Central Eyre Iron Project
Mining Lease Proposal

APPENDIX N

MINE GROUNDWATER IMPACT ASSESSMENT

ABN: 51 128 698 108

REPORT

Central Eyre Iron Project: Mine Groundwater Impact Assessment

E-F-16-RPT-0024

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A	25/07/2014	IRD Review	Rohan Baird	Dougal Currie
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Glossary

Aquifer	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs
Aquitard	A saturated but poorly permeable bed, formation, or group of formations that can store water but only yields it slowly to a well or a spring, it may transmit appreciable water to or from adjacent aquifers
Cone of depression	A depression in the groundwater table or potentiometric surface that has the shape of an inverted cone, and develops around a well or mine pit from which water is being withdrawn, either by pumping or evaporation
Confined aquifer	An aquifer that lies below low permeability material and where the piezometric surface lies above the base of the confining material, eg. artesian and sub-artesian aquifers
Drawdown	The distance between the static water level and the surface of the cone of depression at any one location
Groundwater	The water contained in interconnected pores, gaps or fractures located below the water table
Hydraulic conductivity	A coefficient of proportionality describing the rate at which water can move through a permeable medium
Hydraulic gradient	The change in total head per unit distance in a given direction
Potentiometric surface	The level to which water will rise in wells screening a discrete aquifer, the water table represents the potentiometric surface for an unconfined aquifer
Total dissolved solids	The total amount of dissolved solid matter found in a sample of water
Transmissivity	The rate at which water moves through a unit width of aquifer or aquitard under a unit hydraulic gradient, it is calculated as the product of aquifer thickness and hydraulic conductivity
Unconfined aquifer	A water table aquifer
Water table	The surface between the unsaturated and saturated zones of the subsurface at which the hydrostatic pressure is equal to that of the atmosphere
Well	A borehole that has been cased with pipe, usually steel or PVC plastic, in order to keep the borehole open in unconsolidated sediments or unstable rock, often used interchangeably with the term bore

1 Introduction

1.1 Overview

Iron Road Limited (Iron Road) is proposing to develop an iron ore mining and minerals processing operation at Warramboo, approximately 28 km south-east of Wudinna on the Eyre Peninsula, South Australia. The proposed mineral lease (ML), comprising an area of 8,496 ha, is situated within Iron Road's exploration lease (EL) 4849. The proposed mine and associated supporting infrastructure are referred to as the Central Eyre Iron Project (CEIP).

This report presents an assessment of potential impacts to existing groundwater users arising from water affecting activities (WAA) associated with the proposed CEIP mine. This assessment forms part of the larger mining lease application being submitted for regulatory approval pursuant to the Mining Act 1971. A study area has been defined to encompass an area where effects arising from WAA are predicted to be contained within (Figure 1). The study area also coincides with the numerical groundwater flow model boundary used to assess project WAA.

A separate report addresses potential impacts to existing groundwater users arising from WAA associated with the proposed CEIP infrastructure (including a deep water port facility, a standard gauge railway connecting the port and mine, a water pipeline, borefield and long term employee village).

This Groundwater Impact Assessment (GIA) draws on supporting technical investigations including:

- CEIP Mine Site Hydrogeological Studies (SKM, 2014a)
- CEIP Mine Water Management – Numerical Groundwater Flow Model (SKM, 2014b)
- CEIP Mine Pit Groundwater Management Plan (SKM, 2014c)
- CEIP Groundwater Drilling and Aquifer Testing Completion Report (SKM, 2014d)

1.2 Approach to assessing potential groundwater effects

To understand the potential effects posed to groundwater systems and sensitive receptors as a result of project WAA it is necessary to consider how operations such as dewatering and mine infrastructure development might change the pre-mining groundwater regime.

Direct potential groundwater impacts relate to the physical influence of WAA associated with project activities and supporting infrastructure on groundwater and connected systems. Four categories of direct potential impacts have been identified by Brereton and Moran (2008):

- *Groundwater quantity*;
  Includes consideration of changes to groundwater levels / pressures and flux.
- *Groundwater quality*;
  Includes consideration of salinity and concentrations of other important water quality constituents.
- *Groundwater – surface water interaction*;
  Includes consideration of changes to the level of interaction between groundwater and surface water systems.
- *Physical disruption of aquifers*;
  Includes consideration of whether or not there will be permanent disruption of a groundwater system from the proposed lease activities, and to what extent.

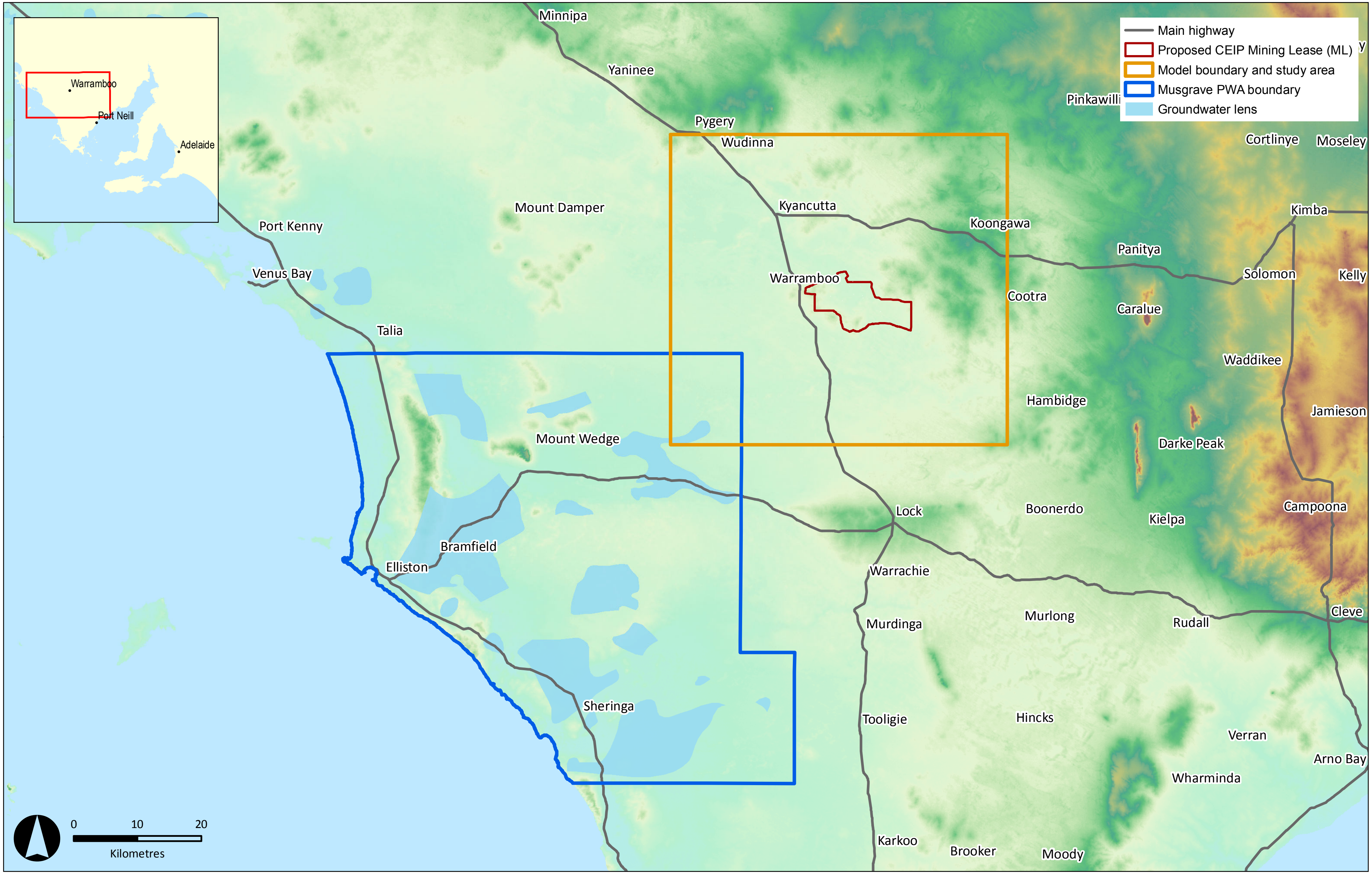

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Figure 1: CEIP mine locality and topography

Direct potential groundwater impacts have the potential to affect 'receptors' within the predicted zone of influence. The term 'receptor' is used here to include environmental, social (and cultural) and economic users of groundwater resources.

1.3 Assessment framework

The National Water Commission (NWC, 2010) developed an assessment framework which provides a risk-based approach to managing local and cumulative effects of mining on groundwater and connected systems. This approach is similar to the traditional 'source, pathway, receptor' model, whereby the assessment of risk posed to a potential receptor is determined by the level of receptor exposure to a threatening process and adverse effect arising from that exposure. Figure 2 presents the assessment framework developed by the NWC (2010) which has been used as a framework for this GIA. For a threat to emerge there needs to be an exposure pathway linking direct groundwater impacts (in relation to proposed mining lease activities) with receptors.

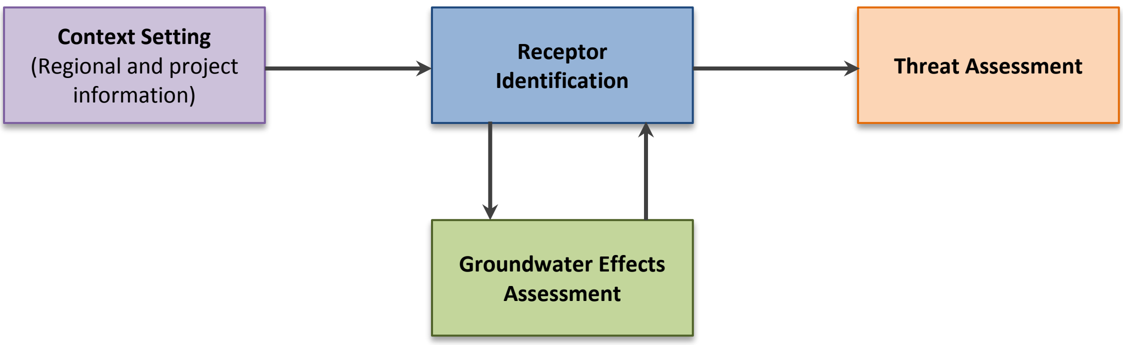

Figure 2: Framework for assessing local and cumulative effects of mining on groundwater systems (adapted from NWC, 2010)

Table 1-1 presents a summary of the framework stages as presented in this report.

Table 1-1: Summary of the groundwater impact assessment framework

Chapter	Framework Stage	Comments
2	Context setting	Involves placing the activity of concern into context, e.g. interactions between groundwater flow systems
3	Receptor Identification	Involves developing an understanding of the receiving environment that will potentially be altered by potential direct effects and clearly identifying those receptors that may be at risk
4	Groundwater Effects Assessment	Comprises identification of direct potential impacts to the groundwater system arising from project activities
5	Threat Assessment	Involves an assessment of the degree to which direct potential impacts will impact on receptors that have been identified as having a linkage to direct impacts, both spatially and temporally

1.4 Legislative requirements

In South Australia, WAA are administered under Section 127 of the *Natural Resources Management Act 2004* (NRM Act). To undertake most types of WAA, a permit is required from the relevant authority, which in most cases is the Minister for Sustainability, Environment and Conservation through the South Australian Government Department of Environment, Water and Natural Resources (DEWNR) or the relevant Regional Natural Resources Management Board (NRM Board). The proposed CEIP mine site is located within the Eyre Peninsula (EP) NRM Board region.

2 Context setting

2.1 Location and project description

The proposed CEIP mine is located near the township of Warramboo on the Eyre Peninsula, South Australia (Figure 3). A study area has been defined within which all effects arising from WAA are predicted to occur.

The CEIP comprises two adjacent mine pits referred to as the Murphy South mine pit and Boo Loo mine pit (refer to Figure 3 for pit locations). The proposed mining method comprises conventional mining (truck and shovel) for pre-stripping during the first three years, followed by in pit crushing and conveying for the life of mine which is scheduled for 25 years. To achieve safe and generally dry mining conditions, it will be necessary to actively manage groundwater inflow to the mine pits.

The waste rock from the in pit crushing and tailings from the processing plant will be transported by covered conveyors and combined into an integrated landform. The integrated landform will be developed progressively by three mobile stackers that spread the waste in concurrent arcs. The proposed footprint of the integrated landform is illustrated in Figure 3.

The major WAA associated with the CEIP mine site include:

- De-watering wells located around the perimeter of the mine pits to manage groundwater inflow;
- In-pit sump pumps to manage groundwater inflow not intercepted by external de-watering wells; and
- Development of the integrated landform which has the potential to influence groundwater recharge.

Within the study area, a large proportion of land has been cleared for agricultural purposes, including broad acre cropping and grazing. Significant areas of native vegetation remain intact, although these areas are largely restricted to conservation reserves such as Hambidge Wilderness Protection Area (Figure 3).

2.2 Climate

The study area is located within an arid to temperate climate zone that experiences hot summers and cool winters. Mean annual rainfall on the Eyre Peninsula ranges from 263 mm at inland areas such as Wudinna, to 381 mm at coastal locations such as Port Lincoln. Mean annual maximum and minimum temperatures at Wudinna and Kimba range from 25.1 ^{o}C to 10.2 ^{o}C and 23.5 ^{o}C to 10.3 ^{o}C respectively.

2.3 Topography

The study area is dominated by sand dune covered plains, with several hilly areas and granite plains. Several low lying depressions also exist within the study area. In the vicinity of the ML, topography is around 75 mAHD.

2.4 Hydrology

Surface water on the Eyre Peninsula is sparse, with the occurrence of creeks and rivers limited by the topography and low rainfall. There are no prescribed surface water areas on the Eyre Peninsula. Within the study area there are no significant ephemeral creek lines present.

2.5 Geological setting

The study area is located within the central portion of the Eyre Peninsula which lies within the Gawler Craton, an extensive region of Archaean to Mesoproterozoic crystalline basement. Towards the southern margins of the study area, the basement is incised by the Polda Trough, an east-west trending geological feature in-filled with Neoproterozoic to Jurassic sediments. Overlying the basement rock and sediments of the Polda Trough is a thin veneer of Tertiary and Quaternary deposits. A summary of the major geological formations located within the study area is presented in Table 2-1.

