L
EQL			50	50	20	100	50	100	0.05	0.1	0.05	1	2	2	0.001	2	2	2
P1M1	P1M1	5/07/2017	120	120	40	<100	<50	120	<0.05	<0.1	0.05	18	6	8	0.032	<2	<2	<2
P1M1	P1M1-ENV-GW	26/07/2017	130	130	40	<100	<50	120	<0.05	<0.1	<0.05	15	5	6	0.026	<2	<2	<2
P1M1	P1M1-ENV-GW	14/08/2017	110	110	20	<100	<50	110	<0.05	<0.1	<0.05	4	<2	3	0.007	<2	<2	<2
P1M2	P1M2	4/07/2017	860	320	<20	390	150	720	<0.05	0.23	0.11	7	<2	<2	0.007	<2	<2	<2
P1M2	P1M2-ENV-GW	25/07/2017	600	420	<20	180	<50	190	<0.05	<0.1	<0.05	4	<2	<2	0.004	<2	<2	<2
P1M3	P1M3	5/07/2017	<50	<50	<20	<100	<50	100	<0.05	<0.1	<0.05	6	<2	<2	0.006	<2	<2	<2
P1M3	P1M3-ENV-GW	25/07/2017	<50	<50	<20	<100	<50	<100	<0.05	<0.1	<0.05	6	<2	<2	0.006	<2	<2	<2
P1M3	P1M3-ENV-GW	15/08/2017	<50	<50	<20	<100	<50	<100	<0.05	<0.1	<0.05	4	<2	<2	0.004	<2	<2	<2

LocCode	Field ID	Sample Date	PAH/Phenols											
			Benzo(a)pyrene TEQ (zero)-(SIM)	7,12-dimethylbenz(a)anthracene	Benzo[b+j]fluoranthene	2,4-dimethylphenol	2-methylphenol	2-nitrophenol	3-&4-methylphenol	4-chloro-3-methylphenol	Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene
			µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL			0.5	2	0.001	1	1	1	2	1	1	1	1	1
P1M1	P1M1	5/07/2017	-	-	<0.001	3	1.4	<1	3.9	<1	<1	<1	<1	<1
P1M1	P1M1-ENV-GW	26/07/2017	-	-	<0.001	3.1	1.2	<1	3.7	<1	<1	<1	<1	<1
P1M1	P1M1-ENV-GW	14/08/2017	<0.5	-	<0.001	3.1	1.1	<1	4	<1	<1	<1	<1	<1
P1M2	P1M2	4/07/2017	-	-	<0.001	1.2	<1	<1	2.4	<1	<1	<1	<1	<1
P1M2	P1M2-ENV-GW	25/07/2017	-	-	<0.001	<1	<1	<1	2.5	<1	<1	<1	<1	<1
P1M3	P1M3	5/07/2017	-	-	<0.001	<1	<1	<1	<2	<1	<1	<1	<1	<1
P1M3	P1M3-ENV-GW	25/07/2017	-	-	<0.001	<1	<1	<1	<2	<1	<1	<1	<1	<1
P1M3	P1M3-ENV-GW	15/08/2017	<0.5	-	<0.001	<1	<1	<1	<2	<1	<1	<1	<1	<1

LocCode	Field ID	Sample Date	PAH/Phenols													Halogenated Phenols					
			Benzo(a) pyrene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	Naphthalene	PAHs (Sum of total)	Phenanthrene	Phenol	Pyrene	2,4,5-trichlorophenol	2,4,6-trichlorophenol	2,4-dichlorophenol	2,6-dichlorophenol	2-chlorophenol	Pentachlorophenol
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL			0.5	1	1	1	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	2
P1M1	P1M1	5/07/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	2.3	<1	<1	<1	<1	<1	<1	<2
P1M1	P1M1-ENV-GW	26/07/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	2.8	<1	<1	<1	<1	<1	<1	<2
P1M1	P1M1-ENV-GW	14/08/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	2.6	<1	<1	<1	<1	<1	<1	<2
P1M2	P1M2	4/07/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.6	<1	4.9	<1	<1	<1	<1	<1	<1	<2
P1M2	P1M2-ENV-GW	25/07/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.6	<1	5.5	<1	<1	<1	<1	<1	<1	<2
P1M3	P1M3	5/07/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<2
P1M3	P1M3-ENV-GW	25/07/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.6	<1	<1	<1	<1	<1	<1	<1	<1	<2
P1M3	P1M3-ENV-GW	15/08/2017	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1	<1	<1	<1	<1	<1	<1	<1	<2

Appendix B: Geotechnical Assessment

Leigh Creek Energy

Geotechnical Assessment
ISG Demonstration Plant

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Date	September 2017
Prepared by	Chris Chamberlain and Geoff Borg

Revision History

Revision	Date	Purpose	Prepared	Reviewed	Authorised
0	26/09/2017	Final	CC/GB	MW	JH
1	19/12/2017	Final	CC/GB	DF/MW	JH
2	3/04/2018	Final	CC/GB	MW	JH

Leigh Creek Energy acknowledge the Adnyamathanha people, the traditional owners of the land on which our operations occur and pay our respects to their Elders past and present.

Contents

Executive Summary

This report presents an assessment of potential key geotechnical risks for the proposed Leigh Creek Energy Limited (LCK) In Situ Gasification demonstration stage gasifier.

Key geotechnical risks which are described by this assessment comprise:

- siting of the gasifier relative to existing geological structures that could provide a migration pathway for gas or fluids;
- potential for excessive thermal rock spalling that could affect ISG reactions within the gasifier;
- potential for uncontrolled/runaway structural failure of the gasifier roof causing ground subsidence; and
- potential for new fracturing or reactivation of existing fracturing of the surrounding rock as a result of operation of the gasifier, forming new migration pathways for gas or fluids, or providing a connection to existing geological structures.

The absence of aquifers above the gasifier, likely absence of faults within 100 m, gasifier depth (over 500 m depth below ground level) and the nature of the overburden rock (500 m of very low permeability carbonaceous mudstone) are recommended site attributes as described by the Independent Scientific Panel report (Moran *et al.,* 2013 and Table 6). Siting of the gasifier at the proposed location is therefore deemed a low risk.

Degradation of the overburden (gasifier roof rock) from thermal effects presents a geotechnical risk. While this risk cannot be adequately quantified at this stage, it will be investigated along with other geotechnical unknowns using data collected prior to and during operation of the demonstration plant. Excessive thermal degradation of the rock surrounding the gasifier is not considered to present an environmental risk.

A study by (Golder Associates, 1985) identified the potential for ground surface subsidence in response to ISG. This study was based on a configuration of gasifier that was 500 m wide and at an average depth of 350 m. The LCK demonstration stage gasifier is a much smaller size (30 m wide and 540 m deep) and will collect geotechnical data required for design of future commercial scale gasifiers at the site. Ground surface subsidence is not expected due to the depth and size of the resulting underground void, and therefore not considered to be an environmental risk.

Geological drilling has shown that there are no faults in the 100 m exclusion zone radius of the gasifier. In addition, formation integrity testing has shown that it is unlikely that a new fracture will be initiated or an existing fracture would be opened by the proposed ISG demonstration. Therefore the potential for a fracture to propagate from the small, deep gasifier to the surface or to connect to an existing fracture or fluid flow pathway is not considered to present an environmental risk.

This report comprises a geotechnical assessment and draws on geotechnical information collected from the drilling of drill hole Playford 5 located 500 m to the west of the current demonstration stage gasifier, in addition to analysis of data gathered from Playford 2.

1 Introduction

1.1 Project Background

Leigh Creek Energy (LCK) plan to produce energy from coal using a process known as in-situ gasification (ISG) at the Leigh Creek Coalfield which is currently operated by Flinders Power Partnership (Flinders Power) in South Australia.

The ISG process converts coal into gas products (syngas) which include methane, hydrogen and other valuable gas components. Syngas can be used to produce electricity directly, or further refined into a variety of products that include synthetic methane and ammonia.

LCK propose to establish and operate an ISG demonstration plant to collect data on gasification performance, environmental and geotechnical effects and further, better define and understand the project risks and also define design criteria for future commercial ISG operations at the Leigh Creek Coalfield. Information collected from preceding investigations and operation of the demonstration plant will inform the design process for a possible commercial facility at the Leigh Creek Site.

The demonstration plant will involve establishment and operation of a gasifier at a depth of approximately 540 m in the Main Series Coal (Telford Coal Measures) and Main Series Overburden. Operation of the gasifier and associated surface equipment is planned for a period of 60 to 90 days.

Previous studies on the feasibility of the Telford Coal Measures for ISG (also referred to as underground coal gasification or UCG) considered the geotechnical conditions and concluded ISG may be feasible, subject to more detailed hydrogeological and geotechnical studies (Murray-Wallace, 1985 and Coffey Associates, 1983). Ultimately, the demonstration plant is designed to collect further detailed data that is required to assess how the Telford Coal Measures respond to ISG and to inform the feasibility and design of potential future commercial ISG operations.

This report comprises a geotechnical assessment drawing on geotechnical information collected from two completed drill holes: Playford 5 located 500 m to the west of the demonstration plant; and Playford 2 located immediately to the east (Figure 1).

Playford 5 was completed as a near vertical hole to collect representative core from the roof, coal, and floor strata for a demonstration gasifier. A total of 84 m of core was collected and was geotechnically logged and field tested. Additional well tests were completed including In situ Stress Tests (IST) and Drill Stem Tests (DST) in the cored section of the drill hole to obtain ground stress and permeability data.

Playford 2 was completed as an angled drill hole to identify and test for the presence of geological structures that could act as fluid flow pathways from the gasifier to the surface. A series of hydraulic packer tests were completed in this drill hole to test the permeability of the rock strata above the gasifier and a geological structure located approximately 150 m north of the demonstration gasifier.

Figure 1. Location of the demonstration plant realtive to drill hole Playford 5 and drill hole Playford 2 and inferred (from seismic interpretation) plane of the nearest fault intersection with target coal seam.

1.2 Key Geotechnical Risks

As the ISG reactions proceed, an underground chamber will develop as the coal seam is converted to syngas. This chamber is referred to as the ISG reaction chamber or gasifier. The operating pressure within the gasifier will be regulated at less than the surrounding hydrostatic pressure (the pressure of the water associated with the pore spaces within the rock).

The rate of chamber growth is dependent on the rate of conversion of coal to syngas and is controlled by regulating the air supply from the ground surface via the inlet well. Mobile products generated by the ISG reactions are removed from the chamber via the outlet well for processing at the ground surface. Figure 2 illustrates an idealised gasifier geometry and configuration of inlet and outlet wells.

Factors that influence the gasifier geometry will include the thickness and dip angle of the coal seam, the chemical makeup of the coal, water content, in situ ground stresses and also the geotechnical properties of the coal seam and surrounding overburden strata. The geotechnical properties of the surrounding strata influence the vertical growth of the chamber (Camp and White, 2015).

The key geotechnical risks considered in this report include:

- siting of the gasifier relative to existing geological structures that could provide a migration pathway for gas or fluids;
- potential for excessive thermal rock spalling that could affect ISG reactions within the gasifier;

- potential for uncontrolled/runaway structural failure of the gasifier roof causing ground subsidence; and
- potential for new fracturing or reactivation of existing fracturing of the surrounding rock as a result of operation of the gasifier, forming new migration pathways for gas or fluids, or providing a connection to existing geological structures.

Geotechnical and groundwater risks are interrelated. Groundwater risks are discussed in detail in a separate report (AWE|Greencap, 2017).

The distance between the inlet well initiation ISG point and outlet well in the coal will be approximately 30 m, roughly forming the long axis of the gasifier. The width of the gasifier is expected to range up to 30 m. A gasifier void height of about 15 m is estimated based on the gasification processes consuming all of the Main Series Coal seam (12 m seam thickness) plus 3 m of the coal seam roof.

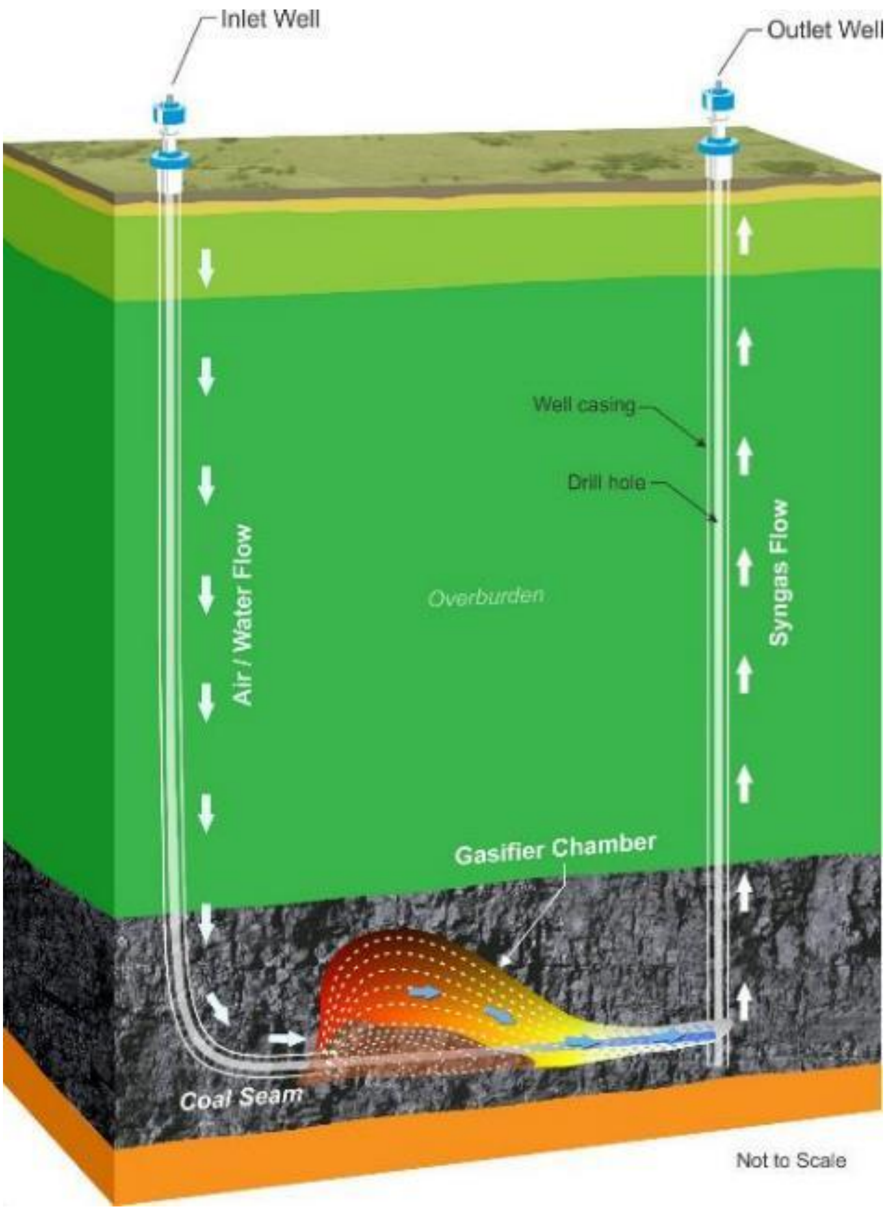

Figure 2. Schematic illustration of the demonstration plant gasifier.

2 Industry Practice Geotechnical Assessment

The geotechnical issues for ISG are similar to those encountered with underground coal mines, and many of the same geotechnical design procedures apply (Camp and White 2015).

In Australia, extraction of coal at depth is commonly by the longwall mining process. In longwall mining, relatively large “panels” of coal are extracted (IESC, 2014) creating underground voids. The layout of the underground workings (voids / non - extracted areas) influence how the coal seam roof and the overlying rocks behave. This mining process can result in ground movements associated with the process known as ground subsidence.

Ground subsidence can be assessed using empirical (experience) and analytical (numerical) methods and is commonly assessed by measurement of tilt, horizontal and or vertical displacement, curvature and strain. A reference standard for empirical analysis of ground subsidence associated with underground mining (mine subsidence) is the Subsidence Engineers’ Handbook (National Coal Board, 1975).

Experience based mine subsidence predictions and impact assessment techniques are well developed for longwall mining (IESC, 2014) through the monitoring of operating mines. Longwall coal mining panels are generally very long and wide and full coal seam extraction often occurs as a result of the coal mining process, sometimes across multiple underground levels. These conditions are different to that of the proposed demonstration plant and the underground void for a typical longwall coal mine will be much larger than the void which will be formed by the demonstration plant gasifier. The potential ground subsidence that would be generated by the demonstration plant is assessed to be significantly less than for longwall coal mining.

3 Site Conditions

3.1 Geology

The Leigh Creek Coal Measures are Late Triassic and Early Jurassic in age and occur within five discrete structural basins (Lobe A to Lobe E) which are bound by deformed (Precambrian age) strata. At the Leigh Creek Coalfield, these rocks are overlain by Quaternary age alluvium, colluvium and mine waste associated with the development of the Leigh Creek Coalfield.

Within Lobe B of the Telford Basin, the Coal Measures consist of three main coal sequences, named informally (youngest to oldest) as Upper Series, Main Series and Lower Series. Each coal sequence is further divided into overburden and coal units. The proposed demonstration plant is located within an area of the Telford Basin where the general geological sequence is as shown in Table 1.

Table 1: Geological sequence at the demonstration plant site

Approximate depth below surface (at the location of the gasifier in metres)	Stratigraphic unit name	General lithology and structure
0 – 12	Telford Gravels	Clays, sands, gravels and cobbles. Variably cemented. Thickness may vary due to paleo-channels. Flat lying
12 – 540	Main Series Overburden	Carbonaceous mudstone with interbedded siderite (hardbars), dip 25 degrees (approx.) to the south
540 – 542	Main Series Coal	Coal (Q seam), dip 25 degrees (approx.) to the south

Approximate depth below surface (at the location of the gasifier in metres)	Stratigraphic unit name	General lithology and structure
542 – 550	Main Series Coal	Interbedded coal and carbonaceous mudstone, dip 25 degrees (approx.) to the south
550 – 570 +	Lower Series Overburden	Carbonaceous mudstone with interbedded siderite (hardbars), dip 25 degrees (approx.) to the to the south

Note: depth may vary due to position and geological structure

3.2 Geological Structures

Key geological structures in the Telford Basin comprise bedding planes, fractures, and faults.

Faults are of primary importance to the siting of the demonstration plant gasifier because depending on their character and geological nature, they could provide a migration pathway for gas or fluids. Adequate siting of the demonstration plant gasifier is required to avoid known or potential faults that could provide a fluid flow pathway adjacent to the gasifier and overburden rock above the gasifier associated with deformation of the gasifier roof.

Faults are known to displace the Main Series Coal and persist (extend) above and below the Main Series Coal seam for tens of metres. Faults which extend from the Adelaidean basement into the Coal Measures and within Lower Series are well documented. The orientation of faults is indicative of the ground stress conditions and style of the deformation of the geological strata during the development of the geological basin. Typically, known faults are steeply dipping toward the basin margins and can extend along strike for hundreds of metres parallel to the long axis of the basin, although faults of various orientations and character will also exist.

Faults have been identified from the historic mining operations (main series pit) and also from drilling work associated with the development of structural geological models for the various coal seams within the Lobe B basin. As such, there is a greater degree of control on the position of faults in areas closer to the recoverable coal resource (pit areas) and a comparatively less control in areas which have not been assessed in terms of economic recovery of the coal resource. In areas of lesser “structural” control, the position of faults may be estimated by projection (along strike) and by other methods such as geophysics (refer below) and construction of specific / localised geological models based on good quality drilling data. The detailed fault database for the area surrounding the demonstration stage gasifier is not currently available to LCK and hence drilling work was necessary to provide geological data which is specific to the demonstration stage gasifier (refer to Section 5).

At the demonstration plant site, the Main Series Coal resource is likely to comprise a 12m thick coal seam with a dip of approximately 25 degrees to the south. Additional drilling to provide further assessment of the ground conditions at the demonstration plant gasifier site is planned occur prior to construction of surface plant and infrastructure. Seismic reflection survey data and drilling (drill hole Playford 5) at a comparable site approximately 500 m to the west was completed in late 2016. Completion of drill hole Playford 5 included recovery and assessment of an 84m section of drill core between 468m and 552m drilled depth. Logging of the core indicated that the natural fractures which occur within the Main Series Overburden generally comprised tight, closed joints. Geotechnical assessment of the drill core did not highlight evidence of (for example) weak material or gouge filled joints / structures that could indicate the presence of faults, or migration pathways for gas or fluids, however this data is specific to the area surrounding drill hole Playford 5. Data reliability reduces with increasing distance from the drill hole.

Exposed sections of the mining pit highwall to the north of Playford 5 and demonstration plant location indicate the Main Series Overburden is laterally and vertically consistent in terms of rock type (Figure 3).

Seismic reflection surveys close to the demonstration plant area were completed in 1978 and 2016 to determine the continuity of coal layers and the nature and distribution of key faults. The interpreted faults are generally steeply dipping and strike parallel with the long axis of the basin, however as with drill hole information, data reliability reduces with increasing geological complexity and distance from the line of the seismic section.

Figure 3. Main Series Pit highwall from the north west showing consistency of strata in the exposed Main Series Overburden. At its lowest point, the highwall is up to 180 m high.

A geological structure was identified in Playford 2 as a distance of approximately 150 m to the north of the gasifier. This occurrence and hydraulic testing of this structure is discussed in later sections of this report.

3.3 Groundwater Conditions

The Quaternary age Telford Gravels (where permeable) may comprise an unconfined groundwater system, where water movement is through the sediment matrix. This system is immediately below the thin soil cover and in the order of 12 m thick in the demonstration plant area with discontinuous groundwater as a result of the location of the Upper Series Pit to the south / south west and the significant Main Series Pit to the north.

The Main Series Overburden, Main Series Coal and Lower Series Overburden form a continuous, low permeability groundwater system with a potentiometric surface approximately 50 m below the ground surface and decreasing in elevation towards the Main Series Pit. The hydraulic conductivity of these geological units is in the order of 10^{-7} m / day when measured using borehole recovery tests, during which the aquifer is not stressed (AWE|Greencap, 2017). On this basis, the Main Series Overburden can be interpreted as very low permeability to practically impermeable. The assessed closed nature of fractures and faults in the rock mass is supported by the low permeability of the overburden units as determined from testing within drill hole Playford 5.

