Central Eyre Iron Project
Environmental Impact Statement

CHAPTER 16
GROUNDWATER

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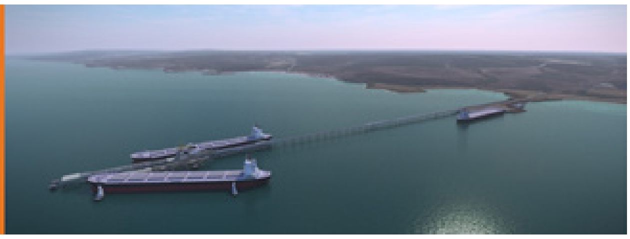

16 Groundwater

This chapter presents an assessment of potential impacts to groundwater resources and existing groundwater users arising from interactions with groundwater associated with the proposed CEIP Infrastructure development.

Groundwater interactions associated with the proposed CEIP Infrastructure include:

- Short-term extraction from two saline groundwater wells located along the infrastructure corridor (within the proposed borefield area and near the Driver River). The wells would operate for two years to supply groundwater during construction.
- Establishment of a saline groundwater borefield near Kielpa, approximately 60 km southeast of the proposed mine to supply water for processing of iron concentrate. Water will be pumped from an aquifer located 150-300 m below ground level (mbgl).
- Excavation below the groundwater table at the proposed port facility to accommodate the rail unloading facility.

Groundwater interactions associated with the proposed railway line and the proposed long-term employee village are not expected as part of normal construction and operation of the CEIP Infrastructure. As such, only a limited discussion of these issues is presented in this chapter (refer to Section 16.5.1).

Risks associated with project-related groundwater interactions that could reasonably occur during construction and operation of the CEIP Infrastructure are also considered.

Further details regarding the approach and outcomes of the groundwater assessment are provided in Appendix U, the Infrastructure Groundwater Impact Assessment Technical Report.

16.1 Applicable Legislation and Standards

The *Natural Resources Management Act 2004* (NRM Act) promotes sustainable and integrated management of the State's natural resources and provides for their protection. The Act includes provisions relating to the sustainable extraction of groundwater resources and provides for prescription of water resources (known as prescribed wells areas) to protect against over use and to minimise adverse effects from development.

Water Affecting Activities (WAA) are regulated under Section 127 of the 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). To obtain a permit, the applicant must demonstrate that the WAA will be appropriately managed to protect environmental values. The proposed CEIP Infrastructure is located within the Eyre Peninsula NRM Board region. Under Section 129(1) of the NRM Act, a permit will generally not be required for CEIP Infrastructure WAA authorised under the *Development Act 1993* as part of this EIS. Section 129(2) creates an exception for the drilling of wells. Therefore the wells required for construction water supply and the saline water borefield will require separate permits. Any WAA not covered or anticipated by this EIS may also need WAA permits as part of the secondary approval process.

The Environment Protection (Water Quality) Policy applies to all underground waters in South Australia and seeks to achieve water quality objectives that will protect or enhance defined environmental values. The protected environmental values for groundwater are beneficial uses of groundwater requiring protection against pollution:

- Aquatic ecosystems (freshwater)
- Recreational use and aesthetics (primary contact and aesthetics)
- Potable use
- Agriculture and aquaculture uses (irrigation, stock watering and aquaculture)
- Industrial use

Meeting of water quality objectives under the Environment Protection (Water Quality) Policy is achieved by compliance with the Water Quality Criteria specified in Schedule 2 of the policy.

The *Environment Protection Act 1993* and Environment Protection (Water Quality) Policy also identify Water Protection Areas in South Australia, which have been delineated for the purposes of providing them with special environmental protection.

The CEIP Infrastructure is not located within a prescribed well area under the NRM Act or a water protection area prescribed under the *Environment Protection Act 1993*.

16.2 Assessment Method

A Groundwater Impact Assessment (GIA) was completed in accordance with the National Water Commission (NWC) *Framework for assessing cumulative potential impacts of mining operations on groundwater systems* (NWC 2010). The assessment framework provides a risk-based approach to managing local and cumulative effects of mining and associated infrastructure on groundwater and connected systems. The assessment incorporated the following tasks:

- Definition of a study area that encompasses all potential groundwater impacts.
- Description of the existing environment within the study area and broader region, including climate, topography, geology, surface water and groundwater resources.
- Identification of potential groundwater users or ‘receptors’ in the study area.
- Investigation of potential direct impacts to groundwater systems due to project WAA comprising:
    - Numerical groundwater modelling of the proposed borefield operation including sensitivity analysis.
    - Analytical modelling of temporary construction bore operation.
    - Analytical modelling of groundwater management at the rail unloading facility at the proposed port site.
- Assessment of the degree to which these impacts would affect receptors.

For a detailed description of the impact assessment methodology and outcomes, refer to the Groundwater Impact Assessment Technical Report in Appendix U. The Groundwater Modelling Report is provided in Appendix V.

16.3 Existing Environmental Values

This section describes the study area defined as relevant to the GIA. It includes consideration of the existing hydrological conditions, geological setting, groundwater conditions and the location and description of receptors.

The study area for the CEIP Infrastructure GIA was defined to encompass all potential groundwater impacts (refer to Figure 16-1). The study area is defined by:

- The boundary of the numerical groundwater flow model which has been developed to assess the viability and impacts of the proposed borefield.
- A conservative 20 km zone either side of the proposed railway line.

Although the Musgrave Prescribed Wells Area (PWA) is located outside of the defined study area, it is considered in this assessment due to its importance in supplying potable groundwater to the Eyre Peninsula.

16.3.1 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. The Tod River, which is located approximately 50 km southwest of the port site, and outside the study area for groundwater and surface water impacts, flows south from Yallunda Flat to its mouth near Port Lincoln. The Tod River is the only permanent stream on the Eyre Peninsula. Other stream systems are ephemeral or seasonal with limited connection to the ocean.

In the southern region of the study area, two ephemeral creek lines are present that flow toward the Spencer Gulf. These are the Dutton River (refer to Plate 16-1) and Driver River (refer to Plate 16-2). These rivers exhibit saline water quality arising from degraded catchments (EPA 2010). In the northern and central regions of the study area, there are no significant ephemeral creek lines present. This is due to the relatively flat topography, lower rainfall and higher infiltration (from sandy geologies) in these areas (RPS-A 2013).

Plate 16-1 Dutton River along Balumbah Road near Intersection with Lincoln Highway

Plate 16-2 Driver River near Verran

16.3.2 Geological Setting

The infrastructure corridor traverses four geological domains which have been defined for the purposes of the GIA as the Northern Domain, Kielpa Domain, Verran Domain and Dutton River Domain (GWS 2014b). These geological domains are summarised in Table 16-1.

Table 16-1 CEIP Geological Domains (GWS, 2014b)

Domain	Description
Northern Domain	Incorporating the northern portion of the study area, this area hosts granite and gneiss of the Sleaford Complex which is overlain by Tertiary and Quaternary Sediments.
Kielpa Domain	This area hosts the Polda Trough, a Permian aged structural depression infilled with up to 400 m of Permian, Jurassic, Tertiary and Quaternary Sediments. The proposed borefield area and one of the proposed infrastructure production wells (IC4) is located within this domain.
Verran Domain	This area hosts the Blue Range Beds characterised by fluvial, massive to cross-bedded sandstone. One of the proposed infrastructure production wells (IC5) is located within this domain.
Dutton River Domain	Incorporating the southern portion of the study area, this area hosts the Lincoln Complex granites overlain by a thin veneer of Quaternary cover.

16.3.3 Regional Hydrogeology

Eyre Peninsula groundwater resources are of variable quality and quantity, and most groundwater occurs in saline or brackish aquifers with generally low yields (Berens et al. 2011).

Groundwater salinity data from recent drilling investigations focusing on the target aquifer in the vicinity of the proposed borefield (Tertiary sediment aquifer), and the broader regional dataset (DEWNR 2014) indicate that salinity ranges from 35,000 to 40,000 mg/L (GWS 2014a) which is comparable to seawater (BHPB 2009). Groundwater in the vicinity of the proposed borefield and the production wells for the infrastructure corridor construction water supply is suitable for industrial use only.