Table 2-1: Regional geological formations

Geological Age	Description	Distribution
Quaternary	Quaternary deposits, consisting of Holocene to Pleistocene aeolion (dune) sands, clayey sand, calcarenite and calcrete	Entire study area except where basement outcrops
Tertiary	Neogene (Miocene to early Pliocene) deposits and older Palaeogene (mostly Eocene) deposits	Entire study area except where basement outcrops
Jurassic	Polda Formation consisting of clayey sand containing detrital muscovite	South-west corner of study area
Archaean	Archaean Sleaford Complex characterised by highly deformed and metamorphosed gneisses derived from sedimentary rocks	Entire study area

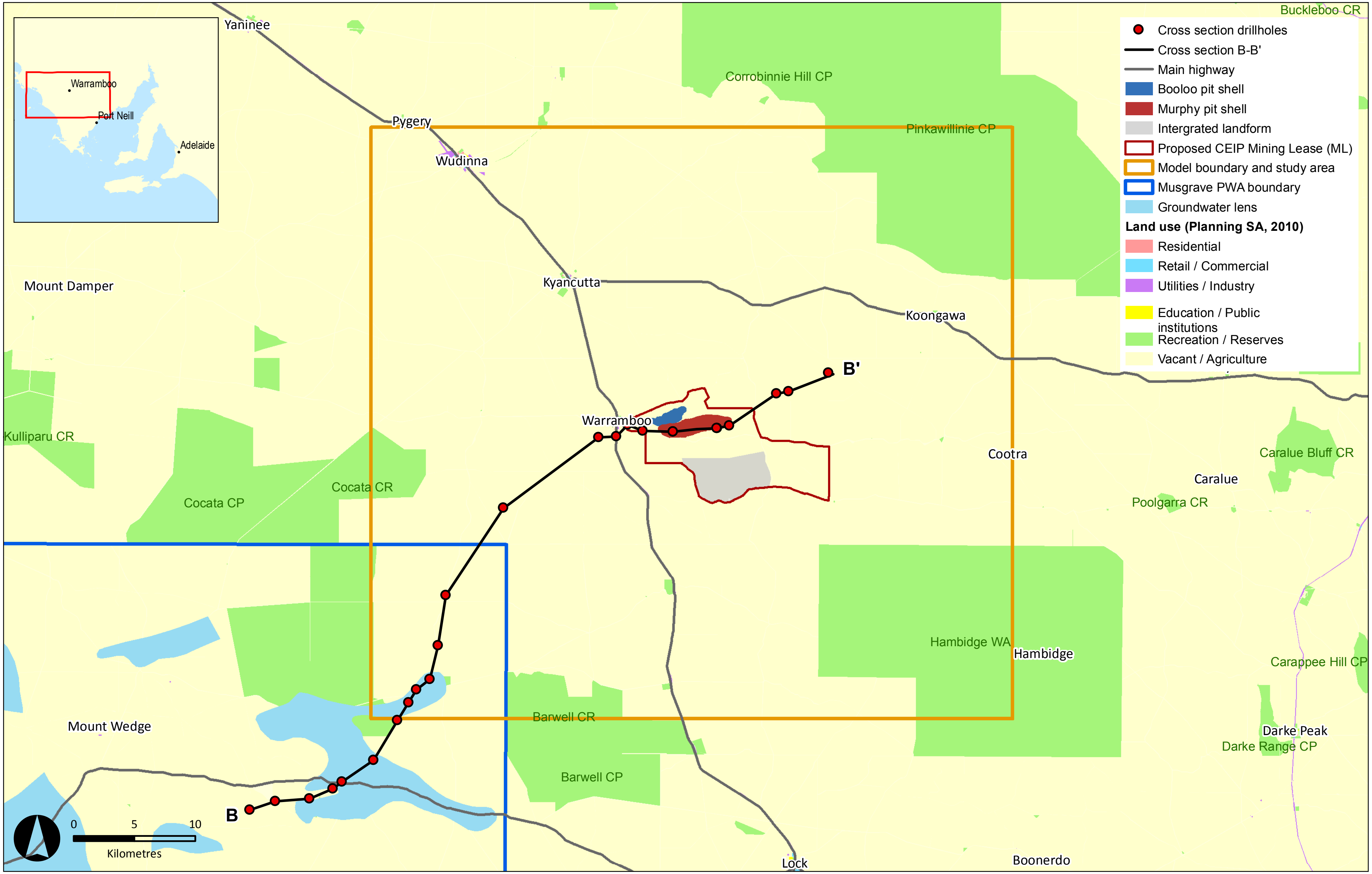

Figure 3: CEIP mine site layout and land use

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2.6 Regional hydrogeology

2.6.1 Overview

Groundwater resources over much of the Eyre Peninsula are of variable quality and quantity and most groundwater occurs in saline or brackish aquifers with generally low yields (Berens *et al,* 2011). This is particularly true for groundwater within the study area.

The following sections provide a summary of the key hydrogeological formations within the study area.

2.6.2 Quaternary

Within the proposed mining lease, the lithology of the Quaternary sediments is largely dominated by quartz sand forming dunes. Calcrete horizons are also found to varying degrees throughout the study area. These conditions are typical of the central, northern and eastern portions of the study area. Within these areas the Quaternary sediments are generally unsaturated. In low lying depressions such as around Lake Warramboo, lacustrine clay deposits are also present.

South-west of the study area, along the coastal margin of the Eyre Peninsula, the Quaternary limestone sediments of the Bridgewater Formation act as isolated aquifers. These aquifers have formed as a result of slightly elevated rainfall (local to the western margins of the Eyre Peninsula) and the surface exposure of suitable host rock (Quaternary Limestone) to receive and store recharge (Department for Water Resources, 2001). The lenses are located within the Musgrave Prescribed Wells Area (PWA) which is the administrative boundary that surrounds the groundwater lenses. Groundwater abstraction within these lenses is licenced due to its importance to supply potable groundwater to the Eyre Peninsula.

The major lenses generally have high yields (from 5 up to 50 L/s) and low salinity (less than 1000 mg/L) (Department for Water Resources, 2001). Groundwater levels within the Bridgewater Formation are generally higher than those in underlying aquifers, and as such a downward gradient is generally observed. The closest groundwater lens to the proposed mine site is the Polda Lens, located some 30 km south-west of the proposed mine site (Figure 3).

The Quaternary groundwater lenses located within the Musgrave PWA are isolated lenses which are not connected with the broader saline Quaternary sediments found in the central portion of the study area.

2.6.3 Tertiary

Within the study area, the Tertiary deposits consist of Neogene (Miocene to early Pliocene) deposits and older Palaeogene (mostly Eocene) deposits. The lithology of the Neogene deposits is predominantly argillaceous (clays and silts), however in some areas erosion and re-deposition of older Palaeogene sediments during the Neogene has resulted in a coarser fluvial and marine sandy facies at the base of the Neogene (Hou et al 2003). Where present, the reworked Palaeogene sediments act as an aquifer. Within the proposed mining lease, wells screened against the Tertiary sediments (interpreted to be the coarser facies at the base of the Neogene) report salinities in excess of 35,000 mg/L. Aquifer thickness is in the range of 5 to 15 m with aquifer transmissivity in the range of 4 to 37 m^2/d (SKM, 2014d).

Palaeogene deposits, as depicted on the available palaeodrainage map (Hou et al 2012), underlie the Neogene deposits to the south and west of the study area and consist of grey to black carbonaceous sand and silt (Flint and Rankin, 1989). The thickness of the Palaeogene deposits is in the order of 20 m and, based on the lithological description, it is expected to act as an aquifer, albeit of low permeability. The Paleogene sediments are regionally termed the Poelpena Formation. Available data indicate a hydraulic conductivity of 0.2 m/d (Coffey, 2013).

Groundwater flow in the Tertiary aquifer is interpreted to be in a south-westerly direction beneath the proposed mining lease. Isolated areas exist where no Tertiary sediments have been mapped (Neogene and Palaeogene), and these coincide with basement and topographic highs.

2.6.4 Jurassic Polda Formation

Towards the south-western edge of the study area, the Polda Trough incises basement rocks of the Gawler Craton. The Polda Trough is an east-west trending geological feature ranging between 10 and 40 km in width, and extending more than 350 km from near Cleve in the east, beyond Elliston to the continental margin in the Great Australian Bight. As the Polda Trough is located on the south-western margin of the study area, some 30 km from the proposed mine site, it is not considered significant in terms of the mine site GIA.

2.6.5 Saprolite

Saprolite within the vicinity of the mine pits is characterised by grey silty clay (a remnant of the original basement rock) at the top, grading down to partially weathered basement with much of the original rock fabric still remaining. Recent drilling indicates that the thickness of the saprolite is in the order of 20 to 40 m within the vicinity of the mine pit and integrated landform (SKM, 2014d).

The saprolite is interpreted to act as an aquitard based on:

- The lithology of the unit which is dominated by clay and silt;
- Permeability (slug) testing undertaken by Coffey at LS4 which calculated a hydraulic conductivity of 0.01 m/d (Coffey, 2013);
- A leaky confined response to aquifer testing undertaken by SKM in the basement material (SKM, 2014d);
- A salinity difference between the basement and tertiary aquifers (SKM, 2014d); and
- A pressure difference between the basement and tertiary aquifers (SKM, 2014d).

2.6.6 Fractured rock aquifers

The basement material within the study area consists of the Archaean Sleaford Complex which is characterised by highly deformed and metamorphosed gneisses derived from sedimentary rocks. Where secondary porosity has developed in this material through fracturing and faulting, the unit acts as a fractured rock aquifer, with yields in the range of 1 to 20 L/s (SKM, 2014a). Aquifer testing of this formation in support of mine dewatering studies indicates a regional transmissivity in the range of 2 to 4 m^2/day (SKM, 2014a).

Elsewhere in the bedrock, where secondary porosity is not as prevalent, yields are negligible. Hydrogeological investigations within the proposed mining lease (SKM, 2014a) reported salinities in the fractured rock aquifer in excess of 100,000 mg/L.

Recharge to the basement aquifer is generally localised, irregular and occurs in areas where the basement outcrops (i.e. surface exposures). The rate of recharge is variable and is a function of the exposure, the degree of fracturing present and the composition of the rock type (Department for Water Resources, 2001). Groundwater flow in the fractured rock aquifer is interpreted to be in a south-westerly direction beneath the proposed mining lease (SKM, 2014a).

2.6.7 Groundwater flow

Water table depths vary between approximately 5 m below ground level (mbgl) near salt (playa) lakes up to 20 mbgl in elevated areas (e.g. sand ridges).

Groundwater flow in both the Tertiary sediment aquifer and fractured rock aquifer is interpreted to be in a southwesterly direction beneath the study area. Figure 4 and Figure 5 illustrate the inferred groundwater contours for the Tertiary sediment (water table) and fractured rock aquifers, respectively (the Tertiary sediment aquifer and fractured rock aquifer are separated by a Saprolite unit which acts as an aquitard). The hydraulic gradient is predominately driven by what is interpreted to be an enhanced groundwater recharge zone to the northeast of the propose mine.

Locally, groundwater is inferred to discharge to salt (playa) lakes where it is lost through evapotranspiration. This interpretation is supported by shallow groundwater levels adjacent to playa lakes and elevated groundwater salinity suggesting evapo-concentration of salts (SKM, 2014a).

2.6.8 Recharge and discharge

Studies of recharge in arid areas of Australia consistently show values of less than 1 mm/yr under natural vegetation conditions (Dawes et al, 2002). Recharge rates inferred from calibration of the numerical groundwater flow model suggest that to balance measured groundwater levels with estimated hydraulic conductivities, recharge rates are likely to be consistent with the observations of Dawes et al (2002). The exception to this is on the elevated areas to the northeast of the proposed mine pit where the basement outcrops. In this area, a recharge rate of 15 mm/yr is required to match the measured groundwater levels within the range of hydraulic conductivity values (SKM, 2014b).

2.6.9 Water quality and beneficial users

The beneficial use of an aquifer can be assessed through the comparison of native groundwater quality with guidelines for specific types of water use. Beneficial use categories commonly used are potable (i.e. drinking water), agriculture and stock watering, and industrial. National standards have been used to compare groundwater quality in the study area.
The groundwater beneficial use assessment found the water quality within Tertiary and Fractured Rock aquifers has no beneficial use other than some types of industry (such as mining) without treatment. The groundwater in the Shallow Quaternary Polder Lens aquifer is considered of beneficial use stock, irrigation and potable use, however as mentioned, this formation is situated 30 km from the proposed mine site and not considered significant in terms of the mine GIA. Table 2-2 presents a summary of the groundwater quality in relation to possible beneficial use.

Table 2-2 Groundwater quality –comparison of water standards (without treatment)

Aquifer	Aquifer Salinity (mg/L)	Potable Beneficial use <1000 mg/L[1]	Agriculture Beneficial use <3,500 mg/L[1]	Stock water Beneficial use <13,000 mg/L[1]
Quaternary (Polder Lens)	<1000	✓	✓	✓
Tertiary	>35,000	✗	✗	✗
Fractured Rock	>100,000	✗	✗	✗

Notes:1. SEPP (1997)