AWE|Greencap (2017) used a hydraulic conductivity of 10^{-3} m / day reported by Sigra (2016) from drill stem tests in Playford 5 to estimate a potential groundwater movement rate of 1 m / year. This rate was used in the EIR to provide a protective assessment of groundwater related risks. A more representative hydraulic conductivity of 10^{-7} m / day results in a rate of groundwater movement in the order of mm / year which would mean the risks would be even lower.

Additional water pressure testing was completed in drill hole Playford 2 following the testing procedure described by Houlsby (1976) and using a double packer arrangement. Analysis of these data provided in situ permeabilities listed in Table 2.

Table 2: Hydraulic conductivity (K, m/day) of Main Series Overburden, Main Series Coal, and Lower Series Overburden (drill hole Playford 2), including potential geological structures in the Main Series Overburden (Test 2). Results report are analysis of water pressure (Lugeon) tests completed in Playford 2 using Burgess Method (SMEC, 2018).

Test	Packer test interval (drilled depth, m)	Top of packer test interval (true vertical depth, m)	Geological strata	K m/day	K m/sec
1	420 - 430	~ 338	Main Series Overburden	1.85 x 10-3	2.15 x 10-8
2	410 - 420	~ 331	Main Series Overburden (geological structure observed in drill hole)	1.68 x 10-3	1.95 x 10-8
3	400 - 410	~ 324	Main Series Overburden	1.24 x 10-3	1.43 x 10-8
4	535 - 560	~ 413	Lower Series Overburden	6.74 x 10-4	7.80 x 10-9
5	507 - 532	~ 396	Main Series Coal	1.12 x 10-3	1.30 x 10-8
6	482 - 507	~ 380	Main Series Overburden	7.86 x 10-4	9.10 x 10-9
7	217.5 – 242.5	~ 185	Main Series Overburden	7.53 x 10-3	9.49 x 10-8

It is of importance to note that two sets of pumping data are recorded when undertaking the test. These analyses use the higher (more conservative) record. Such permeabilities are as expected for the type of materials intersected and recovered whilst drilling and are consistent with the permeabilities measured by Sigra (2016) in drill hole Playford 5. Further assessment by Sigra (2016) indicated there is likely a well bore effect, where increased permeability is created within two to three borehole radii due to the destructive process of drilling, which has the potential to vary the permeability immediately around the borehole. Long term testing, such as the recovery tests, may provide a more representative result for the formation.

Test 2 (Table 2) represents a potential geological structure (a possible fault). It is interpreted that this feature has been healed or closed as the permeability is similar to that of the surrounding rock.

4 Geotechnical Assessment for Demonstration Plant Gasifier

4.1 Siting of the Gasifier

The location of the demonstration plant gasifier relative to the completed reference drill hole Playford 2 is shown below in Figure 4. The drill hole Playford 5 is not shown because it is located approximately 500 m “into” the geological section.

Seismic reflection survey data collected in 1978 and 2016 and reprocessed by Velseis in 2016 was completed close to drill hole Playford 5. This information indicates that the Main Series Overburden comprises “packets” of strata characterised by relatively continuous reflectors, separated by areas showing diffuse / broken reflectors. The latter diffuse areas may represent the influence of structural control such as faulting, however given the distance (500 m) between drill hole Playford 5 and the demonstration plant gasifier, it is unlikely that the existing seismic information is directly applicable, or representative of the geological conditions at the demonstration plant gasifier.

Drill hole Playford 2 was drilled approximately 80 m east of the demonstration plant to identify whether any significant geological structures exist that could act as fluid flow pathways between the gasifier and the surface. Figure 4 provides a schematic south to north cross section through the gasifier location with a combined interpretation of potential structures for the seismic line near drill hole Playford 5 and drill hole Playford 2 drill hole the geological structure intersected approximately 150 m to the north of the gasifier.

The Playford 2 well confirmed there are no structures in close proximity to the gasifier. The structure intersected in Playford 2 is approximately 150 m from the gasifier and, as discussed in Section 4.3, permeability testing indicates it is closed and tight.

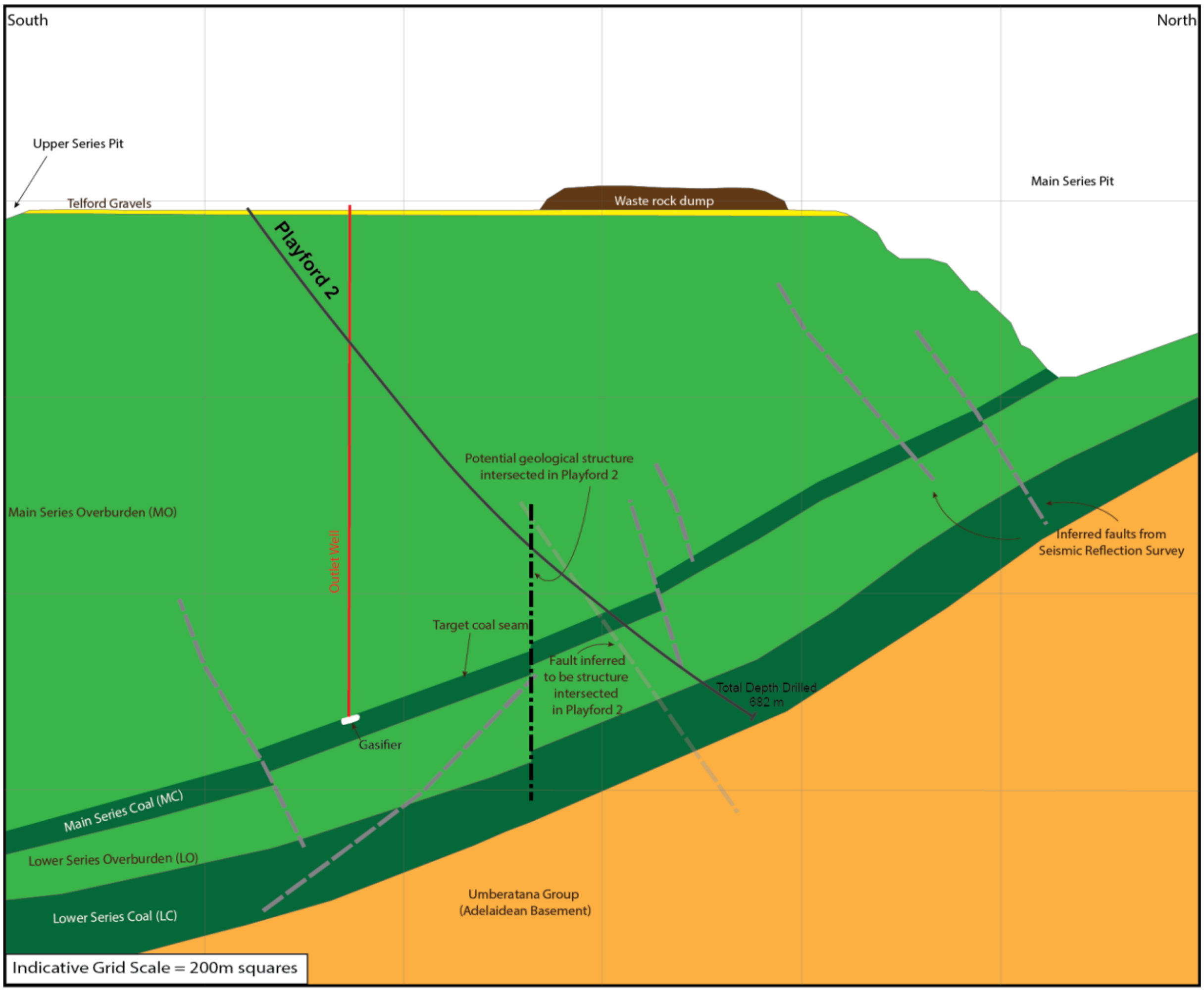

Figure 4. Schematic cross section through the demonstration plant gasifier location with drill hole Playford 2, the location of the structure it intersected and potential interpreted faults projected from the 1978 seismic line near drill hole Playford 5, located approximately 500 m to the west.

4.2 Ground Subsidence

The nature and extent of potential subsidence at the ground surface depends on the size, shape and depth of the gasifier chamber and the properties of the roof rocks.

The underground chamber formed by demonstration plant operation is anticipated to comprise a generally teardrop or pear-shaped structure (Figure 2) measuring:

- approximately 30 m long by 30 m wide with a tapered end profile depending on the position of the inlet and outlet wells; and
- approximately 15 m high, and assumed to comprise (for assessment purposes) the full thickness of the coal seam (12 m) and 1 m of the floor and 2 m of the roof due to heat effects and or partial gasification.

The final shape of the chamber will be influenced by factors including the rate and direction of the gasification reactions (controlled by the rate of air injection through the inlet well), geometry and structural control of the coal seam and the geotechnical nature of the roof and floor of the gasifier. The various processes which take place within a gasifier are complex and dynamic and are likely to yield an underground chamber with an irregular shaped cross section and plan.

For the purpose of providing an assessment of risk associated with underground deformations and ground subsidence, estimates have been considered based on gasifier extraction of the target coal seam across a 30 m x 30 m seam area, full extraction of a 12m thick coal seam and (say) an additional 3m associated with gasification of the coal seam floor and roof, yielding a 15m height gasifier chamber. This extent of coal extraction is considered to be conservative, because the final geometry of the gasifier will likely comprise an asymmetric and tear drop shaped structure similar to that shown by Figure 1, rather than a block geometry. Corrections for the attitude (dip) of the coal seam have not been applied at this stage.

Loss of support to the gasifier roof as a result of the gasification processes will result in progressive flexure of the roof strata leading to fracturing of the rock, rock joint opening and bedding surface flexure / separation, leading to sagging and caving of the coal seam roof strata. The dimensions of this zone are in addition to the dimensions of the demonstration stage gasifier. Estimates of the extent of the resulting caved zone and overlying zone of fractured and deforming rock strata above the gasifier can be made using guideline assessment methods based on coal seam extraction panel width and also coal seam panel length.

Holla and Buizen (1991), in Mine Subsidence Engineering Consultants (2007) describe that based on a coal seam panel width of 30 m, the overall height of the combined collapsed and fractured zones could extend to a height above the coal seam of 60 m (twice the coal seam panel width). Forster (1995) in Mine Subsidence Engineering Consultants (2007) note that the maximum height of the caved zone could extend to a height above the coal seam of 75 m (around five times the coal seam height). We note that for the gasifier situation, the panel width to depth ratio is quite low, and the maximum coal seam height of 15 m would be expected to be more much more localized / asymmetric compared to 30 m by 30 m “block” shaped void.

Based on the estimates described above, ground surface subsidence is not expected and the height of overburden that may be expected to be affected by fluid / gas associated with operation of the gasifier (via rock fracturing, rock joint opening and bedding flexure / separation) would likely be in the order of 60 m to 75 m (Figure 5). Associated (ground surface subsidence) risks in the context of the demonstration plant gasifier at a depth of over 500 m and based on the assessment method described above are not currently assessed as significant.

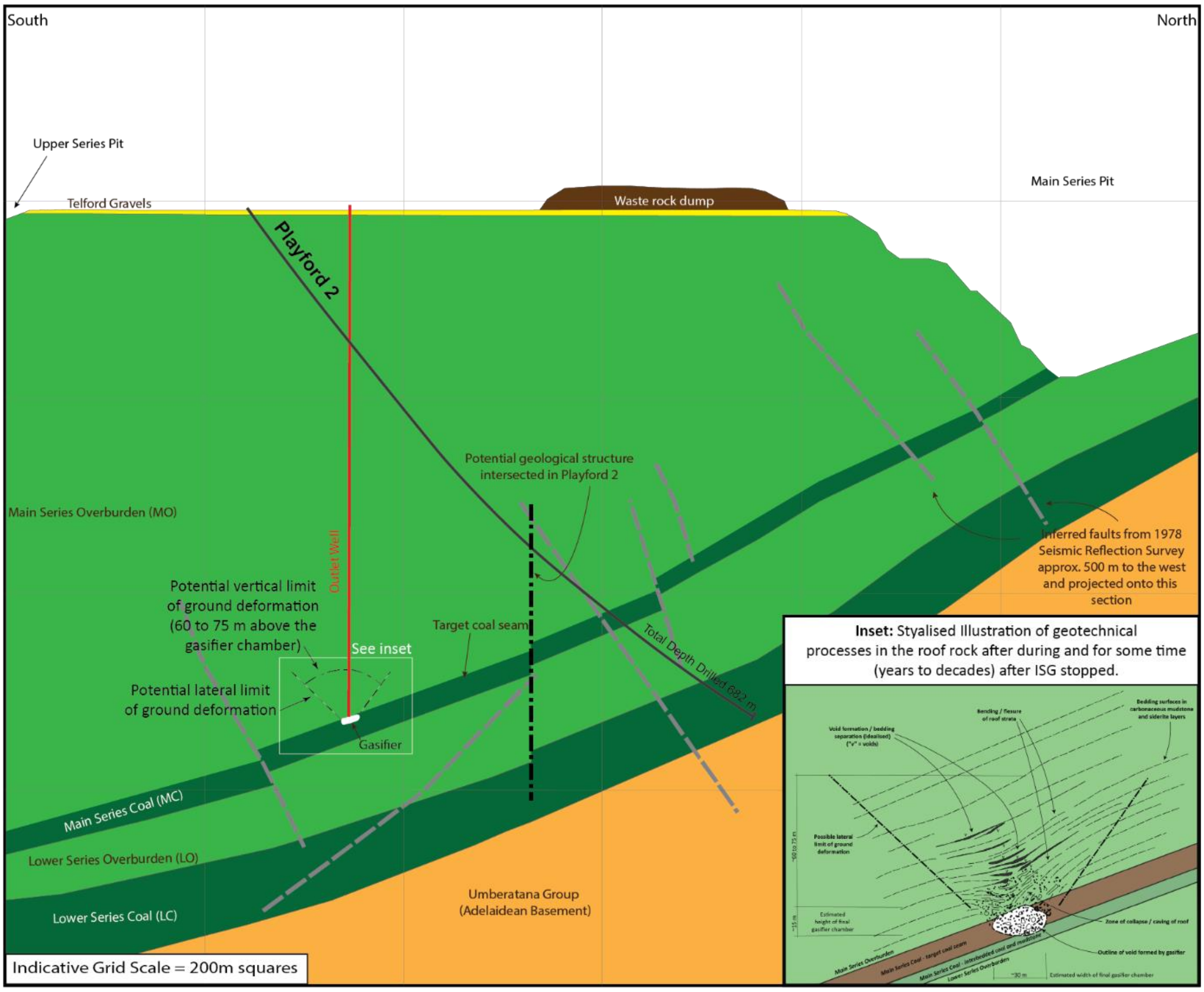

Figure 5. Illustration of the potential extent of fracturing / caving after the gasifier chamber forms.

4.3 Overburden Performance due to Gasifier Void Development

The Main Series Overburden (gasifier roof), Main Series Coal (gasifier chamber and floor) and Lower Series Overburden (gasifier sub-floor) geological units are assessed to have a low permeability and are considered to behave as aquitards. While water-bearing, they have limited ability to transmit fluids (water or gas). The Main Series Coal and the coal layers in the stratigraphic interval (approximately 8m thickness) below the coal seam have a slightly higher (factor of two or three) rock mass permeability compared to the Main Series Overburden. These geological units are considered to behave as continuous, low permeability groundwater systems.

Hydraulic connections will develop between the Main Series Coal and the Main Series Overburden within the extent of the gasifier chamber roof fracture zone (Figure 5). An increase in permeability above the coal seam is expected to be constrained within this zone because the Main Series Overburden surrounding the fracture zone is expected to remain undisturbed.

Assuming that existing migration pathways for gas or fluids do not connect with the fractured zone above the demonstration stage gasifier, it is unlikely that there is an increased risk of developing connections with the ground surface.

As illustrated in Figure 5, drill hole Playford 2 identified no geological structures above the gasifier with the potential to be fluid flow pathways. Structures observed in drill hole Playford 5 and drill hole Playford 2 were closed and tight. This was confirmed by permeability testing of the structure identified in drill hole Playford 2.

4.4 In Situ Ground Stress

In situ ground stress was measured in drill hole Playford 5 by geotechnical specialists Sigra Pty. Ltd. using the overcoring technique between drilled drill hole depths of 482 m and 546 m. IST tests were completed in the Main Series Overburden mudstone and the Lower Series Overburden mudstone (stratigraphic units above and below the Main Series Coal). IST tests were not undertaken in the Main Series Coal seam. The aim of the IST work was to assess the ground stress conditions in the mudstone rock which would form the roof and floor of the potential gasifier. The testing was undertaken to determine if any significant residual tectonic stress could be detected and associated with compressional or extensional development of the coal basin and further, whether a dominant horizontal stress (if detected) could influence the geometry or direction of development of the gasifier.

Eight IST tests in drill hole Playford 5 were attempted, resulting in four successful tests and four unsuccessful tests. The unsuccessful tests were determined to be a function of the ability to drill a suitable geometry pilot hole. This was assessed to be due to layers of harder siderite mineral contamination aligned parallel to the mudstone bedding / fabric, thereby presenting as alternating hard and soft intervals and formation of an unsuitable profile pilot hole (affecting suitable realignment of the pins on the IST tool).

The four successful tests yielded good results and provided the following estimates of in situ stress conditions in the lower part of drill hole Playford 5 in the Main Series Overburden mudstone and the Lower Series Overburden mudstone:

- a major horizontal stress ranging between 3.4 MPa and 4.6 MPa, oriented towards 050 degrees (true north); and
- a minor horizontal stress ranging between 3.1 MPa and 3.5 MPa, oriented towards 140 degrees (true north).

The results of the four successful IST tests indicate that:

- a relatively consistent (orientation and magnitude) horizontal stress is present within the Main Series Overburden mudstone and the Lower Series Overburden mudstone;
- the difference between major and minor horizontal principal stress is not overly significant;
- the major and minor horizontal stress is of a generally low magnitude; and
- the vertical (overburden) stress is approximately twice the value of the major horizontal stress.

This suggests that vertical stress will govern / influence in the development of the underground void. Further, there does not appear to be a dominant residual horizontal tectonic stress associated with compressional (or extensional) development of the coal basin, because the measured major and minor horizontal principal stresses are relatively similar and are of a low magnitude.

It should be emphasised that these results are from drill hole Playford 5 and are appropriate for a previously assessed gasifier site located 500 m to the west of the current demonstration plant.

4.5 Formation Integrity Testing

In order to confirm that the proposed operating pressures of the process will not fracture the ground above and adjacent to the gasifier, assessment of the formation materials (in accordance with conventional petroleum reservoir methods and techniques) was considered appropriate.

Through discussions with the regulatory body, it was considered that Diagnostic Fracture Injection Testing (DFIT) be completed in two (2) locations in drill hole Playford 2. These tests provide sufficient pressure to induce a small fracture, which extends only a few tens of centimetres from the wall of the drill hole, to determine the pressure at which the rock will fail (creating a fracture) and then the pressure at which that fracture will close. These tests are completed in holes that will not be used in the demonstration and will be grouted to surface.

Analysis of the data has indicated that the following parameters apply for the test completed at a depth similar to that of the proposed gasifier (433.29 m to 436.60 m) as shown in Table 3.

Table 3: Fracture Initiation and Closure pressures from DFIT test at gasifier depth (433.29 m to 436.60 m) (Johnson, 2017).

Parameter	Pounds/Square Inch (PSI)	Bar
Initiation Pressure	1654	114
Sustained Pressure	1275	88
Closure Pressure	1258	87

The proposed operating pressure of the gasifier is 36 Bar. As such, it is considered unlikely that a new fracture will be initiated or an existing fracture would be opened by the proposed process.

The second test was completed between 160.61 m to 165.58 m below ground level and was designed only to assist in determining geotechnical parameters: Poisson's Ratio and Young's Modulus. As this test was completed at a shallower depth, the pressures required to generate a fracture are lower than at the gasifier depth (Table 4). Importantly, the initiation pressure (45 bar) is higher than the proposed operating pressure (36 bar). Additionally, this section of the overburden will not be exposed to the pressures of the gasifier as it will be protected by steel casing cemented into the Main Series Overburden.

Table 4: Fracture Initiation and Closure pressures from DFIT test at gasifier depth (160.61 m to 165.58 m) (Johnson, 2017).

Parameter	Pounds/Square Inch	Bar
Initiation Pressure	659	45
Sustained Pressure	423	29
Closure Pressure	420	29

4.6 Drill hole Breakout (Main Series Coal)

The optical televiewer image for the cored section of drill hole Playford 5 which extended through the Main Series Coal indicated consistent drill hole breakout traces on an orientation of 120 / 300 degrees (true north).

The orientation of drill hole breakout corresponds well with the minor horizontal stress direction measured within the coal seam roof (Main Series Overburden) and floor (Lower Series Overburden) and suggests that there is a possible high ratio between the major and minor ground stress in the Main Series Coal.

While the magnitude of the stresses in the Main Series Coal have not been yet assessed, this aspect is relevant for directionally drilled drill holes and underground cavities and particularly those which are developed within the Main Series Coal.

Two effects considered to be relevant for future technical assessment of the demonstration plant site are drill hole collapse, particularly for in seam drill holes, and underground cavity (gasifier) geometry.

4.7 Thermal Rock Degradation

Gasification reactions typically occur at temperatures between 900° C and 1200° C, but may reach 1500°C (Moran et al., 2013). As the coal and surrounding rocks are heated, thermal expansion induces ground stresses at the perimeter of the gasification chamber and can also affect the strength properties of the surrounding rocks (Camp and White 2015). This process has the potential to mechanically degrade the rock at the margins of the gasifier and produce roof / wall failures within and adjacent to the gasifier chamber.

Heating trials were undertaken on Main Series Overburden (carbonaceous mudstone) core samples recovered from drill hole Playford 5 to assess the temperature performance of the rock strata which overlies the Main Series Coal. The mudstone samples were observed to undergo a significant amount of unconfined delamination at relatively low temperatures (up to 300 degrees C). It was not possible to determine whether the delamination was due to temperature or partial combustion of the shale due to the natural hydrocarbon component within the rock.

Thermal rock degradation of the Main Series Overburden is a current unknown geotechnical risk. While this cannot be quantified at this stage, it will be investigated along with other geotechnical unknowns using data collected prior to and during operation of the demonstration stage gasifier. Excessive thermal degradation of the rock surrounding the gasifier is not considered to present an environmental risk.