The following sections provide a summary of the key hydrogeological formations relevant to the CEIP Infrastructure GIA.

Quaternary Aquifers

Within the study area, Quaternary sediments are dominated by quartz sand and clayey sand overlain by white to pale grey aeolian sand dunes. Calcrete horizons are found to varying degrees over the Eyre Peninsula. Quaternary sediments are generally unsaturated within the study area and therefore contain no significant groundwater resources.

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 or disconnected lenses. 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). They are located within the Musgrave PWA which is the administrative boundary that surrounds the groundwater lenses (refer to Figure 16-1).

Fresh groundwater lenses located within the Musgrave PWA are an important potable water source for the Eyre Peninsula. The major groundwater lenses within the Musgrave PWA generally have high yields (from 5 to 50 L/s) and low salinity (less than 1000 mg/L) (Department for Water Resources 2001). The closest groundwater lens within the Musgrave PWA to the proposed borefield is the Polda Lens, located approximately 45 km west of the proposed borefield. The Polda Lens is located in the north-eastern section of the Musgrave PWA. The lens is defined by a layer of fresh groundwater (salinity limit of 1000 mg/L) within the unconfined Quaternary limestone which overlies tertiary clay, acting as a physical barrier between fresh shallow groundwater and the underlying deeper saline groundwater.

Polda Trough

The Polda Trough is a separate and distinct geological unit from the Polda Lens, described above. 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. The Polda Trough is encompassed by basement rocks of the Gawler Craton. Thickened Tertiary Sediments within the Polda Trough are the target aquifer for the proposed borefield. Groundwater contained within the trough is saline.

The Neoproterozoic Kilroo Formation forms the basal unit of the trough and consists of siltstone and mudstone with interbedded volcanics (primarily basalt). The Permo-Carboniferous Coolardie Formation unconformably overlies the Kilroo Formation in the eastern region of the trough. The formation consists of between 40 and 90 m of diamictite with thin inter beds of siltstone, claystone and conglomerate (GWS 2014a).

The Late Jurassic Polda Formation has in-filled topographic lows of the Coolardie Formation, and is therefore variable in thickness across the Polda Trough (between 11 to 282 m). The formation can be divided into two intervals. The lower zone is sand-prone with regular interbeds of coal and siltstone, while the upper zone is dominated by claystone, siltstone and sandstone (GWS 2014a).

Fractured Rock Aquifers

Basement lithology in the study area includes gneisses, volcanics and granites of the Gawler Craton. In the Northern Domain, basement comprises gneiss and granite of the Sleaford complex. Aquifer testing of this formation by Iron Road in support of mine dewatering studies indicates a regional transmissivity (capacity of an aquifer to transfer water) in the range of 2 to 4 m^2/day with salinity ranging from 18,000 mg/L to in excess of 100,000 mg/L (SKM 2014).

The transmissivity of an aquifer is calculated as the product of aquifer thickness and hydraulic conductivity. A thin, conductive aquifer might have the same transmissivity as a thick, less conductive aquifer.

Within the Verran Domain, basement comprises the Blue Ranges Beds which is characterised by consolidated sandstone and gritty conglomeritic sandstone. A single aquifer test in this unit yielded a transmissivity estimate of 16 m^2/day with a groundwater salinity of 63,500 mg/L (GWS 2014b).

Further south within the Dutton River Domain, basement consists of schist and gneiss of the Hutchinson group. Recent investigation drilling revealed little potential for groundwater supply within this area (GWS 2014b). The Hutchinson Group is also interpreted as being present beneath the Polda Trough, however due to the depth of the basement little information exists regarding groundwater yield and salinity.

Groundwater recharge to fractured rock aquifers is considered to be localised and irregular with the volume of recharge governed by the fracture permeability of the rock. Recharge to fractured rock systems on the Eyre Peninsula is not well understood, but recharge may occur where basement material outcrops and sub-crops, as well as via vertical and lateral leakage from adjacent aquifers.

Hydrogeological Cross Section

A schematic representation of the hydrogeological units within and adjacent to the Kielpa Domain is presented in Figure 16-2. The hydrogeological cross sections also show known groundwater levels and salinities from wells located along the section line. The location of the hydrogeological cross section runs from the proposed borefield west to the Musgrave PWA (refer to Figure 16-1 for cross section location).

Key features of the hydrogeological cross section are:

- At the location of the proposed borefield, Quaternary Sediments are characterised by sand, silt and clay, however the sediments are unsaturated and the water table sits within the underlying Tertiary Sediments.
- Thickened Tertiary Sediments within the Polda Trough (150 to 300 mbgl) are the target aquifer for the proposed borefield. Groundwater salinity within this aquifer is in the range of 25,000 mg/L to 40,000 mg/L.
- Approximately 45 km west of the proposed borefield, 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 (Department for Water Resources 2001). The aquifers associated with the Bridgewater Formation are not connected to the Quaternary Sediments found in the vicinity of the proposed borefield.
- Groundwater exhibits a potentiometric gradient from east to west indicating potential for groundwater to flow in that direction.
- There is a marked reduction in thickness of sediments west of Lock Township (marked on the section by drillhole 133039) which indicates a reduction in aquifer transmissivity (i.e. reduced rate of flow) west of Lock.