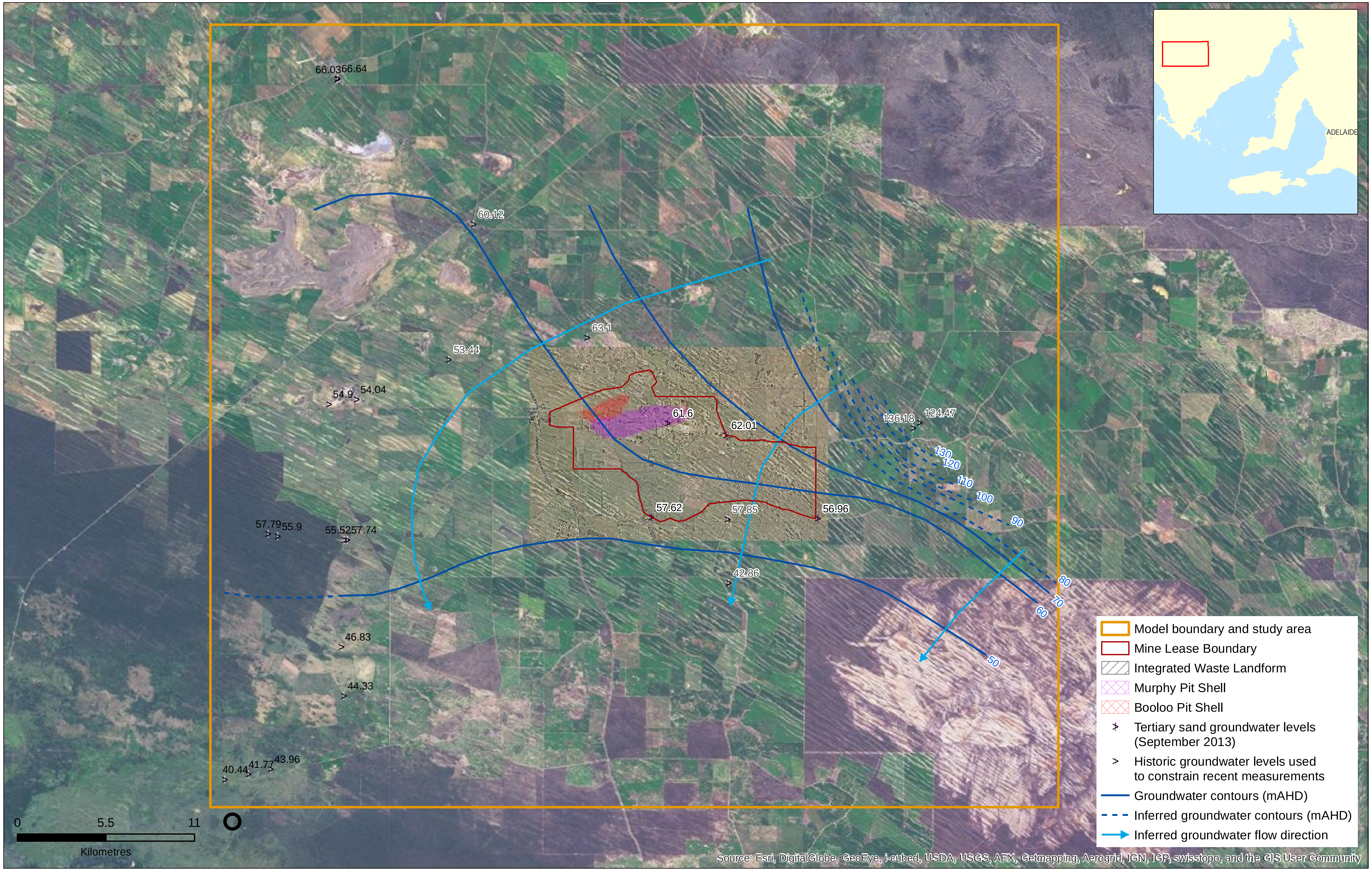

Figure 4: Tertiary sediment inferred groundwater flow direction

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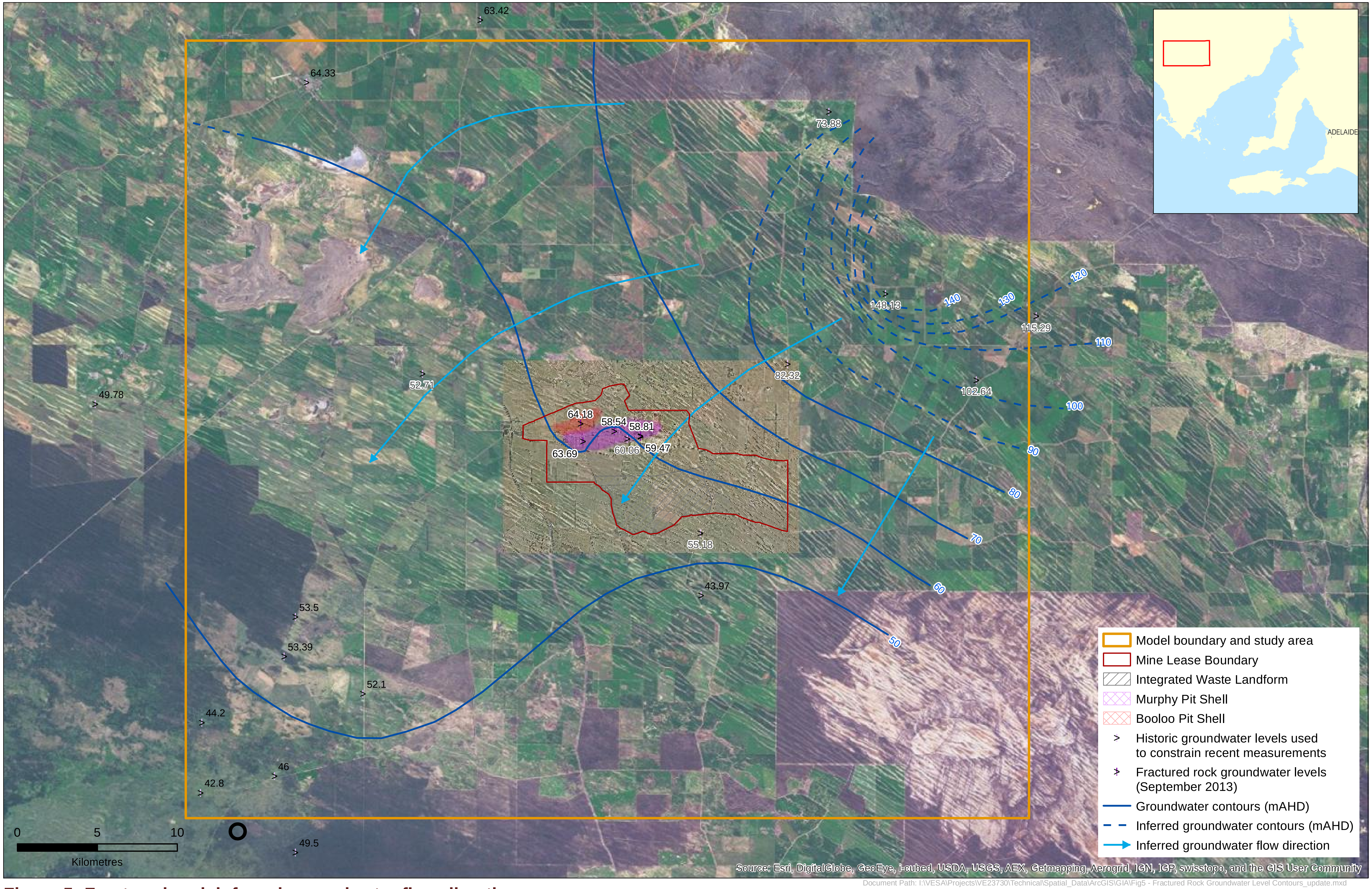

Figure 5: Fractured rock inferred groundwater flow direction

2.6.10 Summary

A summary of the hydrogeological properties including aquifer parameters and water quality data for the key hydrogeological units is presented in Table 2-3.

Table 2-3: Summary of hydrogeological properties

Age	Name	Aquifer type	Approximate Thickness (m)	Description	Hydraulic conductivity (m/d)	Salinity (mg/L)
Quaternary	Undifferentiated Quaternary	Unsaturated	10	Predominantly arenaceous i.e. sands and calcarenite. Holocene to Pleistocene aged	0.02 to 0.004[1]	N/A
Tertiary	Upper Neogene (Miocene / Pliocene)	Confining layer/ Aquitard	20	Predominantly argillaceous i.e. silts, clays with some sand/gravel	N/A	N/A
	Basal Neogene (Miocene / Pliocene)	Confined / Unconfined Aquifer	10	Coarser fluvial and marine sandy facies	0.5 to 3.0[2]	35,000 to 53,500[2]
	Palaeogene (Eocene - Poelpena)	Confined / Unconfined Aquifer	20	Grey to black carbonaceous sand and silt	0.2[3]	30,000[3]
Archaean	Saprolite	Aquitard	20	Highly weathered gneiss consisting of grey silty clay	0.01[3]	124,000[3]
	Fractured basement	Confined Aquifer	180	Broken metamorphics (gneiss, including magnetite gneiss and schist)	0.025 to 2.25[2]	113,000 to 150,000[2]
	Unfractured basement	Low permeability aquifer / aquitard	500+	Metamorphics (gneiss, including magnetite gneiss and schist)	0.001[4]	N/A

Notes [1] Data from Coffey (2012) tailings storage facility geotechnical investigation bores.
[2] Data from SKM (2014d) drilling, construction and testing completion report.
[3] Data from Coffey (2013) hydrogeological investigations groundwater monitoring bore installation and sampling program.
[4] Upper estimate of unfractured rock hydraulic conductivity (Todd and Mays, 2005).

A schematic representation of the hydrogeological units within the study area is provided in Figure 6 along with known groundwater levels and salinities from wells located along the section line. The location of the hydrogeological cross section runs from the proposed mine site south-west to the Musgrave PWA as illustrated in Figure 3.

Key features of the hydrogeological cross section are:

- At the mine site, Quaternary Sediments are characterised by sand, silt and clay whilst towards the coast the Quaternary Sediments are characterised by aeolian calcarenite of the Bridgewater Formation. The Bridgewater Formation contains fresh groundwater recharged via direct infiltration of rainfall within the Musgrave PWA. The aquifers associated with the Bridgewater Formation are not connected to the Quaternary Sediments found in the vicinity of the mine site.
- Tertiary sediments occur over much of the study area, except in areas where basement highs exist (e.g. WR28). In the vicinity of the mine site, groundwater salinity in the Tertiary Aquifer is reported to be in excess of 35,000 mg/L (SKM, 2014a).
- The Polda Formation is located to the south-west of the study area, however due to its distance from the proposed mine site it is not considered significant in terms of the mine site GIA. This point is validated in Section 5.2 which presents the predicted zone of influence as a result of WAA associated with the mine site.
- Basement material is characterised by the Archaean Sleaford Complex across the study area.

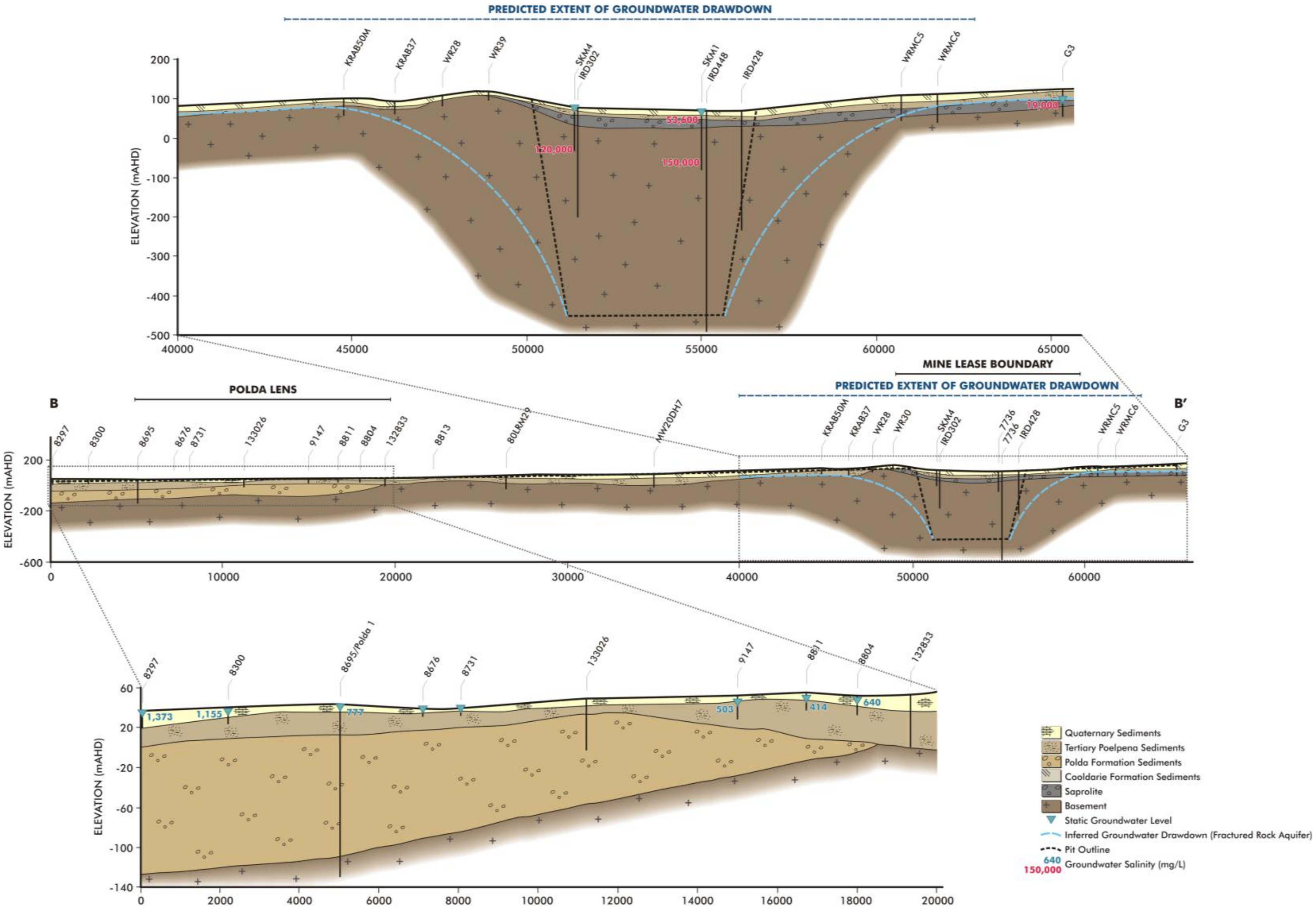

Figure 6: Hydrogeological cross section mine site to Musgrave PWA

3 Groundwater receptor identification

3.1 Introduction

Groundwater forms an important water supply for many regions in South Australia. It is an important resource for domestic and stock water supplies, and can form an important source of water that sustains ecosystems. To meet growing community and regulatory expectations with regard to sustainable use of natural resources, there is a need to balance the water requirements of the pastoral, mining and energy industries with cultural and social values, as well as environmental water requirements.

The following sections outline the environmental, social/cultural and economic receptors within the study area based on available data from public records and studies conducted by Iron Road.

3.2 Environmental

3.2.1 Overview

Some ecosystems rely on groundwater to meet ecological water requirements, and as a result may be sensitive to changes in the natural groundwater regime. Such ecosystems are described as Groundwater Dependent Ecosystems (GDEs). The Australian GDE Atlas (published by the National Water Commission) provides a starting point to assist with the identification of GDEs and the management of their water requirements (SKM, 2011). GDEs, as defined by the Australian GDE Atlas are broadly classified as follows (SKM, 2011):

- Ecosystems dependent on the surface expression of groundwater (e.g. wetlands, lakes, seeps, springs, and river baseflow systems); and
- Ecosystems dependent on the subsurface presence of groundwater (e.g. terrestrial vegetation which depends on groundwater on a seasonal, episodic or permanent basis).

3.2.2 GDEs reliant on sub-surface presence of groundwater

The majority of natural vegetation within the study area has been cleared for agricultural purposes. Other than dedicated conservation parks such as Hambidge (Figure 3), the vegetation that remains is restricted to scattered and isolated scrub blocks of varying size on farmland and as roadside vegetation. Many of these strands of remnant vegetation are identified by the GDE Atlas as potential GDEs. The vegetation within these areas broadly consists of Mallee associations that include mixed or *Melaleuca* dominated shrubland with an understorey of *Triodia* (Spinifex), native grasses or Chenopod species.