4.8 Gasifier Roof / Void Behaviour

Consideration has been given (during the geotechnical work program undertaken in 2016) to develop an understanding of how the coal seam and coal seam roof and floor (Main Series Overburden mudstone and Lower Series Overburden mudstone) will behave in terms of the surrounding rock structure, both during and following the gasification process.

Based on the nature of the geotechnical core recovered from drill hole Playford 5, the mudstone rock mass very limited tensile strength capacity on primary fabric (bedding) to the extent that the rock commences breakdown on bedding / fissile surfaces as soon as the core is removed from the core barrel. Handling of the core requires a considerable amount of care and there is a significant strength anisotropy (axial / diametrical) based on index testing of core recovered from drill hole Playford 5.

The development of new fractures associated with stress release / ground relaxation would (in theory) tend to be perpendicular to the direction of the minor principal stress. Notwithstanding this, the gasifier roof / floor rock has very limited tensile strength and the relatively uniform horizontal stress conditions may suggest that the underground void may preferentially develop in a vertical geometry, rather than along low – angle geometries (which would potentially be influenced by high and non - uniform horizontal stress conditions). This aspect needs to be confirmed by assessment of the ground stress conditions at the demonstration stage gasifier.

4.9 Comparison of Assessment of ISG / UCG at Leigh Creek Coalfield

Golder Associates were engaged to provide a report on the feasibility of UCG at the Leigh Creek Coalfield (Golder 1985) and considered a commercial scale gasifier as described below (compared to LCK operations which propose a demonstration stage gasifier).

It is noted that the Golder study modelled the geotechnical response (cave in and subsidence at the surface) for a hypothetical UCG commercial scale gasifier operated over a 20 year mine life at an average depth of 350 m (14 m thick coal seam) and 500 m wide oriented along the coal seam dip direction (by comparison, the demonstration stage gasifier will be at a depth of 540 m and up to 30 m wide).

Table 5 provides a comparison of the estimated ground surface subsidence between the Golder commercial scale gasifier and the LCK demonstration stage gasifier.

Table 5: Estimated Response to ISG at Leigh Creek Coalfield

Gasifier	Depth	Width	Gasifier height	Calculated roof zone influence	Estimated ground surface subsidence	Estimated mining width at which void closure occurs without ground surface subsidence
2017 LCK ISG Demonstration Gasifier	540 m	30 m	15 m	60 m to 75 m	0 m	810 m
1985 Golder Commercial Scale UCG Gasifier	350 m	500 m	14 m	25 m to 50 m	10 m to 13 m	490 m

Note: Mining width is 1.4 x depth below ground level (Golder, 1985).

Table 5 indicates that the depth and size of the commercial scale gasifier (Golder, 1985) produced significant ground surface subsidence. The LCK demonstration stage gasifier is deeper and much smaller and therefore unlikely to result in ground surface subsidence.

5 Conclusions

Camp and White (2015) provide a summary of attributes of an ideal site for ISG. These site attributes include adequate depth below aquifers, thick and impermeable overlying strata, absence of vertical connectivity, low strata dip angle (5 to 25 degrees), mechanically competent overlying rock and few faults.

The demonstration stage gasifier site meets these ideal site attributes and the recommended site attributes contained in the Independent Scientific Panel report (Moran *et al.,* 2013) as indicated in Table 6.

Table 6: Comparison of demonstration plant site with (Independent Scientific Panel's) recommended site attributes for ISG.

Recommended site attributes for ISG	LCK demonstration plant site	Comments
Coal seam at sufficient depth to ensure that any potential environmental contamination can be demonstrated to have minimal environmental consequences. With deeper coal, there are fewer useable aquifers and, if appropriate sealing horizons are present above the gasification depth, there is a much lower probability of materials (gas or liquid) moving to the surface.	✓	Coal is at depth of several hundred metres (approx. 540 m) with no aquifers above or within 500 m of the gasifier.
Coal seam sufficiently thick to sustain gasification with reasonable likelihood of economic viability.	✓	Coal seam thickness in the order of 12 m and considered suitable for gasification.
Rank of coal should be lignite to non-swelling bituminous coal.	✓	Coal is of sub-bituminous / lignite rank and is suitable for ISG.
Hydraulic head sufficient to contain efficient gasification.	✓	Hydraulic pressure above the coal seam measured to be 490 m and sufficient to contain gasification.
Coal seam capped by impermeable rock.	✓	Coal seam is overlain by 530 m of carbonaceous mudstone, which is an aquitard with low hydraulic conductivity (in the order of 10^{-7} to 10^{-3} m/d).
Target coal located so that there is sufficient thickness between the target coal seam / measure and any valuable aquifer higher up the geological succession.	✓	There are no aquifers above the demonstration plant gasifier.
Sufficiently distant from rivers, lakes, springs and seeps to avoid contamination should chemical escape the cavity.	✓	No rivers, lakes, springs and seeps within 2.5 km of the demonstration plant site.
Absence of faulting or intrusions in the vicinity of the site. This is dependent on the size of the cavity.	✓	Site is located over 100 m from inferred faults to the north and south. Faults do not penetrate the full thickness of the Main Series Overburden or the basement rocks.
Sufficient distance from the nearest town and / or intensive surface infrastructure, e.g., irrigation or feedlots, and areas of significant environmental value, e.g., world heritage forests or wetlands, to avoid contamination should chemicals escape the cavity and to minimise impacts of odours.	✓	Site is over 8 km from Copley and 12 km from Leigh Creek township. The demonstration plant is located within the Leigh Creek Coalfield.

6 References

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Appendix C: Flora and Fauna Information

Table C-1: Plant species recorded in the vicinity of the demonstration plant site, May 2016

Species	Common name
Acacia victoriae ssp. *victoriae*	Elegant Wattle
Atriplex lindleyi ssp.	Baldoo
Atriplex vesicaria	Bladder Saltbush
Brachyscome ciliaris var. *lanuginosa*	Woolly Variable Daisy
Carrichtera annua	Ward's Weed
Cymbopogon ambiguus	Lemon-grass
Lotus cruentus	Red-flower Lotus
Maireana astrotricha	Low Bluebush
Maireana pyramidata	Black Bluebush
Malvastrum americanum var. *americanum*	Malvastrum
Minuria cunninghamii	Bush Minuria
Myoporum montanum	Native Myrtle
Nitraria billardierei	Nitre-bush
Osteocarpum acropterum var. *acropterum*	Tuberculate Bonefruit
Pimelea microcephala ssp. *microcephala*	Shrubby Riceflower
Pterocaulon sphacelatum	Apple-bush
Ptilotus obovatus	Silver Mulla Mulla
Rhagodia spinescens	Spiny Saltbush
Salsola australis	Buckbush
Santalum lanceolatum	Plumbush
Scaevola spinescens	Spiny Fanflower
Sclerolaena decurrens	Green Bindyi
Sclerolaena divaricata	Tangled Bindyi
Sclerolaena limbata	Pearl Bindyi
Senecio lanibracteus	Inland Shrubby Groundsel
Vittadinia sulcata	Furrowed New Holland Daisy

Table C-2: Rare or Threatened species potentially occurring in the vicinity of demonstration plant site

Species	Status		Location / comment
	SA[1]	Cth[2]	
Flora			
Australian Broomrape (*Orobanche cernua* var. *australiana*)	R		Record 4 km S of PEL (Mountain of Light mine), Record 15 km W of PEL (Mt Parry). Herb 15-45 cm, found in dry sandy creek beds.
Bentham's Goodenia (*Goodenia anfracta*)	R		Record 15 km N of PEL (N of Lyndhurst). Perennial herb, occurs in saline or sub-saline conditions.
Blackfruit Blue-bush (*Maireana melanocarpa*)	R		Record 8 km N of PEL (Punch's Rest), 18.5 km NE of PEL (Strzelecki Track). Perennial shrub, found on sandy rises around salt lakes.
Bushy Peppercress (*Lepidium pseudoruderale*)	R		Record (1883) 15 km W of PEL (Mt Parry). Rare annual or ephemeral herb species in semi-arid regions.
Eichler's Saltbush (*Atriplex eichleri*)	R		Record (1917) 12 km N of PEL (Lyndhurst). Small annual to 30 cm tall, usually on heavier soils and associated with drainage lines or floodplains.
Five-wing Bonefruit (*Osteocarpum pentapterum*)	E		Records 15 km W of PEL (Mt Parry). Small perennial shrub. Occurs in heavy soils subject to flooding.
Flinders Ranges Goodenia (*Goodenia saccata*)	R		Record 6.5 km SW of PEL (Aroona Dam). Shrub to 1 m. Found on stony slopes and creek beds in the Flinders Ranges.
Frankenia cupularis	R		Record 15 km N of PEL (N of Lyndhurst). Small sea-heath. Occurs in floodout areas in Lake Eyre region. Prefers saline to semi-saline soils subject to flooding.
Frankenia plicata	V	E	Predicted by EPBC database. Grows in a range of habitats, including on small hillside channels, which take the first run-off after rain (Leigh et al., 1985). Species is found in a wide range of vegetation communities that have good drainage (Neagle, 2002).
Frankenia subteres	R		Records in PEL 650 and north. Small shrub. Grows in rocky drainage lines in Lake Eyre, Flinders Ranges region.
Georgina Gidgee (*Acacia georginae*)	R		Record in PEL 650. Stocky, gnarled or spreading tree 2-7 m high with a dense crown. Most records in far north of SA (low open woodland) and Georgina Basin in Queensland.
Atriplex morrisii	V		Record 12 km N of PEL (Lyndhurst rail line). Branching annual forb. In good seasons may be found in small localised patches in various habitats including rocky hillsides.
Lee's Swainson-pea (*Swainsona leeana*)	R		Record 6.5 km SW of the PEL (Aroona Dam). A small prostrate annual or perennial to 10 cm. Found in the northern Flinders Ranges in South Australia in dry stony soil or clay-loam in tussock grassland, saltbush and mulga woodland.

Species	Status		Location / comment
	SA[1]	Cth[2]	
Murray Swainson-pea *Swainsona murrayana*	V	V	Predicted by EPBC database. Prostrate, ascending to erect perennial herb. Often grows in heavy soils, especially depressions. Grey and brown heavy clay and clay loam soils in bladder saltbush, blackbox and grassland communities.
Sandalwood (*Santalum spicatum*)	V		Record in PEL 650, 8 km W of PEL; Leigh Creek township 6 km S of PEL. Shrub or small tree in woodland or shrubland. Found throughout the arid to semi-arid zone In E of range in SA occurs in clayey soils on stony hillsides and flats in gullies, and along watercourses.
Short-stem Daisy (*Brachyscome eriogona*)	R		Record 4 km S of PEL (Mountain of Light mine). Small ephemeral herb to 25 cm occurring on sandy clay soils to cracking clays in chenopod shrublands on gibber plains or herblands in run-off or floodplain areas
Slender Bell-fruit (*Codonocarpus pyramidalis*)	E	V	Predicted by EPBC database. Record (1938) 12 km N of PEL (Lyndhurst); 24 km NW of PEL (1958). Small tree with scruffy drooping appearance and smooth grey-green bark. Occurs on sandy soils and stony rises and creek banks in the Flinders Ranges.
Wilga (*Geijera parviflora*)	R		Record at Leigh Creek township 6 km S of PEL. Shrub or small tree to 8 m. Usually occurs on areas with calcareous red clay loams, less common on alluvial soils and hillslopes with shallow soils.
Yellow Burr-daisy (*Calotis lappulacea*)	R		Record (1883) 15 km W of PEL (Mt Parry). Perennial herb or undershrub 20-50 cm. Occurs on loamy sand to clay loam red earths. Found in all mainland States.
Birds			
Australasian Darter *(Anhinga novaehollandiae)*	R		Found across most of mainland Australia. Inhabits lakes, rivers, swamps and estuaries.
Australian Painted Snipe *(Rostratula australis)*	V	E, Ma	Predicted by EPBC database. EPBC Act database predicts presence. Inhabits wetlands. No suitable habitat present at the site.
Australasian Shoveler (*Anas rhynchotis*)	R		Records in PEL 650 (retention dam). Nomadic and dispersive across SE and SW Australia. Occurs in wetlands in good years.
Banded Stilt (*Cladorhynchus leucocephalus*)	V		Record in PEL 650 (retention dam). Nomadic and often in dense flocks. Occurs in fresh and saltwater marshes and large ephemeral lakes.
Bluebonnet (*Northiella haematogaster*)	R (ssp.)		Record 14 km W of PEL (Myrtle Springs homestead) Inhabits semi-arid woodlands. Naretha Bluebonnet *N. h. narethae* (which occurs in the Nullarbor region) is listed as Rare; this subspecies would not occur here.
Blue-billed Duck (*Oxyura australis*)	R		Records in PEL 650 (retention dam) and Aroona Dam. Occupies a range of wetlands, relatively sedentary.
Blue-winged Parrot (*Neophema chrysostoma*)	V		Record 11 km E of PEL. Usually seen in grasses in a wide variety of habitats, nests in hollows in eucalypt or stump.

Species	Status		Location / comment
	SA[1]	Cth[2]	
Cattle Egret (*Ardea ibis*)	R	Ma, Mg	Predicted by EPBC database. Inhabits tropical and temperate grasslands, wooded lands and terrestrial wetland and uses shallow, open and fresh wetlands. Records in arid and semi-arid regions are rare.
Chestnut-backed Quailthrush (*Cinclosoma castanotum*)	R (ssp.)		Record 3 km SE of PEL (1900) at Woolly Bore and 19 km E (1925) at Depot Springs. Inhabits casuarina-cypress woodland, mallee woodland, sand-plain hummock grassfields. *C. c. castanotum* (which occurs in the Murray Mallee and Flinders Ranges) is listed as Rare.
Chestnut-breasted Whiteface (*Aphelocephala pectoralis*)	R		Records 12 km N of PEL (Lyndhurst), 13 km W of PEL (Myrtle Springs homestead) Inhabits stony plains.
Common Greenshank (*Tringa nebularia*)		Ma, Mg	Predicted by EPBC database. Sewveral records in the Flinders Ranges. Migratory wader. Found in a wide variety of inland wetlands and lakes and sheltered coastal habitats.
Common Sandpiper (*Actitis hypoleucos*)	R	Ma, Mg	Records in PEL 650 (retention dam). Migratory wader. Widespread in small numbers and found along all coastlines of Australia and in many areas inland.
Elegant Parrot (*Neophema elegans*)	R		Multiple records in PEL 650 (retention dam) and region surrounding the PEL. Occurs in open country and semi-arid scrublands.
Fork-tailed Swift *(Apus pacificus)*		Ma, Mg	Predicted by EPBC database. Known to use many habitat types, including coastal, arid and urban areas, migrating across broad regions of Australia.
Freckled Duck (*Stictonetta naevosa*)	V		Records in PEL 650 (retention dam) Prefers heavily vegetated permanent freshwater swamps, moving to permanent open lakes during drought. Breeds in large swamps created by floods in Bulloo and Lake Eyre Basins.
Glossy Ibis (*Plegadis falcinellus*)	R		Record in PEL 650 (retention dam). Frequents swamps and lakes throughout much of the Australian mainland.
Great Crested Grebe (*Podiceps cristatus*)	R		Records in PEL 650 (retention dam). Found on fresh or saline waters such as lakes and lagoons.
Great Egret (*Ardea alba*)		Ma, Mg	Predicted by EPBC database. Occurs in all states/territories of mainland Australia and in Tasmania. Breeding colonies in Channel Country (NE SA and SW Qld).
Grey Wagtail (*Motacilla cinerea*)		Ma, Mg	Predicted by EPBC database. Included in international agreements but extremely uncommon migrant. Strong association with water, particularly rocky substrates along water courses but also lakes and marshes.
Hooded Robin (*Melanodryas cucullata*)	R (ssp.)		Record 3 km SW Leigh Creek. Found in Eucalypt woodland and mallee and Acacia shrubland. *M. c. cucullata* (which occurs in south-east SA to Port Augusta) is listed as Rare.

Species	Status		Location / comment
	SA[1]	Cth[2]	
Musk Duck (*Biziura lobata*)	R		Records in PEL 650 (retention dam). Found in permanent swamps with dense vegetation from north-west Australia through the south and east to southern Queensland.
Night Parrot (*Pezoporus occidentalis*)	E	E	Predicted by EPBC database. Thought to inhabit *Triodia* grasslands and samphire and chenopod shrublands in arid and semi-arid Australia. Current distribution is possibly limited to western Queensland and the Pilbara but is poorly understood due to difficulty in detection and very limited numbers of sightings.
Painted Finch (*Emblema pictum*)	R		Record S of the PEL (1940). Occurs on spinifex covered stony hills and rocky landscapes across Northern and Central Australia.
Peregrine Falcon (*Falco peregrinus*)	R		Record in PEL 650 (retention dam). Inland and coastal areas, with a preference for heavily timbered and rugged mountainous country. Most of Australia, except central Australia, western SA and Tasmania.
Plains-wanderer (*Pedionomus torquatus*)	E	CE	Predicted by EPBC database. Inhabits sparse, treeless, lowland native grasslands with around 50% bare ground and occasionally in chenopod shrublands (Harrington et al. 1988).
Oriental Plover (*Charadrius veredus*)		Ma, Mg	Predicted by EPBC database. Known to occupy dry plains and semi-arid regions, highly mobile, migrating annually between Mongolia, China, and Australia. Prefers to forage among short grass or on hard stony bare ground (McCrie 1984, Close 1982).
Rainbow Bee-eater *(Merops ornatus)*		Ma, Mg	Predicted by EPBC database. Common migrant from September to April in woodland and timbered plains throughout Australia. Nests in sand banks or sloping sandy soil.
Restless Flycatcher (*Myiagra inquieta*)	R		Record W of the PEL (4 Mile Bore). Inhabits open forests and woodlands. Migrant or nomadic in much of its range.
Slender-billed Thornbill (*Acanthiza iredalei*)	R		Records in PEL 650 (1900, 1910). Inhabits chenopod and samphire shrublands and saline flats around salt lakes.
Thick-billed Grasswren (*Amytornis modestus*)		V	Predicted by EPBC database. Distributed in Northern Territory and catchments of Lake Frome and western Lake Eyre Basin in South Australia. Preferred habitat is chenopod shrublands dominated by Atriplex spp. and Maireana spp., generally on gibber or other hard soils.
Yellow Wagtail *(Motacilla flava)*		Ma, Mg	Predicted by EPBC database. Included in international agreements but extremely uncommon migrant. Mostly well-watered open grasslands and the fringes of wetlands.

Species	Status		Location / comment
	SA[1]	Cth[2]	
Mammals			
Plains Rat (*Pseudomys australis*)	V	V	Predicted by EPBC database. Generally associated with low lying patches of deep cracking clay soils characteristic of drainage depressions and gilgais in stony plains and gentle slopes supporting sparse chenopod shrublands and other ephemeral vegetation after rain.
Yellow-footed Rock-wallaby (*Petrogale xanthopus xanthopus*)	V	V	Predicted by EPBC database. Inhabits rocky outcrops in semi-arid country, ranging from sandstones, limestones and conglomerates in the Flinders Ranges, to granites in the Gawler Ranges and Olary Hills (Copley & Alexander 1997)

1. *South Australian National Parks and Wildlife Act 1972* status: Endangered (E); Vulnerable (V); Rare (R). Subspecies (ssp) indicates that a subspecies is listed under the NPW Act but database records do not identify which subspecies was recorded
2. *Environment Protection and Biodiversity Conservation Act 1999* status: Critically Endangered (CE), Endangered (E); Vulnerable (V); Rare (R), Listed Marine (M), Listed Migratory (Mg)

Database records within approximately 25 km of the PEL have been included in this table

Appendix D: Air Quality Modelling Summary

Overview

Air emissions and air quality impacts from the proposed Leigh Creek Energy in situ gasification demonstration plant have been modelled by Pacific Environment Limited (Pacific Environment 2017). The assessment included dispersion modelling of:

- Standard operations for the in situ gasification demonstration plant with emissions from the thermal oxidiser and on-site generators and compressors
- Emissions from non-routine operations such as purging and venting.

The assessment shows that for the standard operations, with normal gas flows for the thermal oxidiser for destruction of the syngas, compliance with South Australian Environment Protection (Air Quality) Policy 2016 (Air EPP) assessment criteria is demonstrated at surrounding sensitive receptors with no exceedances predicted outside of the PEL 650 boundary.

Non-routine high and low flow venting operations are unlikely to occur, and very unlikely to co-occur with worst dispersion conditions. However, should venting take place in poor dispersion conditions in wind directions towards sensitive receptors, the modelling indicates that odour at receptors can occur. Health-based air quality assessment criteria are not predicted to be exceeded for the venting events.

Assessment Methodology - Standard Operations

Combustion emissions during operation of the demonstration plant were modelled using the CALPUFF dispersion model and used the following data:

- Meteorological data from Leigh Creek Airport
- Thermal oxidiser emissions estimated from the maximum emissions performance guarantees provided by the supplier and flow rates of 10,000 Sm^3/hr
- Air compressor and generator emissions based on maximum diesel consumption estimates provided by Leigh Creek Energy and NPI emission factors for small stationary engines
- Stack details for the thermal oxidiser provided by the supplier and typical stack details for the compressors and generators.

The site location and sensitive receptor locations are shown in Figure D-1.