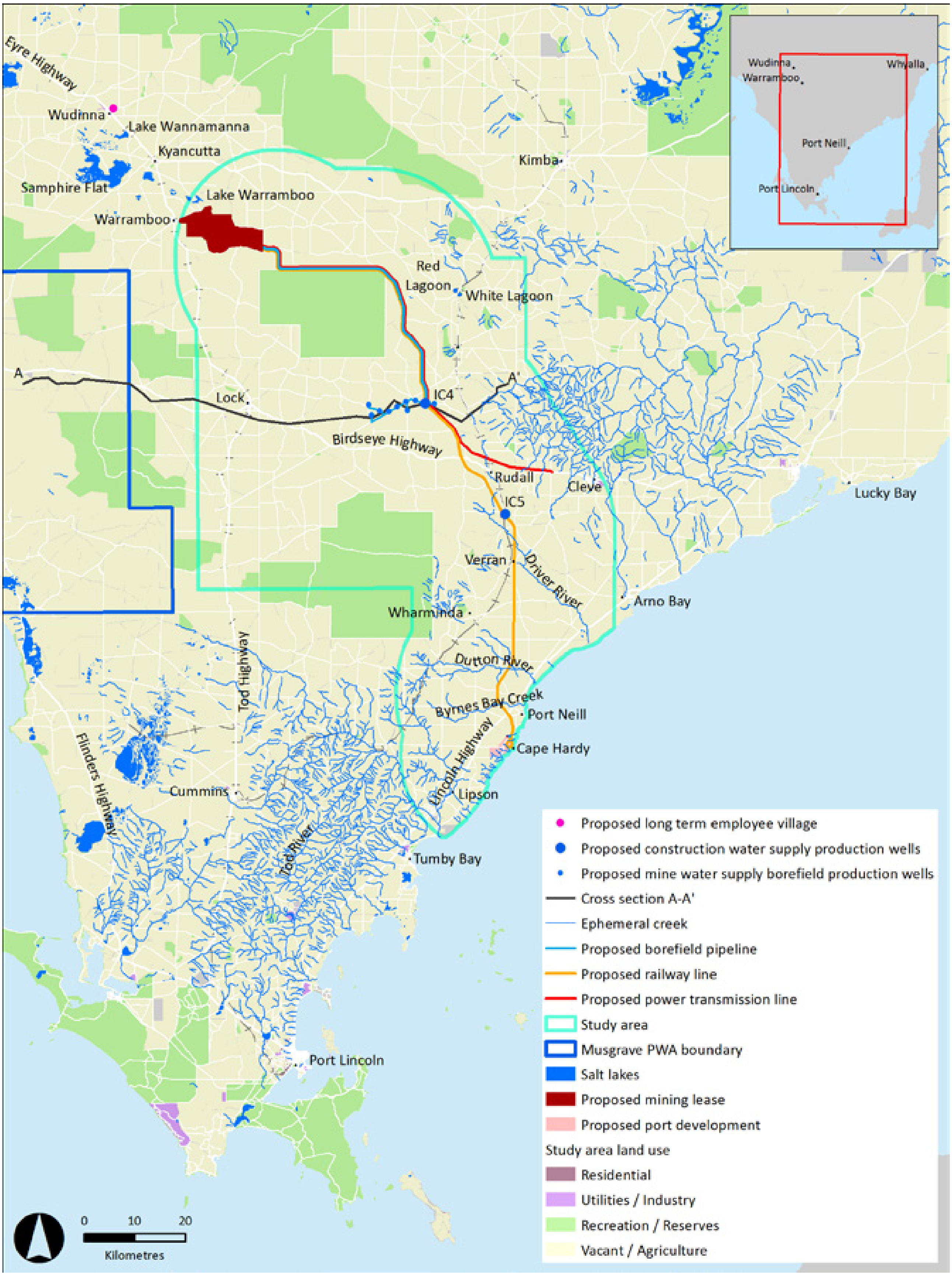

Figure 16-1 Project Components, Groundwater Impact Assessment Study Area and Land Use

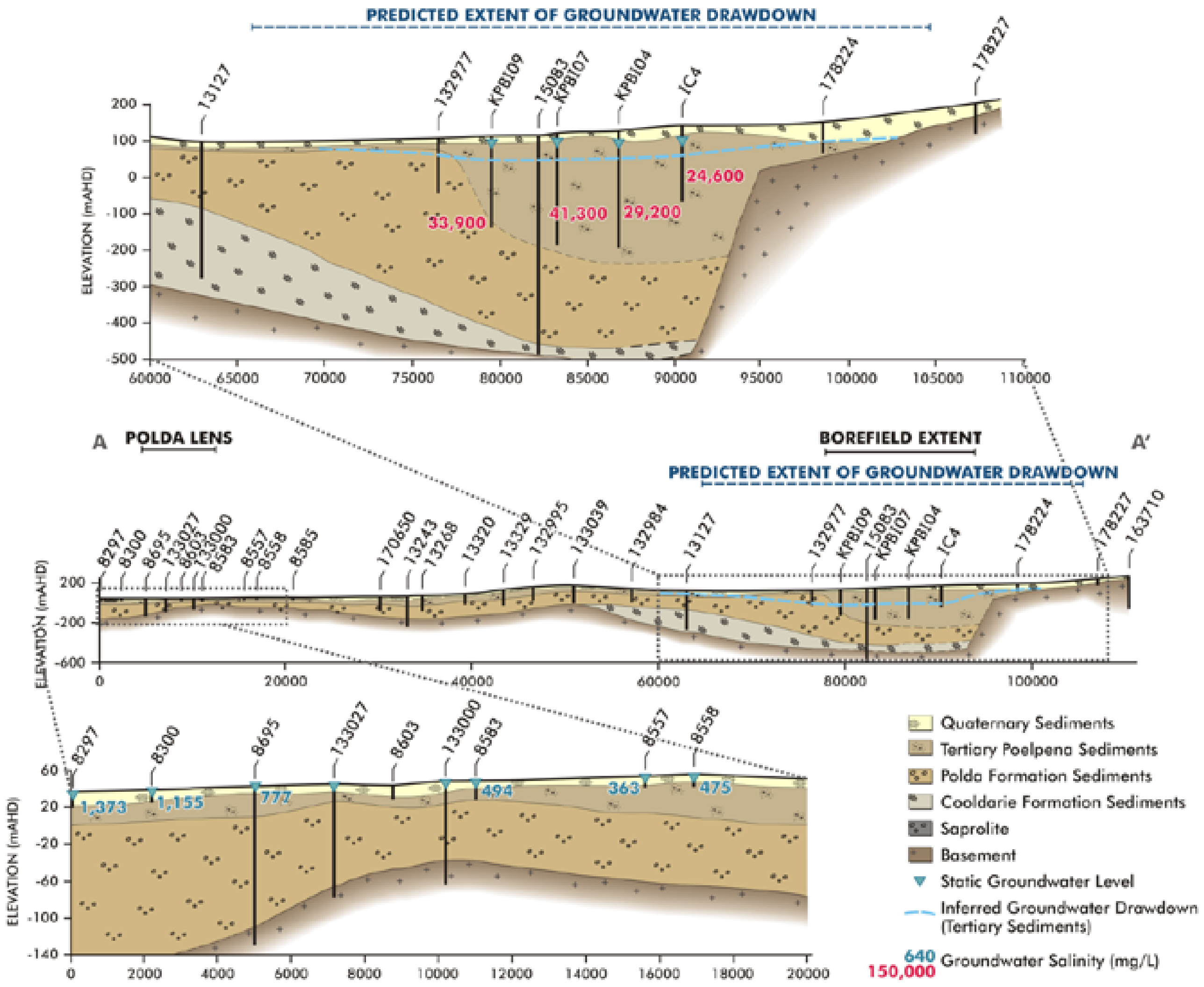

Figure 16-2 Hydrogeological Cross Section – Proposed Borefield to Musgrave PWA

16.3.4 Groundwater Receptors

Groundwater receptors include environmental, social, cultural and economic elements of the receiving environment that may be altered by changes to groundwater conditions. For the CEIP Infrastructure GIA, potential groundwater receptors identified within the study area include:

- Groundwater Dependent Ecosystems (GDEs) – ecosystems which may be sensitive to changes in groundwater conditions due to a reliance on groundwater to meet ecological requirements
- Existing users of groundwater
- Economic (commercial) receptors including agriculture and mineral deposits

In undertaking the GIA, all potential groundwater receptors within the study area were identified, and are summarised below. Further investigation to confirm the existence of potential groundwater receptors was completed for a defined assessment area following prediction of the zone of influence for groundwater drawdown. These subsequent investigations are summarised in Section 16.5, as part of the impact assessment.

Groundwater Dependent Ecosystems

The Australian GDE Atlas (published by the National Water Commission) provides a high-level starting point to assist with the identification of GDEs and the management of their water requirements (Richardson et al. 2011). The mapping in the GDE Atlas relies on broad scale analysis, existing datasets and remote sensing methods and shows only general locations where groundwater interaction may occur (BoM 2014). Further, the GDE Atlas makes no assessment of ecosystem value, condition, sensitivity, threat or risk (BoM 2014).

GDEs, as defined by the Australian GDE Atlas are broadly classified as follows (Richardson et al. 2011):

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

Ecosystems Dependent on the Subsurface Presence of Groundwater

Although the GDE Atlas has identified patches of remnant vegetation within the study area as potential GDEs, they are considered unlikely to be ecosystems dependent on the sub-surface presence of groundwater. Assessment of the site conditions in the vicinity of the proposed borefield reveals that groundwater salinity in the water table aquifer is in the range of 25,000 to 40,000 mg/L and groundwater levels are in excess of 20 mbgl (GWS 2014a). Therefore, vegetation within the study area and in particular within the vicinity of the proposed borefield is unlikely to be reliant on groundwater given these conditions.

Ecosystems Dependent on the Surface Expression of Groundwater

The following environmental features have been identified as having potential for supporting GDEs:

- The Dutton River and Driver River, which are ephemeral creek lines present in the southern portion of the study area that flow towards the Spencer Gulf.
- A number of other small creek lines which flow from the ranges south of Darke Peak (Gum Creek, Sheoak Creek, Yadnarie Creek and Mangalo Creek). These creek lines have been identified as having a low to moderate potential for supporting GDEs.
- A small number of salt lakes are also present in the study area, which become periodically inundated as a result of surface water following large rainfall events. These areas may provide a temporary refuge for migratory birds when flooded. The salt lakes identified in the study area include White Lagoon and Red Lagoon located approximately 10 km north of Darke Peak and Lake Warramboo located within the study area approximately 1.5 km north of the proposed mining lease boundary.