Although these areas have been identified as potential GDEs, assessment of the site conditions reveals that groundwater salinity is in excess of 35,000 mg/L and groundwater levels are typically 10-15 m below ground level which makes it unlikely that these systems are in fact dependent on groundwater.

3.2.3 GDEs reliant on surface expression of groundwater

There are no permanent watercourses or surface water bodies within the study area. A small number of salt lakes are present in which surface water pools following significant rainfall events. These areas may provide, at best, a temporary refuge for migratory birds when flooded. At these locations, groundwater is shallow, however it is not known to discharge to the surface and provide a permanent water source (i.e. evaporation exceeds groundwater discharge for the majority of the season). Groundwater may influence, to a certain extent, the length of time in which water pools, but this is primarily controlled by the magnitude of rainfall and evaporation during pooling times.

The GDE Atlas highlights several such areas as potential GDEs including Lake Warramboo which comprises a series of small salt lakes, located approximately 1.5 km to the north of the proposed mining lease boundary. A series of other small salt lakes are also present within the northern extent of the ML. Potential GDEs reliant on the surface expression of groundwater within the study area are illustrated in Figure 7.

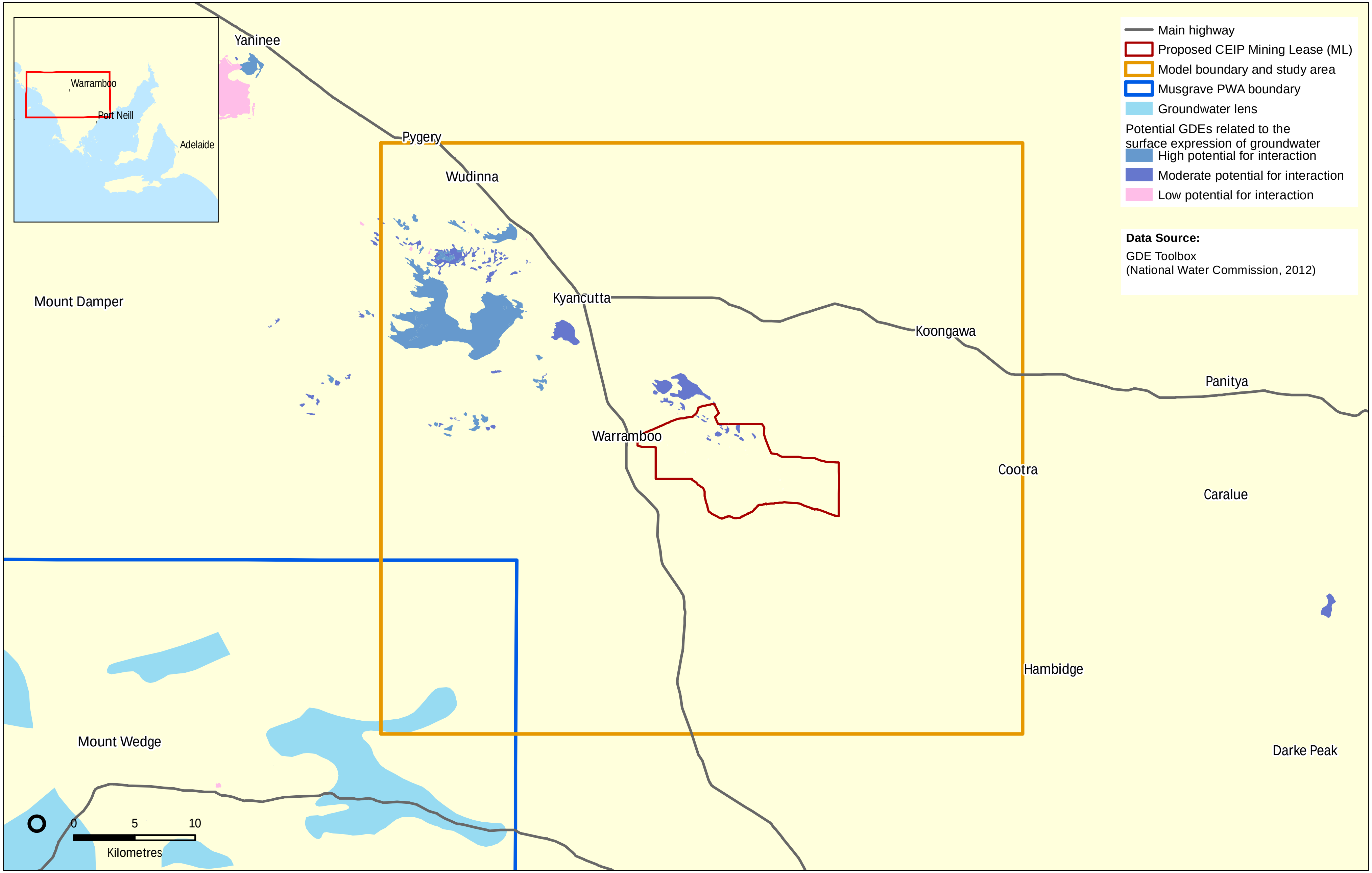

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Figure 7: Potential GDEs reliant on the surface expression of groundwater

3.3 Social and cultural

3.3.1 Existing users

Iron Road undertook a bore audit to identify any groundwater users whom may be affected by CEIP impacts on groundwater. The bores were selected by a groundwater impacts investigation undertaken by Jacobs based on the bore being located within a 10km of the modelled radius of influence for the borefield and mine pit dewatering operations. The impacts investigation identified 10 bores suiting the criteria from data obtained from the South Australian State Government online Water Connect database (https://www.waterconnect.sa.gov.au).

The landowners of the bores were contacted and it was found out of the ten bores identified nine no longer exist. The remaining bore (6030-803) was reported by the land owner to be too saline and was never used for stock watering. This bore was used for a short period in 2013 by Centrex Mining for mining exploration but is currently not in use. All land owners interviewed advised that no groundwater was used for stock in the area. Table 3-1 presents the 10 bores identified and their current status.

Table 3-1 Water bore status

Well ID	Easting	Northing	Date Drilled	Current Status
6030-1	592485	6288970	5/12/1969	Non existent
6030-13	579814	6266713	2/12/1958	Non existent
6030-803	581138	6269009	9/05/1966	Not used[1]
6031-23	569843	6310604	4/12/1975	Non existent
6031-24	567714	6311332	4/12/1975	Non existent
6031-129	558913	6326555	29/08/1961	Non existent
6031-130	562803	6324579	1/09/1961	Non existent
6031-160	579181	6320935	20/03/1986	Non existent
6031-161	579565	6321269	16/02/1987	Non existent
6130-115	615621	6286113	4/12/1969	Non existent

Note: 1. No future use intended by landholder due to high salinity

3.3.2 Indigenous heritage

Indigenous heritage is being assessed as a part of the broader impact assessment for Iron Road.

3.4 Economic

3.4.1 Agriculture

The dominant land use in the study area is production from dryland agriculture (Figure 3), including mixed cereal crops and grazing. Project WAA have the potential to generate changes in the groundwater table which may lead to impacts on agricultural productivity.

Lowering of the groundwater table is unlikely to generate any issues for crop production as crops are reliant on seasonal rainfall held in the unsaturated zone rather than being reliant on groundwater. This is especially true for the CEIP study area where groundwater salinity in the water table aquifer exceeds 35,000 mg/L (SKM, 2014a).

Increasing the groundwater table has the potential to generate waterlogging and salinisation within soils which may adversely affect crop production, particularly where the groundwater table approaches the surface. An assessment of the pre-mining depth to groundwater for the proposed mine lease has been undertaken to identify areas which may be susceptible to increases in the water table elevation. A depth to water table grid has been generated using digital elevation model (DEM) data and an inferred water table elevation surface (GWS, 2014b). The inferred depth to water table is presented in Figure 8.

The depth to water table grid highlights areas where groundwater is currently close to the surface. The analysis identifies areas south east of the integrated landform where the current water table is between 5 and 10 m below ground level. These areas coincide with swales between sand ridges and are likely to be sensitive to any increases in water level due to enhanced recharge from the waste rock integrated landform.

The depth to water grid also highlights the previously identified salt pans, delineated on the figures using the extent of the Yamba Formation (lacustrine playa lake sediments). These salt pans are located within and adjacent to the proposed mine pit and are likely to be impacted by mine dewatering which will result in a reduction in the water table beneath the salt pan. Water table rise and increased salinisation is not likely to be an issue in these areas.

3.4.2 Mineral and energy industry

There are 15 mineral deposits recorded within the study area, none of which are currently active (Figure 9).

3.5 Summary

Table 3-2**Error! Reference source not found.** presents a summary of the identified groundwater receptors within the study area that may be impacted by WAA occurring within the proposed mining lease. As identified inTable 3-2 there are a number of receptors that have been identified as being unlikely to be impacted by WAA and these are therefore not discussed further in this report. These include GDEs reliant on the sub-surface presence of groundwater Existing groundwater users and the mining and energy industry. Receptors that will be reviewed as a part of the impact assessment include GDEs reliant on the surface expression of groundwater and agriculture.

Table 3-2: Receptor identification summary

Receptor group	Receptor	Potential for impact	Comment
Environment	GDEs reliant on sub-surface presence of groundwater	✗	Mallee vegetation not considered to be reliant on groundwater
	GDEs reliant on surface expression of groundwater	✓	Playa lakes (e.g. Lake Warramboo)
Social and cultural	Existing groundwater users	✗	Stock and industrial wells
	Indigenous communities	N/A	N/A
Economic	Agriculture	✓	Potential for impact if the groundwater table increases in low lying areas
	Mining and energy industry	✗	Nil

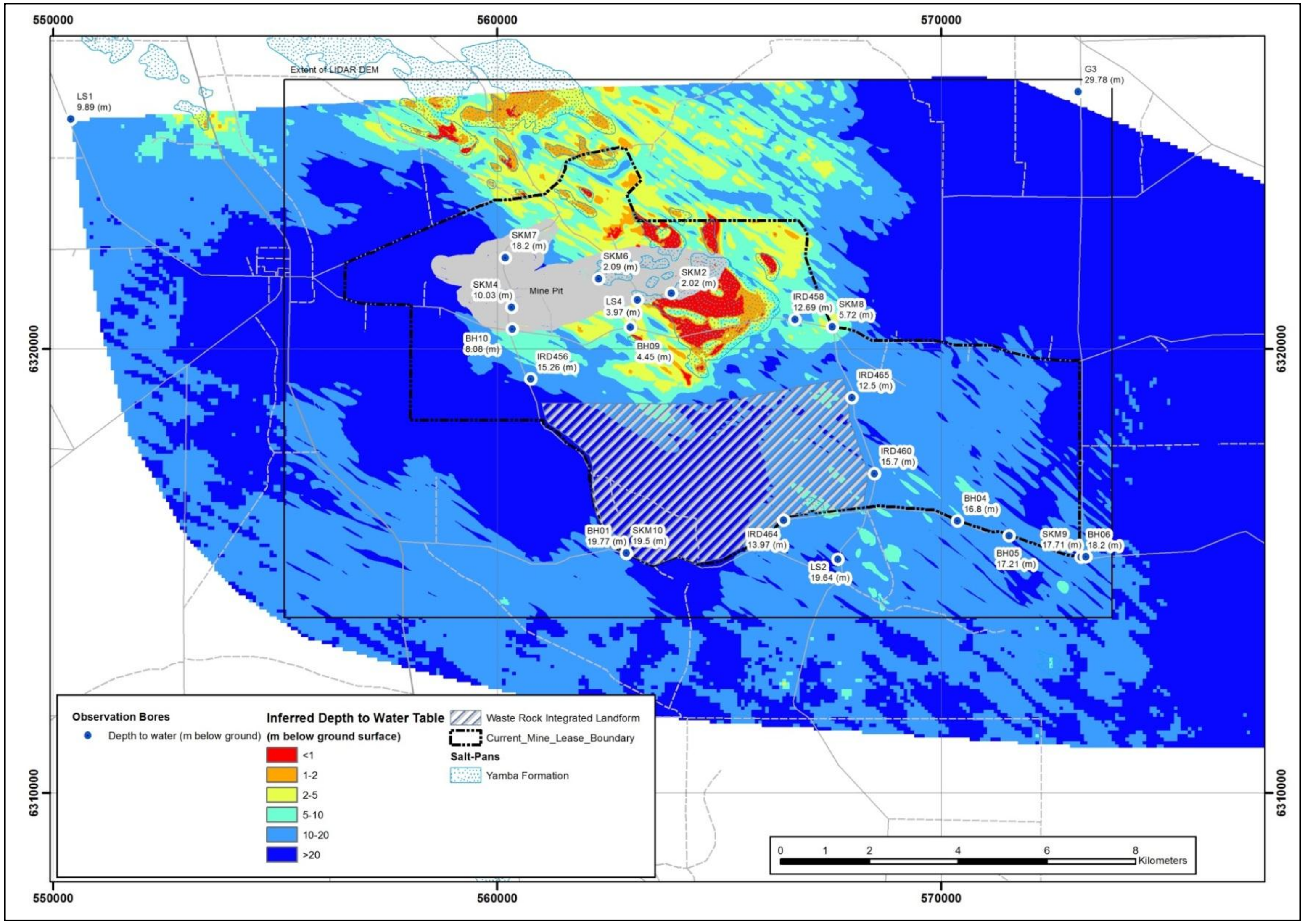

Figure 8: Inferred depth to water table (GWS, 2014b)