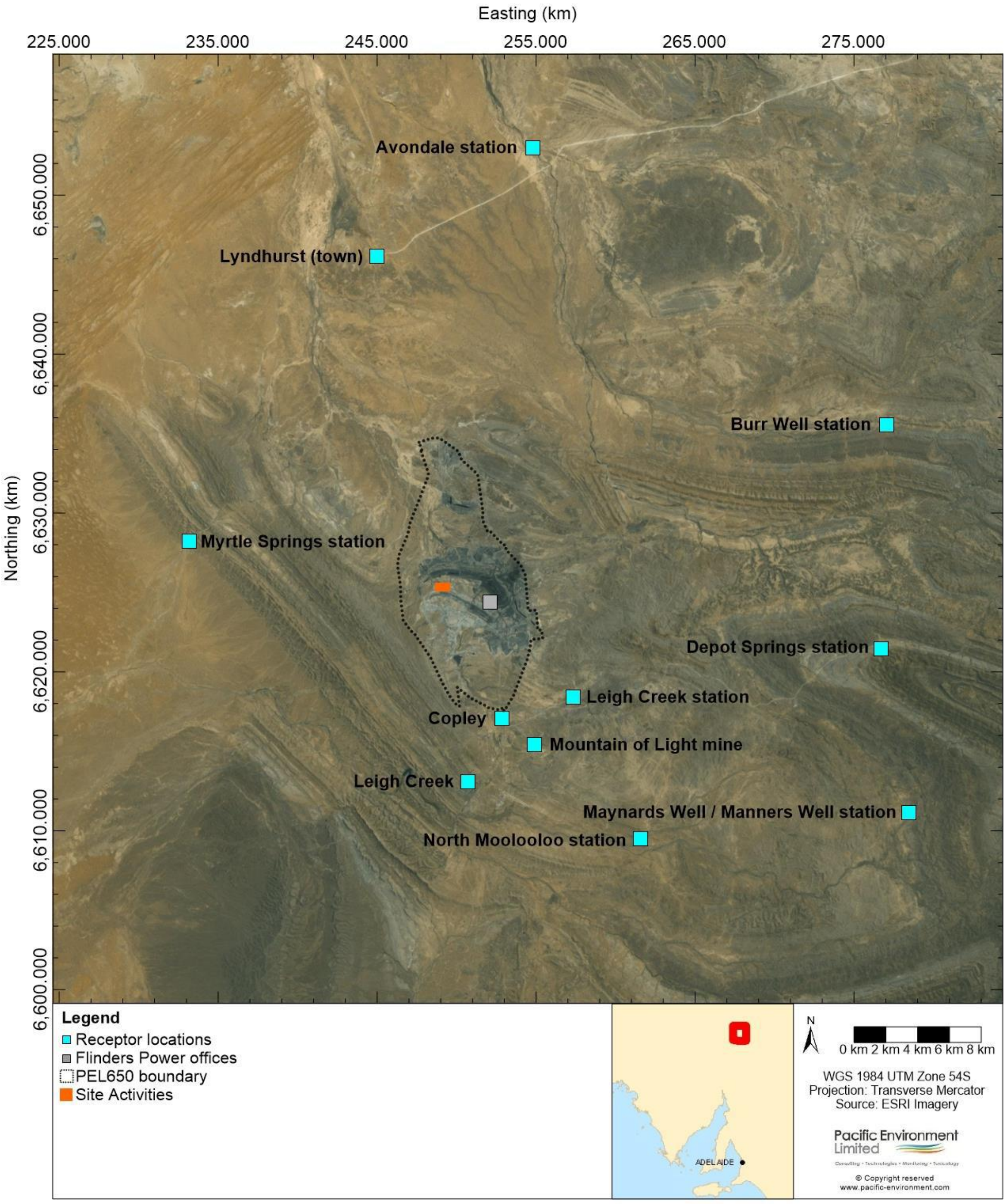

Figure D-1: Site location and PEL 650 with surrounding townships and receptor locations

The emissions modelled included nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur trioxide (SO_3), hydrogen sulphide (H_2S) and particulates (PM_{10}) from the thermal oxidiser, and NO_2, CO, sulphur dioxide (SO_2) and PM_{10} from the compressors and generators. Source parameters and emission rates are provided in Tables D-1 and D-2.

A preliminary site layout and location was used for the modelling. Sensitivity testing was undertaken for differing layouts and locations within an envelope that encompassed potential demonstration plant locations, to ensure that the predicted results at receptors were not sensitive to changes in the layout and location (and were therefore representative of the final location selected).

Predicted ground level concentrations were evaluated against the maximum values specified in the Air EPP. These values are ambient air quality criteria that are used by the EPA in evaluating applications for new licences or works approvals under the Environment Protection Act. Although they are not technically applicable to the project due to its status as a short-term exploration activity, they provide a useful measure of acceptable ground level concentrations.

Table D-1: Source parameters for thermal oxidiser, air compressors and generators

Source	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exhaust Temperature (°C)
Thermal oxidiser [a]	10.1	4.2	0.78 [b]	850 [c]
Primary compressor [d]	2.5	0.2	60	450
Booster compressors [d]	2.5	0.2	60	450
Generators [d]	2.5	0.2	60	450

a. Source: (LCK, 2016A)
b. Average exit velocity calculated based on normal flow rate of the thermal oxidiser – 10,000 Sm^3/hr
c. Minimum design temperature of the thermal oxidiser used in the modelling for conservative assessment
d. Based on assumptions from similar air compressor and generator equipment

Table D-2: Emission rates for thermal oxidiser, air compressors and generators

	Emissions (g/s)					
Source	NO_x	CO	PM_{10}	SO_3 [a]	SO_2 [a]	H_2S [a]
Inlet end generator	0.24	0.053	0.017	-	0.000057	-
Primary compressors [b]	2.0	0.45	0.14	-	0.00048	-
Booster compressors [c]	0.60	0.13	0.043	-	0.00014	-
Outlet end generator	0.80	0.18	0.057	-	0.00019	-
Thermal oxidiser	0.18	1.8	0.003	0.02	-	0.0035

a. Emissions for these pollutants were not available.
b. 4 units in total
c. 3 units in total

<u>Modelling Results - Standard Operations</u>

The dispersion modelling indicated that predicted maximum ground level concentrations were below the maximum values established in the Air EPP at all sensitive receptors and all locations outside PEL 650.

In close proximity to the demonstration plant (within PEL 650 and the mine site), the model predicted minor exceedances of Air EPP criteria for NO_2. Importantly, the predicted maximum levels are within Safe Work Australia exposure standards, which are more relevant than the Air EPP criteria in these locations. Maximum levels of H_2S were also predicted to be above odour criteria established in the Air EPP at some locations within PEL 650 and the mine site, indicating that odour would be detectable inside PEL 650 under some conditions.

The main contributors to the 1 hour NO_2 ground level concentrations are the diesel air compressors at the plant inlet. It is noted that the predicted levels of NO_2 were based on very conservative assumptions (e.g. short stack heights and 100% conversion of NO_x to NO_2) and are likely to overestimate predicted maximum concentrations (the conversion ratio would be much lower, approximately 10%, in which case NO_2 would be within Air EPP criteria).

Analysis undertaken to address the sensitivity of the modelling results to moving the plant location approximately 500 m to the east of the modelled location indicated that the outcome of the assessment would be similar (i.e. no significant change). In such situations with large distances to receptors, variations in predicted ground level concentrations are typically minor due to site layout changes.

Results of air quality modelling of combustion emissions are shown in Table D-3.

Table D-3: Maximum predicted ground level concentrations from combustion emissions (**bold** text indicates predicted maximum above Air EPP criteria).

				Maximum Predicted Concentration (mg/m^3)		
Pollutant	**Classification**	**Assessment Criteria (mg/m^3)**	**Averaging Period**	**On the Grid**	**At Copley**	**At Copley % of Criteria**
NO_2	Toxicity	0.25	1 hour	**1.69**[c]	0.052	21%
NO_2	Toxicity	0.06	Annual	0.041[c]	0.00012	0.2%
CO	Toxicity	31.24	1 hour	0.37	0.012	<0.1%
CO	Toxicity	11.25	8 hours	0.27	0.0060	0.1%
PM_{10}	Toxicity	0.05	24 hour	0.046[d]	0.00071	1%
SO_2 [a]	Toxicity	0.57	1 hour	0.00040	0.000012	<0.1%
SO_2 [a]	Toxicity	0.23	24 hours	0.00015	0.00000021	<0.1%
SO_2 [a]	Toxicity	0.06	Annual	0.0000098	0.000000028	<0.1%
H_2SO_4 [b]	Toxicity	0.036	3 minutes	0.0024	0.000048	0.1%
H_2S [b]	Odour	0.00015	3 minutes	**0.00038**	0.0000093	6%
H_2S [b]	Toxicity	0.51	3 minutes	0.00038	0.0000093	<0.1%

a. Air compressors and generators only
b. Thermal oxidiser emissions only
c. Excluding background concentration. The 70th percentile and annual average background concentration for Elizabeth (for 2010) were 0.008 mg/m^3.
d. Excluding background concentration

Results of air quality modelling of combustion emissions for NO_2 (assessed against health-based criteria) and H_2S (assessed against odour criteria) are shown in Figures D-2 and D-3. To explain what the contour plots show:

- The contours as presented in the plots are drawn from the maximum predicted ground level concentrations at all receptor locations across the modelling domain for the entire assessment period.
- The contour plots show the maximum ground level concentrations as they are predicted to occur at any time throughout the modelling period (12 months) and not the worst-case conditions at any point in time. The footprint impact area at any point in time when a maximum ground level concentration occurs is typically much smaller and typically plume shaped downwind from the source location.

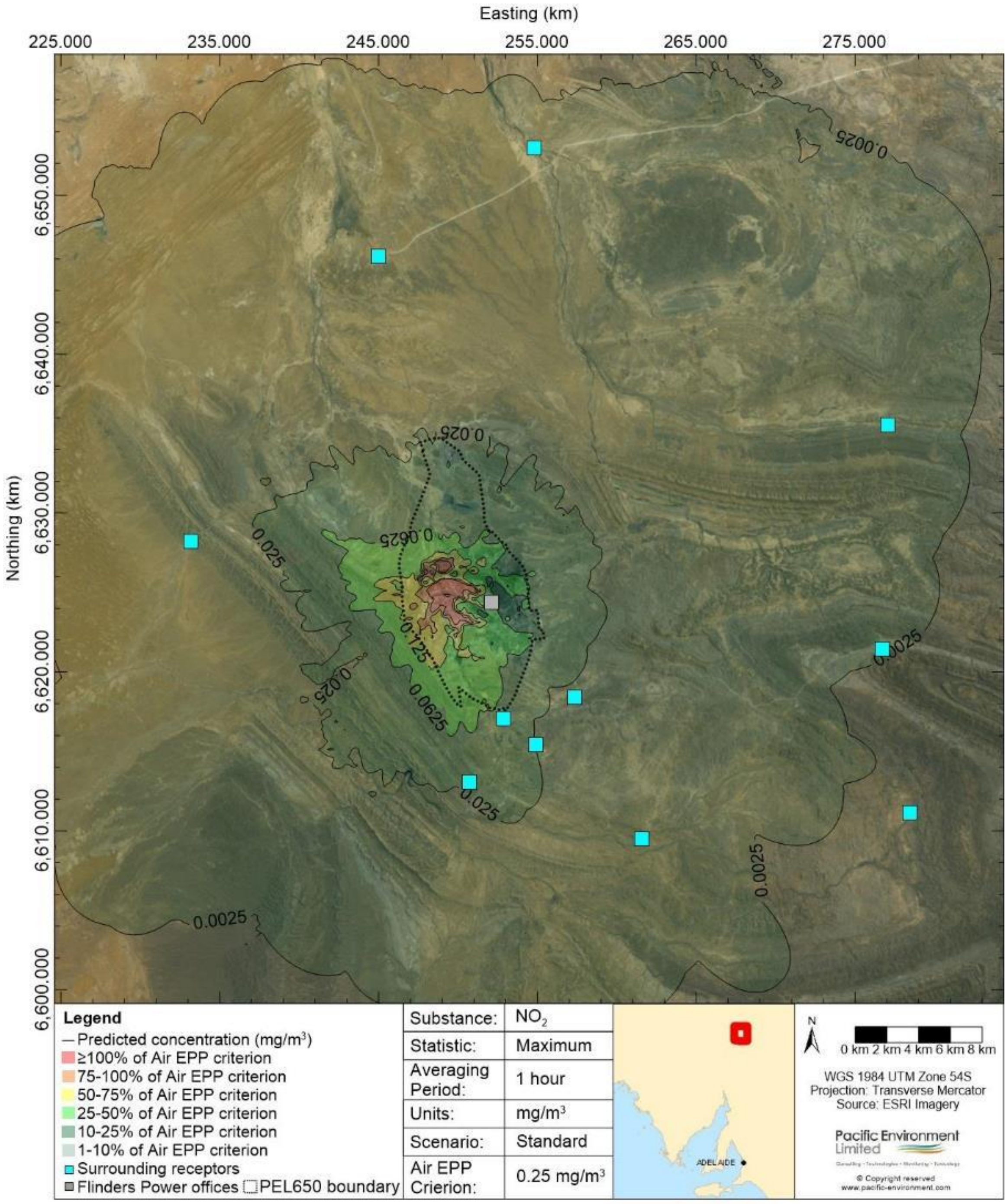

Figure D-2: Contour plot for maximum 1 hour average NO_2 concentrations from combustion emissions. Red shading indicates predicted maximum above Air EPP criteria.

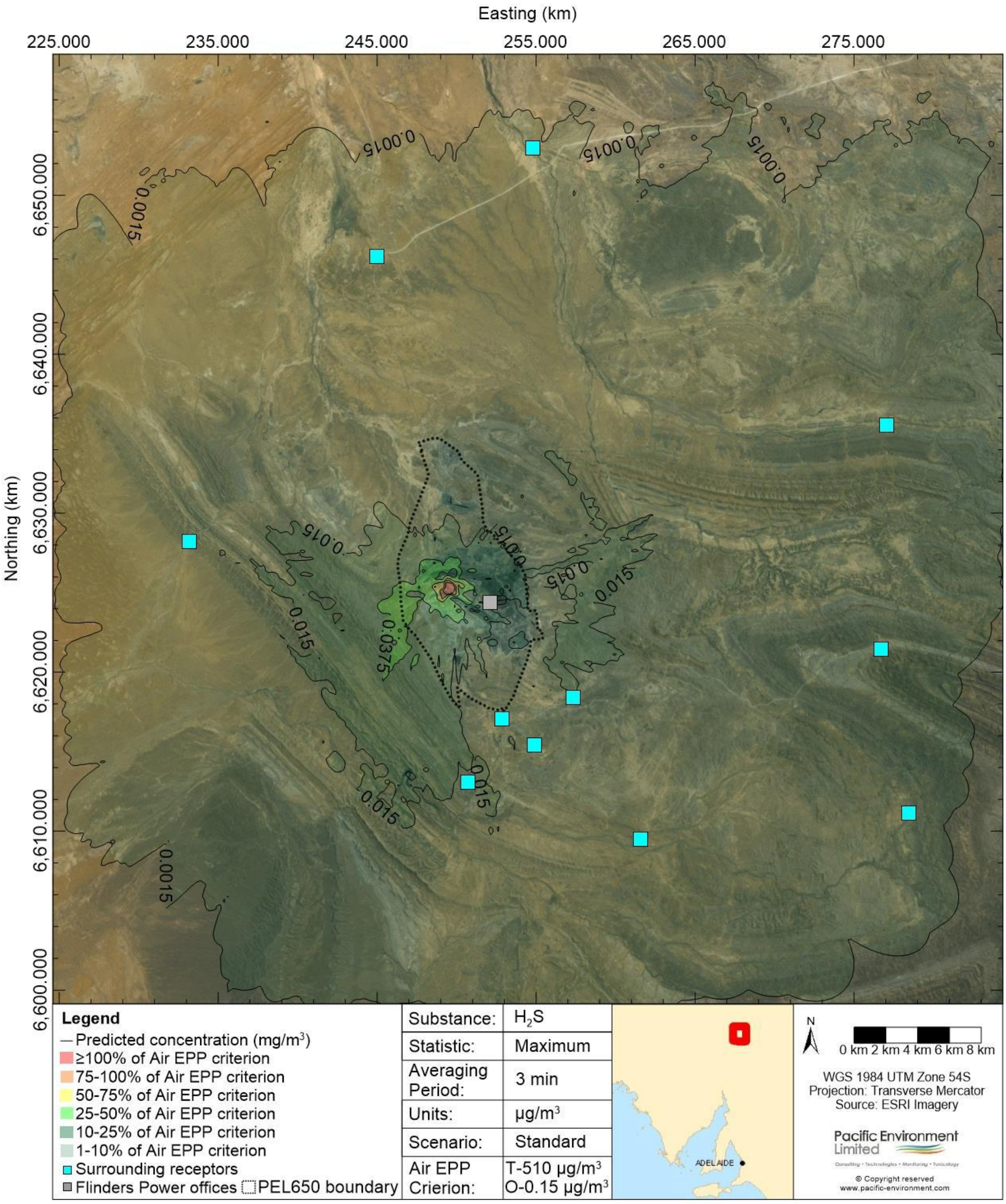

Figure D-3: Contour plot for maximum 3 minute average H_2S concentrations (assessed against odour criteria) from combustion emissions. Red shading indicates predicted maximum above Air EPP odour criteria.

Assessment Methodology - Venting Scenarios

Air quality modelling has also been undertaken to assess the potential air quality impacts from venting during non-routine operating conditions. Three main scenarios that encompass the range of possible operating conditions for the vent described above have been modelled:

- vessel purge venting (venting of small amounts of gas to remove oxygen-rich gas mixtures from vessels or pipework at startup or following maintenance)
- low flow venting (venting of moderate flows for up to several hours)
- high pressure/flow venting (venting of high flows e.g. in an emergency shutdown).

The flow rates and estimated durations of these venting scenarios are summarised in Table D-4. These flow rates and durations are quite conservative, and any actual venting scenarios that could reasonably be expected to occur (e.g. during gasifier initiation, process trips or maintenance) are likely to be much shorter duration (e.g. in the order of 30-60 minutes). Flow for these actual scenarios would be in the order of the purging or low flow venting flows. High pressure/flow venting is highly unlikely to occur but was modelled as a worst case scenario.

Table D-4: Modelled venting scenarios

Scenario	Estimated venting flow rate (Sm^3/hr)	Estimated venting event duration
Vessel purge venting	150	Approx. 1 hour
Low flow venting	5,000	Approx. 6 hours
High pressure/flow venting	36,900	Approx. 48 hours. Full rate at peak pressure that would reduce to ¼ pressure within 24hrs.

The dispersion model CALPUFF was used to model potential air quality impacts, using the model setup described above for standard operations. Emission rates and stack parameters used in the modelling are summarised in Table D-5 and Table D-6. Emissions of H_2S and CO were assessed for the venting scenarios, as all other pollutants are expected to be present either in only trace levels within the purging gas or not listed in the Air EPP as relevant for assessment (e.g. methane, ethane) (see Section 3.8.2 in Main Report).

Modelling of venting was initially undertaken assuming continuous emissions from the vent stack, at the flow rates outlined in Table D-4. This is a very conservative assumption and does not provide a realistic assessment for infrequent and short-term venting emissions, however it does provide an understanding of where venting could potentially result in impacts under all possible conditions at any time of year. To provide sensitivity analysis of the results, two hour duration, high flowrate emission events were also modelled using a release on each day of the year at the time of day (late afternoon) when initial modelling runs indicated that higher concentrations at the nearest receptor (Copley) was most likely.

Table D-5: Source parameters for purge venting, low flow venting and high pressure/flow venting scenarios

Parameter	Units	Purge venting	Low flow venting	High flow venting
Gas design/peal flow rate	Sm^3/hr	150	5000	39,600
Exhaust temperature	°C	20 (ambient)	50	50
Exit velocity	m/s	0.9	33	324[a]
Stack height	m	9	9	9
Stack diameter	m	0.25	0.25	0.25

a. Extremely high discharge velocity due to release of 40 bar of well pressure

Table D-6: Emission rates for purge venting, low flow venting and high pressure/flow venting scenarios

	Emission Rate (g/s)			
Pollutant	Gas Composition	Purge Venting	Low Flow Venting	High flow venting
CO	11%	5.64	188	1,367
H_2S	0.03%	0.02	0.63	4.67

Modelling Results - Venting Scenarios

The dispersion modelling indicated that for all venting scenarios, predicted maximum ground level concentrations for all criteria except odour were below the maximum values established in the Air EPP at all sensitive receptors and all locations outside PEL 650.

This means that venting is not predicted to result in a health risk in Copley or any other receptor locations, regardless of the time of day or weather conditions during venting.

The modelling predicted that for high and low flow venting scenarios, levels of H_2S could exceed Air EPP odour criteria at any receptor location, depending on weather conditions and wind direction. Predicted maximum H_2S[16] concentrations at receptors are less than 4% of the health-based criteria, so do not represent a health risk, however odour would be detectable at receptors if venting occurred under certain conditions.

The sensitivity analysis of two-hour venting scenarios (for the high flow venting scenario at the worst-case time of day for impacts at Copley) indicated that odour was predicted above the Air EPP odour criterion for less than 10% of the total number of hours that venting was occurring in the modelling. This means that if non-routine venting occurred, and if it occurred at the worst time of day for impacts, there is less than a 1 in 10 chance that odour would then be detectable at Copley.

The vessel purge-venting scenario is unlikely to result in odour at any sensitive receptor.

The model also predicted that the high and low flow venting scenarios could result in exceedance of Air EPP ambient air quality criteria for CO within PEL 650 in close proximity to the demonstration plant, however the predicted maximum levels are within Safe Work Australia exposure standards, which are more relevant than the Air EPP criteria in these locations.

Results of air quality modelling of non-routine venting emissions are shown in Tables D-7 to D-9.

[16] Hydrogen sulphide (H_2S) is a naturally occurring colourless gas which is produced during breakdown of organic materials. It can be released from swamps, sewers, volcanic gases and is produced in the human body in low concentrations.
At low concentrations hydrogen sulphide is not toxic but has a characteristic rotten egg smell.
In South Australia the Air EPP odour criteria for H_2S is very low (at the limit of human detection) and is 0.15 µg/m^3 (3 min average). In other states the odour criteria is higher (in NSW it is 2.9 µg/m^3 (1 hr average) and in QLD it is 7.5 µg/m^3 (30 min average)). These interstate criteria are comparable to the worst-case levels at receptors predicted by the modelling (which range from 2.7 to 17.9 µg/m^3).
Hydrogen Sulphide can be toxic at high concentrations. The health based ambient air quality criteria in SA is 510 µg/m^3. The Safe Work Australia exposure standard is 14,000 µg/m^3 (8 hr average).
Note: Modelling results are reported in mg/m^3 (1 mg/m^3=1000 µg/m^3)

Table D-7: Maximum predicted ground level concentrations for vessel purge venting (**bold** text indicates predicted maximum above Air EPP criteria).