The location of potential GDEs reliant on surface expression of groundwater within the study area are illustrated in Figure 16-3.

Existing Users of Groundwater

Thirty five recorded groundwater abstraction wells have been identified within the study area as having the potential to be affected by the proposed CEIP Infrastructure WAA. Identified well classifications include stock, domestic, town water supply, industrial and irrigation wells. The location of the wells identified in the study area is shown in Figure 16-3. These groundwater well records were used as a starting point for further investigation of impacts (see Section 16.5.2).

Economic Receptors – Agriculture

The dominant land use in the study area is dryland agriculture (see Figure 16-1). In some low-lying areas within the study area, agricultural crops and native vegetation are currently influenced by saline groundwater interactions with surface soils (see Figure 16-4):

- Crops are reliant on seasonal rainfall stored in top-soils and sub-soils rather than being reliant on (saline) groundwater.
- Where saline groundwater approaches the root-zone of both native and agricultural crops, plants are subjected to stress (with the exception of salt tolerant native species and weeds).

As demonstrated in Figure 16-4, agricultural values will not be impacted by changes to groundwater as a result of the proposed CEIP Infrastructure activities because:

- There are no WAA associated with the CEIP Infrastructure identified as having the potential to increase groundwater levels, and therefore bring saline groundwater closer to the surface into the crop root zone.
- All WAA associated with the CEIP Infrastructure are predicted to lower the saline groundwater table, potentially improving the soil conditions in low lying areas within the area of effect.

Economic Receptors – Mining and Energy Industry

There are 73 mineral deposits recorded within the study area, two of which are currently recorded as active mines (Figure 16-3):

- A gypsum mine (Bayley Plain) to the west of the proposed borefield which commenced operation in 2008.
- An active mine targeting a sand commodity (Port Neill Sand) located 10 km north of the port facility which commenced operation in 2011.

16.3.5 Summary of Key Environmental Values

The key environmental values are the potential groundwater receptors identified within the study area. These are:

- The potential users of the groundwater (primarily stock wells)
- GDEs reliant on surface expression of groundwater (Playa lakes and ephemeral creek lines)
- Existing mining operations

Although the Musgrave PWA is located outside of the defined study area, it is considered in the GIA due to its importance in supplying potable groundwater to the Eyre Peninsula.