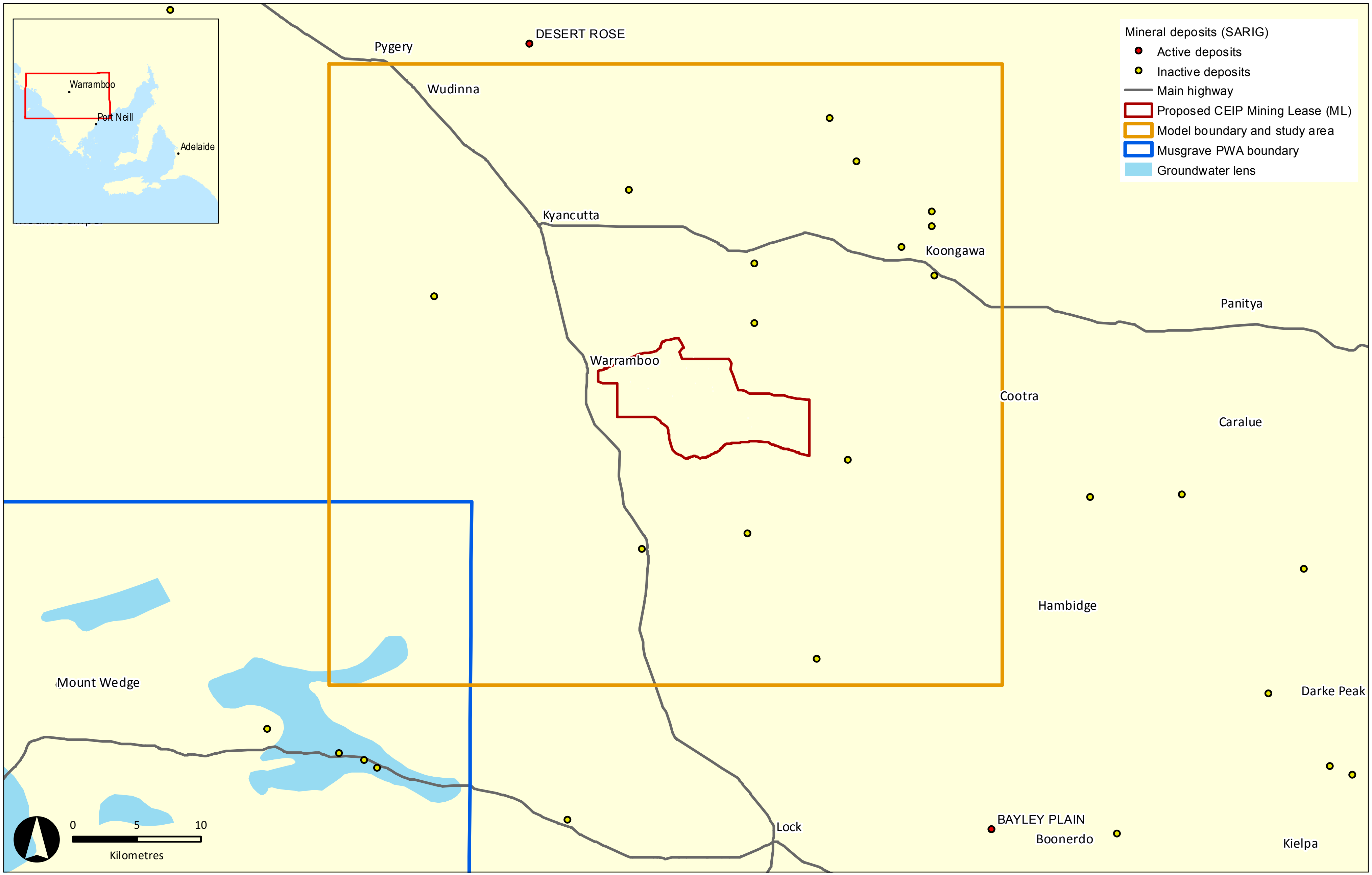

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Figure 9: Mineral deposits

4 Groundwater effects assessment

4.1 Water affecting activities (WAA)

4.1.1 Overview

WAA are activities that can affect the existing water regime, which may in turn cause adverse impacts to receptors. The following sections present a description of the WAA occurring within the proposed mining lease that have the potential to alter groundwater conditions within the study area.

4.1.2 Pit construction and groundwater inflow management

The CEIP mine site layout consists of two adjacent mine pits as presented in Figure 3. Mining is proposed to commence on the Murphy South resource for the first 15 years after which mining will commence in the Boo Loo pit through to the life of mine at 25 years. The Murphy South and Boo Loo pits are to be developed to approximately 600 m and 300 m below ground level, respectively.

To achieve safe and generally dry mining conditions, it will be necessary to actively manage groundwater inflow to the pit. The dewatering strategy includes abstracting groundwater from both dewatering wells and in-pit sump pumps. A numerical groundwater flow model has been used to estimate the volumes of groundwater to be abstracted to achieve effective mining conditions. A summary of the dewatering strategy and predicted abstraction volumes is provided below:

- 11 dewatering wells (four in-pit and seven ex-pit), with predicted individual abstraction rates ranging from approximately 0.43 to 1.73 ML/day (around 5 to 20 L/sec); and
- In-pit sump pumps that force groundwater levels to the base of the active mine pits (the number of sumps is determined by pit floor topography), with predicted total abstractions ranging between 4 and 17 ML/day from Murphy South pit (46 to 200 L/sec, years 0 through 25) and between 0.5 and 6 ML/day from Boo Loo pit (1 to 70 L/sec, years 15 to 25).

The predicted ex-pit (dewatering well) and in-pit (sump pump) abstraction volumes are illustrated in Figure 10. The predicted groundwater pit inflows in Figure 10 have been broken down into the relative contribution from each hydrogeological formation. A detailed description of the dewatering strategy is provided in the CEIP Mine Pit Groundwater Management Plan (SKM, 2014c).

Saline groundwater abstracted from dewatering wells and in-pit sumps will be transferred to the mine site process water pond. Groundwater abstracted from dewatering wells during advanced dewatering will be used during the construction phase for earthworks and dust suppression. If the dewatering volume exceeds construction requirements, dewatering rates may need to be reduced or selected wells turned off. The priority for dewatering during the construction period is the Murphy South mine pit. The salinity of abstracted groundwater from the dewatering wells and in-pit sumps is expected to be in excess of 100,000 mg/L (SKM, 2014a).

The overall saline water demand for the project is 14 GL/year, of which the majority will be supplied from the proposed Kielpa Borefield located approximately 60 km south of the mine site. The impacts of the proposed Kielpa Borefield are presented and discussed in the CEIP Infrastructure GIA (Jacobs, 2014).

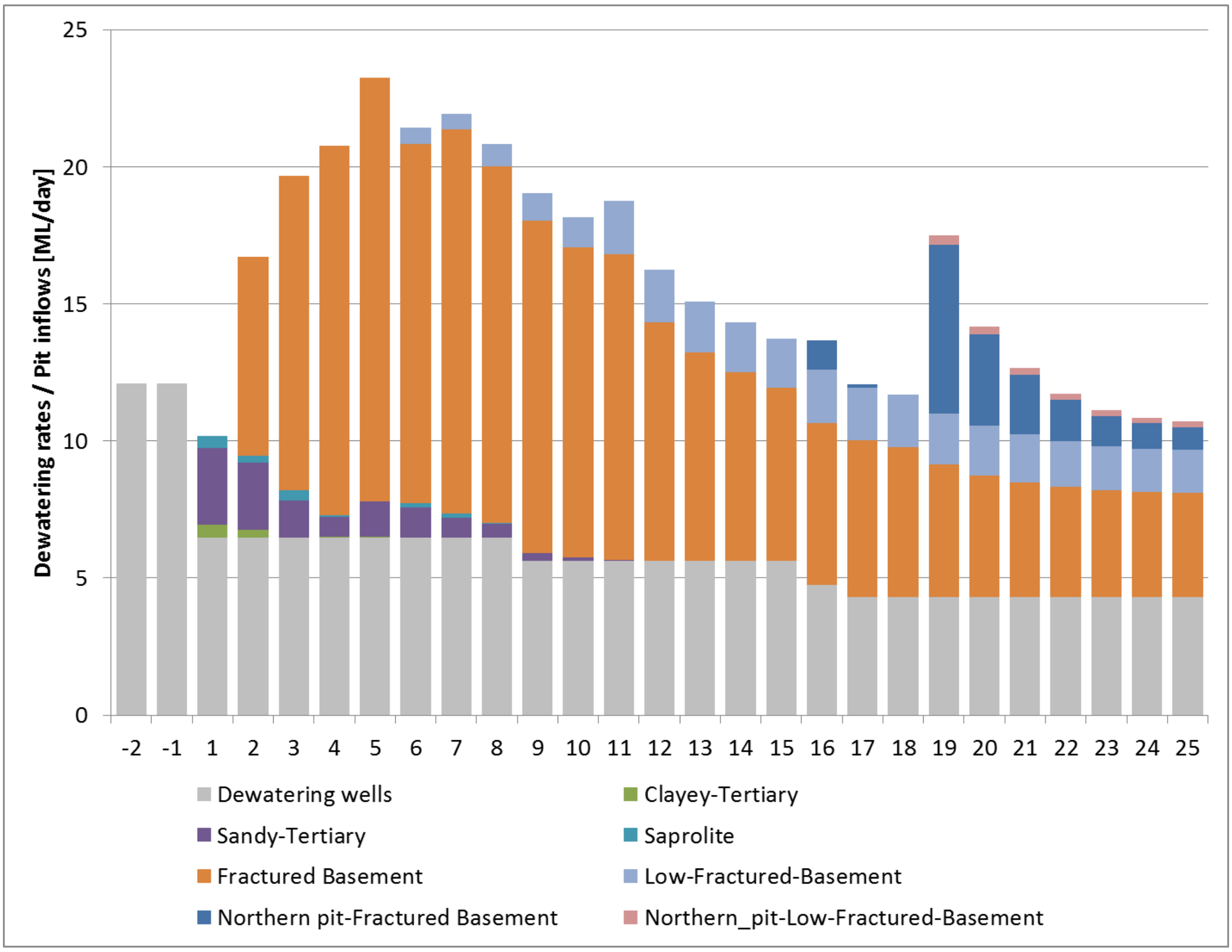


Figure 10: Predicted average annual dewatering rates during the 25 years of mine operation

4.1.3 Integrated landform

The project proposes to utilise a stack technique for storage of waste produced from ore processing. The waste will be a combination of waste rock from the in-pit crushing and conveying and waste tails from the ore processing facility. The location of the proposed stacked waste storage, referred to as the integrated landform, is illustrated in Figure 3. The integrated landform will be developed in a progressive manner using three mobile stackers.

The integrated landform has the potential to change the amount of water that recharges to the groundwater system. A coupled soil-plant-atmosphere model of the unsaturated zone was used to assess the changes associated with the development of the integrated landform. A base case model was set-up using current soil type, vegetation cover and climatic conditions. This model estimated that the amount of steady state recharge currently reporting to the groundwater system is in the order of 1 mm/yr. This value is consistent with the amount of recharge applied to the numerical groundwater flow model to achieve successful calibration (SKM, 2014b).

Following validation of the base case model, enhanced recharge from the integrated landform was simulated using available particle size distribution from the combined waste rock and waste tails. The integrated landform was modelled above ground level at the proposed height of 135 m. As a result of the altered surface material and the removal of vegetation cover, the rate of enhanced recharge to the groundwater system is predicted to be around 50 mm/yr under the footprint of the integrated landform prior to rehabilitation.

During closure, several land use options are considered including agricultural production, agroforestry and re-instating native woodland. The seepage model has been used to assess the rate of recharge to the groundwater system under the agricultural scenario. This scenario was tested as it is the scenario which is likely to create the highest recharge rate of the current closure options (in comparison to agroforestry and native vegetation). The assessment indicates that 6 mm/yr of recharge is possible. Progressive rehabilitation of the integrated landform is planned, with rehab scheduled to occur approximately one year after the integrated landform has reached its design height.

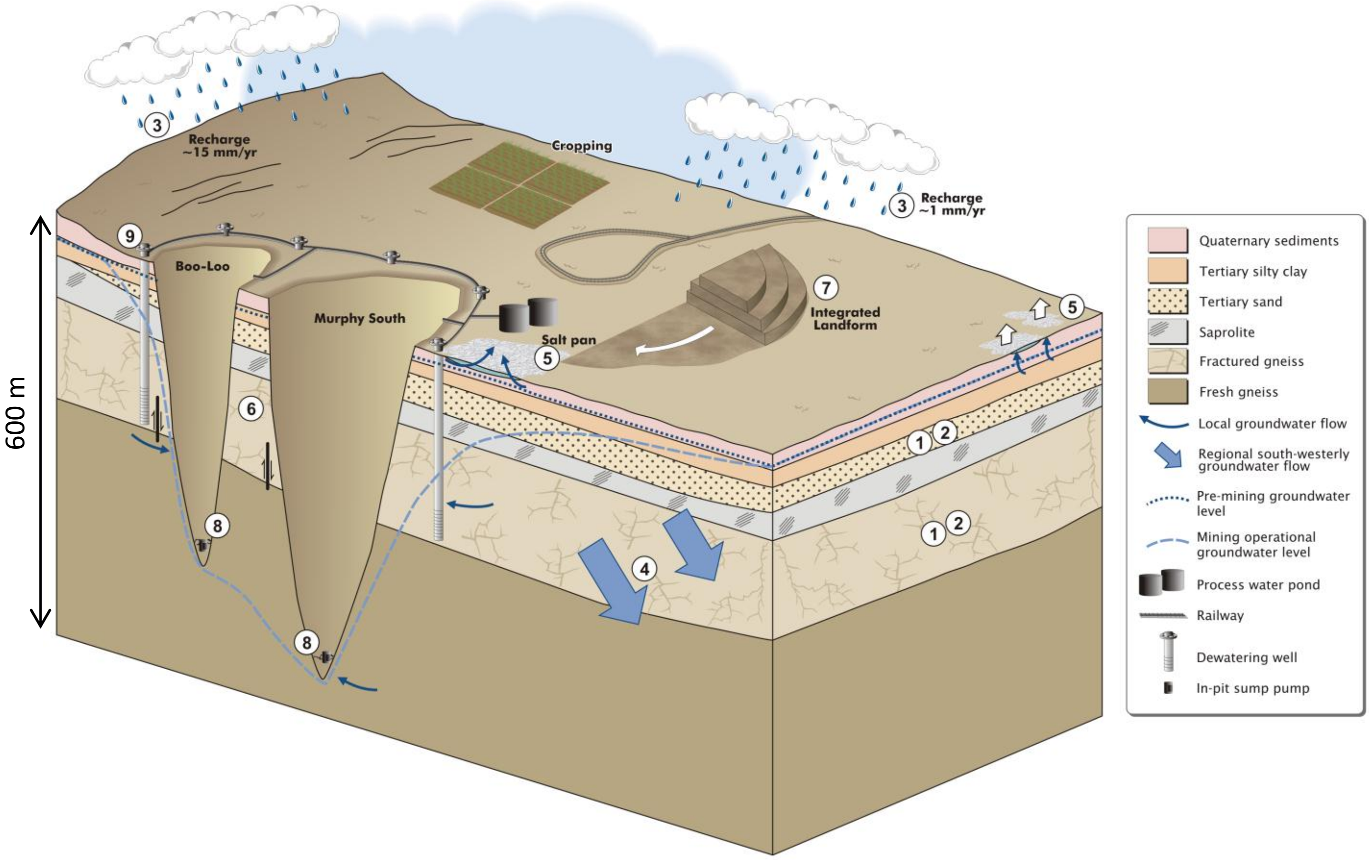
It is also expected that a lag time will occur between recharge entering the top of the integrated landform and it reaching the water table (a distance of approximately 145 m). Assessment using the seepage model indicates the lag time may be in the order of 20 years (SKM, 2014b).