				Maximum Predicted Concentration (mg/m³)		
Pollutant	Classification	Assessment Criteria (mg/m³)	Averaging Period	On the Grid	At Copley	At Copley % of Criteria
CO	Toxicity	31.24	1 hour	3.1	0.013	<0.1%
CO	Toxicity	11.25	8 hours	1.9	0.0039	<0.1%
H_2S	Odour	0.00015	3 minutes	**0.019**	0.000076	51%
H_2S	Toxicity	0.51	3 minutes	0.019	0.000076	<0.1%

Table D-8: Maximum predicted ground level concentrations for high flow venting (**bold** text indicates predicted maximum above Air EPP criteria).

				Maximum Predicted Concentration (mg/m³)		
Pollutant	Classification	Assessment Criteria (mg/m³)	Averaging Period	On the Grid	At Copley	At Copley % of Criteria
CO	Toxicity	31.24	1 hour	**76**	2.0	6%
CO	Toxicity	11.25	8 hours	**14.6**	0.5	4%
H_2S	Odour	0.00015	3 minutes	**0.47**	0.013	>100%
H_2S	Toxicity	0.51	3 minutes	0.47	0.013	3%

Table D-9: Maximum predicted ground level concentrations for low flow venting (**bold** text indicates predicted maximum above Air EPP criteria).

				Maximum Predicted Concentration (mg/m³)		
Pollutant	Classification	Assessment Criteria (mg/m³)	Averaging Period	On the Grid	At Copley	At Copley % of Criteria
CO	Toxicity	31.24	1 hour	**37.3**	0.9	3%
CO	Toxicity	11.25	8 hours	**32.6**	0.5	4%
H_2S	Odour	0.00015	3 minutes	**0.227**	0.0053	>100%
H_2S	Toxicity	0.51	3 minutes	0.227	0.0053	1%

Appendix E: Summary of Public Consultation Submissions and Responses

#	Topic	Public Submission #	Summary of the submissions	Response
1	**General Opposition**			
	Opposition without specific issue	4, 6, 7, 13, 14, 21, 22, 24, 30, 32, 34, 35, 36, 37, 39, 57	A number of submissions were received stating general opposition to the proposed project without providing a specific reason or question, such as "I write to submit my view against the underground coal gasification trial project at Leigh Creek".	LCK acknowledges these submissions and as outlined in Section 7 of the EIR will continue to provide opportunities for engagement and communications for all stakeholders. LCK notes that in situ gasification, either by exploration or production, is regulated by the PGE Act and Regulations, and will develop the project within this legislative framework. In addition, LCK recognises that excellence in environmental management is essential to the success of the proposed project. Environmental objectives for the proposed activities have been developed in the accompanying SEO (LCK 2017). These objectives have been designed to provide a clear guide for the management of environmental issues.
2	**General Support**			
	Support without specific issue	71	A number of submissions were received stating their support for the project based on the appropriate site location for providing the project with essential infrastructure, whilst potentially being a supplier to other resource projects. In particular, submissions considered the proposed project would be of economic benefit to the local area, the region and the State, potentially providing employment and energy security.	LCK also notes that the proposed project may also provide an increased understanding of the water, air, fauna and flora of the region and Aboriginal heritage aspects of the region (in collaboration with the Traditional Owners).
	Site selection: the Leigh Creek coal resource is technically suitable for ISG demonstration	45, 51, 52, 54, 59, 60, 62, 67, 70, 72, 77, 79, 83, 85, 89		
	Site location: the Leigh Creek region is well serviced by local infrastructure and services	52, 53, 59, 60, 67, 70, 84, 89, 90		
	Regional location: project success at Leigh Creek may be an enabling project for other future resource projects in South Australia	52, 59, 60, 67, 74, 90		
	Environmental assessment: LCK has undertaken a thorough investigative process for potential environmental impact	51, 52, 53, 54, 55, 59, 60, 62, 65, 66, 67, 75, 77, 83, 84, 89, 90		
	Employment opportunities: the people of the Leigh Creek region will have both direct and indirect employment opportunities during the proposed demonstration and any future commercial development	45, 51, 52, 53, 54, 55, 59, 60, 62, 63, 65, 66, 67, 69, 70, 72, 74, 75, 77, 79, 83, 90, 92, 93		
	Economic benefits: the potential to develop a long term, large scale commercial project with significant positive impacts for the economy	45, 51, 52, 53, 54, 55, 59, 60, 61, 62, 63, 66, 67, 69, 70, 72, 73, 74, 75, 77, 79, 83, 84, 85, 90, 92, 93		
	Energy security: an opportunity to unlock a significant and stranded energy resource in a state that is short of energy	45, 52, 53, 55, 59, 60, 61, 62, 65, 66, 67, 72, 73, 75, 77, 89, 90, 92		
	Continued use of an existing resource	64, 66, 73, 77, 84, 85		
3	**Aboriginal heritage**			
	General opposition to project	10, 49, 82	In their submission ATLA states opposition to the project on a number of grounds, primarily in the area of protection of Aboriginal heritage, as well as native title and environmental.	A submission was received from the Adnyamathanha Traditional Lands Association (ATLA) in relation to the proposed demonstration project. In their submission ATLA states opposition to the project on a number of grounds including protection of Aboriginal heritage, native title issues, environmental impacts, and application of the Petroleum and Geothermal Energy Act to ISG in these circumstances. LCK acknowledges the significance of the Leigh Creek area in the context of the Yurlu Ngukandanha mura, and the disturbance to the mura from historical coal mining operations. LCK is committed to conducting its operations in accordance with the requirements of the Aboriginal Heritage Act 1988 and will continue to engage with ATLA to build a co-operative and mutually beneficial relationship with the Traditional Owners of the region. Native title matters in relation to the PEL are issues to be addressed between ATLA and the South Australian Government and are outside the scope of this EIR. These comments have been deferred to the government.
	Disturbance to Aboriginal heritage	76, 82		
	Native title	82		
	Definition of ISG and application of the PGE Act	81, 82		
4	**UCG projects in other jurisdictions**			
	General opposition based on media (newspaper/tv/others)	1, 2, 5, 12, 18, 22, 31, 43, 44, 46, 48, 86, 87, 88	A significant number of submissions raised issues relating to environmental impacts caused by a number of UCG trials undertaken in Queensland, particularly in relation to impacts to groundwater. Comments were also provided regarding the Queensland Government decision in 2017 to no longer permit UCG projects in Queensland. A small number of comments also raised the issue of 'fracking'. One submission commented on the status of UCG in Scotland.	Section 3.12 notes that the LCK demonstration plant project will apply learnings from previous ISG projects to ensure that environmental risks are identified and appropriately managed, and that the project does not result in significant adverse impacts. As noted in Section 3.12, the project will follow the recommendations of the Independent Scientific Panel (Moran et al. 2013) and other recently published information (e.g. Hyder 2012, Camp and White 2015, Camp 2017). All publicly available results and reports of recent pilot projects in Queensland (including the successfully operated and decommissioned Carbon Energy project) have also been reviewed by LCK personnel, and learnings have been incorporated into the design of this project. As noted in Section 3.12, factors that have been raised as issues in some of the Queensland trials (e.g. shallow depth of coals, sensitive land use and presence of aquifers with beneficial uses) do not occur at the Leigh Creek site and techniques that have been raised as potentially problematic in some Queensland pilots, such as hydraulic fracturing of the coals will not be used for this project. As noted in Section 3.1.5, the Carbon Energy pilot in Queensland did meet the recommended requirements of the Independent Scientific Panel, and demonstrated safe and effective decommissioning of the pilot panel (Garrett 2016). LCK are following Carbon Energy's management and operating philosophy which includes a robust, science and risk based approach to project development, and open and honest dialogue with all stakeholders. ISG in South Australia, either by exploration or production, is legally governed by the PGE Act and Regulations, and LCK is committed to developing the project within this legislative framework.
	Environmental impacts	1, 2, 3, 8, 11, 12, 16, 17, 18, 19, 23, 28, 29, 31, 42, 43, 44, 46, 47, 48, 50, 56, 88, 91, 94		
	Hydraulic fracturing (fracking)	56		
	Ban on ISG	2, 3, 10, 17, 30, 31, 43, 48, 81, 86, 91, 94		
	QLD pilot trials in general	12, 43,81, 87, 97, 91, 94		
	UCG in Scotland	94		

#	Topic	Public Submission #	Summary of the submissions	Response
5	**Reliance on Fossil Fuels and Renewable Energy**			
	General opposition to fossil fuel projects	8, 17, 23, 27, 40, 41, 76	A number of submissions opposed the proposed project because of the respondent's desire for a reduced reliance on fossil fuels and increased reliance on renewable energy.	As stated in Section 3.13, developing suitable strategies for management of greenhouse gases, particularly carbon dioxide, will be an important element in planning for any future commercial-scale ISG development. A key outcome from the demonstration plant is an understanding of the composition of the gases produced, their volumes, temperature, pressure and flowrates. The information developed on carbon dioxide production will allow LCK to identify the most appropriate mitigation strategies and carbon dioxide capture technology for any future development.
	Global warming/greenhouse gas emissions	27, 38, 39		
	Support renewable energy	2, 8, 9, 11, 15, 16, 17, 19, 20, 23, 25, 26, 27, 29, 31, 33, 37, 38, 39, 41, 42, 44, 47, 48, 91, 94		
6	**Environmental Impacts**			
	General environmental impacts	1, 2, 6, 11, 31,33	A number of submissions were received expressing environmental impact concerns, including potential impacts to groundwater quality, biodiversity / ecosystems, soil and geological integrity.	LCK provided a detailed discussion in the EIR (Section 5 Environmental Impact Assessment) of the components of the environment that are potentially impacted by the proposed activities. As outlined in Section 5.2, the risk to groundwater posed by the demonstration plant is low as the gasifier is surrounded by very low permeability aquitards, there are no groundwater receptors present in the Telford Basin and no credible pathways to groundwater receptors.
	Impacts to soil and water	3, 27, 46, 56, 81, 82		
	Impacts to ecosystem/biodiversity	3, 76		
	Impacts to geological structure	91		
	Uncertainty	91		
7	**Experimental Technology and Process**			
	Uncertainty around chemical composition of emissions	46	A number of submissions were received that commented on issues seen as arising from the 'experimental' nature of in situ gasification technology.	A number of submissions were received of a general nature around the uncertainty of in situ gasification technology and issues about chamber collapse and uncontrolled underground fire. The EIR (*Section 3.12 Integration of Learnings from Previous Projects*) notes that approximately one hundred experimental, pilot and demonstration ISG operations have been undertaken globally in the last eighty years. These have shown the process to be technically feasible, and over this time the technology and understanding of the process has continually improved. [illegible]
	Experimental technology	3		
	Risk of chamber collapse	27, 76		
	Known to be dangerous	44		
	Drilling issues	46		
	Issues with extinguishing gasifier	46		

#	Topic	Public Submission #	Summary of the submissions	Response
8	**Adequacy of the Statement of Environmental Objectives**			
	Objective 3 - No loss of gasification products to the surface or subsurface environment via pre-existing drill holes and/or transmissive geological features.	68	Comprehensive survey undertaken across different times to determine the current rate of VOC release, methane and other gases, to establish baseline for comparison. Undertake in a way that describes current rates across sufficient locations to establish understanding of fugitive emissions and well characteristics. Undertake scenario plan to determine feasibility of fire containment, should fault pathways establish and give oxygen to underground fire. Carry out for the trial and projected at full production rates.	Monitoring of gaseous emissions will be undertaken as part of the demonstration project, this will include the installation of near surface monitoring sites which will be sampled, pre, during and at decommissioning as documented in the EIR (*Section 3.10 Monitoring and Data Collection* and Table 3.6). LCK has indicated in the EIR *(Section 3.11.5 Spills and Emergency Response*) that an emergency response plan will be in place. It is documented in the EIR (Section 5.9.3 Explosion or Fire) that an uncontrolled fire in the gasifier and hence adjacent coal is very unlikely and would managed by shutting down the oxygen supply and flooding the chamber with water. The geotechnical assessment has indicated that it is highly unlikely that the project would result in opening up of geological structures (such as faults) to the extent that there would be migration form the chamber. By correlation this would also negate the addition of oxygen from these features.
	Objective 4 - Well integrity is maintained to prevent loss of gasification products to the surface or subsurface environment.	68	Couple identifying need for well integrity with objective for maintaining geological stability and seal to prevent movement and escape pathways from failing.	Maintenance of the well integrity will prevent loss of gasification products to the surface either directly up the well annulus or a combination of well annulus and though fractures in the near surface rock formations. The investigations have indicated that the rock formations above the gasifier are of low hydraulic conductivity and the risk of loss of gasification products is low. The assessment has indicated there were no continuous geological structures that could form fluid low pathways within the area of the gasifier. LCK is of the opinion that the Objectives in the SEO are sufficient to manage and mitigate potential risks.
	Objective 5 - No gasifier induced subsidence measured at the surface.	68	Consider objective against total viability of process in full production (beyond just the trial). If there is sufficient concern that subsidence could as when the site is a few years into full production, then an early 'no' would be in order.	The monitoring proposed to be undertaken and geotechnical information that will be collected from the demonstration will provide data that can be used for detailed design and to assess the potential for subsidence for a commercial facility, which would be subject to additional studies in support of any application for a commercial facility.
	Objective 9 - Avoid the introduction or spread of weeds, plant pathogens or pests (including feral animals).	68	Requires a dedicated resource to ensure that the site and access roads are improving continuously rather than worsening. Weed spraying is not sufficient as total weed and soil management is required.	As documented in the EIR (*Table 5.4*) LCK will implement a weed management plan in consultation with the relevant NRM officer, if required.
	Objective 10 - Air pollution and greenhouse gas emissions reduced to as low as reasonably practical	68	Actions described against this objective are unsatisfactory. Baseline and monitoring of GHG emissions essential. Investigate productive capture and storage of syngas produced. Reporting of GHG emissions described is unacceptable - "Greenhouse gas emissions recorded and reported in accordance with NGER requirements where applicable". Integrate use of an appropriately sized solar power and battery installation to cover operational electricity needs. All scope 1, 2 and 3 emissions associated with this trial should be publicly reported (regardless of any NGER requirements).	The demonstration is part of an exploration program to collect data to assess whether a commercial facility is feasible. The project represents a short duration demonstration with a small footprint and low environmental risk. The comments in relation to carbon capture and storage are considered to be relevant for consideration for a commercial facility and would be informed by the data collected from the demonstration project. Similarly, the proposed reporting requirements are consistent with the requirements for exploration projects under the PGE Act.
9	**Closure and Rehabilitation**			
	Clean up liability (inc financial)	12, 33, 91	Several submissions stated concerns around financial security for potential ongoing liability and remediation.	As a licensee under the PGE Act, LCK is required by Section 75 to have adequate technical and financial resources to ensure compliance with environmental obligations (including the rehabilitation of land adversely affected by regulated activities carried out under the licence).
	Compensation to landholders for cleanup	33		
10	**Other issues**			
	Adequacy of groundwater assessment and connectivity of aquifers	58, 87	During 2017 copies of the EIR and Draft SEO were circulated to stakeholders as part of LCK's stakeholder relations and engagement activities. These issues were raised in a letter to the regulator in December 2017.	The comments and queries relating to groundwater studies undertaken by independent groundwater consultants Australian Water Environments were assessed by LCK, and where necessary additional, clarifying information was included in the EIR (Section 4.7 Hydrogeology and Appendix A Hydrogeological Conceptual Site Model) prior to submission and formal consultation by the regulator.
	Integrity of well casing	58, 87		The queries relating to well integrity were assessed by LCK and additional, clarifying information was included in the EIR (Section 5.2.1 Loss of containment due to loss of well integrity) prior submission and formal consultation by the regulator.
	Seismic and tidal impact on project	58		The queries relating to seismic and tidal impact on the project were assessed by LCK and additional, clarifying information was included in the EIR (Section 4.7 Hydrogeology and Appendix A Hydrogeological Conceptual Site Model) prior submission and formal consultation by the regulator.
	Decommissioning success	58		Statement that 'no successful decommissioning worldwide' of a UCG project is erroneous. The Queensland Chief Scientist Dr Geoff Garrett AO confirmed in July 2016 that the Carbon Energy trial at Bloodwood Creek met the key recommendations of the government appointed Independent Scientific Panel (ISP). The proposed decommissioning methods have been documented in the EIR (Section 3.9 Decommissioning and Rehabilitation) and are consistent with requirements under the PGE Act.
	Location of the demonstration plant and PEL 650 in relation to the town of Copley	58		The information provided in the EIR (Section 4.1 Overview) in relation to the distance of the demonstration site to the town of Copley is considered correct.
	Information on additional investigations	58		Additional geological investigations were undertaken by LCK at the request of the regulator to provide information on fault proximity and nature. The results of the investigation were included in the EIR (Appendix B Geotechnical Assessment) and confirm the expected geological conditions at the proposed demonstration site.

#	Topic	Public Submission #	Summary of the submissions	Response
	Fauna entrapments	68	Publicly report all fauna entrapments. Establish systems to render assistance for any birds or animals found injured on site or injured by vehicles in travel. Turkey nest lined dams should have animal escape mesh or other traction gaining surface materials on all sides on day 1 to prevent the inevitable drownings that occur when such structures are left with slippery sides.	The proposed fauna entrapment management measures are considered acceptable for an exploration project taking into consideration the potential risks. Additional information on fauna entrapment management measures are included in the EIR (*Table 5.4*). As documented in the EIR (*Section 5.5 Flora and Fauna*) the activities will not have a significant impact on fauna populations due to the size and duration of the project components, disturbed environment from past mining activities and distribution of fauna.
	Public and community reporting	68, 87	It is not sufficient for Leigh Creek Energy to just report to Government agencies. On GHG emissions, incidents, fauna entrapments, good news stories and key findings, community should be informed as well.	Reporting requirements are consistent with the requirements for exploration projects under the PGE Act.
	Water allocation	87	Arrangements with SA Water, costing of water usage and anticipated volumes over the lifecycle of the project.	As documented in the EIR (Section 3.11.1 Water Supply/Use) water for injection is expected to be sourced from the existing mine industrial catchment (i.e. the same water used currently to water roads) with potable quality water potentially supplied by a third-party supplier (such as SA Water or others) injected into the outlet well as well as used for cementing of wells. Water will be either trucked to the demonstration plant site and stored on-site in tanks, the capacity of which will be equivalent to approximately two days' supply, or supplied from a pipeline joining the SA Water pipeline feeding the Flinders Power offices.
	Independent hydrologist promised by government and concerns with aquifer pollution	86, 87	Concerned that the hydrology assessment and groundwater modelling done by the proponent is not reliable	All environmental studies and assessments undertaken for inclusion into the EIR and SEO were completed by independent scientist experts with suitable qualifications, experience and high standing reputations in their professions. In particular groundwater (hydrogeological) studies were undertaken by Australian Water Environments, whom have a long involvement with the Leigh Creek Coalfield and an extensive understanding of the hydrogeological conditions of the Telford Basin. Experienced hydrogeologists in the Environment Protection Authority (EPA) and Department of Environment, Water and Natural Resources (DEWNR) will determine the adequacy of groundwater components of the EIR and SEO and will provide comments to the regulator to enable an assessment of the proposed project. EPA and DEWNR would assess whether additional hydrogeological expertise over and above those within their departments is required.
	Air pollution monitoring – baseline study not undertaken	87	Baseline study done at drill site but not at Copley or Leigh Creek	As documented in the EIR (Section 4.10 Air Quality and Appendix D Air Quality Modelling Summary), baseline studies and air quality modelling were undertaken to assess whether the demonstration plant was likely to result in impacts to the environment and nearby receptors (towns and pastoralists). Regular air quality monitoring will occur as documented within the EIR (Section 3.10 Monitoring and Data Collection) and the SEO (Table 1 Environmental Objectives and Assessment Criteria).
	Impact of self-combusting coal fires	87		For spontaneous combustion to occur the coal has to be able to be oxidised, oxygen has to be present and sufficient heat generated to ignite the coal. If the heat is dissipated, the temperature of the coal will not increase to an extent that will lead to ignition. The absence of any one of these elements will result in at least the temporary cessation of burning. In underground coal mines, the primary cause of spontaneous combustion is crushed coal (either left in goaf areas or in highly stressed pillars) that is in contact with a sluggish airflow. Good ventilation will remove heat, preventing a rise in temperature, while extremely poor ventilation will not supply sufficient oxygen to support the process. On surface areas that may be subject to spontaneous combustion are usually associated with the stockpiling of coal, or waste dumps containing rejected coal material, in unconsolidated heaps where oxygen can come into contact with the coal and heat cannot dissipate, and during transportation of the coal. The ISG process involves the introduction of air into the inlet well and use of an initiation source to heat the coal and start the chemical process forming the synthesis gas. The process can be stopped by shutting off the source of oxygen (i.e. the air supply from surface). At the end of the ISG process the air supply is shut off and the process quenched with water. Under these scenarios the chemical reactions forming syngas would cease. With regards to the existing coal waste dumps on the Leigh Creek Coalfield, LCK is not responsible for the rehabilitation and maintenance of the mining operations and any spontaneous combustion that may occur within these activities.
	Use of compressed air and query of other chemical use	87		As documented in the EIR (Section 3.11.4 Fuels and Chemical Storage and Management), the typical chemicals used on site will include fuel (diesel), oils, paint, solvents and corrosion inhibitors. Although the ISG process is a chemical process, no chemicals are introduced other than oxygen from air injection and hydrogen from water injection.
	Waste generation by the process and treatment	87		As documented by the EIR (Section 3.11.3 Waste Management) the range of wastes generated during the proposed operations and their management options are summarised in Table 3 7.

