Appendix G

Water Assessment

Balranald Mineral Sands Project

Water Assessment

Prepared for Iluka Resources Limited
May 2015

ILUKA

EMM
EMGA Mitchell McLennan

Balranald Mineral Sands Project

Water Assessment

Iluka Trim Reference No: 1305937

Prepared for Iluka Resources Ltd | 1 May 2015

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Balranald Mineral Sands Project

Final

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1 Introduction

1.1 Overview

Iluka Resources Limited (Iluka) proposes to develop a mineral sands mine in south-western New South Wales (NSW), known as the Balranald Mineral Sands Project (the Balranald Project). The Balranald Project includes construction, mining and rehabilitation of two linear mineral sand deposits, known as West Balranald and Nepean. These mineral sands deposits are located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald. Figure 1.1 shows the location of the Balranald Project and its major features.

Iluka is seeking development consent under Part 4, Division 4.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the Balranald Project, broadly comprising:

- open cut mining of the West Balranald and Nepean deposits, referred to as the West Balranald and Nepean mines, including progressive rehabilitation;
- processing of extracted ore to produce heavy mineral concentrate (HMC) and ilmenite;
- road transport of HMC and ilmenite to Victoria;
- backfilling of the mine voids with overburden and tailings, including transport of by-products from the processing of HMC in Victoria for backfilling in the mine voids;
- return of hypersaline groundwater extracted prior to and during mining to its original aquifer by a network of injection borefields;
- an accommodation facility for the construction and operational workforce;
- gravel extraction from local sources for construction requirements; and
- a water supply pipeline from the Murrumbidgee River to provide fresh water during construction and operation.

Separate approvals are being sought for:

- the construction of a transmission line to supply power to the Balranald Project; and
- project components located within Victoria.

1.2 Approval process

In NSW, the Balranald Project requires development consent under Part 4, Division 4.1 of the EP&A Act. Part 4 of the EP&A Act relates to development assessment. Division 4.1 specifically relates to the assessment of development deemed to be State significant development (SSD). The Balranald Project is a mineral sands mining development which meets the requirements for SSD.

An application for SSD must be accompanied by an environmental impact statement (EIS), prepared in accordance with the NSW *Environmental Planning and Assessment Regulation 2000* (EP&A Regulation).

An approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is required for the Balranald Project (with the exception of the transmission line which will be subject to a separate EPBC Act referral process). A separate EIS will be prepared to support an application in accordance with the requirements of Part 8 of the EPBC Act.

1.3 Secretary's environmental assessment requirements

The EIS has been prepared to address specific requirements provided in the Secretary's environmental assessment requirements (SEARs) for the SSD application, issued on 2 December 2014.

This water assessment has been prepared to address specific requirements for groundwater and surface water in the SEARs. It has also been prepared to adequately address the key requirements of the NSW Office of Water (NOW) and other NSW Government agencies with jurisdiction over aspects of surface and groundwater management. The SEARs relating to water are listed in Table 1.1 and include the section of the report where they are addressed.

Table 1.1 Relevant SEARs for this assessment

Requirement	Section addressed
An assessment of the likely impact of the development of the quality and quantity of the regions surface and groundwater resources, having regard to the EPAs and NOW requirements.	Chapter 13 and 14
An assessment of the likely impacts of the development on aquifers, water courses, riparian land, water related infrastructure and other water users.	Chapter 13 and 14
A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures.	Chapter 3 and Chapter 12
Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP).	Chapter 2
A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo.	Chapter 2
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	Chapter 15

1.4 Purpose of this report

A number of consultants were commissioned to undertake various water related technical studies for the SSD application for the Balranald Project. The water assessment was prepared using a number of technical assessments which have been appended to the water assessment, including:

- CDM Smith: Groundwater dependent ecosystems impact assessment report (February 2015) (Appendix J of the EIS report);
- Earth Systems: Geochemistry assessment for the Balranald Project (March 2015) (Appendix Q of the EIS report);
- Iluka 2015 Balranald Mineral Sands Project, Radiation risk assessment April 2015 (Appendix S of the EIS report);
- Jacobs: Balranald Project DFS1 groundwater modelling (February 2015) (Appendix I of the EIS report);

- Land and Water Consultants: Regional groundwater monitoring information, commenced in 2011 on a quarterly basis;

- Land & Water Consulting: Summary of landholder discussions as part of the beneficial use assessment (June 2014) (Appendix A of this report); and

- WRM: Balranald Mineral Sands Project surface water management report (February 2015) (Appendix H of the EIS report).

These have been carried out accordance with the SEARs and with reference to the following key legislation, standards, guidelines and policies:

- *Australian groundwater modelling guidelines*, National Water Commission (NWC) 2012;

- *Australian and New Zealand guidelines for fresh and marine water quality*, Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council(ANZECC/ARMCANZ) 2000;

- *The Basin Plan for the Murray-Darling*, The Murray Darling Basin Authority (MDBA) 2012;

- Environmental Protection and Biodiversity Conservation Act 1999;

- *Groundwater monitoring and modelling plans - Information for prospective mining and petroleum exploration activities*, NOW (2014);

- *Guidelines for the assessment and management of groundwater contamination*, Department of Environment and Conservation (DEC) 2007;

- *National water quality management strategy guidelines for groundwater protection in Australia*, ANZECC/ARMCANZ (2000);

- *NSW Aquifer Interference Policy* (AIP), NOW 2012;

- *NSW State government policy framework document*, (Department of Land and Water Conservation (DLWC) 1997;

- NSW *Water Act 1912* (WA 1912);

- NSW *Water Management Act 2000* (WMA 2000);

- *Murray Darling Basin groundwater quality sampling guidelines, technical report no. 3*, Murray-Darling Basin Commission (MDBC) 1997;

- *Water Sharing Plan for the NSW Murray-Darling Basin Porous Rock Groundwater Sources 2011* (MDB Porous Rock WSP), NOW (2011); and

- *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2003* (Murrumbidgee River WSP), NOW (2003).

There are additional policies, guidelines and plans detailed in the SEARs, however these have not been included in this assessment as they relate to detailed aspects of water resources, ie urban stormwater, sewage treatment.