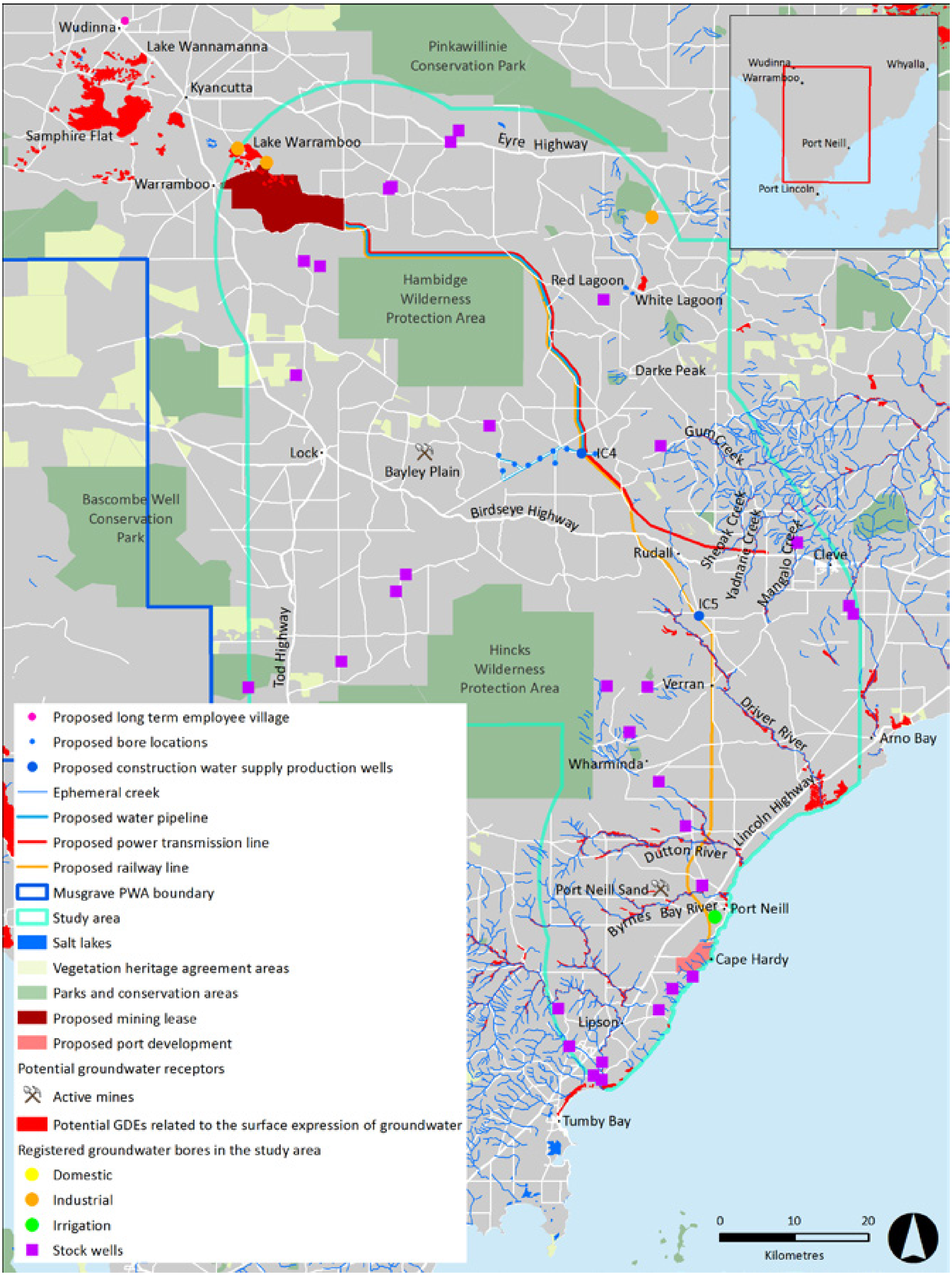

Figure 16-3 Potential Groundwater Receptors in the Study Area

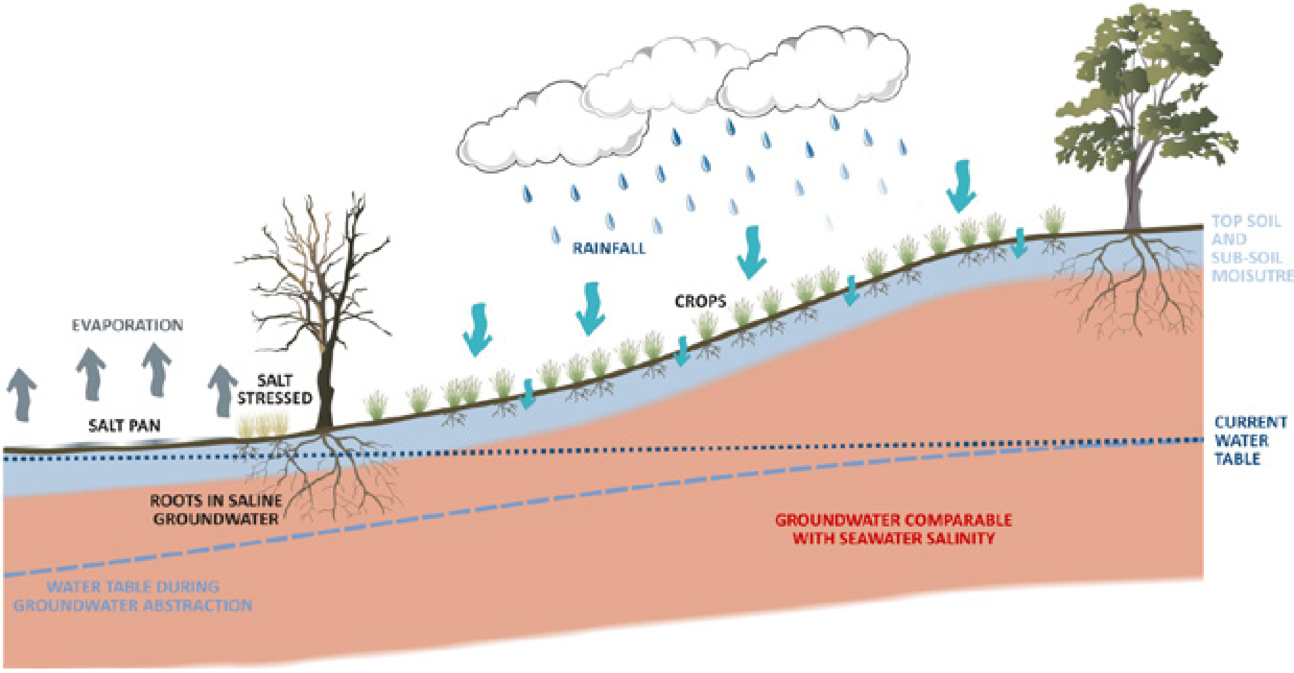

Figure 16-4 Diagram of Indicative Surface Water – Groundwater Interaction

16.4 Design Modifications to Protect Environmental Values

The design of the CEIP Infrastructure has incorporated several measures to protect groundwater resources including:

- Use of a saline groundwater resource (considered suitable for limited industrial purposes only) which is of minimal value to surrounding users and will not impact on distant potable groundwater resources in the region.
- Identification of a groundwater resource capable of sustainably supplying the project water requirement (up to 15 GL per year) for the 25 year mine life.
- The proposed railway line has been engineered to current Australian Rail Track Corporation (ARTC) standards. Bridges are proposed for the Dutton River crossing and one unnamed water course. However, the majority of the line will be supported on appropriate embankments with culverts where required to minimise the restriction of natural flow of water in ephemeral creeks and rivers and redistribute pressure on underlying soils.

  Specific geotechnical investigation will be carried out in areas of the rail corridor where there is potential for the rail to affect shallow groundwater flows and appropriate drainage measures will be installed to maintain flows, if necessary.
- Long-term employee village adjacent to Wudinna will utilise the town's existing wastewater treatment system which will be upgraded if required.
- Permanent drainage will be provided at the base and perimeter of the excavation required to accommodate the rail unloading facility at the port site. Groundwater will be collected in trench drains positioned around the perimeter of the excavation and collected in sumps for disposal to the transfer pump station header tank.
- Hydrocarbon and chemical storage facilities will be designed in accordance with Australian Standards, relevant legislation and best practice guidelines.
- Fuel and lubricant storage and dispensing facilities will be designed and installed in accordance with:
  - AS 1940-2004: The storage and handling of flammable and combustible liquids
  - AS 1692-2006: Steel tanks for flammable and combustible liquids

- Relevant South Australian legislation
- Best practice guidelines

16.5 Impact Assessment

This section assesses groundwater impacts on surrounding receptors that may result from the construction and operation of the proposed CEIP Infrastructure. Four categories of direct potential impacts were considered as part of the GIA:

- Groundwater quantity including consideration of changes to groundwater levels and pressure.
- Groundwater quality including consideration of salinity and water quality impacts.
- Groundwater and surface water interaction including consideration of changes to the level of interaction between groundwater and surface water systems.
- Physical disruption of aquifers including consideration of whether or not there would be permanent disruption of a groundwater system from the proposed activities, and to what extent.

Impacts have been assessed in accordance with the impact assessment methodology outlined in Chapter 9 and Section 16.2. A summary table of these impacts is provided in Section 16.5.7.

16.5.1 CEIP Infrastructure Water Affecting Activities

Activities occurring in support of proposed CEIP Infrastructure operations that may be expected to alter groundwater conditions in the study area are summarised in Table 16-2. There are not expected to be any WAA associated with CEIP Infrastructure that will cause elevation of groundwater, or aquifer disruption or affect groundwater quality.

Groundwater interaction due to construction and operation of the proposed railway line or the proposed long-term employee village will not occur because:

- The railway line will be engineered to ARTC standards to distribute the mass of trains and to prevent buckling of the line and compaction of soils and subsequent effects on groundwater.
- The long-term employee village adjacent to Wudinna will utilise the town's existing waste water treatment system which will be upgraded if required.

Table 16-2 Summary of CEIP Infrastructure Water Affecting Activities

Project Component	Category of Direct Impact	Description
Proposed borefield	Groundwater Quantity	Groundwater drawdown from the operation of 10 bores operating for the life of the mine (25 years).
Infrastructure corridor construction water supply production wells	Groundwater Quantity	Groundwater drawdown from the operation of two production wells along the proposed infrastructure corridor for a two year duration.
	Groundwater and surface water interaction	Operation of the production well in proximity to the Driver River (refer to Plate 16-2) has a radius of influence where current groundwater level would be reduced and the level of interaction between the aquifer and river may be altered.
Port facility	Groundwater Quantity	Permanent drainage at the base and perimeter of the excavation required to accommodate the rail unloading facility has a radius of influence that will reduce current groundwater level.

16.5.2 Predicted Effects of Proposed Borefield Operation

This section presents predicted changes to groundwater conditions due to the operation of the proposed borefield. The GIA is based on modelling completed using hydraulic parameters derived from field testing and hydrogeological data (GWS 2014a) and a sensitivity analysis to define the credible range of drawdown that could be expected from operation of the proposed borefield over 25 years (GWS 2014a).

The GIA for proposed borefield operation is based on the following assumptions:

- Proposed borefield location approximately 60 km southeast of the proposed mine site, 7.5 km west of Kielpa (see Figure 16-1).
- Supply of 15 GL per year of saline water from the borefield for the life of the mine (25 years).
- Operation of 10 groundwater wells each operating at 4000 m^3/day for the life of the mine (25 years) (see Figure 16-1 for location of individual wells).
- Groundwater abstraction to occur from the aquifer located approximately 150 to 300 mbgl.

The cone of drawdown (defined by the location of the one metre drawdown contour) is predicted to extend approximately 12 km from the proposed borefield under the base case hydrogeological conditions (see Figure 16-5).

Sensitivity Analysis

The sensitivity analysis was conducted by varying aquifer diffusivity, which is a function of aquifer transmissivity and storage capacity. The sensitivity analysis considered credible ranges of aquifer diffusivity as follows:

- High aquifer diffusivity (high transmissivity and low storage) resulting in an extensive, relatively flat cone of depression.
- Low aquifer diffusivity (low transmissivity and high storage) resulting in a less extensive, relatively steep cone of depression.

The zone of influence (a one metre drawdown contour) is predicted to extend 20 km for the high diffusivity scenario and 7 km for the low diffusivity scenario (Figure 16-5).