#	Topic	Public Submission #	Summary of the submissions	Response
	Worst case scenario would impact land prices and who is responsible for compensation	87		As documented in the EIR (Section 3 Description of Activities) the demonstration plant is a small-scale and short-term program of 30 to 60 days. LCK has undertaken an environmental risk assessment (Section 5.11 Environmental Risk Assessment Summary) and committed to the best practice recommendations as outlined previously. LCK has adopted the recommendations of the Lawrence Livermore National Centre and the Independent Scientific Panel's recommendations for in best practice in site selection, and in implementing these measures to mitigate and manage risk, LCK are committed to reducing risks to as low as reasonably practicable.
	Clarification sought in the ISG process and difference to fracking	87		As documented in the EIR (Section 3.1 Overview of the ISG Process) in the simplest ISG configuration, two wells are drilled into a coal seam, one for the inlet and the other for the outlet (as shown in Figure 3 1). A combination of horizontal and vertical wells is often used to create a direct linked system. Hydraulic fracturing (fracking), a well stimulation technique in which rock is fractured by a pressurised liquid, will not be used to connect the inlet and outlet wells.
11	**Issues raised outside the scope of the EIR and SEO**			
	Transparency of the process	87		These issues have been recorded and noted by LCK but are are considered to be outside the scope of the EIR and SEO.
	LCK corporate history	87, 94		
	LCK staff history	81, 88, 94		
	Questions directed to government	86		
	No previous regulator experience with this process	91		
	Regulatory framework	27, 86		
	Commercial plant	27		

Appendix F: Summary of Government Agency Consultation Submissions and Responses

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
	Safework SA				
1	Safework SA	EIR p.16	Other Legislation	Applicable legislation also includes: - *Dangerous Substances Act 1979 (SA)* - *Electricity Act 1996 (SA)*	Noted. EIR has been updated.
2	Safework SA	EIR p.23	Compounds directly generated by the ISG process	LCK has a duty to manage and control health and safety risks associated with hazardous chemicals as per requirements of the *Work Health and Safety Act 2012* (SA) and Regulations and the relevant schedules including assessment of Schedule15 hazardous chemicals and thresholds for determination of the regulatory requirement as a Major Hazard Facility.	Noted. The aim of the demonstration plant is to demonstrate the safe production of syngas and liquid condensate by In-Situ Gasification (ISG) of underground coal. Any products from the ISG process will be analysed and promptly disposed of via thermal oxidation. The main chemicals required to be stored on site are: - Water- For process cooling; - Nitrogen- Stored in cylinders for purging and gas inerting; - LPG- Stored in 45kg bottles for cold vent pilot ignition. - Diesel: For air compressors, light vehicles and Thermal Oxidiser supplemental firing. Leigh Creek Energy has undertaken an initial assessment of expected quantities of chemicals on site against the threshold values outlined in the Work Health and Safety Regulations 2012 for a Major Hazard Facility. This assessment has indicated will not be any significant (threshold) quanities of Schedule 15 hazardous chemicals present on site.
3	Safework SA	EIR p23-24 (also pp.26,29)	Containment	LCK 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). - For pressure vessels there is a requirement for design registration and in many instances plant item registration is required. - 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. - 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. - 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.	Noted. Added AS 4041 to Table 3-3 in EIR. Pressure vessels have been designed to AS1210, and Design Registration is complete with Plant Registration undrtaken once installed on site. Noted. All pressure equipment has been designed to recognised standards, either AS1210 or ASME B31.3. Pressure piping has been designed to ASME B31.3. AS 4041 (Section 1.6 Alternative Standards) allows for use of alternative standards, therefore the piping is deemed to comply with AS 4041. A third party inspector will be used on site for inspections as part of the Plant Registration process.
4	Safework SA	EIR p23-24 (also pp.26,29)	Containment	It is noted that: - 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.	Noted. A third party inspector will be used on site for inspections as part of the Plant Registration process.
5	Safework SA	EIR p23-24 (also pp.26,29)	Containment	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. It is noted at Page 34, "The engineering design and Safety in Design (SID) processes will include Hazard and Operability (HAZOP) study, Risk Assessments, Safety Integrity Level (SIL) Analysis, Hazard Construction (HAZCON) study"	Noted These requirements will be adopted/complied with.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
6	Safework SA	EIR p23-24 (also pp.26,29)	Containment	The environment is likely to be highly 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.	Noted. Experience from other QLD projects has shown no corrosion, however management and investigation of corrosion is an integral part of the demonstration plant project.
7	Safework SA	EIR p23-24 (also pp.26,29)	Containment	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 and minimise disruption where sections need to be made available for maintenance, repair or modification.	Each of the section of the demonstration plant are able to be isolated and shut down to allow for maintenance activities. The methodology for the shutdown and isolation of each section is outlined in the system shutdown sections of the respective Area SOPs. The methodology for the (controlled) Isolation of the source of pressure to the gasifier i.e. the injection air system, is outlined in the SOP for operations. This method would be used to isolate the system for maintenance, repair or modification purposes. In addition to the controlled shutdown and isolation of each PCD area, an Emergency Shutdown system (ESD) has also been incorporated into the PCD design.
8	Safework SA	EIR p.27	Leigh Creek Coalfield Location	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. - Risks to health and safety of persons (including the Public) from hazards associated with the "operational complexities" of the proposed ISG Demonstration Plant and the concurrent Mine rehabilitation activities being undertaken must be managed and controlled. - It follows that the PCBU in management and control of the ISG Demonstration Plant, and the Mine Operator (PCBU), 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"). 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, cooperate and co-ordinate activities with all other persons who have a duty in relation to the same matter	Noted. Leigh Creek Energy consults with Flinders Power on an ongoing basis to ensure that both parties' activities and associated risks are appropriately managed and controlled.
9	Safework SA	EIR p. 28	Recommended attributes for ISG Sites; Hydraulic head measured above the coal seam measured at 490 mm	Should the hydraulic head measured above the coal seam be 490 metres?	Yes. Corrected in the EIR.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
10	Safework SA	EIR p.35. pp.140 & 141	Preventative controls and mitigation strategies for the demonstration plants Stakeholder Consultation	LCK has a duty to prepare, maintain and implement an emergency plan. It is noted at Page 140 and 141 "Stakeholder Consultation" that: - There is no evidence of consultation with the primary emergency services organizations' with responsibility for the area in which the ISG Demonstration Plant ("the Plant") is proposed to be located and - Consultation and testing of the Emergency Response Plan with Stakeholders is advised prior to commissioning of the Plant.	LCK has undertaken discussions with the following emergency service providers and ascertained they have the following equipment and capabilities - Leigh Creek Country Fire Service (CFS) and State Emergency Services (SES): A fully equipped Fire appliance including Breathing Apparatus (BA) with HAZMAT and road crash rescue capabilities and trained volunteers. - Leigh Creek South Australian Ambulance Service SAAS: Fully equipped Ambulance and trained volunteers. - Leigh Creek Health Services: Medical clinic staffed by two fulltime, remote area nurses, providing a 24/7 on call service. The Leigh Creek Health service also provides a General Practitioners service once weekly - Leigh Creek South Australian Police (SAPOL): A fulltime, staffed police station - Royal Flying Doctors Service (RFDS): Emergency flights based out of Adelaide and Port Augusta - Hawker Memorial Hospital: Fully operational, and staffed, regional hospital, 156 km south of Leigh Creek, providing both medical and surgical, hospital services - Flinders Power (currently available on site): Volunteer Emergency Response Team, Fully equipped Ambulance, Fully equipped Fire Appliance, HAZMAT Response In addition, LCK provides an auto defibrillator, remote area first aid kits, portable burns kit and portable eyewash station. LCK also has a least one staff member on site, who is trained to Occupational First Aid level (as a minimum) at all times. LCK will continue to liaise with the relevant emergency services providers around the project and implementation of the Emergency Services Plan.
11	Safework SA	EIR pp. 51-52	Existing Environment - Overview	Incorrect - Mining operations include mine rehabilitation which is ongoing and includes: - Use of heavy earthmoving equipment for contouring of excavations and waste rock stock piles and - Spontaneous combustion control. For clarity, currently there is no coal mining operations being undertaken at the Leigh Creek Coalfields	Page 51 indicates that Flinders Power Parnership is currently undertaking closure activities. There is no intention to imply on page 52 that there is no activity at the site. Text has been modified to clarify this.
12	Safework SA	EIR p109	Note 13 at footer	How was the "gasifier releasing stress up to 75m above the gasifier" determined? Noted that the gasifier will not operate at a pressure above 36 bar.	The determination of this value is outlined in Section 4.6.4 and Appendix B.
13	Safework SA	EIR p110	Gasifier chamber growth intersecting potential migration pathway	Noted that "additional roof collapse as a result of temperature generated by the gasifier could potentially reduce the success of gasification but could not feasibly result in chamber growth through 400m of overburden"	Noted.
14	Safework SA	EIR p.118	Dust Generation	Management and control of risk to health and safety of persons regarding exposure to dust would include mitigation of visibility hazards. Dust suppression of unsealed roadways and works would be needed to control these risks.	Noted.
15	Safework SA	EIR p.119	Combustion emissions	- Controls to monitor and withdrawal persons when combustion and odour emissions exceed the exposure standards' would need to be managed. - Compressor diesel combustion engines and the like would need to be adequately located to minimise exposure of persons to diesel particulate matter.	Noted. Air quality modelling does not predict exceedance of Safe Work Australia exposure standards.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
16	Safework SA	EIR p.115	Spills or leaks of produced fluids	Noted that control measures outlined in Section 5.2.1 and 5.9.3 are proposed to be implemented to minimise the risks of explosion or fire hazards 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. 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: o The provision and maintenance of a work environment without risks to health and safety, o The provision and maintenance of safe plant and structures, o The provision and maintenance of safe systems of work and 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.	Noted.
17	Safework SA	EIR p.135	Use of roads; movement of heavy machinery and vehicles	Each Person Conducting a Business or Undertaking (PCBU) retains 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. The LCK (PCBU) has the capacity to influence traffic journeys to the EPL 650 work 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.	Noted.
18	Safework SA	EIR p.138	Incident Management, Recording and Corrective Actions	The system will also need to provide a mechanism for reporting, recording and remediating "Notifiable incidents", as prescribed under the *Work Health and Safety Act 2012* (SA)	Noted. Reporting systems include this mechanism.
19	Safework SA	EIR p.218	Geotechnical Assessment for Demonstration Plant Gasifier	Do the design earthquake loadings for the Site consider the potential for gasifier chamber induced seismic activity near or adjacent to faults?	Section 5.9.4.1 of the EIR provides an assessment of the risk of the demonstration plant causing seismic events and concluded that the activities at the site are unlikely to generate seismic events, due to the small scale, limited duration and depth of the gasifier.
	Department for Health & Ageing				
20	DHA	EIR p.46 (3.11.1)	Waste water	This section could make mention of reference to the South Australian Public Health (Wastewater) Regulations 2013. Only because it makes reference to the possibility of a holding tank for wastewater (with removal to offsite by pumping). Discussions with Leigh Creek Energy have suggested a simple septic/soakage system onsite so it may be best to keep this section broad whilst in the planning phase	Noted. Regulations are also referred to elsewhere in the EIR.
21	DHA	EIR p.135 (Table 5-4)		Good reference made to Regulations here	Noted
22	DHA	EIR Table 7-1	Stakeholder consultation	There is no reference to the DHA – good for LCE to include as they have had discussions with us.	Added to EIR
23	DHA	SEO		Good reference made to the Regulations in Objective 13	Noted
	EPA				
24	EPA	Air quality assessment		The modelling appears to have been undertaken accordingly, with a conservative approach. However, there are several issues the EPA requests clarification:	

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
25	EPA	Air quality assessment		The modelling's meteorological input was based on data from the Leigh Creek Airport. There does not appear to be any information regarding the validity of this data. Over what period of time was this data taken? What parameters were monitored? What were the averaging periods? How does it compare to the meteorology from 2009, a 'typical' meteorology year requested by the EPA for consistency?	A review of meteorological data (predominantly wind data) from Leigh Creek Airport was performed to select a representative year for the assessment. Data for the years 2010 to 2013 (the data that were available at the time of modelling) were reviewed and it was determined that 2010 was suitable for the assessment on the basis of being a recent year with representative wind data for the area and good data availability. The meteorological data for the dispersion modelling was processed in two ways for evaluation of the best model performance. The processing was based on: - gridded TAPM data - single station observation data as hourly averages from Leigh Creek Airport. The evaluation of the processed meteorological data showed that there were limitations with both approaches. Overall, the gridded TAPM data option was favoured on the basis of providing better characterisation and adaptation of the wind field to local terrain features, which is important for impact predictions at larger distances from the emission source. The Leigh Creek Airport observations data provided better adaptations to local wind speeds (underestimated by the TAPM) but showed poor adjustment to local terrain features. The TAPM data meteorological model was selected for the dispersion modelling. The TAPM data option meteorological data was processed in a two steps. Synoptic scale meteorological data were first processed in TAPM. TAPM outputsb were then further processed in CALMET to produce the meteorological data for the dispersion modelling. Processing of meteorological data with TAPM as input for CALMET has been found to provide better characterisation and adaptation of the wind fields for locations with significant terrain features in South Australia, compared to reliance on single observations station meteorological data input. CALMET was processed for an outer and inner grid to allow for best wind field development to local terrain features. A smaller, higher resolution terrain model was used for the near field modelling. The terrain data for this model was also updated with elevations data provided by Leigh Creek Energy.
26	EPA	Air quality assessment page D-2		Page D-2: states that modelling of emissions from the thermal oxidiser is for NO2, CO, SO3, H2S and particulates. The thermal oxidiser is meant to oxidise flue gas pollutants, and it appears that for sulphur trioxide to exist suggests oxidation must be effective, yet CO and H2S suggests otherwise since their existence indicates ineffective oxidation. Furthermore, given SO3 tends to be a mist, we would have expected SO2 to also be modelled.	SO2 emissions from the thermal oxidiser were not modelled for the standard operations scenario because the emissions guarantee for the thermal oxidiser did not include SO2 emissions data. To address the information request additional SO2 emission details were provided by the thermal oxidiser supplier. The dispersion modelling was updated with the SO2 emissions data. The results are presented below and show compliance with significant margin.

Table 2.1: *Maximum predicted SO_2 concentrations updated modelling including thermal oxidiser SO_2 emissions*

Pollutant	Classification	Air EPP Assessment criteria (mg/m^3)	Averaging period	Maximum predicted SO_2 concentration on the grid	Maximum predicted concentration of assessment criteria
SO_2	Toxicity	0.57	1 hour	0.033	6%
		0.23	24 hour	0.014	6%
		0.06	Annual	0.0014	2%