1.5 Scope of assessment

EMGA Mitchell McLennan Pty Limited (EMM) was commissioned by Iluka to assess potential water impacts from the construction and operation of the Balranald Project based on the above technical studies. The key objectives of the assessment include:

- identify and assess potential impacts on groundwater and surface water from the development of the Balranald Project;
- satisfy the SEARs relevant to groundwater and surface water impacts; and
- inform the wider community about the project and its potential impacts on the local and regional water environments.

To achieve these objectives the water assessment:

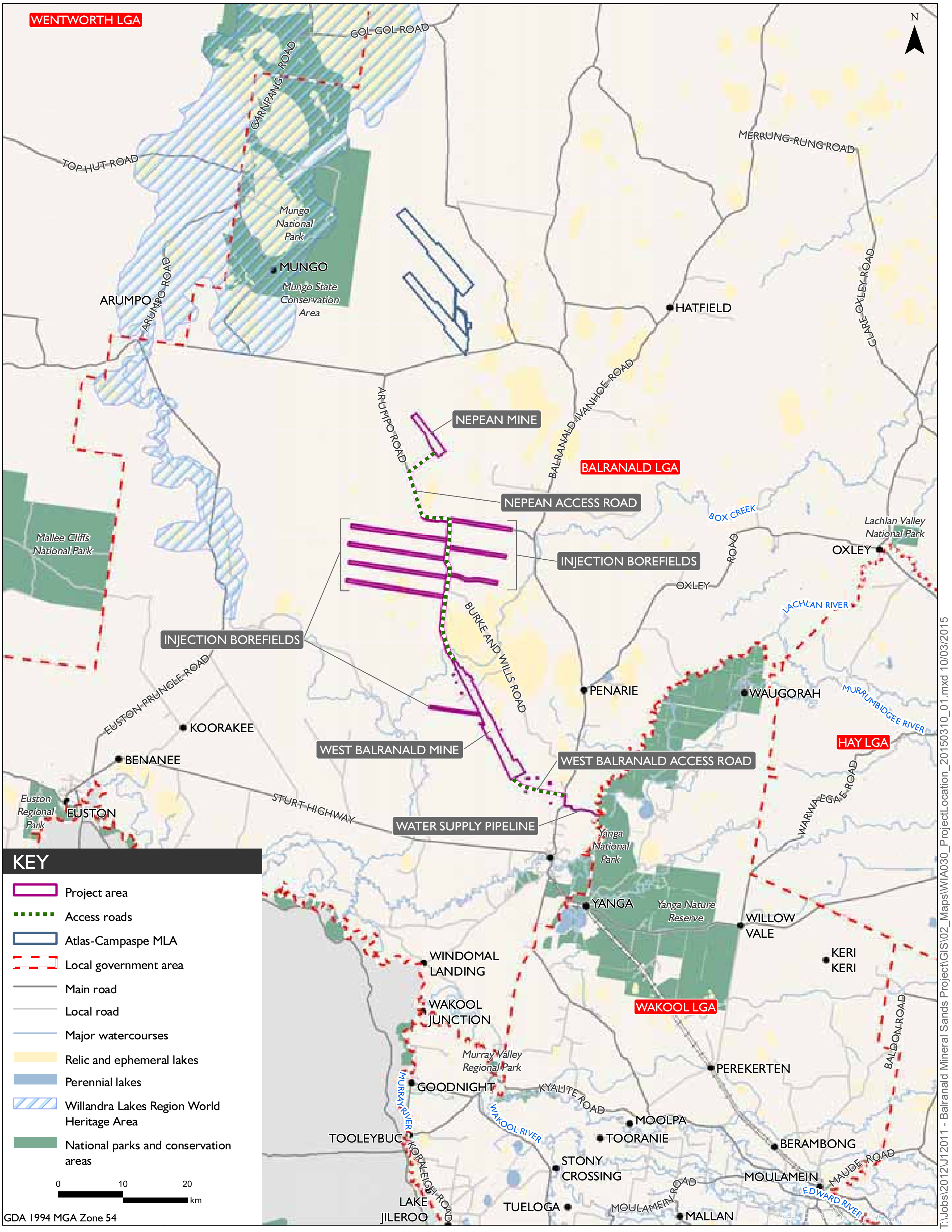
- assessed the existing hydrological and hydrogeological environments and baseline conditions within the Balranald Project area and surrounding area;
- identified and quantified the potential impacts of the Balranald Project on the current surface water and groundwater resources, and on water users both environmental and extractive (including cumulative impacts);
- proposes mitigation and management measures, and monitoring requirements for surface water and groundwater; and
- discusses water licensing requirements in accordance with the relevant legislation.

1.6 Report structure

The structure of this report is as follows:

- Chapter 1 provides an introduction to the water assessment, including an overview of the Balranald Project, and the purpose and scope of the water assessment;
- Chapter 2 provides an overview of the relevant legislation, policies and guidelines to the Balranald Project area;
- Chapter 3 provides a description of the Balranald Project, including site water management;
- Chapter 4 outlines an overview of the impact assessment methodology;
- Chapter 5 describes the regional and local setting of the assessment area, including climate, topography, land use, surface water, geology, hydrogeology and water dependent ecosystems;
- Chapter 6 provides as overview of the field investigation programs;
- Chapter 7 describes the regional and project area surface water resources in detail, including surface water levels and quality;
- Chapter 8 describes the project area and surrounding geology;

- Chapter 9 describes the regional and project area groundwater resources in detail, including the hydrogeological units, groundwater levels, head pressure gradients, hydraulic conductivity and geochemistry;
- Chapter 10 outlines the site conceptual model for surface water and groundwater;
- Chapter 11 summarises the groundwater modelling undertaken including model set up and design, model calibration and predictive simulations;
- Chapter 12 provides an overview of the site water balance and the water budget;
- Chapter 13 discusses the Balranald Project's potential impacts on local and regional surface water resources, surface water users and potential surface water availability to ecosystems;
- Chapter 14 discusses the Balranald Project's potential impacts on local and regional groundwater resources, groundwater users and potential groundwater availability to ecosystems;
- Chapter 15 outlines the mitigation and management measures, and monitoring requirements for surface water and groundwater, including a water management plan; and
- Chapter 16 provides the conclusions of the water assessment.