Further information regarding the methodology and assumptions used to estimate recharge from the integrated landform is provided in the CEIP Mine Water Management – Numerical Groundwater Flow Model Report (SKM, 2014b). The impacts of the increased recharge below the integrated landform during both the operational and closure phase have been assessed using the mine site numerical groundwater flow model.

Conceptual hydrogeological model

Figure 11 presents a conceptual model to illustrate the WAA within the proposed mining lease during operation of the project, which includes the pit development, groundwater inflow management and the development of the integrated landform. The following describes important features of the hydrogeological conceptual model:

1. Two main aquifers exist in the project area, the Tertiary sediment aquifer and fractured rock (gneiss) aquifer. The aquifers are separated by the low permeability saprolite layer which acts as an aquitard, limiting flow between the aquifers;
2. Local to the proposed mine area, groundwater salinity in the Tertiary sediment aquifer ranges from 35,000 to 53,600 mg/L, while groundwater salinity in the fractured rock aquifer is significantly higher ranging from 113,000 to 150,000 mg/L;
3. Recharge rates are around 1 mm/yr over the majority of the study area, while in the topographic highs in the northeast, recharge may be an order of magnitude higher (approximately 15 mm/yr);
4. Regional groundwater flow in both aquifers is in a southwesterly direction toward the coast;
5. Locally, groundwater also discharges through evaporation to salt pans and playa lakes;
6. Two significant fracture zones have been inferred running in an east-west orientation through the Boo Loo pit and Murphy South pit which exhibit higher groundwater yields and estimates of hydraulic conductivity;
7. Modelling work suggests that enhanced recharge from the integrated landform is expected to be in the order of 50 mm/yr for a period of one year during the construction of the integrated landform. Following this, progressive rehabilitation will occur and the seepage is estimated to reduce to 6 mm/yr.
8. In-pit seepage is to be collected and transferred to the process water pond via in-pit sump pumps. The predicted inflow rates range from 4 to 17 ML/day from the Murphy South pit and from less than 0.5 to around 6 ML/day from the Boo Loo pit; and
9. Dewatering wells (four in-pit and seven ex-pit wells) are predicted to abstract a further 12 ML/d (2 years prior to mining) to 4 ML/d (end of mining at year 25).



NOTE: vertical elevation exaggerated

Figure 11: CEIP mine conceptual hydrogeological model

5 Groundwater impact assessment

5.1 Overview

The WAA described in this section have been assessed using the mine site numerical groundwater flow model which was constructed using the US Geological Survey's MODFLOW code. Various data sets have been used to assist in model construction, including lithological and drill-hole data sourced from government databases (WaterConnect and SARIG) and other drilling and testing programs undertaken in support of the CEIP. The model confidence level classification as described by the Australian Groundwater Modelling Guidelines (Barnett *et al*, 2012) is targeted at Class 2, which reflects the availability and accuracy of existing data sets. A Class 2 model is described by the guidelines as suitable for "providing estimates of dewatering requirements for mines and excavations and assessing the associated impacts".

The assessment assumes the following WAA are occurring:

- Advanced dewatering using ex-pit and in-pit wells two years prior to the commencement of mining at a combined rate of up to 12 ML/d;
- Dewatering during life of mine using both ex-pit bores and in-pit sump pumps at a combined rate of 4 to 23 ML/d;
- Development of the Murphy South mine pit to 537 m below ground level and development of the Boo Loo mine pit to 220 m below ground level; and
- Enhanced recharge from the integrated landform at a rate of 50mm/yr applied in a progressive manner for one year followed by 6 mm/yr of recharge once rehabilitation has taken place (i.e. one year after the landform material is deposited). The groundwater model has been used to simulate the closure phase (simulated as 1000 years).

The impact assessment relies on predictions made by the numerical groundwater model developed for the project, and documented in the CEIP Mine Water Management – Numerical Groundwater Flow Model Report (SKM, 2014b). The assessment follows the NWC (2010) framework in terms of direct effects relating to groundwater quantity, groundwater quality, surface water – groundwater interaction and aquifer disruption. A model uncertainty analysis was also undertaken whereby aquifer parameters were varied within credible ranges to assess the extent of potential groundwater impacts (refer to Appendix B and SKM, 2014b). The model results presented herein are thought to be most reflective of the values derived from field testing and have therefore been used as the basis for the groundwater impact assessment.

5.2 Groundwater quantity

Groundwater levels provide a means of assessing the degree to which the quantity of groundwater within the regional groundwater system may change in response to mine WAA. The predicted drawdown at the completion of mining (year 25) for the water table aquifer (Tertiary aquifer) and the fractured rock gneiss aquifer is presented in Figure 12 and Figure 13, respectively. Drawdown (expressed as the 1 m drawdown contour) is not predicted to extend more than 7 km from the mine pits in both aquifers.

During the life of the mine (25 years) groundwater levels beneath the integrated landform are not predicted to increase, as enhanced recharge is controlled by the magnitude and extent of the cone of depression caused by pit dewatering.

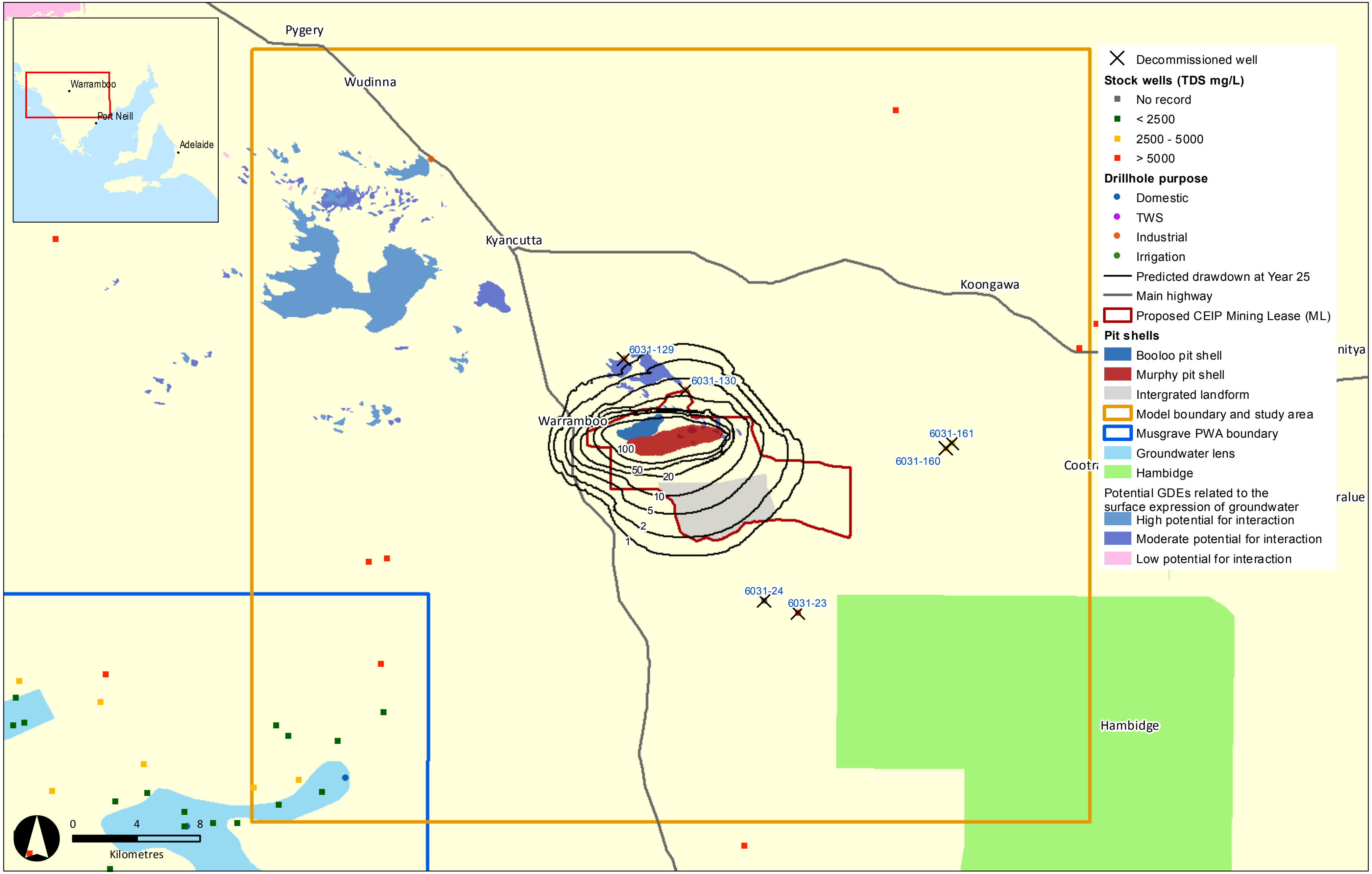


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Figure 12: Drawdown in the Tertiary aquifer (Layer 3 watertable) at year 25

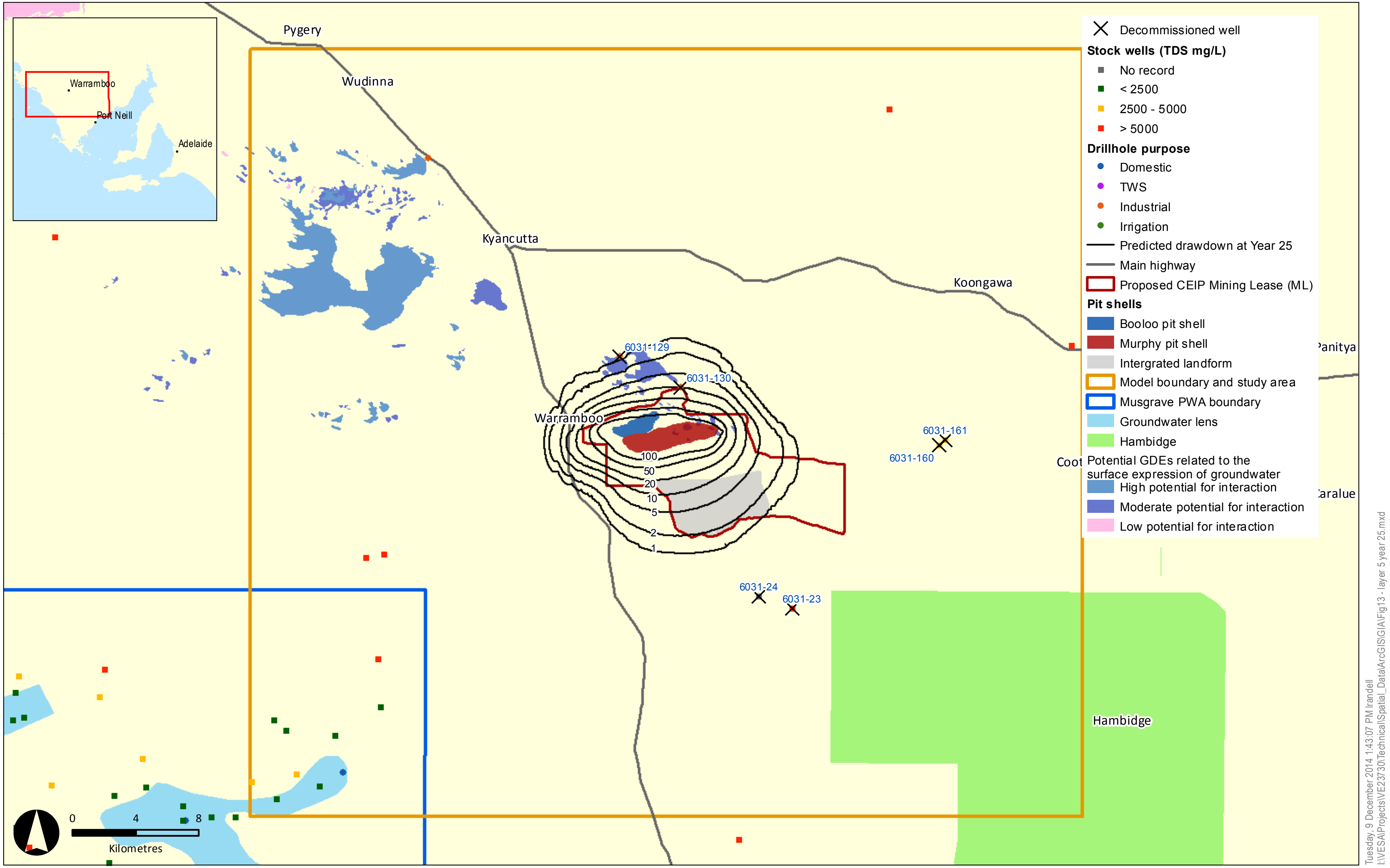

Figure 13: Drawdown in the Fractured rock aquifer (Layer 5) at year 25

At the completion of mining, when the dewatering system is decommissioned, groundwater will continue to discharge into the pit and a pit lake is predicted to form. The pit lake water level is predicted to stabilise at approximately -275 m AHD approximately 1000 years post closure (Figure 14). This is approximately 335 m below the pre-mining groundwater level, and as such a permanent cone of depression is predicted to form around the pit. Once the pit lake level has stabilised, a new steady state groundwater flow regime will be maintained.

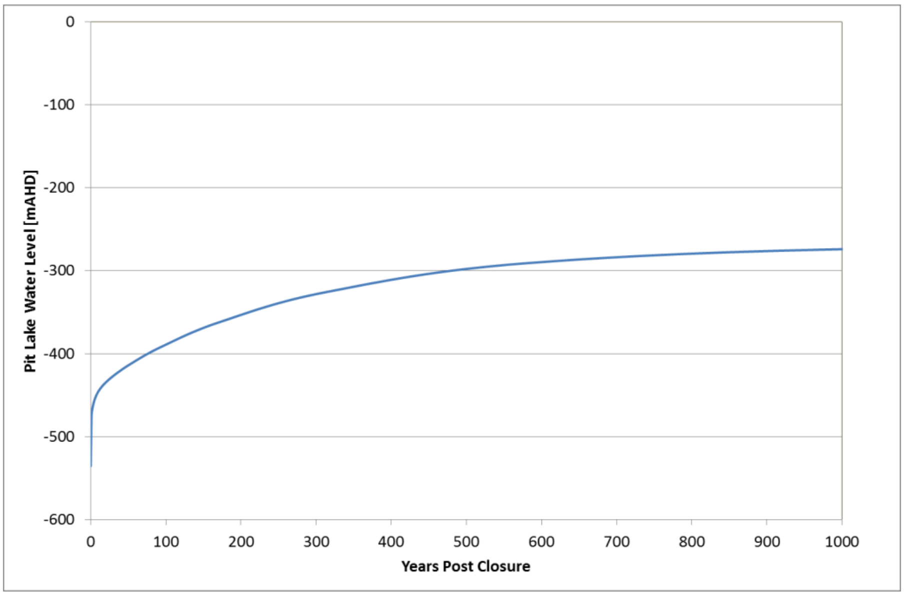

Figure 14: Predicted pit lake level post closure

The predicted change in the water table aquifer (Tertiary sediments) 1,000 years post closure is illustrated in Figure 15. Drawdown (expressed as the 1 m drawdown contour) is not predicted to extend more than 10 kilometers from the mine pits. Similarly, groundwater drawdown in the Fractured Basement aquifer (Layer 5) is not expected to extend more than 10 km from the mine pits (SKM, 2014b).