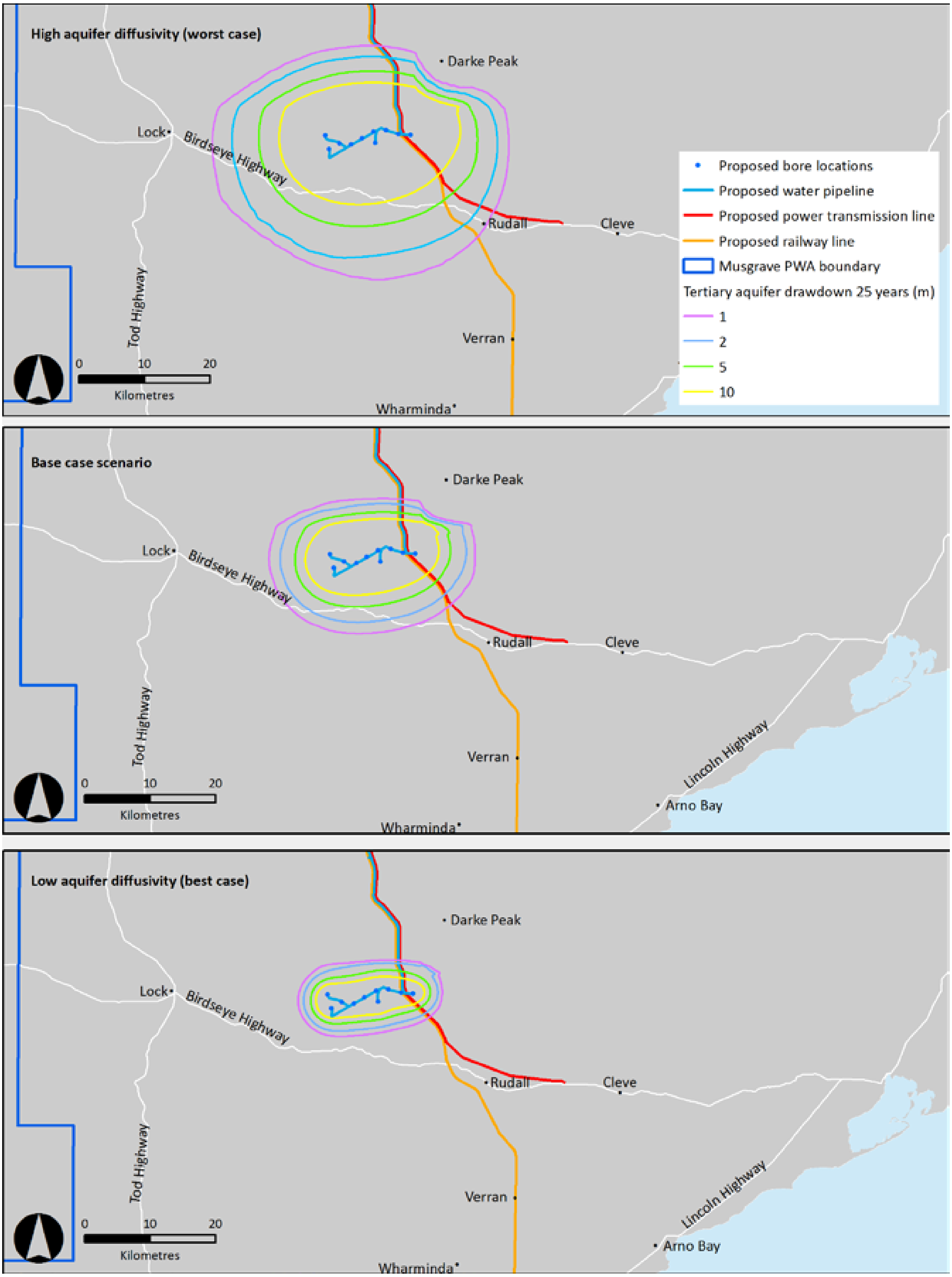

Figure 16-5 Predicted Drawdown Following 25 Years of Proposed Borefield Operation

Predicted Impacts to Groundwater Receptors

The assessment of impacts to receptors is based on an area within the study area extending approximately 20 km from the borefield. This assessment area comprises the zone of influence predicted by the modelling, including sensitivity analysis.

Four registered stock wells were identified within the assessment area. An audit of these recorded wells conducted by Iron Road determined that only one water bore exists within the assessment area. This well (6030-803) is not in use, with the last reported salinity (14,198 mg/L) precluding groundwater use for agricultural purposes.

The Bayley Plain gypsum mine is located within the predicted zone of influence of the proposed borefield. However, no abstraction wells have been identified in association with this deposit.

The Musgrave PWA is outside the predicted cone of drawdown associated with the proposed borefield. As shown in Figure 16-2, the distance between the predicted drawdown impacts for the base case scenario and Musgrave PWA is greater than 40 km.

The predicted drawdown contours and receptor locations are illustrated in Figure 16-6. As the drawdown associated with the operation of the proposed borefield is not predicted to change identified environmental values, the impact is considered **negligible**.

Groundwater Recovery

The numerical groundwater modelling considered a range of recharge rates (1, 7 and 15 mm per year) to predict credible time ranges for groundwater level recovery following cessation of groundwater pumping (GWS 2014a). The predicted time required for complete recovery of groundwater levels ranged from approximately 350 years for the 1 mm scenario (conservative) to approximately 75 years for the 15 mm scenario.

Plate 16-3 Example Well in Road Reserve (corner of Lock Road and Kimba Road)

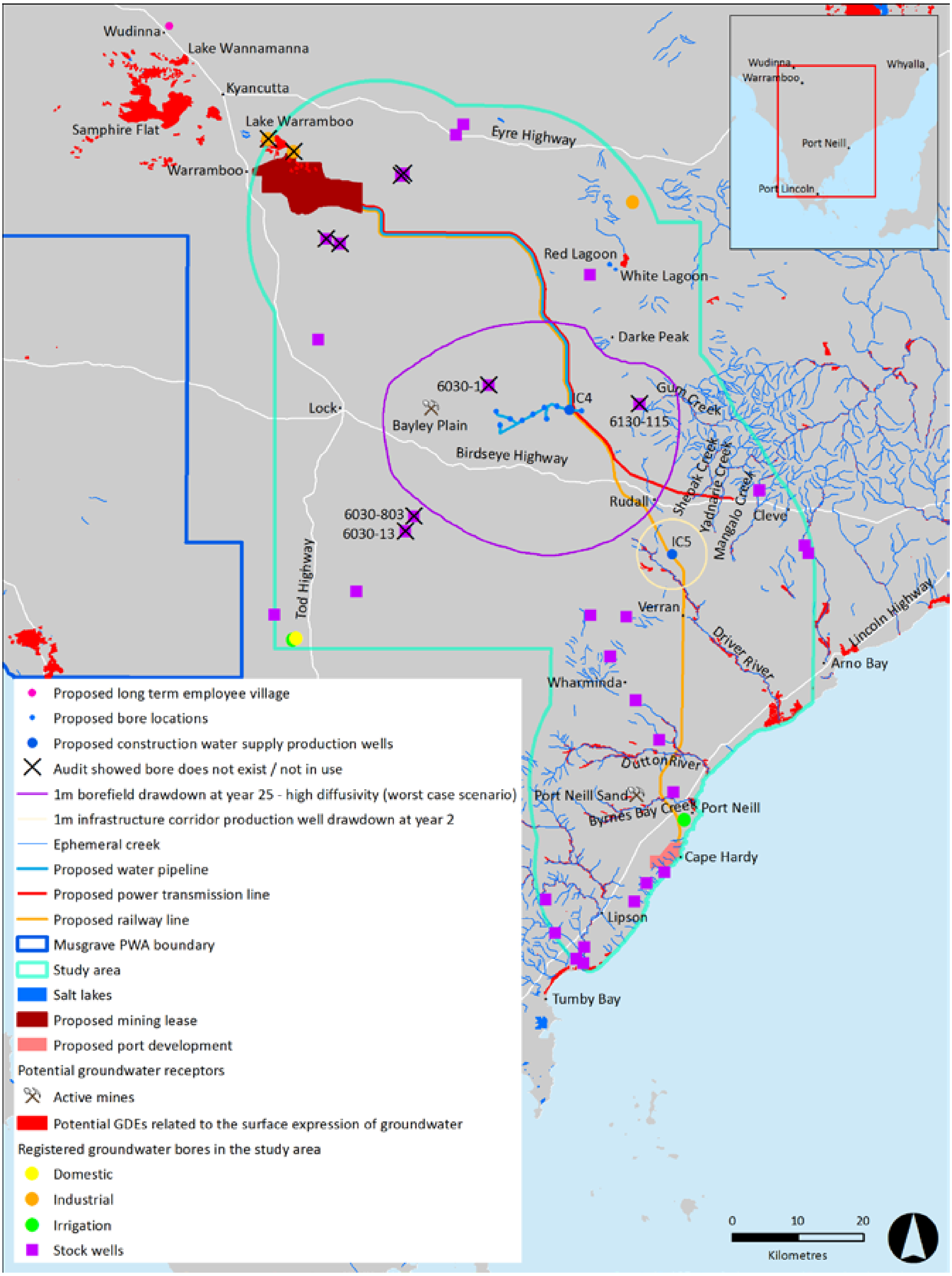

Figure 16-6 Predicted Zone of Drawdown Influence (Worst Case Scenario) and Receptor Identification

16.5.3 Predicted Effects from Infrastructure Corridor Construction Wells

This section presents predicted changes to groundwater conditions due to the operation of water supply wells along the proposed infrastructure corridor during construction. Analytical modelling has been used to predict the radius of influence during production well operation. Input data used in the calculations were sourced from the *Utilities Corridor Construction Water Supply Investigation* (GWS 2014b).