Location of the project area

Balranald Mineral Sands Project
Water Assessment
Figure 1.1

2 Regulation

2.1 Introduction

This chapter discusses the water regulation for both the NSW and the Commonwealth Governments, and supporting policies and guidelines.

In NSW there are two main pieces of legislation that regulate water, the: WA1912 and the WMA 2000. The WA 1912 is gradually being repealed and replaced by the WMA2000 as WSPs are developed for water sources across NSW, and as new regulations are made. However, some aspects of water management are still regulated under the WA1912. Other water policies of interest to this project, such as the AIP and the proposed return flow regulation are also discussed as they pertain to the Balranald Project.

2.2 NSW Water Act 1912

The WA 1912 has historically been the main legislation for the management of NSW water resources. However the WA 1912 is progressively being repealed and replaced by the WMA 2000 on a water source by water source basis as WSPs commence. The water sources in the vicinity of the Balranald Project have WSPs that have commenced and therefore most aspects of water management for the project come under the WMA 2000.

However, some aspects of the WA 1912 are still operational across all of NSW, such as licenses for monitoring bores, and licensing of groundwater reinjection activities. Licensing of monitoring bores continues under the WA 1912 until a regulation surrounding aquifer interference activities provides a mechanism for an approval for these activities. Licensing of reinjection into groundwater systems is also still currently still managed under the WA 1912.

2.3 NSW Water Management Act 2000

The WMA 2000 applies to those areas where a WSP has commenced. WSPs are statutory documents under the WMA 2000 that apply to individual water source areas and contain the rules for sharing and managing the water resources of NSW. The WMA 2000 outlines the requirements for the taking and trading of water through water access licenses (WALs), water supply works and water use approvals.

Groundwater and surface water within the project area is governed under the WMA 2000 within the relevant WSPs which are discussed below.

2.3.1 Water sharing plans

WSPs aim to ensure sustainable and integrated management of NSW water by providing clear arrangements for activities that affect water quality and quantity. The plans sets management rules for WALs, water allocation accounts, dealings in licenses and water allocations, water supply works approvals, and the extraction of water. WSPs also define the water management rules for things such as trading water and granting of access licenses.

There are provisions in the surface water WSPs to provide water to support the ecological processes and environmental needs of rivers, and direct how the surface water available for extraction is to be shared. While the provisions in the groundwater WSPs provide water to support the ecological processes and environmental needs of high priority groundwater dependent ecosystems (GDEs) and rivers, and direct how the water available for extraction is to be shared.

There are a number of surface and groundwater WSPs that relate to water sources in and surrounding the project area, including:

Groundwater

- *Water Sharing Plan for the* MDB Porous Rock 2011;
- *Water Sharing Plan for the Lower Lachlan Groundwater Source 2003*; and
- *Water Sharing Plan for the Lower Murrumbidgee Groundwater Sources 2003* (Lower Murrumbidgee Groundwater WSP).

Surface water

- *Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2003*;
- *Water Sharing Plan for the Lachlan Regulated River Water Source 2003*;
- *Water Sharing Plan for the New South Wales Murray and Lower Darling Regulated Rivers Water Sources 2003*;
- *Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources 2012*; and
- *Water Sharing Plan for the Murrumbidgee Unregulated and Alluvial Water Sources 2012*.

Combined

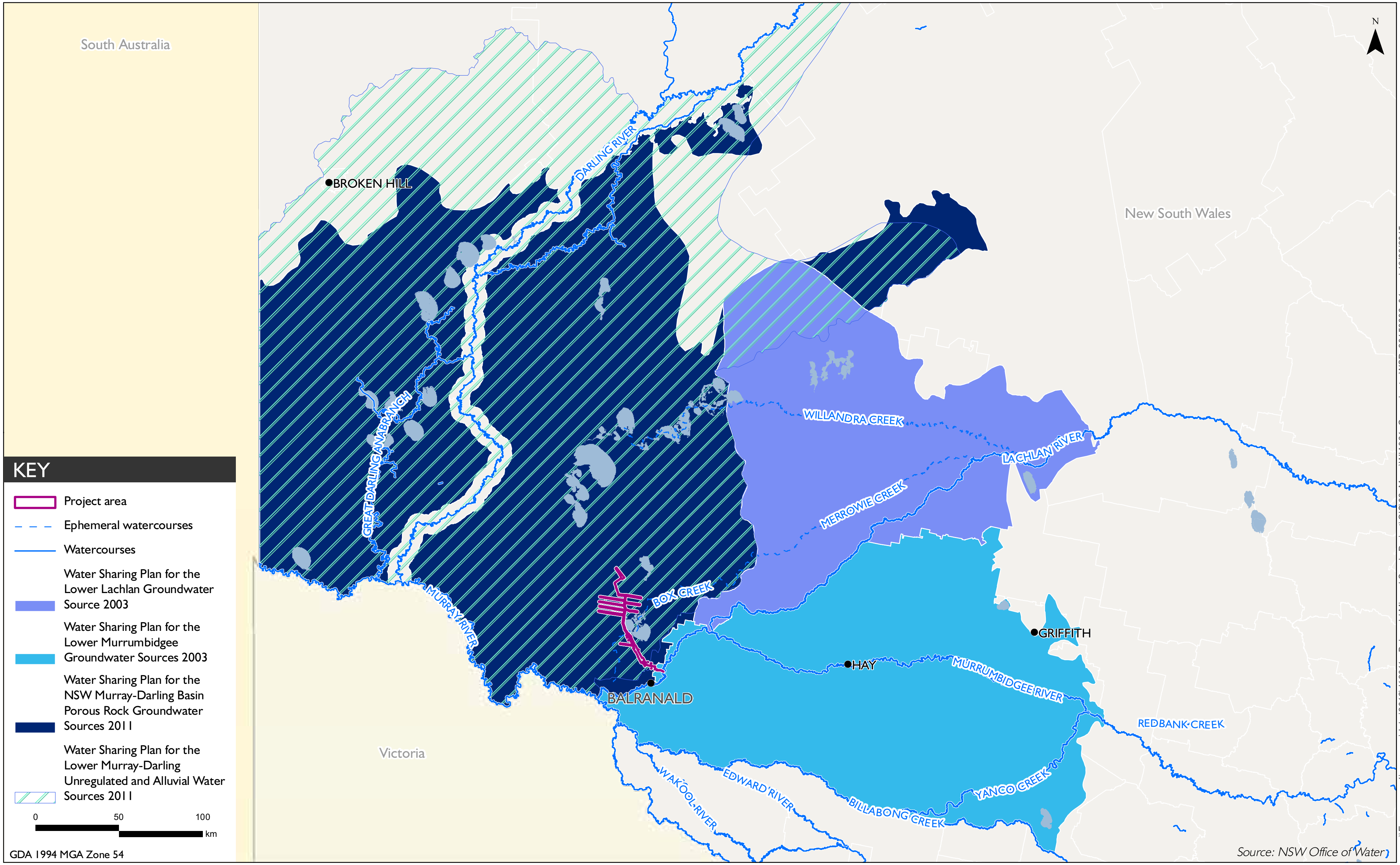
- *Water Sharing Plan for the Lower Murray-Darling Unregulated and Alluvial Water Sources 2011*.