During the closure simulation (1000 years) there is no predicted increase in the groundwater level beneath the integrated landform, as enhanced recharge is controlled by the magnitude and extent of the cone of depression caused by ongoing evaporation from the pit.

Although the numerical groundwater flow model does not predict any increase in the water table elevation, it is acknowledged that there are several areas located to the southeast of the integrated landform where groundwater is currently within 5 to 10 m of the surface (Figure 8). These areas may be sensitive to increase in the water table elevation. Observation wells located between the integrated landform and the shallow watertable areas should be considered.

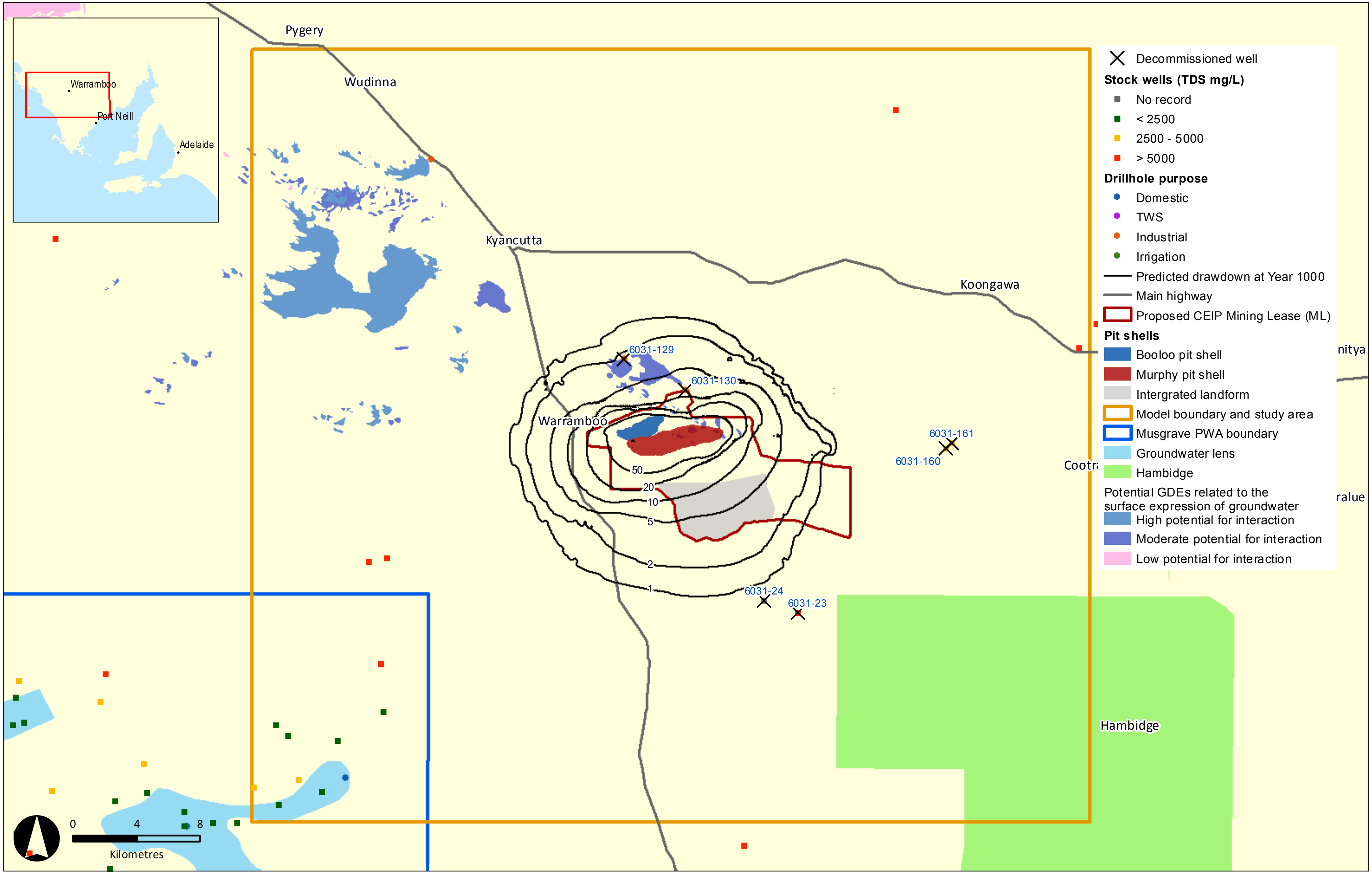

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Figure 15: Drawdown in the Tertiary aquifer (Layer 3 watertable) at year 1000

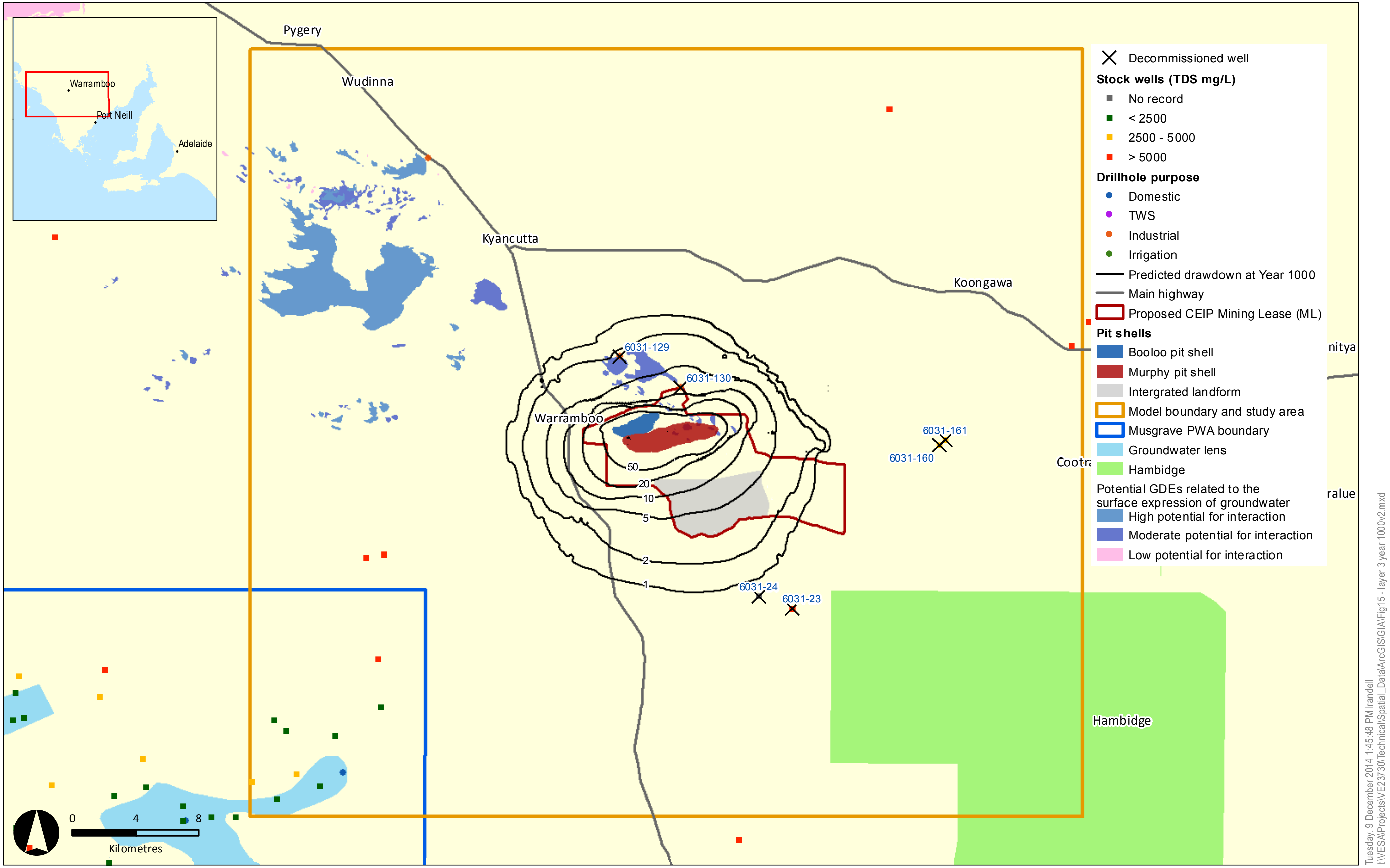

Figure 15: Drawdown in the Tertiary aquifer (Layer 3 watertable) at year 1000

The following observations are made based on the groundwater modelling predictions:

- Groundwater drawdown impacts during operation and closure are not predicted to extend more than 10 km from the mine pits.
- The zone of influence is not predicted to reach the Musgrave PWA. The distance from the Polda Lens and the predicted zone of influence is approximately 20 km as illustrated in Figure 6.
- There is no predicted increase in the groundwater level beneath the integrated landform during or after mining.

5.3 Groundwater quality

Current groundwater salinity data for the Tertiary sediment aquifer indicates that salinity ranges from 35,000 to 53,600 mg/L, and fractured rock (gneiss) aquifer salinity is in excess of 100,000 mg/L (SKM, 2014a). Based on the available groundwater salinity data, the beneficial use category of these aquifers is considered suitable for limited industrial purposes only.

There are a number of activities that are required to support the proposed project which may have the potential to impact on groundwater quality through the release of potential contaminants into the environment, e.g. hydrocarbons, solvents and nutrients. These activities include, but are not limited to, camp and lease operations, waste water treatment facilities, and fuel storages. These facilities will be engineered and constructed according to appropriate industry guidelines to reduce the likelihood of uncontrolled releases. In the case of hazardous goods and fuel storages, secondary containment to capture uncontrolled releases will be included to further reduce the potential for contaminants entering the environment.

5.4 Groundwater – surface water interaction

Lake Warramboo and its adjacent playa lakes have been identified as being within the predicted zone of groundwater drawdown. Based on the numerical modelling results, groundwater levels are predicted to decrease by approximately 1 to 5 m in the vicinity of Lake Warramboo. It is possible that some level of effect may be felt , depending on the degree of reliance these systems have on groundwater discharge. For information about terrestrial flora and fauna at these locations please refer to the accompanying report.

5.5 Aquifer disruption

Groundwater will begin to drain into the pit void once the proposed operations break through the watertable aquifer. At this stage active dewatering of the mine will be required to maintain safe and dry conditions.

Following the completion of mining when the dewatering system is decommissioned, the pit void will remain open and a pit lake is expected to form at an elevation below that of the pre-mining groundwater level. The resultant cone of depression will alter the baseline flow processes of groundwater beneath the proposed mining lease, the effects of which are discussed in Section 5.2.

6 Summary

Table 6-1 presents a summary of the groundwater receptors that have the potential to be affected by WAA occurring on the proposed mine lease. Although existing groundwater users and the agricultural industry have been identified as potential groundwater receptors, the impact assessment indicates that there will be no impacts to these receptors.

The potentially sensitive receptor that may be impacted by mine WAA is Lake Warramboo and its adjacent salt lakes.

The results of the impact assessment indicate that:

- Groundwater levels within the vicinity of Lake Warramboo are predicted to reduce by 1 to 5 m in the long term.
- Groundwater levels are not predicted to increase beneath or adjacent to the integrated landform as a result of enhanced recharge. Observation of groundwater levels may be warranted through the operational phase to confirm this response, especially to the south east of the integrated landform where groundwater is shallower.

Table 6-1: Summary of potential effects to groundwater receptors

Receptor	Groundwater quantity	Groundwater quality	Groundwater – surface water interactions	Aquifer disruption
Lake Warramboo	✓	✗	?✓?	✗
Agriculture	✗	✗	✗	✗

7 References

Barnett *et al* (2012). Australian groundwater modelling guidelines, Waterlines report, prepared for National Water Commission, Canberra.

Berens V, Alcoe DW, Watt EL, (2011). Non-prescribed groundwater resources assessment – Eyre Peninsula Natural Resources Management Region. Phase 1 - Literature and Data Review, DFW Technical Report 2011/16, Government of South Australia, through Department for Water, Adelaide.

Brereton D. & Moran, C. (2008). Cumulative effects: what are they and how can they be better understood and managed? In: Sustainable Development Conference Workbook, Darwin 2008.

Coffey Environments (2013). Groundwater Monitoring Bore Installation and Sampling Program Summary, prepared for Iron Road Limited (IRD Reference E-F-16-RPT-0001).

Coffey (2012) Geotechnical Investigation, Central Eyre Iron Project, Tailings Storage Facility. Report by Coffey Mining Pty Ltd for Iron Road Ltd. (IRD Reference E-F-24-RPT-0001).

Dawes, WR, Gilfedder, M, Stauffacher, M, Coram, J, Hajkowicz, S, Walker, GR and Young, M (2002) Assessing the viability of recharge reduction for dryland salinity control: Wanilla, Eyre Peninsula, Australian Journal of Soil Research 40, 1407-1424.

Department for Water Resources (2001). Understanding the Musgrave Prescribed Wells Area http://www.epnrm.sa.gov.au/Portals/4/Water/Understanding_Musgrave.pdf

Groundwater Science (2014a). CEIP Definitive Feasibility Study Report – Kielpa Groundwater Supply Study, prepared for Iron Road Limited (report reference no. E-F-66-RPT-2001).

Groundwater Science (2014b). Inferred Water Table Elevation Technical Note, prepared for Iron Road Limited (report reference no. E-F-16-MMO-0006).

Hou, B., Frakes, L.A. & Alley, N.F. (2003). Palaeochannel evolution, northwestern Gawler Craton, South Australia. CRC LEME Volume, Perth.

Jacobs, 2014. CEIP Infrastructure Groundwater Impact Assessment, prepared for Iron Road Limited.