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
27	EPA	Air quality assessment Page D-8		Despite health related ground level concentrations expected to be well below the standards in Schedule 2 of the *Environment Protection (Air Quality) Policy 2016* (the "Air EPP"), the potential for exceedance of the H2S odour criterion at Copley due to purge venting (low or high flow) is a concern, particularly given the separation of Copley from the demonstration plant being 8.5km. Page D-8 describes a 'sensitivity analysis' and predictions of 10% for exceedance of the odour Ground Level Concentrations for H2S. The EPA requests a greater level of explanation as to how this assessment has resulted in this prediction. The EPA suggests it is in the proponent's interest to determine an estimate for the residents in Copley, of what would be a realistic period and frequency when they will most likely experience a detectable H2S odour.	An analysis of odour impacts for the worst case, non-routine venting conditions was carried out to understand the potential frequency of events. The high flow venting was modelled with emissions for 2 hours every day at the time of day (late afternoon) when peak impacts were predicted at Copley, which is the nearest sensitive receptor location and township. The top 2% of the predicted H2S 3-minute average, ground level concentrations at Copley were ranked from highest to lowest. Then odour concentrations above the Air EPP H2S odour assessment criterion (which is set at detection threshold) could occur for 55 hours (for the year of assessment) for the Copley township. This indicates that odour was predicted above the Air EPP criterion for less than 10% of the total number of hours that venting was occurring in the modelling for the high flow venting scenario. Non-routine high and low flow venting operations are unlikely to occur, and very unlikely to co-occur with worst dispersion conditions. However, should venting take place in poor dispersion conditions in wind directions towards sensitive receptors odour from the venting at receptors can occur. While higher concentrations of odour are predicted to be possible, these impacts are below the Air EPP health based air quality assessment criteria.
28	EPA	EIR pp.129-130, 133	Site contamination assessment (in relation to potential groundwater contamination issues)	Table 5-4 *Environmental Risk Assessment for ISG demonstration plant in PEL 650* has identified the following situations: p.129 - loss of well integrity may potentially result in loss of contaminant resulting in the contamination of groundwater, soil and surface water (as well at atmospheric emissions p.129 - where gasified pressure exceeds surrounding groundwater pressure causing potential migration of COPC in groundwater away from gasifier and reach surface or near surface environments p.130 - where contamination may reach the surface or impacting shallow groundwater or soil vapour via the direct escape of COPC from the gasifier through drill holes or transmissive faults p.130 - where contamination may reach the surface or impacting shallow groundwater or soil vapour via gasifier chamber growth intersecting potential vertical and lateral pathways leading to migration of COPC p.130 - where contamination may reach the surface or impacting shallow groundwater or soil vapour via increases in permeability of surroundings by mechanical stress changes and fracturing (including significant gasifier chamber collapse) leading to a migration of COPC p.130 - where contamination may reach the surface or impacting shallow groundwater via the the migration of COPC from gasified chamber after decommissioning /rehabilitation p.133 - where contamination may reach the surface or impacting shallow groundwater via leaks or spills of produced fluids at surface, spills or leaks associated with fuel or chemical storage, handling and transport & water supply /use Under each of these circumstances, where there is a loss of contaminants which potentially results in threatening serious or material environmental harm, the EPA should be notified as soon as reasonably practicable (in accordance with section 83 of the *Environment Protection Act 1993*).	It is noted that whilst the EP Act does not apply to the proposed exploration activities it is considered that Section 85(1)(c) of the PGE Act and Table 2 in the SEO covers issues that would be equivalent to incidents that could result in serious and material environmental harm as defined in the EP Act.
29	EPA		Site contamination assessment (in relation to potential groundwater contamination issues)	The proponent should also determine that if any impacts results in site contamination of groundwater, environmental harm can be adequately managed (during site operations) to prevent any harm to human health or the environment, or if remediation is required. Any site contamination of groundwater resultant from the activities at site should be also remediated (if required) in accordance with the guidance in the National Environmental Protection Measure (NEPM) to prevent any harm to human health or the environment as appropriate (for the intended future use of the land).	Noted. As presented in the EIR the conceptual site model for the site indicates groundwater related risks from ISG at this site are low due to the geology, existing groundwater conditions, and the limited time and scale of the PCD operation. As such, changes to groundwater are expected to be limited to the immediate vicinity of the gasifier. The intent of the monitoring well network to be installed is to quantify these groundwater changes to inform both compliance against the SEO and design of commercial ISG operations.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
30	EPA		Groundwater assessment	The following points attempt to seek clarity/confirmation on groundwater and how it relates to the ISG project proposed. It is understood that a Groundwater Monitoring Plan is currently under development which may address these items.	
31	EPA	EIR Summary p.9 para 3 (and numerous other sections	Groundwater assessment	Leigh Creek Energy (LCE) states that there are no aquifers present at or near the demonstration site. This statement is considered to be incorrect, and at best misleading. The studies undertaken by Flinders Power and various predecessors show that there are several aquifers at Leigh Creek coal mine site, including the Telford Gravels aquifer, Aquifers 1 to 4 of the Upper Series Overburden, and the fractured rock aquifer of the weathered basement. LCE must state the presence of otherwise of these specific aquifers at their site.	It is noted the Mine Closure Plan identifies these aquifers at the Leigh Creek Coalfield. The EIR similarly identifies these at a regional scale relative to the ISG Demonstration Plant site. With regard to the LCK demonstration site these aquifers are either: • not present within close enough proximity to be affected or have an effect (Upper Series Overburden and Adelaidean Basement); or • the strata do not have the hydraulic properties that would permit their classification as an aquifer (Telford Gravels).
32	EPA	EIR summary p.10. end 1st para	Groundwater assessment	States that further groundwater sampling is planned. What groundwater sampling will be undertaken, and when will this work be undertaken?	Details of the proposed monitoring program are included in Section 3.10 and Table 3.6 of the EIR with additional details to be provided in the Groundwater Management Plan.
33	EPA	EIR Section 3.3.2, dot point 3	Groundwater assessment	Reference is made to the demonstration plant location being more than 100m from potential leakage pathways (old drill holes), however the proposed horizontal and vertical drilling methodology complicates this statement. Is the above ground infrastructure of the plant site greater than 100m from old drill holes, or is the gasifier and inlet and outlet wells locations greater than 100m from old drill holes? A large number of old drill holes are located at Leigh Creek coal mine – LCE should provide a map showing old drill holes near their above and below ground infrastructure	The 100 m separation distance is specific to the gasifier. All other surface and subsurface infrastructure (i.e. wells) have multiple layers of protection (design and construction, operating procedures, etc.) to reduce the risk of gas or gasification products entering the environment in an uncontrolled manner. The ISG gasifier is by design in the coal seam as such cannot be allowed to intersect structures that could provide a pathway for gas to impact receptors, in particular, the surface environment. Not including drill holes planned or completed by LCK there are over six thousand historic drill holes known across the Leigh Creek Coalfield based on data provided to LCK by Alinta / FPP. No historic drill holes are present within 100 m of the planned gasifier.
34	EPA	EIR Section 3.3.3, p.28 Table 3-2, row 5	Groundwater assessment	Should units be m, rather than mm?	Yes. Corrected in the EIR.
35	EPA	EIR Section 3.3.3, p.29, last para	Groundwater assessment	It would be helpful if LCE included all the Camp and White (2015) site attributes in a table and addressed each of these attributes individually.	LCK considered that it was more appropriate to address the recommended site attributes developed by the Independent Scientific Panel in detail. The summary of ideal site attributes provided in Section 5.1 in in Camp and White (2015) that are referred to (which are summarised in the EIR on page 29) are less comprehensive than the ISP attributes.
36	EPA	EIR Section 3.10, p.42 GW quality, para 2	Groundwater assessment	When will the Groundwater Monitoring Plan (Groundwater Monitoring Plan) be developed? The Groundwater Monitoring Plan should also include detail on sampling methodology and quality assurance/quality control (QA/QC) procedures.	A Groundwater Monitoring Plan is being prepared as part of the PGE Act process and will be provided to EPA for information. The Groundwater Monitoring Plan will include details of sampling methodology and QA/QC provisions.
37	EPA	EIR Section 3.10, p.42 GW quality, para 4	Groundwater assessment	Define how monitoring stability will be determined. Also, define how groundwater quality will be shown to have not been adversely impacted.	The SEO provides clarification of this issue (it uses three or more scheduled monitoring events deviating more than two standard deviations from background averages in sentinel monitoring wells to define a sustained change) and further detail will be provided in the Groundwater Monitoring Plan.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
38	EPA	EIR Section 3.10, p.44 Rationale for GW monitoring frequency, para 1	Groundwater assessment	The sentinel groundwater monitoring wells are to be placed closer than 50m from the gasifier. What was the rationale for this distance and has consideration been given to the placement of these wells closer to gasifier?	Placement of Sentinel Wells at 50 m from the gasifier is based on the conservative 1 m/year groundwater movement rate to place the wells at the midpoint between the gasifier and the buffer zone boundary at 100 m. This enables area for further investigation and response actions should changes due to the gasifier be detected. Technical issues with installation of 500+ m deep wells is also a consideration due to deviation from vertical during drilling. LCK is also installing: 1. Operational Monitoring Well (approximately 10 m from the gasifier) to monitor groundwater conditions proximal to the gasifier; 2. A network of 5 piezometer (pressure) wells to monitoring formation pressure within a 50 m lateral radius of the gasifier and above the gasifier; and 3. Gasifier Observation Well pre-installed to enable access to the gasifier cavity as soon as pressure and temperature in the gasifier permits after ISG is stopped.
39	EPA	EIR Section 3.10, p.44 Rationale for GW monitoring frequency, dot point 1	Groundwater assessment	Define 'Any sustained increase in pressure…..'	Pressure monitoring in the gasifier and the piezometer wells will be continuous. The piezometer network will provide a three dimensional network of pressure sensors (vibrating wire piezometers) around the gasifier and these, along with the gasifier pressure itself, will be the lead indicators for a potential loss of containment. By design the gasifier will be operated at a pressure less than that of the surrounding pre-ISG formation pressure resulting in a pressure gradient towards the gasifier (a centre of relative low pressure). A "sustained increase in pressure" means this gradient is reversed and the gasifier and piezometer pressure indicating a continuous reverse pressure gradient has formed radiating from the gasifier. Further definition will be provided in the Groundwater Monitoring Plan.
40	EPA	EIR Section 3.10 p.45	Groundwater assessment	LCE need to provide rationale for the distribution of the groundwater monitoring wells.	Refer to comment #38 above. Further information will be provided in the Groundwater Monitoring Plan.
41	EPA	EIR Figure 4-6, p.65	Groundwater assessment	Are the sites marked contaminated sites on the plan all considered to be contaminated sites, or are they 'areas of environmental concern'?	The sites are 'areas of environmental concern' and the caption has been amended.
42	EPA	EIR Section 4.6.2, p.71.	Groundwater assessment	Figures 4-10 & 4-11 should state the drill holes used to generate the cross-sections.	Noted. These figures are based on several sources: • Alinta / FPP drill hole data base and mine surveys; • LCK interpretation of Alinta / FPP stratigraphic data; • Seismic surveys completed in 1978 (ETSA) and 2016 (LCK); and • LCK drill holes Playford 1, 4, 5, and 6.
43	EPA	EIR Section 4.6.2, p.73	Groundwater assessment	Where is the location of the geological type section?	Noted. Figure 4-12 is based on the geology encountered in LCK drill hole Playford 5.
44	EPA	EIR Section 4.6.4, p.76	Groundwater assessment	Siting of the gasifier paragraph – '…at least 100m from faults…' – Is this distance 100m from edge of the fault/fracture zones, or from the centre of the fault/fracture zone?	The distance is measured from the outer extent of the gasifier and the fault boundary closest to the gasifier
45	EPA	EIR Section 4.7.1.3, p.81, Table 4-5 (and Appendix A, p.10, Table 2.1)	Groundwater assessment	This table should state the water quality categories as detailed in the *Environment Protection (Water Quality) Policy 2015* .	The Environment Protection (Water Quality) Policy indicates the following environmental values for underground waters: • TDS < 1200 mg/l – drinking water, irrigation, livestock • TDS > 1200 and less 3000 mg/l – irrigation, livestock • TDS >3000 and less 13000 mg/l – livestock The policy indicates higher salinities can potentially be used for livestock. However, in the EIR, LCK sought to put into context to the reader and interested stakeholders that the high salinities encountered on site would not be suitable for maintaining the good health of stock, particularly cattle. It is noted that pastoralists in the region do not use groundwater with salinities encountered at the site for stock water.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
46	EPA	EIR Section 4.7.3.1, p.83	Groundwater assessment	It is not clear whether the Telford Gravel aquifer has been encountered in drill holes undertaken at site	Noted. The Telford Gravel strata was encountered in all drill holes completed to depths of approximately 12 m below ground. It is shown on all cross-sections but the scale makes it difficult to depict. Groundwater in the Telford Gravel at the ISG PCD site is expected to be discontinuous with water-bearing sections of the strata likely to be of relative low permeability and drained by the Upper and Main Series pits. The Groundwater Monitoring Plan will cover this in more detail.
47	EPA	EIR Section 4.7.3.2, p.83	Groundwater assessment	The assignment of strata to be 'aquitards' need careful consideration and definition. The use of the term 'low permeability' is not specific, and reference should be provided to a 'textbook definition' of aquitards with respect to permeability.	Noted. The terms aquifer and aquitard are often used to describe the relative hydraulic properties of strata within specific geological environments. The definitions provided are written to be understood by the lay person in a local context and specifically avoids highly technical discussion. Technical detail, including specific hydraulic conductivity values for the site strata, is provided in Appendix A.
48	EPA	EIR Section 4.7.3.3, p.84	Groundwater assessment	'practically impermeable' is not considered scientific terminology.	Noted. LCK consider 'practically impermeable' a relevant descriptor for the hydraulic properties on the formations described. It may not be strictly scientific terminology but it is not inconsistent with engineering descriptions of materials used in the construction of subsurface water barriers (e.g. Designing with Geosynthetics (fifth Edition) by Robert M Koerner).
49	EPA	EIR Section 4.7.5, p.89, dot point 1, last sentence	Groundwater assessment	The potential issue regarding fresh water remaining in the groundwater wells after flushing of the well screen can be avoided by utilising the appropriate sampling methodology. If well flushing water remains in the groundwater well, then these wells should have been purged dry several times if possible. The concern over well flushing water suggests that all sampling results may not be representative of actual groundwater conditions.	Noted. More detail on well development and sampling will be provided in the Groundwater Monitoring Plan. The technical challenges of developing wells and collecting groundwater samples from 500+ m deep wells are significant because: 1. All deep wells are required to be installed and completed to DPC standards and DWNR Water Affecting Permit requirements; 2. Depth and well construction limit pump options for developing wells; 3. Low permeability formations mean multiple purging events is not possible. Groundwater recovery rates (after swabbing) in the three deep wells LCK installed indicate recovery times measured in years for wells to reach equilibrium with the formation again; and 4. Remaining well flushing water has a lower salinity than formation water (groundwater) and will therefore remain stagnant in the well casing above groundwater; and 5. LCK are employing sampling methods consistent with NEPM for collecting undisturbed samples in low permeability formations suited to Volatile Organic Compound laboratory analysis.
50	EPA	EIR Section 4.7.5, p.89, dot point 2 (& p.90 dot point 1)	Groundwater assessment	Petroleum hydrocarbons in the C15-C28 range are stated, however in Table 4-6 different petroleum hydrocarbon ranges are provided. It should be stated whether the results are total petroleum hydrocarbons or total recoverable hydrocarbons.	The text is correct, as both C15-C-28 and C16-C34 petroleum hydrocarbon ranges exhibit the trend discussed (see Appendix A). However the text on page 89 has been modified to match the range reported in the table. These ranges are total recoverable hydrocarbons.
51	EPA	EIR Section 4.7.5, p.89, last para, last sentence	Groundwater assessment	This statement should be substantiated by the preparation of a results table showing the data obtained compared with the relevant guideline concentrations.	Extensive comparison with guideline concentrations is not warranted as these are indicative baseline samples of naturally occurring groundwater. The comparison in the text was intended to broadly contextualise the quality of the groundwater (i.e. the quality is relatively poor). Data has been added to the text to provide clarity.
52	EPA	EIR Section 4.7.5, p.90, Table 4-6	Groundwater assessment	The table should detail how many samples were analysed; all nutrients, metals and any other analytes not in the table should be listed in the table; were any dioxin groundwater samples taken, and if not, why not? Lab pH has a 6 hour holding time – it should be stated whether the pH data is lab or field pH, and if lab pH is reported, the conformance (or otherwise) with the 6 hour holding time should be detailed. Are metals concentrations total or soluble? From Appendix A, it appears that the reported metals are soluble metals, however ANZECC (2000) comparison concentrations are for total metals, so the reported metals data cannot be directly compared to ANZECC (2000).	This table presents indicative initial sample results which will be superseded by ongoing sampling. This will be presented in the Groundwater Monitoring Plan. Detailed results tables for these indicative samples are provided in Appendix A.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
53	EPA	EIR Section 5.2	Groundwater assessment	There is a large amount of water in pit lakes often present at the Leigh Creek coal mine site. There should be a discussion of this in the groundwater section, as these observations don't seem to agree with the LCE position that there are no aquifers present at site.	The EIR considers the Main Series Pit as a receptor. This would include any pit lakes. Section 4.7.3.4 and Figure 4-18 address this and discuss the low rate of groundwater movement to the pit and lack of groundwater discharge in the mine high wall. The Upper Series Pit is not considered a receptor for the PCD as this is up hydraulic gradient from the site.
54	EPA	EIR Section 5.2	Groundwater assessment	A groundwater water elevation contour (potentiometric surface) plan should be provided.	A potentiometric surface is shown in Figure 4-18. There is insufficient groundwater data to develop potentiometric contours over the area of the site. As indicated in the Conceptual Site Model (Appendix A) groundwater is expected to be moving toward the Main Series Pit following the geological strata. The piezometer well network around the gasifier will be used to assess and monitor the potentiometric surface across the LCK site.
55	EPA	EIR Section 5.2.3, p.113, para 2	Groundwater assessment	Explain why the presence of the Main Series and Upper Series pits are expected to keep the 'potential aquifer' dewatered.	Prior to mining the Telford Gravel along with Recent sediments in active drainage areas covered almost all of the Leigh Creek Coalfield (Figure 3.3 in Appendix A). It is expected the water-tables would have existed over much of this area in response to precipitation and stream flood events. Both the Upper Series Pit and Main Series Pit fully intersected and removed the Telford Gravels as overburden. The extents of these pits and their locations relative to the LCK site mean the extent of the Telford Gravel is completely removed to the north and south with the full sequence of strata exposed in the pit walls allowing free drainage of any groundwater, if present, into the pits.
56	EPA	EIR p.129, Table 5-4 Key Management Measures, Measure number 7	Groundwater assessment	Are the cement bond logs undertaken over time, or just once (at time of installation)?	Cement bond logs are run during installation. In addition fruther cement bond logs will be run on those wells subjected to high temperatures to assess the performance of the high temperature grout.
57	EPA	EIR Appendix A, p.3, last sentence	Groundwater assessment	COPCs are also likely to be absorbed by materials, however it should be noted that desorption can still occur.	Noted. The Groundwater Monitoring Plan will further address this as one of the objectives is to understand groundwater processes before, during and, after ISG.
58	EPA	EIR Appendix A, p.3, para 4	Groundwater assessment	States '…groundwater…not likely to move away from this site in the foreseeable future…', however this report states that groundwater will move away from the site in 2-20 years. 'Foreseeable' should be defined, with inclusion of the timeframe for groundwater migration.	Noted. Use of foreseeable future was intended to give the layperson an indication of the low permeability of the rock strata and consequent low potential for movement of chemicals away from the gasifier. The 2 to 20 years refers to the time it may take for the cavity created by ISG to naturally fill with groundwater all the while causing groundwater to move to the gasifier and not past or away from it. Based on the measured hydraulic permeability the more likely time for this to occur is decades rather than years. On this timescale any chemicals remaining in the chamber will be immobile and as such not likely to move with groundwater once the chamber is full.
59	EPA	EIR Appendix A, p.9, Aquitard section	Groundwater assessment	This definition is non-specific. It must define 'low hydraulic conductivity' and 'quantities sufficient for use as a water supply.'	Refer to submissions 47 and 48 above.
60	EPA	EIR Appendix A, p.21, Figure 4.2	Groundwater assessment	What depth does this type geology figure begin from? Are the Telford Gravels present at this site?	Refer to response to Submission 43.
61	EPA	EIR Appendix A, section 4.4, p.22, para 2	Groundwater assessment	LCE to provide detail of the 'swabbing technique', including why this work was undertaken (purpose).	"Swabbing" refers to a method of cleaning and purging wells using a cup shaped tool lowered on a wireline into a to a depth below the standing water level and then retrieving the tool and the column of water above it out of the well. This is repeated, getting ever deeper in the well. This action both purges the well of water while creating a surging and suction action of the remaining water in the well. This combined action cleans the well, removes fluids, and develops the well (i.e. stimulates connection between the formation and the well to allow groundwater to flow). Swabbing occurs after the well is flushed with clean water to remove all drilling fluids and water from the drilling process. It also helps remove residual cement grout from the inside of the well casing.
62	EPA	EIR Appendix A, section 4.8.2	Groundwater assessment	LCE to provide QA/QC methodologies for the groundwater sampling	QA/QC methodologies will be documented in the Groundwater Management Plan. Data provided in the EIR is intended as indicative of background groundwater chemistry.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
63	EPA	EIR Appendix A, p.33, Table 4.8	Groundwater assessment	Are hydrocarbons reported as TPH or TRH? There is an error in column 1, below the row 'ethylbenzene'.	The hydrocarbons are reported as TRH. The word below ethylbenzene should be toluene.
64	EPA	EIR Appendix A, section 5.1, para 2	Groundwater assessment	Numerical modelling is referred to, however this has not been provided. Please provide details of this, including why it was omitted from the EIR document.	Rudimentary numerical modelling was used to test flow assumptions in development of the conceptual site model. There was insufficient data to develop this modelling to a level that could be reported.
65	EPA	EIR Appendix A, section 5.1.2, para2	Groundwater assessment	What is the expected radius of influence of the gasifier on surrounding groundwater?	The radius of influence of the gasifier is expected to be within 60 m of the gasifier. The monitoring network is designed to quantify this during the ISG trial.
66	EPA	EIR Appendix A, section 6.1, para 1	Groundwater assessment	LCE provide discussion regarding beneficial use. Environmental values of groundwater in SA are defined in the Environment Protection (Water Quality) Policy 2015. Based on the salinities of groundwater at site, groundwater has a Livestock Water environmental value.	Refer to submission 45.
67	EPA	EIR Appendix A, Figure 6.1	Groundwater assessment	LCE to explain how natural attenuation is expected to occur in 200-300 days when highly persistent chemicals (e.g. phenols and PAHs) are expected to be mobilized.	The conceptual model presented indicated mobilisation of COPC in the gasifier is unlikely. The conceptual model presented in Figure 3.1 is designed to illustrate the relative groundwater processes through the life of the gasifier. The inclusion of specific timescales is not based on specific assessment or modelling. As such, the "200-300 days" should be read is indicative relative to the chamber filling time.
68	EPA	EIR Appendix A, section 7, p. 42, 4.8	Groundwater assessment	The baseline groundwater sampling reported is inadequate (only three samples from well P1M1, one sample from well P1M2 and three samples from well P1M3 taken over a two month period). There is also doubt over the representativeness of groundwater samples due to fresh water remaining in the groundwater wells after flushing of the well screen. The last reported data is from 6 months ago.	It is noted that the sample results reported are not comprehensive. They are intended as indicative of groundwater water baseline chemistry available at the time of preparation of the EIR. The Groundwater Management Plan will detail monitoring objectives and reporting and assessment criteria.
69	EPA	EIR Appendix A, section 7, p.42, 4.9	Groundwater assessment	The claim of 'adsorption potential of the groundwater saturated material is likely to be significant' is unsubstantiated, and thus attribute 4.9 has not been met. Substantiation is required to meet this attribute, including chemical analysis, column leach tests etc.	The geology of the gasifier site is made up of carbonaceous shale and coal, i.e. high carbon content and fine grained rock. Further, drill core samples from Playford 5 were analysed for Total Organic Carbon (TOC) as a potential indicator for adsorption capacity: • Carbonaceous mudstone above the coal – 7 % TOC • Coal – 40 % TOC • Carbonaceous mudstone beneath the coal – 16 % TOC
70	EPA	EIR Appendix A, section 7, 7.6	Groundwater assessment	Not enough information has been provided to determine whether or not this attribute has been met.	Further detail on the groundwater monitorng network will be provided in the Groundwater Monitoring Plan.
71	EPA	EIR Appendix A, section 7, 8.3	Groundwater assessment	It is considered that this attribute relating to long term water quality will not be met by the proposed three years of post-shutdown groundwater monitoring. Justification for this timeframe should be provided.	Further detail will be provided in the Groundwater Monitoring Plan.
72	EPA	EIR Appendix A, Appendix B	Groundwater assessment	Very high concentrations of ammonia as N and Total Kjedahl Nitrogen are reported, however these are not mentioned or reported in the body of the main document (Table 4-6).	Noted. The data presented in the EIR are reported as indicative of natural groundwater chemistry.
73	EPA	EIR Appendix A, Appendix B	Groundwater assessment	High pH values are reported for P1M2 and P1M3, including a rapid increase in pH in well P1M3 from 8.22 to 11.2 over a three week period. This increase should be discussed.	Noted. This is likely due to issues with cement grout and remedial activities undertaken during well construction to meet petroleum requirements.
74	EPA	SEO p.8, Table1, row 2	Groundwater assessment	'Gasifier buffer zone' should be defined via use of a figure or similar	Noted. The buffer zone will be illustrated and discussed in the Groundwater Monitoring Plan. It is a 100 m radius around the gasifier. SEO wording has been modified to clarify this (see also comment #137).
75	EPA	SEO p.8, Footnote 2	Groundwater assessment	It should be noted that appropriate background groundwater quality averages have not been yet been collected and analysed for.	Noted. Additional groundwater monitoring wells have been installed and groundwater monitoring will be undertaken in accordance with the project timelines indicated in Section 3.10 and Table 3.6
	DSD - AAR				

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
76	DSD - AAR	General	Cultural Heritage Management Plan	LCK states it has developed, in consultation with the traditional owners, a series of cultural heriatge discovery protocols as well as a cultural heriatge agreement for the priject. In addition to these frameworks, it may be prudent for LCK to develop an overarching Cultural Heritage Management Plan for the projhect if this is not already included in the Cultural heriatge Agreement. A CHMP would augment LCK's existing heritage management frameworks by laying out measures to be undertaken before, during and after project activities to adequately manage the protection of Aboriginal heritage.	LCK has a Culutral Hertitage Risk Management Plan developed in 2016 and provided this to ATLA prior to undertaking the Work Area Clearances.
77	DSD - AAR	General	Reporting discovery	Section 20 of the AHA provides that if Aboriginal sites, objectsor remains are discovered, LCK is required to report the discovery to the Minister for Aboriginal affiars and Reconciliation (the Minister) through DSD-AAR as soon as practicable. Discoveries can be reported to DSD-AAR on (08) 8226 8900 or via email at dsdaarheritagesites1@sa.gov.au	Noted
78	DSD - AAR	General	Central Archive and Register	The Cental Archive currently holds records for one registered Aboriginal site, one report Aboriginal site and one reported Aboriginal object within PEL 650 (Attachment 1). There are no Aboriginal sites, objects and reminas recorded at, or in the vicinity of, the ISG Demonstration Plant. The closest Aboriginal site or object included on the Central Archive is located approximately 1km to the west. Please note that the records held in the Central Archive are not comprehensive and as such Aboriginal sites, objects and remains may nevertheless exist within PEL 650. The Central Archive is regularly updated with new site records. Therefore requests for searches of the central Archive are recommended prior to any planned ground disturbing activities commencing. Requests for a search of the Cental Archive can be sent to dsdaarheritagesites1@sa.gov.au	Noted
79	DSD - AAR	General	Aboriginal Sites, Objects and Remains	DSD-AAR notes that LCK has engaged Adnyamathanha Traditional Lands Association (ATLA) members to undertake work area clearances in relation to the ISG Demonstration Plant. Despite the fact that the area has been heavily disturbed through previous ground disturbing works, LCK shold be aware that ground disturbing activities may still pose a risk to Aboriginal sites, objects and remains which exist below the ground. Further, where ground disturbing works occur in areas which have not been cleared as part of a work area clearance, the risk of discovery is increased. LCK should refer to Attachment 2 and Attachment 3 for further advice on how it can manage its obligations under the AHA.	Noted
80	DSD - AAR	EIR p.9	Cultural heritage discovery procedure	Delete - "A Cultural Heritage Discovery Procedure is in place to ensure that Aboriginal and non-Aboriginal Heritage sites and or items are protected if they are discovered during site activities." and replace with - "A Cultural Heritage Discovery Procedure is in place to ensure that Aboriginal sites, objects and remains, as well as non-Aboriginal Heritage sites and or items are protected if they are disovered during site activities.	Text has been modified in the EIR.
81	DSD - AAR	EIR p.54 Section 4.2.1		The following paragraph should be added at the top of this section: "The AHA applies to the entirety of the Leigh Creek Mine Site (PEL 650 inclusive) and provides for the protection of all Aboriginal sites, object and remains, including recorded, reported, or undiscovered heritage. The protection extends to Aboriginal sites, object and remains which may exist in areas which have been disturbed in the past and / or subject to a cultural heritage survey or work area clearance."	Text has been modified in the EIR.