Of these, the Balranald Project will be required to be licensed to take (or extract) water in relation to two WSPs, namely:

- MDB Porous Rock WSP; and
- Murrumbidgee River WSP.

The WSP boundaries are shown in Figures 2.1 and 2.2, and further details on each plan are provided below.

Under section 89J of the EP&A Act, water use and management approvals (under sections 89, 90 and 91 of the WA 1912) are not required for SSD. However, SSD is not exempt from the obligation to secure an aquifer interference approval (under section 91(3) of the WMA 2000) and WALs (under section 56 of the WMA 2000). It should be noted that Section 91(3) of the WMA 2000 has not yet commenced and aquifer interference approvals do not actually exist. The Balranald Project is required to comply with the AIP which requires licenses for all water taken and intercepted from each relevant water source. This will be required for the Balranald Project under the relevant WSPs.



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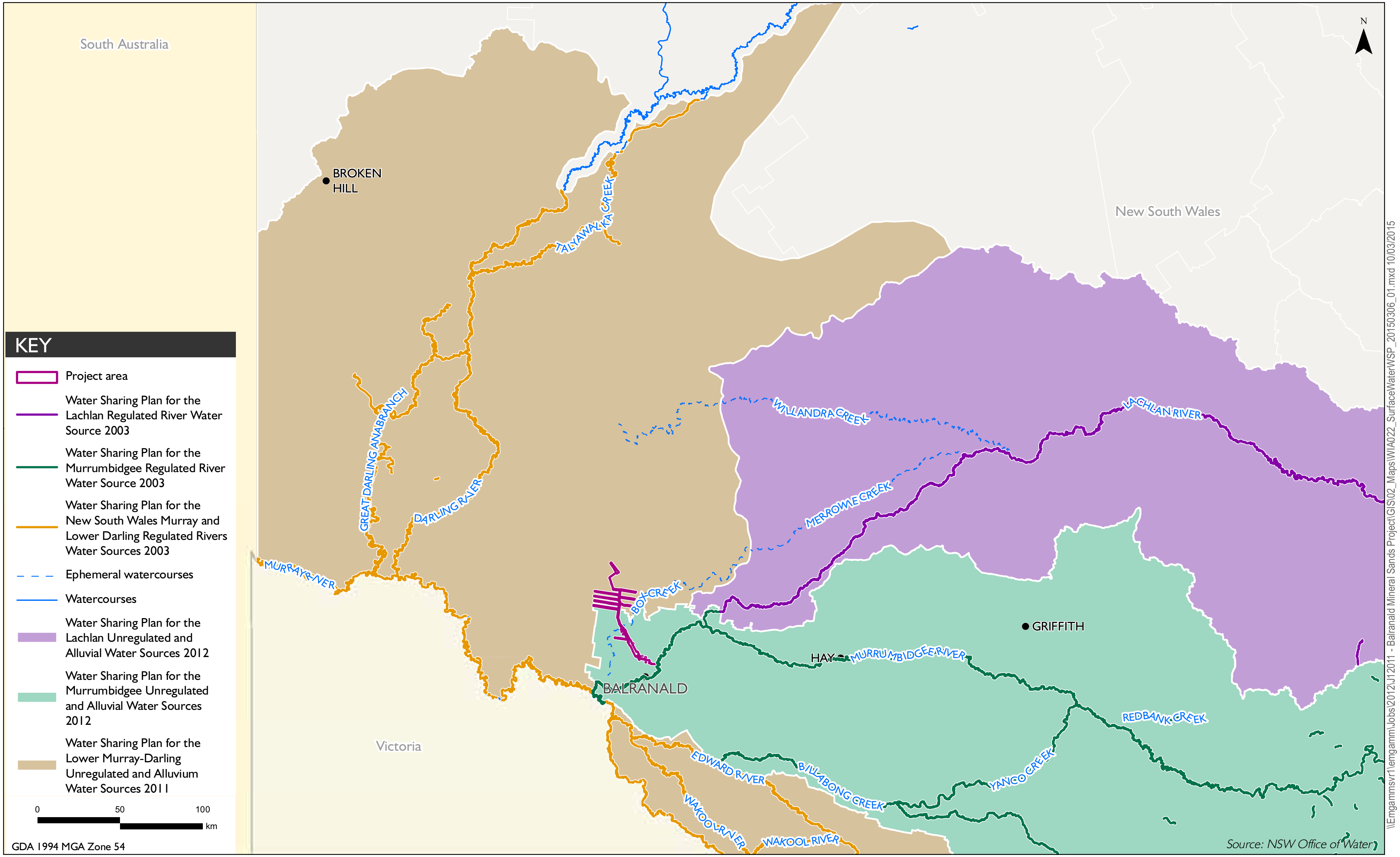
Groundwater WSP boundaries

Balranald Mineral Sands Project

Water Assessment

Figure 2.1



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Surface water and unregulated alluvium WSP boundaries

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Figure 2.2

An access license may be either traded on the water market, or granted where the right to apply for the license has been acquired in accordance with an order made under section 65 of the WM Act. Section 65 provides that:

> The Minister may, by order published in the Gazette, declare that the right to apply for an access license for a specified water management area or water source is to be acquired by auction, tender or other means specified in the order.