The GIA for the production wells for the infrastructure corridor construction is based on the following assumptions:

- Two water supply wells will be required (one in the Kielpa geological domain, and one in the Verran geological domain).
- Water demand at each water point will be 430 m^3/day (GWS 2013).
- Each well will operate continuously for two years.

A summary of the predicted drawdown for the two wells is provided in Table 16-3. The location of each well is shown in Figure 16-5.

Table 16-3 Predicted Infrastructure Corridor Production Well Drawdown

Domain	Well Identifier	Transmissivity (m^2/day)[1]	Extent of 1 m Drawdown Contour (m)
Keipla	IC4	450	40
Verran	IC5	18	5,300

Notes: 1. Average transmissivity calculated from constant rate testing (GWS 2014b)

Predicted Impacts to Groundwater Receptors

No existing wells or mining activities were identified within the zones of influence of the infrastructure corridor construction water supply production wells. However, infrastructure corridor production well IC5 is located approximately 2.5 km from the Driver River. The predicted zone of influence in relation to the river is shown in Figure 16-6.

The analytical modelling predicts groundwater levels in the vicinity of the Driver River would decrease by approximately 3 m after two years of continuous well operation. Drawdown can impact a river system, depending on the degree of connection the river has with groundwater.

The Driver River typically flows from autumn to spring. It is slow moving and saline. High recorded salinities, a lack of special environmental features, limited natural riparian vegetation and erosion caused by direct stock access has led the EPA to assign the river a condition overview score of "poor" (EPA 2010).

The EPA (2010) has also identified saline groundwater inflow as a threat to the Driver River which has the potential to reduce the ecological integrity of the system. As such, any drawdown of groundwater level beneath the Driver River is not expected to adversely impact ecosystems supported by the Driver River. Therefore, the predicted impact of the operation of well IC5 is considered **negligible**.

There are no environmental values identified within the zone of influence of well IC4, and so the impact of the operation of this well is considered **negligible**.

16.5.4 Predicted Effects due to Groundwater Management at the Proposed Port Site

This section presents predicted changes to groundwater conditions in the vicinity of the proposed port site due to permanent drainage associated with the rail unloading facility. Analytical calculation has been used to predict the radius of influence resulting from abstraction of the collected groundwater. Details are provided in Appendix U.

The predicted zone of influence is approximately 500 m, which is a conservative estimate as it assumes no recharge to the groundwater system. The actual extent of influence may also be limited by the lateral continuity of fracturing in the basement over this distance.

Predicted Impacts to Groundwater Receptors

The zone of influence is within the proposed port facility footprint and does not interact with any of the identified receptors. As the drawdown associated with groundwater management at the proposed port site is not predicted to change identified environmental values, the impact is considered **negligible**.

16.5.5 Predicted Effects to Groundwater as a Result of Infrastructure

As identified in Section 16.5.1, altered groundwater conditions due to compression of soils from the railway line are not expected as part of normal construction and operation of the CEIP Infrastructure and therefore have not been considered as an impact. However, the issue is addressed as a project risk in Section 16.7.

16.5.6 Potential Impacts to Groundwater Quality through Release of Contaminants

Long-term employee village operations, wastewater treatment facilities and fuel storages have the potential to impact groundwater quality through release of contaminants. However this is not expected as part of normal operations, so is considered a project risk rather than an impact, and as such is addressed in Section 16.7.

16.5.7 Summary of Impacts

The residual impacts to groundwater due to construction and operation of the proposed CEIP Infrastructure are presented in Table 16-4.

Table 16-4 Residual Impacts: Groundwater

Impact	Comment	Level of Impact
Operation of production wells along infrastructure corridor for a two-year duration will result in drawdown that will reduce the current groundwater level.	No impact predicted to environmental values/receptors.	Negligible
Operation of production well in proximity to Driver River will result in a radius of influence where current groundwater level will be reduced and level of interaction between aquifer and river may be altered.	Saline groundwater inflow is a threat to Driver River. Drawdown may reduce this saline groundwater inflow.	Negligible
Groundwater drawdown around borefield from operation of 10 bores for life of mine (25 years).	No impact predicted to environmental values as no users of saline water identified.	Negligible
Permanent drainage at base and perimeter of excavation to accommodate rail unloading facility will result in a radius of influence that will reduce current groundwater level.	Predicted zone of influence is within site boundary. No impact predicted to environmental values, as no receptors identified.	Negligible

16.6 Control and Management Strategies

In order to minimise the impact on, and potential risks to groundwater during construction and operation, a series of control strategies and management approaches will be incorporated into the Construction Environmental Management Plan (CEMP) or Operations Environmental Management Plan (OEMP) and implemented for each project component. Key control and management strategies are summarised in Table 16-5. Chapter 24 provides a framework for implementation of these strategies. A draft CEMP is contained in Appendix AA and a draft OEMP is contained in Appendix BB.

Table 16-5 Control and Management Strategies: Groundwater

Control and Management Strategies	EMP ID
Construction	
A CEMP will be developed, capturing all of the company commitments and government approval conditions to minimise and manage environmental impacts and risks. The CEMP will contain, as a minimum, information on the following: · Appropriate permits obtained for the construction of the two saline water construction supply wells. · Controlled and recorded abstraction of water in accordance with defined water requirements and approved abstraction volumes for the saline construction wells. · Groundwater monitoring at designated locations to assess whether groundwater drawdown is consistent with numerical model predictions throughout the operation of the borefield and the requirement for further investigation where differences are observed. · Appropriate permits obtained for the construction of the Keilpa borefield. · Construction camp at the port will maintain a licensed waste water treatment plant during its operation, which will be removed upon completion of construction works. · All hazardous materials (oils, fuels and chemicals) will be managed in accordance with relevant regulations and guidelines, including appropriate storage and bunding, material safety data sheets, spill response etc.	GD_C1 GD_C2 GD_C3 GD_C4 GD_C5 CHS_C2
Operation	
An OEMP will be developed, capturing all of the company commitments and government approval conditions to minimise and manage environmental impacts and risks. The OEMP will contain, as a minimum, information on the following: · Controlled and recorded abstraction of water in accordance with defined water requirements and approved abstraction volumes for the Keilpa borefield · Visual inspection of the port rail loop excavation to ensure any seeping groundwater is being appropriately managed · All hazardous materials (oils, fuels and chemicals) will be managed in accordance with relevant regulations and guidelines, including appropriate storage and bunding, material safety data sheets, spill response etc.	GD_O1 GD_O2 CHS_C2

16.7 Residual Risk Assessment

This section identifies and assesses risks to groundwater that would not be expected as part of the normal operation of the project, but could occur as a result of faults, failures and unplanned events. Although the risks may or may not eventuate, the purpose of the risk assessment process was to identify management and mitigation measures required to reduce the identified risks to a level that is considered to be as low as reasonably practicable and therefore acceptable. The groundwater management and mitigation measures identified are presented in Section 16.6 and form the basis of the Environmental Management Framework presented in Chapter 24.

Through the adoption of design modification or specific mitigation measures, all identified risks were reduced to low, which is considered as low as reasonably practicable and therefore acceptable. The key environmental risks will be monitored through the CEIP environmental management framework.