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82	DSD - AAR	EIR p.54 Section 4.2.1		Delete - " A search of the register of Aboriginal Heritage Sites and Objects (DSD-AAR 2016) indicated that there are 22 registered or reported sites within 10 km of PEL 650" and replace with - "A search of the Cental Archive, which containas the Register of Aboriginal Sites and Objects (DSD-AAR 2016) indicated that there are 22 registered or reported sites within 10 km of PEL 650"	Text has been modified in the EIR.
83	DSD - AAR	EIR p.54 Section 4.2.1		Note: DSD-AAR updates the Central Archive regularly. As such it is recommedned that proponents submit periodic search requests to dsdaarheritagesites1@sa.gov.au. Requesting a search f the central Archive is especially prudent prior to commencing any ground disturbing activities.	Noted
84	DSD - AAR	EIR p.54 Section 4.2.1		Delete - "There are no Aboriginal cultural heritage sites recorded at or in the immediate vicinity of the demonstration plant site" and replace with - "There are no Aboriginal cultural heritage sites registered at or in the immediate vicinity of the demonstration plant site. However undiscovered Aboriginal sites may still be present in areas which have been previously disturbed."	Text has been modified in the EIR.
85	DSD - AAR	SEO p.8 Table 1		Insert the following as the final point in the thrid column: "If Aboriginal sites, objects and remains are discovered, the discovery is reported to the Department of State Development, Aboriginal Affairs and Reconciliation on (08) 8226 8900 or via email at dsdaarheritagesites1@sa.gov.au	Text has been modified in the SEO.
86	DSD - AAR	Environmental Significance Assessment p.5 Section 5.1		Ensure that the word 'journey' is spelled correctly.	N/A
	DEWNR Science				
87	DEWNR Sci	EIR Summary p.9, para 3	Aquifers	A statement is made that there are no aquifers present at or near the demonstration site. Clarification is required regarding this statement as the EIR and work undertaken by Flinders Power have identified aquifers within the Telford Gravels and upper series overburden.	Refer to response to Submission 31.
88	DEWNR Sci	EIR Summary p.10, para 1	Groundwater and soil sampling	Additional information is required regarding the additional groundwater and soil sampling that is to be undertaken. (What aquifer is to be sampled, locations of sampling, frequency, parameters to be measured, timing, etc.)	Details to be provided in Groundwater Monitoring Plan.
89	DEWNR Sci	EIR Section 2.2.1 p.17	MNES	Clarification is required regarding the statement 'no matters of national environmental significance present or likely to be significantly impacted.' Statement appears to be a contradiction. The paragraph does not consider aquifers in the underlying sediments or above the main series overburden. (refer comment 1)	On the basis of site investigations undertaken at the site there are no matters of national environmental significance recorded at the site. However if they were to occur on the site the size and short duration of the project would be such that no significant impact would occur, which would not require a referral or approval. No 'water resource' will be impacted. Refer to submission 31 for discussion of aquifers.
90	DEWNR Sci	EIR Section 2.2.4 p.17	Well permits	To note that well permits are also required for the modification to and for decommissioning of existing wells.	Noted.
91	DEWNR Sci	EIR Section 3.1.1	Concentrations of ISG products	What are the likely concentrations of ISG products and COPCs and how do these compare to existing baseline (background) values?	The aim of the environmental monitoring of the demonstration is to gain an understanding of what changes to baseline data may occur.
92	DEWNR Sci	EIR Section 3.1.5	Geology and hyrdogeology cf QLD and USA	How do the geology and hydrogeology of the Leigh Creek site compare with the examples of clean shut down achieved in Qld and USA and are any procedural variances required at Leigh Creek?	The main differences of the Leigh Creek project from QLD projects specifically are that the Leigh Creek resource sits at depth, under thick, very low permeability mudstone within a defined basin with no conflicting land use issues. The Queensland UCG projects have occurred in extensive, relatively shallow, flat lying sandstones within areas also being used for coal seam gas projects and open cut mining. With regards to the clean cavity shutdown, the procedure will be similar to the one implemented by Carbon Energy at the Bloodwood Creek project.
93	DEWNR Sci	EIR section 3.2	Well construction	Due to the small area over which the EIR applies more detail regarding the construction of the wells could have been provided regarding formations / lithological units, casing diameters strength and materials.	Noted. The Groundwater Monitoring Plan will provide more details of monitoring well construction.
94	DEWNR Sci	EIR section 3.2	Well construction	A site specific schematic diagram of well would be useful.	See Submission 93 above.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
95	DEWNR Sci	EIR section 3.2	Well construction	What is the official grade of 'premium casing'?	The premium casing being used is a proprietary product knowns as 'Tenaris Blue', this is a L80 steel casing and is ISO 13679 (Petroleum and natural gas industries — Procedures for testing casing and tubing connections) tested and field proven.
96	DEWNR Sci	EIR Table 3.2, p.28		Row 8 – Comments field states site is located approximately 100m south of an inferred fault. This does not match the 2nd dot point in section 3.3.2 on pg 27.	These are not inconsistent - the gasifier is greater than 100 m from the fault identified in Playford 2 (refer Fig 5 (p. 15) in Appendix B of the EIR).
97	DEWNR Sci	EIR Table 3.2, p.28		Row 4 – comments field – is the unit of measure mm or m (490mm).	Refer to Submission 9.
98	DEWNR Sci	EIR Table 3.4, p.35 1st row		Description ignores the presence of Telford gravels.	The Telford Gravels was encountered in all investigation wells. Prior to mining the Telford Gravels along with recent sediments in active drainage areas covered almost all of the Leigh Creek Coalfield (Figure 3.3 in Appendix A). It is expected the water-tables would have existed over much of this area in response to precipitation and stream flood events. Both the Upper Series Pit and Main Series Pit fully intersected and removed the Telford Gravels as overburden. The extents of these pits and their locations relative to the LCK site mean the extent of the Telford Gravel is completely removed to the north and south with the full sequence of strata exposed in the pit walls allowing free drainage of any groundwater, if present, into the pits. As such, groundwater in the Telford Gravels in the immediate vicinity of the demonstration site is not considered to have quality or yield that would facilitate any beneficial use.
99	DEWNR Sci	EIR section 3.9., p.41, last para		If any of the water wells are of use to Flinders Power for closure monitoring, consideration to be given to transfer of wells prior to decommissioning.	LCK are in discussions with FPP about both their and LCK's groundwater wells. The limited extent of the wells installed by LCK for the demonstration plant do not assist FPP in their mine closure monitoring.
100	DEWNR Sci	EIR Section 3.10, p.42	Groundwater quality	1st paragraph – groundwater sampling should also be undertaken prior to the commencement of operation to determine baseline levels for ISG products and COPCs	Noted. This is being undertaken.
101	DEWNR Sci	EIR Section 3.10, p.42	Groundwater quality	When is the groundwater monitoring plan to be developed. To note that monitoring information presented in the EIR may be changed when the groundwater monitoring program is developed. The monitoring plan is to be approved by regulators prior to commencement of activity.	Refer to response to Submission 36. DEWNR expects Groundwater Monitoring Plan to be approved by regulators prior to commencement of activity.
102	DEWNR Sci	EIR Section 3.10, p.42	Groundwater quality	Various purposes of monitoring wells may be required – compliance wells and wells to detect impact. The rate of groundwater movement is very low therefore well to measure impact will need to be close to the gasifier chamber. Groundwater movement of <1m/year has been presented in the report, therefore, the placement of wells at 50m from the gasifier chamber will need to be reviewed.	Noted. Details of proposed monitoring will be included in the Groundwater Monitoring Plan.
103	DEWNR Sci	EIR Section 3.10, p.42	Groundwater quality	Due to the slow rate of groundwater movement post-operation monitoring beyond 3 years may be required	Noted. Details of proposed monitoring will be included in the Groundwater Monitoring Plan.
104	DEWNR Sci	EIR Section 3.10, p.42	Groundwater quality	Use of the term compliance rather than sentinel	Details of proposed monitoring and well naming will be included in the Groundwater Monitoring Plan.
105	DEWNR Sci	EIR Section 3.10, p.42	Groundwater quality	Monitoring of units underlying the gasification chamber also need to be considered	Noted. Details of proposed monitoring will be included in the Groundwater Monitoring Plan.
106	DEWNR Sci	EIR Section 3.10, p.43	Groundwater temperature	Groundwater temperature to be measured concurrently with water levels to account for temperature effects on the water levels	Noted. Details of proposed monitoring will be included in the Groundwater Monitoring Plan.
107	DEWNR Sci	EIR Figure 4.8, p.67 & Table 4.4, p.69	Coal seam geological age	There is conflicting information as to the geological age of the coal seams. An explanation as to the difference is required	Noted. There is some inconsistent use of terminology for the time periods describing the age of the geological strata. This results from varying terminology used in different geological source references. For example, Late Triassic is to be read the same as Upper Triassic.

#	Agency	EIR/SEO Reference	Topic/ Issue	Issue Raised in Submission	Response
108	DEWNR Sci	EIR Figure 4.14. p.75	Hydraulic conductivity	The figures for hydraulic conductivity and groundwater velocity are for different parameter scenario. Refer to section 5.1.1 in Appendix A. A hydraulic conductivity of 10^{-7} corresponds to a velocity of mms/yr whilst a hydraulic conductivity of 10^{-3} corresponds to a velocity of m/yr. This is repeated on a number of figures in the report.	Noted. DEWNR's understanding is correct. Hydraulic conductivity is reported in Appendix A to range between 10-3 and 10-7 m/day based on different testing methods. AWE reports that 10-7 m/day is more representative of actual formation conditions as it is based on groundwater recovery into wells from the formation. This corresponds to a calculated groundwater velocity in the order of mm/year. To assess groundwater risks a groundwater velocity of 1 m/year was used (based on the hydraulic conductivity of 10-3 m/d) as this faster rate of movement introduces an additional margin of safety. LCK notes the text in the identified figures is not clear but also that left written as is does not change the conclusions of the AWE report or the EIR.
109	DEWNR Sci	EIR Section 4.7.1.3 & Table 4.5	Water Quality EPP	Water quality categories should be as per the EPP Water Quality	Refer to response to Submission 45.
110	DEWNR Sci	EIR Section 4.7.2, p.81	Natural springs map	It would be useful to display the natural springs on a map to show their location with respect to the trial site.	Noted.
111	DEWNR Sci	EIRSection 4.7.3, p.81	Regional fractured rock aquifer	Possible connection of the Telford Basin to the regional fractured rock aquifer has not been addressed. LCK to consider presenting a regional potentiometric surface. Information presented by Flinders Power supports a through flow system trending south – north	There has been insufficient data to prepare potentiometric controls for the Telford Basin and regional Adelaidean groundwater. The scale of the ISG demonstration and its location means it is unlikely there will be any change in groundwater conditions beneath the Telford Basin, over 100 m below the site at its closest point. The EIR in section 4.7.3 does include discussion on the potential groundwater interaction between the Telford Basin strata and the Adelaidean Basement. The relatively impermeable nature of the Telford Coal Measures strata will likely cause groundwater in the basement strata to flow under and around the basin in the south to north direction, the regional (topographic driven) direction of the water flow.
112	DEWNR Sci	EIR Section 4.7.6, p.91, 1st dot point	Beneficial use?	Use of the term beneficial use. The reported groundwater quality suggests that the groundwater has a beneficial use. In the context of the sentence are LCK referring to existing users?	The text is referring to existing site users. In the area of the ISG demonstration plant groundwater in the Telford Gravels may have limited beneficial uses based on water quality and yield is expected to be low with continuity of groundwater limited.
113	DEWNR Sci	EIR Chapter 5	Editorial	There are aspects of the ISG activity that are mentioned for the 1st time in chapter 5 Environmental Impact Assessment rather than in the previous chapters 3 (Description of Activities) or 4 (Existing Environment)	LCK is unaware of any aspects of the activity that are not previously mentioned. This section necessarily identifies details of potential hazards that are not appropriate to document elsewhere in the report.
114	DEWNR Sci	EIR Section 5.2.2.1	Absorption properties	High absorption properties of the coal and carbonaceous mudstones. Details / references are required on this topic. Has it been measured on site?	Analysis of the carbonaceous mudstones above and below the coal and the coal itself for Total Organic Carbon content along with the fine-grained nature of the strata suggests a high chemical absorption capacity. The Groundwater Monitoring Plan will detail the data to be collected to verify water and chemical movement before, during, and after ISG.
115	DEWNR Sci	EIR Section 5.2, p.107	Groundwater receptors.	The main series pit, located to the north of the demonstration site is considered a groundwater receptor and potential impacts to the pit need to be addressed in the EIR	Appendix A discusses the current groundwater connection between the demonstration site and the Main Series Pit. The low permeability of the strata and the observed absence of groundwater discharge from the pit high wall suggests a slow rate of groundwater movement that likely results in groundwater evaporating behind the high wall before it can discharge. This is supported by modelling in the Mine Closure Plan that indicates groundwater will not be a significant contributor to inflow the Main Series Pit lakes. The depth of the mine voids in which these pit lakes will form is significantly below the expected saturated water (and potentiometric level – 30 to 50 m below ground) in the Main Series Overburden at the demonstration site.
116	DEWNR Sci	EIR Table 5.4	Groundwater receptors.	Refer to comment above, consideration of the main series pit as a groundwater receptor needs to be addressed in the relevant risk events in the table.	Refer to response to submission 115.

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117	DEWNR Sci	EIR Table 5.4		Risk event sub group – loss of containment underground has restricted the potential environmental impact to shallow groundwater for a number of risk events. Why has only shallow groundwater been considered rather than groundwater in general?	As there are no aquifers at the site, shallow groundwater and the surface were identified as the most appropriate receptors to address in the risk assessment.
118	DEWNR Sci	EIR Sections 6.1 & 6.3	Monitoring plans	It is not clear if the various monitoring plans are part of the EMS. If they are section 6.3 to be inserted into section 6.1.	The monitoring plans will link to the EMS, but stand-alone documents and and are dealt with appropriately in a separate section in the EIR
119	DEWNR Sci	Appendix A Section 1 Exec Summary p.2, para 2	Editorial	Consistency in reporting of age of deposition – 240-190 million years stated in exec summary, yet 250-200 stated in chapter 3.	Noted. There is some variation in source references of different ages. It is not material to the findings of the EIR.
120	DEWNR Sci	Appendix A Section 1 Exec Summary p.3, para 5	foreseeable future'	Use of the term foreseeable future. This is subject to misinterpretation and it is preferred if a year range is presented. In paragraph 6 it is stated that it is expected to take between 2 to 20 years for groundwater to reach equilibrium with the surrounding strata.	Refer to response to submission 58.
121	DEWNR Sci	Appendix A Figure 3.6, p.16		To consider displaying drainage lines to statement that drainage is to the north and east	Drainage lines, catchment boundaries and surface water flow direction are included in Figure 4.24 of the EIR.
122	DEWNR Sci	Appendix A Section 3.2, p.16, para 1	Surface water ponding	Ponding of surface water could also have recharge the shallower Telford Gravels	Noted
123	DEWNR Sci	Appendix A Section 4.3, p.22	Figure 4.3	Some discussion is required explaining the interpretation of Figure 4.3.	Fig. 4.3 illustrates a 2016 interpretation by Velseis (contracted by LCK) of seismic reflection data collected by ETSA in 1978. The drill holes completed by LCK at the time of preparation of the EIR were sited on this seismic line to provide direct geological data to aid in this interpretation and development of the schematic geological cross section (Fig. 4.6).
124	DEWNR Sci	Appendix A Section 4.4, p.22	Swabbing'	Details of the 'swabbing' sampling technique are to be provided. This could be included in the groundwater monitoring plan	Refer to Submission 61.
125	DEWNR Sci	Appendix A Figure 4.5, p.24	VWP data	Comments are required to explain the anomalies (sudden changes in trends) in the VWP data.	No detailed review of this VWP data has yet to be undertaken. LCK drilling activities and mine closure activities may explain these anomalies.
126	DEWNR Sci	Appendix A Figure 4.5, p.24	VWP data	Are these the same VWPs displayed in figure 4.1? Different VWP naming convention has been used.	Yes. The difference in naming convention between figures is noted.
127	DEWNR Sci	Appendix A Section 4.5, p.25, para 2	Salinity values	The last sentence states that a salinity profile needs to be run on well 3967, yet a salinity range is reported for the well in the start of section 4.6. Are these values suitable for calculating an accurate pressure at the monitoring depth? LCK to comment.	No vertical salinity profile in the well has been obtained. Salinity reading have been collected during water level gauging events.
128	DEWNR Sci	Appendix A Section 5.1, p.34	Groundwater model	Reference has been made to the use of a numerical model in the conceptualisation of groundwater movement. Details of this model have not been provided for assessment.	Refer to Submission 64.
129	DEWNR Sci	Appendix A Section 5.1.2, p.35	Gasifier radius of influence	Reference is made to a radius of influence of the gasifier on surrounding groundwater. Additional information is required as to what is the anticipated size (as a range) of the radius of influence. This information can also be used in the design of the groundwater monitoring program	Refer to submission 65.
130	DEWNR Sci	Appendix A Section 5.1.4, p.36	Groundwater sampling	Consideration is to be given to sampling the groundwater in the gasification chamber post operation to determine the extent of residual COPCs and whether additional remediation activities are required	Agreed. After cessation of gasification, sampling of the source, i.e. groundwater and ash in the chamber, is a key part of the post closure monitoring strategy. The Observation Well is a pre-drilled well into the location of the gasification chamber with the express purpose of having direct access to the chamber after the gasifier is decommissioned and the temperature and pressure are at safe levels for sampling. The Groundwater Monitoring Plan will detail the intended sampling regime.
131	DEWNR Sci	Appendix A Section 6.1, p.39	Editorial	There is no section 3.3.4 in the appendix.	Noted - this is an erratum
132	DEWNR Sci	Appendix A Section 6.1, p.39	Groundwater quality	To note that the reported groundwater qualities in table 4.8, give the groundwater a beneficial use suitable for stock. LCK to comment	Refer to response to Submission 45
133	DEWNR Sci	Appendix A Section 7, p. 42, item 4.8	Baseline sampling	Baseline water quality sampling to date has shown potential contamination resulting from well construction. Is additional baseline sampling planned?	Additional baseline sampling is proposed.
134	DEWNR Sci	SEO Section 1.1 Purpose para 2	Text edit	To add word 'construction' to the 1st sentence – …environmental objectives to which construction, operation and decommissioning	SEO text has been modified.

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135	DEWNR Sci	SEO Section 1.2 1st sentence	Text edit	Also add – This SEO applies to the construction, operation	SEO text has been modified.
136	DEWNR Sci	SEO Obj 2		Further discussion is required regarding this environmental objective. Sustained change is defined (pg8) as water chemistry deviating more than 2 standard deviations from background averages. Therefore, changes to groundwater chemistry of up to 2 standard deviations are proposed to be acceptable, which could result in substantial changes to the background water chemistry. The potential magnitude of changes that could occur need to be reported.	Noted. The Groundwater Monitoring Plan will provide additional information on the groundwater quality objectives.
137	DEWNR Sci	SEO Obj 2		Information presented in the EIR/SEO documents include: - During operation, pressure within the gasifier is to be lower than groundwater pressure. - Groundwater movement at 1m/year or less. Based on these 2 facts groundwater contamination, should it occur is likely to occur within the immediate vicinity of the gasifier. Upon completion of the operational phase there will be a hydraulic gradient towards the gasifier chamber which will move any contamination back towards the chamber. Monitoring of water chemistry of groundwater within the chamber could determine the magnitude of groundwater contamination, removed as required and the length of time required for groundwater quality to return to background levels. The reported rate of groundwater movement means that groundwater will not move more than 1m over the duration of the trial. Design of the groundwater monitoring plan will need take this into consideration. What is the purpose of establishing a 100m buffer zone to measure groundwater quality and assess impacts on groundwater? To consider changing this environmental objective to 'No long-term change to background groundwater quality.' For discussion – is to establish an impact zone beyond which no change to baseline groundwater quality are to change.	The 100 m buffer zone is proposed to define a zone around the gasifier within which monitoring to understand its interaction and effects in the surrounding formation is undertaken. This distance corresponds to a 100 year travel time (based on groundwater movement at 1 m/year). A deep groundwater monitoring network network is largely within 50 m of the gasifier and includes: 1. Observation Well to access the gasifier chamber after gasification to assess "source" concentrations of COPC; 2. Operational Groundwater Monitoring Well approximately 10 m down hydraulic gradient of the gasifier (and designed to survive connection with the gasifier if its growth encroaches) to detect near gasifier changes in groundwater conditions; 3. Five Piezometer Wells (with six vibrating wire piezometers grouted in each) located about 30 to 40 m from the gasifier up, down, and across hydraulic gradient from the gasifier and above the gasifier. These will provide a real time three-dimensional pressure and temperature monitoring network around the above the gasifier; and 4. Four Sentinel Groundwater Monitoring Wells (three down gradient and one up hydraulic gradient) approximately 50 m from the gasifier for monitoring groundwater quality. The spacing of all deep wells also needs to consider well deviation during drilling. As these wells are all around 500 m deep the precision to which the bottom of the hole can be located is much less than that for locating the top of the hole. As such, separation of wells to avoid potential collision at depth had to be considered in the spacing of wells. Vertical monitoring of groundwater quality above the gasifier will be undertaken in two 80 m deep Sentinel Groundwater Monitoring wells to provide vertical assessment of water quality above the gasifier. The SEO wording has been modified to provide clarification around the gasifier buffer zone (see also comment #74). The 100m zone has been defined (to match the wording that was contained in the EIR) and the assessment criteria now reads: *Groundwater monitoring in accordance with the monitoring plan does not indicate a sustained change to background groundwater quality at the gasifier buffer zone boundary as a result of demonstration plant activities. A sustained change to background*
138	DEWNR Sci	SEO Objective 4		The Assessment criteria does not match the environmental objective. Suggest rewording to 'There is no uncontrolled flow from a well.', or 'There is no uncontrolled flow to surface or subsurface.'	SEO text has been modified.
139	DEWNR Sci	SEO		Monitoring well locations: Provision of a cross section of the site through the inlet and outlet well displaying features including the approximate locations and well depths, VWP's, gasifier chamber and gasifier buffer zone would assist in the understanding of the project.	The Groundwater Monitoring Plan will provide additional information.

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140	DEWNR Sci	SEO Section 3 Reporting		The groundwater monitoring plan which is to be developed will likely also have some reporting requirements. Reference to this should be made in the SEO.	Noted. The Groundwater Monitoring Plan will align with the reporting described under Section 3.1 (Table 2) and Section 3.2, in particular reporting of: - 'Loss of containment of the gasifier is detected (e.g. via sustained change from background water quality in sentinel monitoring wells or sustained change in levels of COPC in soil vapour monitoring wells).' - changes in groundwater quality greater than two standard deviations above baseline mean conditions (which will allow DPC-ERD and LCK to agree upon any further monitoring requirements to determine whether a 'sustained change' to groundwater quality has resulted) - changes in soil vapour monitoring greater than two standard deviations above baseline mean conditions (which will allow DPC-ERD and LCK to agree upon any further monitoring requirements to determine whether a 'sustained change' to soil vapour quality has resulted) - 'environmental monitoring including air quality, groundwater, surface water, soil and soil vapour.'
141	DEWNR Sci	SEO Table 2 Serious incidents, item 5, dot point 3		To be consistent with the environmental objective suggest editing wording to 'Identification of uncontrolled flows to the surface or subsurface.'	SEO text has been modified.