The Balranald Project will require:

- WALs under section 56 of the WM Act for the extraction of water (groundwater and surface water) from the relevant WSPs; and
- compliance with the AIP.

Further discussion on the water impacts of the Balranald Project is provided in Chapters 13 and 14.

i Water sharing plan for the NSW Murray-Darling Basin porous rock groundwater sources 2011

The MDB Porous Rock WSP applies to the NSW portion of the Murray Darling Basin (MDB) porous rock groundwater sources. The MBD Porous rock WSP commenced on 16 January 2012 and is due for extension or replacement in July 2022.

In general, the MBD Porous Rock WSP area includes all porous rock groundwater sources within the Murray Darling Basin that are not included in other WSPs, such as porous rock groundwater sources in the *Water Sharing Plan for the Great Artesian Basin Groundwater Sources 2008*. The plan also includes minor miscellaneous, unmapped alluvial sediments that overly outcropping porous rock groundwater sources as well as fractured rocks that occur within groundwater sources that are predominantly porous rock.

The groundwater sources within the MBD Porous rock WSP cover an area of:

- approximately 8,642,000 ha, which includes only the outcropped portions (ie that portion of the groundwater source with a surface expression); and
- approximately 3,436,000 ha, which includes only the buried portions (ie that portion of the groundwater source that is buried under another groundwater source and, therefore, has no surface expression).

There are four groundwater sources within the MBD Porous Rock WSP:

- the Gunnedah-Oxley Basin MDB Groundwater Source (a portion on the north-eastern side of the NSW Murray Darling Basin between Narrabri, Gunnedah and Dubbo eastward to the Murray Darling Basin border);
- the Oaklands Basin Groundwater Source (a portion in the south-central area of the state that is completely buried by the Murray Basin alluvial sediments near Jerilderie);
- the Sydney Basin MDB Groundwater Source (a small portion of the Sydney Basin that occurs west of the dividing range on the eastern side of the Basin extending southward along the Basin border to nearly Bathurst); and

- the Western Murray Porous Rock Groundwater Source (a portion in the far west of the state from south of Broken Hill southward to the state border and to the west of the Lower Lachlan, Lower Murrumbidgee, and Lower Murray Groundwater Sources westward to the state border).

The project area lies within Western Murray Porous Rock Groundwater Source (see Figure 2.1).

Section 4(6) of this WSP states that:

> (6) Subject to subclause (8), the Western Murray Porous Rock Groundwater Source includes all water contained in:
>
> (a) all rocks of Tertiary and Quaternary age within the outcropped and buried areas, and
>
> (b) all alluvial sediments within the outcropped areas,
>
> within the boundary of the Western Murray Porous Rock Groundwater Source as shown on the Plan Map.

The Western Murray Porous Rock Groundwater Source covers an outcrop area of 7,302,000 ha. It is located within the MDB, extending from the boundary with the Adelaide and Kanmantoo Fold Belts in the north to the Murray River in the south. To the east the water source is bound by the boundary between the Kanmantoo and Lachlan Fold Belts. The water source incorporates the alluvial Renmark Group and Calivil Formation in the east (as described by Kellett 1991) which grade into the Murray Group Limestone and Loxton-Parilla Sands to the southwest.

Section 8 of the MDB porous rock WSP states that:

> The vision for this Plan is to provide for healthy and enhanced groundwater sources and water dependent ecosystems and for equitable water sharing among users in these groundwater sources.

The objectives of this Basin Groundwater WSP are to:

> (a) protect, preserve, maintain and enhance the high priority groundwater dependent ecosystems and important river flow dependent ecosystems of these groundwater sources,
>
> (b) protect, preserve, maintain and enhance the Aboriginal, cultural and heritage values of these groundwater sources,
>
> (c) protect basic landholder rights,
>
> (d) manage these groundwater sources to ensure equitable sharing between users,
>
> (e) provide opportunities for enhanced market based trading of access licenses and water allocations within environmental and system constraints,
>
> (f) provide water allocation account management rules which allow sufficient flexibility in water use,
>
> (g) contribute to the maintenance of water quality,
>
> (h) provide recognition of the connectivity between surface water and groundwater,
>
> (i) adaptively manage these groundwater sources, and

(j) contribute to the environmental and other public benefit outcomes identified under the Water Access Entitlements and Planning Framework in the Intergovernmental Agreement on a National Water Initiative (2004) (hereafter the NWI).

There are approximately 40,746 unit shares of entitlement (under license) in the area covered by the MDB Porous Rock WSP. The majority of these licenses are for industrial and mining purposes. Of these shares, 21,782 unit shares are licensed for the Western Murray Porous Rock Groundwater Source. In addition, a number of salt interception schemes operate in the Western Murray Porous Rock Groundwater Source; these are expected to be issued entitlements in the order of 14,582 unit shares. Basic landholder rights within the Western Murray Porous Rock Groundwater Source are estimated at 26,747 ML/year, and represent a significant volume of the total rights within this water source. There is also a significant amount of unassigned water within the source estimated to be 467,377ML/yr (refer to Table 2.1).

The MDB Porous Rock WSP sets the annual groundwater recharge volumes for each identified groundwater source and the volumes of water available for sharing (the long-term average annual extraction limit). Provisions are made for environmental water allocations, basic landholder rights, domestic and stock rights and native title rights. The statistics for the Western Murray Porous Rock Groundwater Source availability are presented in Table 2.1, and an overview of water availability is provided in Figure 2.3.