16.7.1 Construction Groundwater Risks

During construction, the residual risks to groundwater receptors near to the CEIP Infrastructure include:

- *Drawdown is greater than predicted by the groundwater modelling due to unexpected hydrogeological conditions which may increase drawdown effects and interaction with Driver River system.*

  Drawdown is not expected to adversely impact ecosystems supported by the Driver River, so the consequence is considered **insignificant**, although it is **possible** that drawdown effects may be greater than predicted. As such, the risk to the Driver River is considered to be **low**.

- *Failure by construction crews to implement the controls specified in the CEMP resulting in (soil and) groundwater contamination from leaks or spills of fuels, chemicals or wastewater and inadequate control measures specified in the CEMP which fail to effectively manage releases of fuels or chemicals, resulting in contamination of (soils and) groundwater.*

  It is considered likely that contamination resulting from a spill would be localised and would have minimal impact on groundwater receptors, given the limited use of groundwater in the study area. Therefore, the consequence has been assessed as **minor**. It is considered possible that a leak or spill could occur during construction of CEIP Infrastructure, and therefore the risk to groundwater as a result of unmanaged releases of fuels or chemicals is considered to be **low**.

16.7.2 Operation Groundwater Risks

During operation, the residual risks to groundwater receptors near to the CEIP Infrastructure include:

- *Drawdown is greater than predicted by the groundwater modelling due to unexpected hydrogeological conditions which may impact groundwater receptors.*

  A **minor** consequence rating has been assigned, reflecting the high salinity of groundwater in the study area and limited groundwater receptors with the potential to be affected should the zone of influence increase beyond the buffer zone. The potential for drawdown effects to be greater than predicted has been accounted for in the impact assessment through a sensitivity analysis and inclusion of a buffer zone. Based on this conservative approach, it is considered **rare** that additional impacts due to drawdown would occur, resulting in a **low** risk rating.

  Protection of the fresh groundwater resources within the Musgrave Prescribed Wells Area is recognised as a critical community value. The likelihood of impacts on these resources is also considered **rare** on the basis of groundwater modelling including sensitivity analysis. As such, the risk to the Musgrave Prescribed Wells Area is considered to be **low**. However, groundwater level monitoring to quantify aquifer response to pumping and groundwater model validation will be implemented as a leading indicator of drawdown. Where differences are observed, investigations will be undertaken to reassess the impacts.

- *Failure by operators to implement the controls specified in the OEMP resulting in (soil and) groundwater contamination from leaks or spills of fuels, chemicals and wastewater and inadequate control measures specified in the OEMP, which fail to effectively manage releases of fuels or chemicals, resulting in contamination of (soils and) groundwater.*

  It is considered likely that contamination resulting from a spill would be localised and would have minimal impact on groundwater receptors, given the limited use of groundwater in the study area. Therefore, the consequence has been assessed as **minor**. It is considered **possible** that a leak or spill could occur during operation of CEIP Infrastructure, and therefore the risk to groundwater as a result of unmanaged releases of fuels or chemicals is considered to be **low**.

- *Altered groundwater conditions (including river inflows) due to compaction of soils caused by the railway line.*

  Compression of soils due to the introduction of infrastructure has the potential to influence groundwater flows within the upper aquifers. Industry accepted design measures and standards will be adopted for the railway line, including ARTC Standards; and embankments, ballast and sleepers to dissipate and distribute the weight of the locomotives and wagons.

  Based on a typical rail sleeper width of 2.6 m, the approximate depth of influence of the applied pressure bulb from the rail track at grade is anticipated to be approximately 8 m. Typical maximum applied sub-grade pressure from railway track loading can be expected to be about 150 kPa. The applied pressure spreads out and reduces with depth such that at a depth of 2.6 m the pressure is about 50% (i.e. 75 kPa) of that at the sub-grade and at 7.8 m it is about 20% (i.e. 30 kPa).

  The effect of such applied near surface pressure combined with vibration in a predominantly granular soil is a localised increase in soil density. The credible worst case increase would be from a 'loose' condition prior to rail construction to a 'dense' condition post construction. It is noted that at depths of more than approximately 3 m, the effects are likely to be minimal.

It is anticipated that the soils at waterway locations are predominantly granular in nature and could range from fine SAND to coarse SAND / GRAVEL. Preene et at. (2000) provides indicative relationships between the density and permeability of soils. Based on these relationships, the changes in permeability for different relative densities are summarised in Table 16-6.

Table 16-6 Indicative Relationships between the Density and Permeability of Soils

Soil Type	Soil relative density	Permeability (m/s)
Coarse SAND / GRAVEL	Loose	1.5×10^{-3}
	Medium Dense	1.0×10^{-3}
	Dense	0.8×10^{-3}
Medium SAND	Loose	6.0×10^{-5}
	Medium Dense	4.5×10^{-5}
	Dense	4.0×10^{-5}
Fine SAND	Loose	1.5×10^{-4}
	Medium Dense	7.0×10^{-5}
	Dense	5.5×10^{-5}

The information presented in Table 16-6 suggests that even under credible worst case conditions, the permeability of the soil profile underlying the rail track will not be significantly impacted and therefore the impact on the flow of groundwater within the shallow aquifers will be minimal. A consequence rating of **insignificant** has been assigned, reflecting the localised and minimal change in groundwater flow and the limited groundwater receptors with the potential to be affected.

Further, the use of appropriate embankments and culverts will result in the redistribution of pressure on the underlying soils. Even, if shallow groundwater flow is affected, the redistribution of pressure is likely to result in natural sub-surface channels that should enable unrestricted flow of shallow groundwater. If necessary, further drainage measures will be installed. Therefore, the likelihood of impacts to groundwater due to the railway line is considered **rare** on the basis of these design measures. As such, the risk is considered to be **low.**

16.7.3 Summary of Risks

The key environmental risks to groundwater due to construction and operation of the project are presented in Table 16-7. Through the adoption of design modification or specific mitigation measures, all identified risks were reduced to levels of low, which is considered to be as low as reasonably practicable and therefore acceptable. The key environmental risks will be monitored through the CEIP Environmental Management Framework.

Table 16-7 Residual Risk Assessment Outcomes: Groundwater

Risk Event	Pathway	Receptor	Project Phase	Likelihood	Consequence	Residual Risk
Drawdown from operation of construction water supply wells is greater than predicted by groundwater modelling impacting groundwater receptors.	Actual hydrogeological conditions differ from assumed conditions.	Driver River	Construction	Possible	Insignificant	Low
Groundwater contamination from leaks or spills of fuels, chemicals and wastewater during construction and operation.	Failure to implement management controls. Inadequate control measures specified in CEMP.	Economic (agriculture) Stock wells	Construction Operation	Possible	Minor	Low
Drawdown from proposed borefield operation is greater than predicted by groundwater modelling impacting groundwater receptors.	Actual hydrogeological conditions differ from assumed conditions.	Stock wells Fresh ground-water within Musgrave PWA	Operation	Rare	Minor	Low
Altered groundwater conditions (including river inflows).	Compaction of soils from railway line.	Economic (agriculture) Driver River and ephemeral creeks	Operation	Rare	Insignificant	Low

16.8 Findings and Conclusion

The GIA has identified that the only receptor expected to be affected by CEIP Infrastructure activities is the Driver River. Groundwater levels in the vicinity of the river are predicted to reduce by up to 3 m during the construction period, due to operation of a water supply well (IC5) for two years. Although a change in groundwater/surface water interaction may occur, the impact is considered **negligible** as current saline water inflow to the Driver River is reported to be detrimental to the ecosystem it supports (EPA 2010).

The GIA reveals that no stock wells are being used within the predicted zone of influence of the mine water supply borefield due to the very high salinity of groundwater precluding agricultural use. There are no other groundwater receptors, including GDEs or industrial users within the zone of influence. Therefore, a **negligible** level of impact to groundwater receptors is expected from CEIP Infrastructure activities.

Mitigation measures would be implemented to reduce the risk of impacts to groundwater receptors associated with releases of fuels, chemicals and wastes to the environment. Changes to hydrogeological process as a result of soil compaction are not anticipated. Monitoring of groundwater levels will be undertaken to assess compliance with predicted drawdown.

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