NWC (2010). Framework for assessing cumulative potential impacts of mining operations on groundwater systems. Report 3. National Water Commission.

SEPP 1997 State Environment Protection Policy: Groundwaters of Victoria. No S 160 Wednesday 17 December 1997.

SKM (2011). Australian Groundwater Dependent Ecosystems Toolbox - Part One: Assessment Framework. Waterlines reports No 69 and No 70 - December 2011, National Water Commission. http://www.nwc.gov.au/publications/waterlines/australian-groundwater-dependent-ecosystems-toolbox/

SKM (2014a). CEIP Mine Site Hydrogeological Studies, prepared for Iron Road Limited (report reference no. E-F-16-RPT-0005).

SKM (2014b). CEIP Mine Water Management – Numerical Groundwater Flow Model, prepared for Iron Road Limited (report reference no. E-F-16-RPT-0017).

SKM (2014c). CEIP Mine Pit Groundwater Management Plan, prepared for Iron Road Limited (report reference no. E-F-16-RPT-0020).

SKM (2014d). CEIP Groundwater Drilling and Aquifer Testing Completion Report, prepared for Iron Road Limited (report reference no. E-F-16-RPT-0015).

Todd DK, Mays LW (2005) Groundwater Hydrology. 3rd ed., Hoboken: John Wiley & Sons.

Water Connect (2013) Government of South Australia database. www.waterconnect.sa.gov.au.

Appendix A Recorded groundwater wells located within the study area

Well ID	Easting	Northing	Bore Depth (m)	Purpose	EC	EC Date	DTW	DTW Date
5931-40	544018.7	6314000	5.49	STK	32018	31/01/1963	4.57	13/07/1962
5931-41	542880.8	6313792	5.18	STK	17809	16/01/1962	4.57	9/08/1961
5931-45	543643.6	6307360	11.58	STK	23525	21/07/1961	10.67	21/07/1961
5931-48	535605.6	6299612	5.15	STK	5040	26/06/1976	3.55	26/06/1976
5931-53	537027.7	6303518	6.2	STK	875	21/06/1979	4.1	21/06/1979
5931-54	537816.6	6302889	8.53	STK	1610	21/06/1979	3	21/06/1979
5931-57	538462.8	6300062	0	STK	5200	21/06/1979	3.4	21/06/1979
5931-60	537222.6	6298505	0	STK	1760	21/06/1979	3.5	21/06/1979
5931-65	540920.7	6302533	0	STK	856	5/01/1963	4.5	21/06/1979
5931-66	541414.7	6300217	0	DOM	2480	21/06/1979	5	21/06/1979
5931-73	543800.6	6304309	15.5	STK	2730	26/06/1979	14.6	26/06/1979
5931-84	539907.7	6299317	4.1	STK	891	26/06/1979	3.1	26/06/1979
6031-5	588664.8	6328764	0	STK	18565	25/09/1961	20.42	25/09/1961
6031-23	569842.6	6310604	39	STK	47500	21/01/1976	-	-
6031-24	567713.7	6311332	42	STK	-	-	29	10/12/1975
6031-38	546810.8	6339100	14.02	IND	17100	6/12/1961	7.32	20/12/1960
6031-129	558912.7	6326555	13.72	IND	29569	2/09/1961	1.52	29/08/1961
6031-130	562802.7	6324579	11.28	IND	29569	31/08/1961	-	-
6031-160	579180.7	6320935	15.85	STK	5330	14/03/1987	13.89	30/03/1987
6031-161	579564.8	6321269	15.24	STK	5192	14/02/1987	13.4	16/02/1987
6031-162	575994.9	6342199	55	STK	68038	13/08/1988	40	13/08/1988
6031-219	587528.7	6327221	84	STK	9130	26/03/1992	-	-

Appendix B Numerical model sensitivity analysis

Model sensitivity analysis was conducted to assess the extent and magnitude of drawdown that could be expected in response to mine operation. The sensitivity analysis was conducted by varying aquifer transmissivity and storage parameters within credible ranges. For a given pumping duration, the radius of the cone of drawdown is a function of the square root of transmissivity divided by the storage coefficient, a term called aquifer diffusivity. A high aquifer diffusivity (high transmissivity and low storage) will generally produce an extensive relatively flat cone of drawdown while a low aquifer diffusivity (low transmissivity and high storage) will produce a less extensive relatively steep cone of drawdown. Hydraulic conductivity and storage parameters were doubled and halved accordingly to assess model sensitivity. Detailed information regarding the sensitivity analysis is provided in the mine site numerical groundwater flow model report (SKM, 2014b).

The results of the numerical modelling are presented in Figure 16 and Figure 17 for Layer 3 (Tertiary aquifer) and Layer 5 (fractured bedrock aquifer), respectively. The results indicate that there is only a modest difference in the extent of the drawdown cone in the three different model scenarios. The areas contained within the 1 m drawdown contour have been estimated and are detailed in Table 7-1. The results illustrate that the extent of the 1 m drawdown contour is directly proportional to the diffusivity at all times.

Results suggest that at steady state (1000 years post closure) the 1 m drawdown contours for the different diffusivity cases are almost coincident in some locations. This observation can be explained by:

a. Aquifer storage parameters included in the diffusivity adjustment do not influence the steady state result,
b. Changes in evapotranspiration fluxes impact on the shape and extent of the drawdown cone. Since evapotranspiration is a head dependent flux and the modelled heads vary with diffusivity, then the drawdown cone is affected differently for each of the three diffusivity assumptions.
c. The hydraulic conductivity distribution also impacts on the shape and areal extent of the drawdown cone.

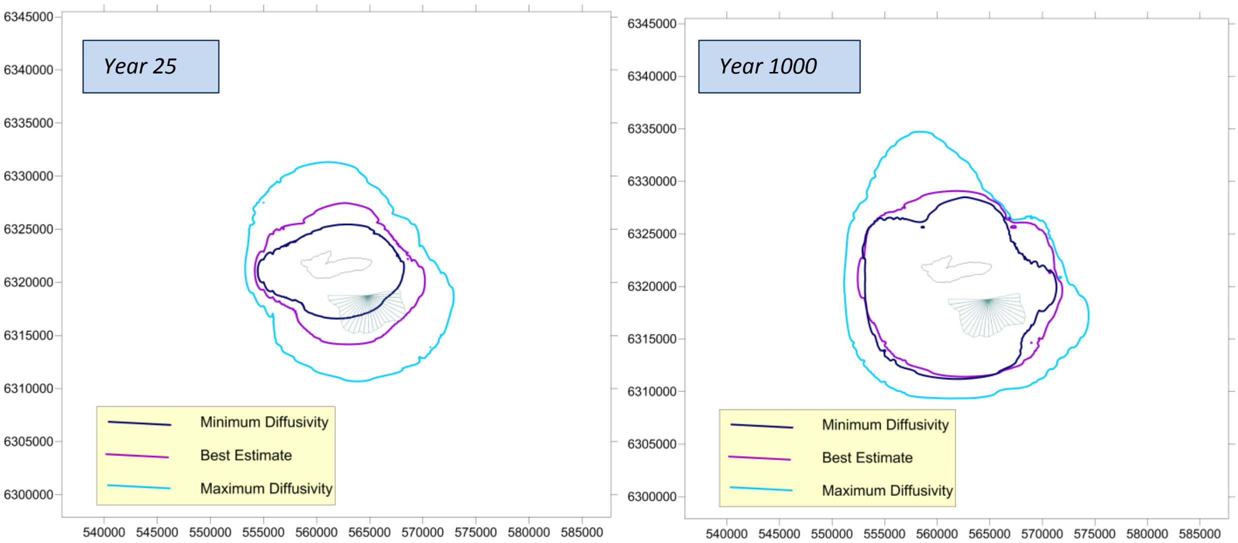

Figure 16. . Model sensitivity – extent of drawdown (1 m contour) in the Tertiary aquifer (Layer 3) at the end of mining (year 25) and 1000 years after closure

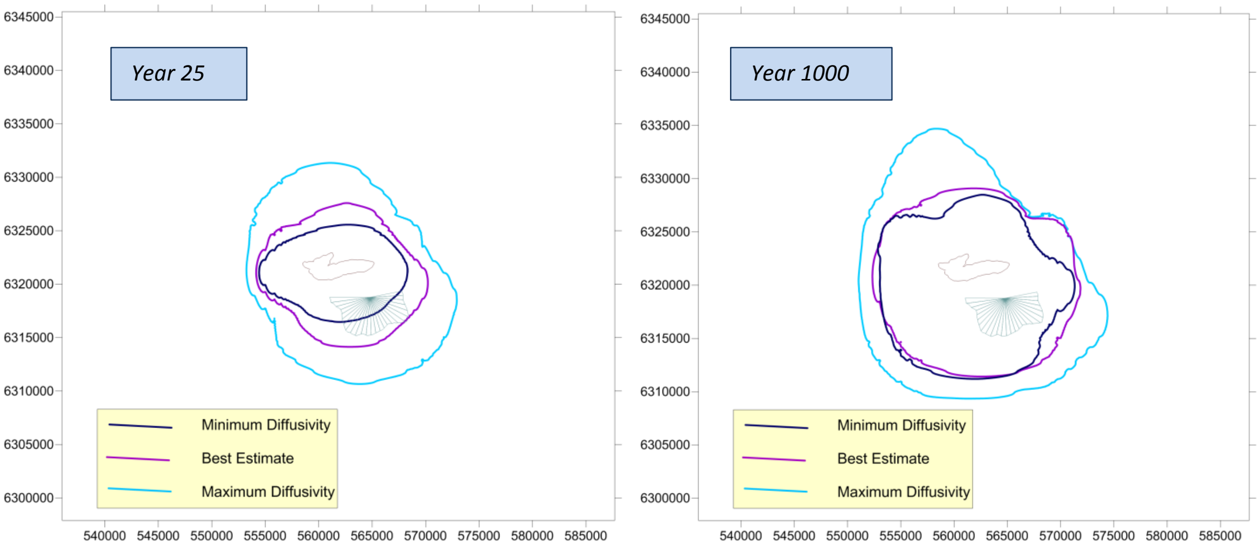

Figure 17. Model sensitivity – extent of drawdown (1 m contour) in the fractured bedrock aquifer (Layer 5) at the end of mining (year 25) and 1000 years after closure

Table 7-1: Model Sensitivity – estimated areas of drawdown as defined by the 1 m contour.

	1m Drawdown Contour Area (km^2)		
Layer 3	**Maximum Diffusivity**	**Best Estimate**	**Minimum Diffusivity**
25 years	291.0	148.6	89.3
45 years	374.4	184.1	115.8
1000 years	413.6	267	235.6
Layer 5			
25 years	293.0	151.7	94.4
45 years	376.2	185.7	116
1000 years	414.9	270.6	237

The predicted recovery of the pit water levels following mine closure is also impacted by the diffusivity included in the model parameters. The sensitivity of the simulated water level recovery in the mining pit is illustrated in Figure 18. The results indicate pit lake water levels that range between -300 and -225 m AHD with the best estimate model simulating a level of -275 m AHD after 1000 years.

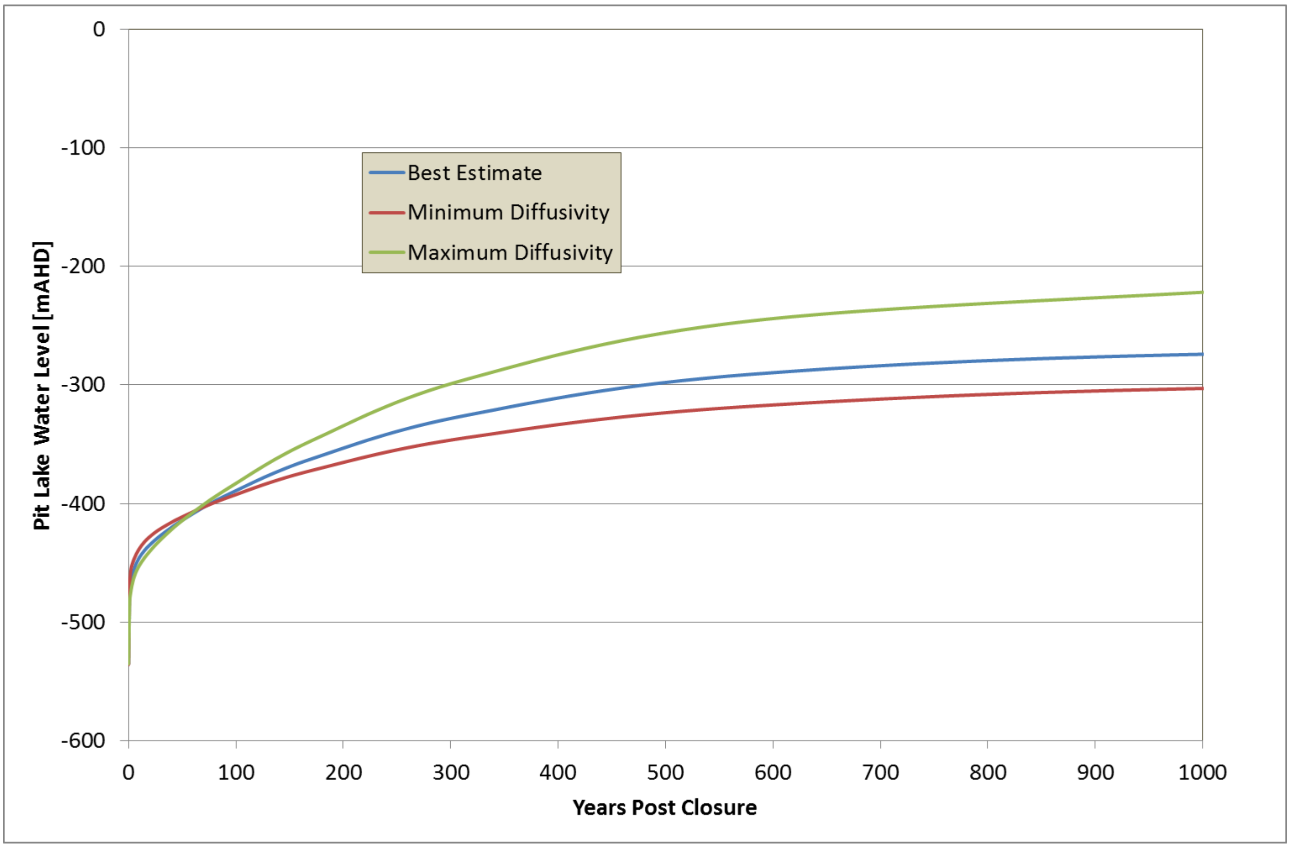

Figure 18. Model sensitivity – predicted water levels in the pit post mine closure.