Table 2.1 Requirements for water sharing (Western Murray Porous Rock Groundwater Source)

Use	Share component
Recharge	1,060,971 ML/yr (not high environmental value) 42,994 ML/yr (high environmental value)
Environmental water	530,485 (50% of recharge for not high environmental value) 42,994 ML/yr (100% of recharge for high environmental value) Plus all groundwater in storage
Long-term average annual extraction limit (LTAAEL)	530,486 ML/yr
Town water supply	0 ML/year
Basic rights (domestic and stock)	26,747 ML/yr
Native title	0 ML/yr
Aquifer access licenses	21,780 unit shares[3]
Salinity and water table management	14,582 ML/yr
Total water requirements[1]	63,109 ML/yr
Unallocated water[2]	467,377 ML/yr

Notes: *1. This number is not listed in the MDB Porous Rock WSP, but is calculated by summing all requirements for water under Part 5 of the plan for the Western Murray Porous Rock and assuming 1 unity share is equal to 1 ML.*

2. This number is not listed in the MDB Porous Rock WSP, but is calculated as the difference between the long-term average annual extraction limit, minus the total water requirements.

3. A unit share is defined in section 29(2)(b) of the MDB Porous Rock WSP as being a maximum of 1 ML per unit share, or a lower amount if the volume of water extraction from the water source is deemed to be in excess of the LTAAEL over a three year rolling period by 5% or more.

As Table 2.1 and Figure 2.3 shows, there is a significant amount of unallocated water within the Western Murray Porous Rock Groundwater Source of the MDB Porous Rock WSP.

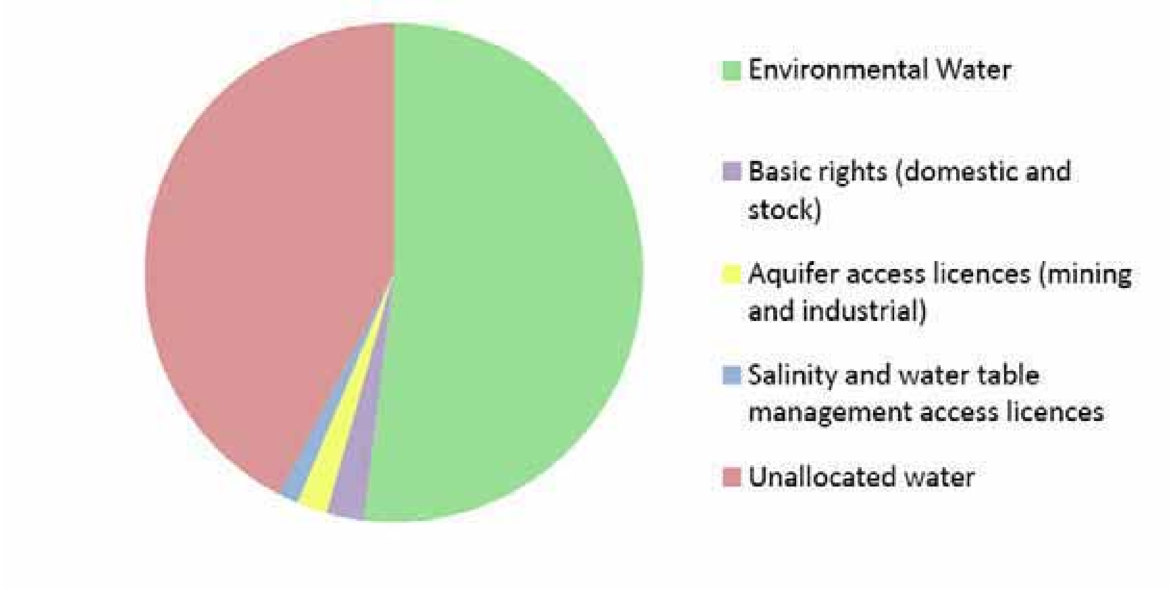


Figure 2.3 Water availability (of total recharge) in west Murray Porous Rock water source

The WSP does not however distinguish between aquifers containing highly saline water (ie requiring dewatering and injection into the same aquifer as part of the Balranald Project) and those aquifers containing water that has beneficial use.

The Balranald Project would take groundwater over 10 years, with a peak take spanning over six years. Over this six year peak, Iluka would seek to take a 'gross' volume of groundwater in the order of between 20,000 and 30,000 ML/year, of which, approximately 90%, would be injected back into the same aquifer. These gross extraction volumes (notwithstanding injection) are well within the sustainable limits of the Western Murray Porous Rock Groundwater Source and constitute only 6% of the current level of unallocated water within this source.

In accordance with the WM Act a WAL may be granted where the right to apply for the license has been acquired in accordance with an order made under section 65 of the Act. Iluka currently have two WALs (WAL 31101 and 31102) that are, and have been, used to assign groundwater allocations for relevant trade periods with water supply works approval extraction locations nominated. As part of the Balranald Project, Iluka will continue to use one or both of these WALs to assign future groundwater allocations, while additional WALs may be applied for in accordance with the WM Act.

Iluka negotiated third party water trades under the WM Act in the order of 1,100 ML (in 2013/14) and 900 ML (in 2014/15) to support field program activities. The groundwater allocation was secured from the Western Murray Porous Rock Groundwater Source and assigned to nominated water supply works approvals to facilitate Iluka's hydrogeological programs and a mining trial.

Iluka would obtain further allocations to support the Balranald Project from the Western Murray Porous Rock Groundwater Source through third party water trades and/or through controlled allocation orders under section 65 of the WM Act. These allocations would be obtained with consideration to return flow rules which the NSW government proposes to introduce in 2015. As part of a controlled allocation order made on 9 September 2014, the NSW government stated that:

> Return flow rules are likely to be made for aquifer access licenses in the second half of 2014. Once these rules are put in place, license holders will receive a credit to their water allocation account for water returned to the same groundwater source from which it was taken, providing specific conditions are met. License holders will only need to hold enough license shares to account for the net amount of water extracted, ie the amount of water initially extracted minus the amount of water returned. Water usage fees will only be applied to the net amount of water extracted.

Iluka would seek credits for all injected water under the return flow regulation once it is enacted. As stated above, this regulation was set to commence in late 2014, but is yet to commence. Under this regulation Iluka would only required to hold the license volume for the difference between the 'net' and 'gross' take of groundwater.

Iluka will continue to engage with the NSW Government regarding when the return flow rules are enacted and on the timing of a future controlled allocation order to secure a WAL for the Balranald Project.

ii Water Sharing Plan for the Murrumbidgee Regulated River Water Source 2003

The Murrumbidgee River WSP lies within the Murrumbidgee Water Management Area and the Murray Water Management Area. The water source is defined as the water between the banks of all rivers, from the upper limit of Burrinjuck Dam water storage (being the Taemas Bridge crossing) and Blowering Dam water storage (being the dam wall and spillway for Jounama Pondage), downstream to the junction of the Murrumbidgee River and the Murray River. This includes the Murrumbidgee River at Balranald where fresh water for project supply is proposed (see Figure 2.2).

The Murrumbidgee River WSP commenced on 1 July 2004 and applied for a period of 10 years to 30 June 2014. In May 2014, the Minister for Natural Resources, Lands and Water approved an extension to the plan until its date of replacement (by 1 July 2015 or sooner). Section 9 of the Murrumbidgee River WSP states that:

> The vision for this Plan is to provide for equitable sharing of limited water resources to sustain a healthy and productive river and the welfare and well being of Murrumbidgee regional communities.

The objectives of this Murrumbidgee River WSP are to:

(a) protect and restore in-river and riparian habitats and ecological processes,

(b) provide for appropriate watering regimes for wetlands,

(c) sustain and enhance population numbers and diversity of indigenous species,

(d) protect basic landholder rights, including native title rights,

(e) maximise early season general security allocations,

(f) protect town water supply,

(g) protect end-of-system flows,

(h) provide for commercial consumptive use,

(i) provide for identified recreational water needs,

(j) protect identified indigenous and traditional uses of water, and

(k) within the ability of this Plan promote the recovery of known threatened species.

The provisions in the Murrumbidgee River WSP provide water to support the ecological processes and environmental needs of the Murrumbidgee River and direct how the water available for extraction is to be shared. The plan also sets rules that effect the management of WALs, water allocation accounts, the trading of or dealings in licenses and water allocations, the extraction of water, the operation of dams and the management of water flows.

At the commencement of the Murrumbidgee River WSP, the following unit shares were available from the Murrumbidgee River:

- general security - 2,043,432 unit shares;
- high security - 298,021 unit shares;
- domestic and stock - 35,572 ML/year;
- local water utility - 23,403 ML/year;
- Murrumbidgee irrigation (conveyance) - 243,000 unit shares;
- Coleambally irrigation (conveyance) - 130,000 unit shares; and
- supplementary water - 220,000 unit shares.

The share components of licenses such as local water utility and domestic and stock are expressed as a number of megalitres per year. The share components of high security and general security, conveyance and supplementary WALs are expressed as a number of unit shares.

The unit share equivalent in megalitres varies from year to year depending on water availability in the Murrumbidgee Regulated River system. An Available Water Determination (AWD) is made annually to determine what each unit share is equal to in megalitres. The mechanism for this is outlined in Part 8 Division 2 of the Murrumbidgee River WSP.

An AWD for regulated river (high security) access licenses will generally be between 0.95 ML/unit share and 1 ML/unit share. There are some exceptions to this for extreme drought conditions. An AWD for regulated river (general security) access licenses will not be made until the AWD for high security licenses is greater than 0.95 ML/unit share. Iluka will obtain a surface water license volume of 450 ML/yr.

The reliability of supply history for both general security and high security surface water licenses in the regulated the Murrumbidgee River is presented in Figure 2.4. These figures represent the final availability at the end of each water year, with the water year often starting at a lower availability and ramping up over time to this final percentage. The reliability difference between high security and general security is apparent, with general security being much lower in drought and dry times (as seen over the period from 2001/02 through to 2009/10).

Table 2.2 tabulates average availability over recent years, with the past 5 years having an average for General Security of 78%, but over the last 10 years this average was 53%. This reliability of supply is being considered by Iluka in their volumetric requirement to trade a mixture of both high and general security water for ongoing Project Supply.

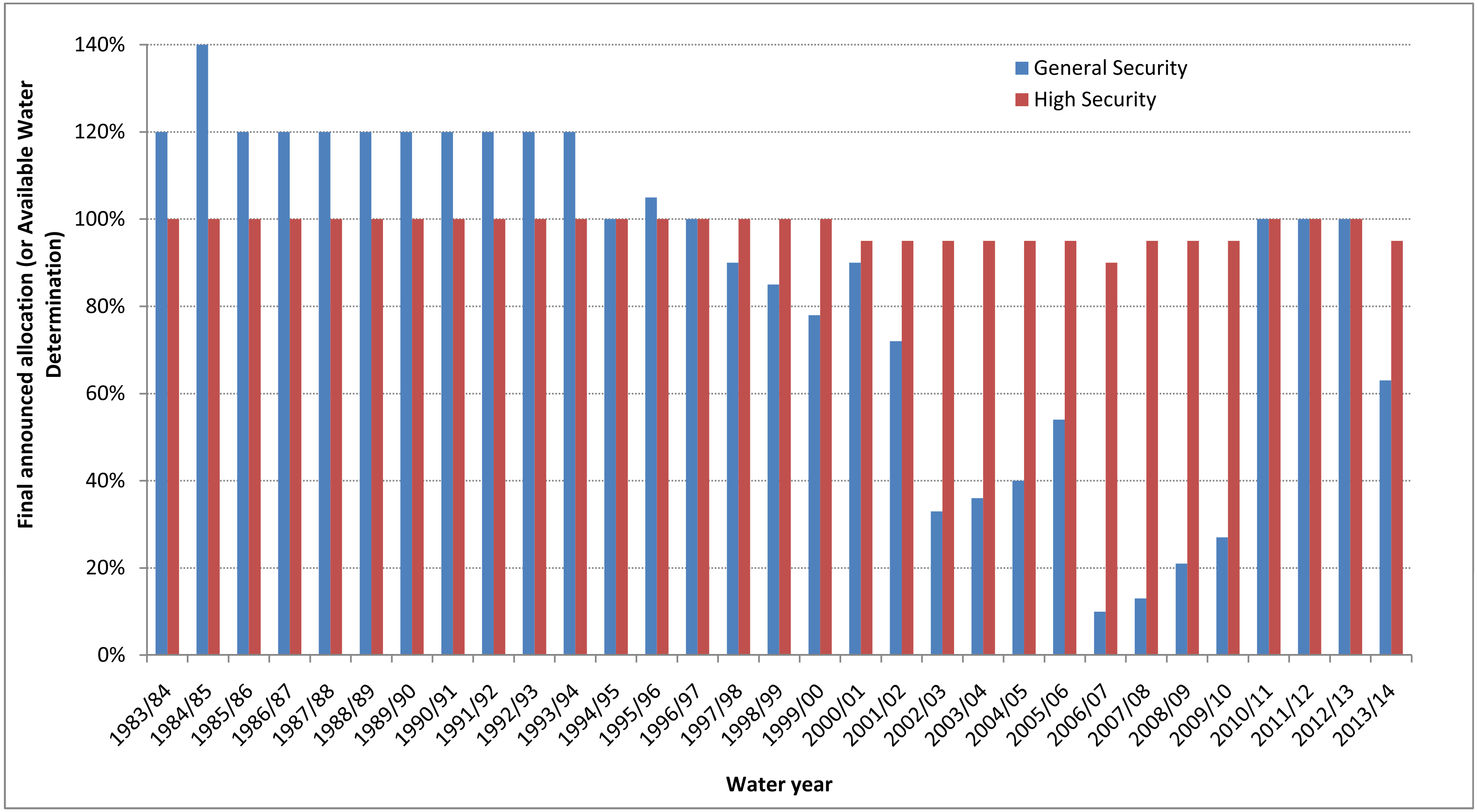
Table 2.2 Average availability of high and general security water from the Regulated Murrumbidgee River in recent years

Average availability	General security	High security
Average last 5 years	78%	98%
Average last 10 years (since commencement of the WSP)	53%	96%
Average since 1983/84 (period of record)	86%	98%

An embargo on applications for new commercial (or industrial) WALs has been in place since 1985. Under the WMA 2000, the only applications that can be made are for those categories or sub-categories specified in either the NSW *Water Management (General) Regulation 2011* or in the Murrumbidgee River WSP. This includes replacement access licenses as a result of access license dealings (or water dealings) which include:

- sale or transfer of the ownership of an access license (called a transfer);
- change in the location where a WAL can be used;
- sale of the share component of an access license (called assigning share component);
- subdivision of an access license or consolidation of access licenses;
- sale of allocation water (called an assignment of water allocation);
- change in the category of an access license (called a conversion); and/or
- rental of a WAL (called a term transfer).

Iluka estimates it requires up 450 ML high security unit shares for the provision of fresh water for the Balranald Project. Iluka will obtain these shares through access license dealings which would most likely be through the sale of allocated general and high security water.



EMGA Mitchell McLennan

Recent average water availability

Balranald Mineral Sands Project

Water Assessment

Figure 2.4

2.4 NSW policies and guidelines

2.4.1 Aquifer Interference Policy 2012

NOW released the AIP in 2012 to address water licensing and the potential impacts of aquifer interference activities within NSW. The AIP defines the regime for protecting and managing the impacts of aquifer interference activities on NSWs water resources and assists proponents in the preparation of necessary information for activities (or developments) that have will have an interference on aquifers.

The AIP aims to:

- clarify water license and impact assessment requirements for aquifer interference activities;
- ensure equitable water sharing among different types of water users;
- ensure that water taken by aquifer interference activities is properly licensed and accounted for in the water budget and water sharing arrangements; and
- enhance existing regulation, resulting in a comprehensive framework to protect the rights of all water users and the environment.

The AIP states that the activity must address potential water table, water pressure and water quality impacts. It requires that a plan is implemented that monitors conditions and mitigates impacts should actual impacts become greater than predicted impacts.

The AIP focuses on high risk activities such as mining, coal seam gas, sand and gravel extraction, construction dewatering, aquifer injection activities, and other activities that have the potential to contaminate groundwater or decrease aquifer storage and yields. Impacts on connected alluvial aquifers and surface water systems, as well as impacts to other water dependent assets, such as water supply bores and GDEs are also considered.

Approval is required for each aquifer interference activity. All water taken from a water source by an aquifer interference activity, regardless of its quality, is required to be accounted for within the long term average extraction limit specified for that water source. In this instance this is the MDB Porous Rock WSP. This is to ensure that the amount of water taken from each water source does not exceed the extraction limit set in the WSP. Where an aquifer interference activity results in the movement of adjacent, overlying or underlying water into the groundwater source there may be a need to obtain multiple licenses.

The AIP requires that two years of baseline groundwater data be collected and incorporated into an impact assessment prior to lodging a development application for an activity. For the Balranald Project, groundwater will principally be taken incidentally via dewatering to allow effective and safe operation of dry mining activities.

2.4.2 Groundwater monitoring and modelling plans – information for prospective mining and petroleum exploration activities

The groundwater monitoring and modelling plans – information for prospective mining and petroleum exploration activities (NOW 2014) contains advice for proponents with a view to ensuring they have sufficient baseline monitoring data to inform an impact assessment that meets the AIP criteria.

The document defines the purpose of the monitoring network as identifying hydrogeological strata and their depths and thicknesses, hydraulic behaviours, interaction between layers, and connection to surface waters. It goes on to state that both quality and levels must be obtained, and that prediction of impacts on sensitive receptors (users) should be established.

The document recommends that dataloggers be used to monitor water levels in dynamic systems such as alluvium and that monthly intervals is a minimum time step for other monitoring. It requires that monitoring of groundwater quality considers major ions along with field parameters such as salinity, and that chemistry sampling is undertaken quarterly. The guideline also comments on aquifer testing methods, and states that isotopes can be used to more accurately determine system characteristics, particularly surface and groundwater connectivity.

2.4.3 NSW State Groundwater Policy Framework Document

The NSW State Groundwater Policy Framework Document (Department of Land and Water Conservation (DLWC) 1997) comprises three policies, namely:

- *NSW State Groundwater Quantity Management Policy* (DLWC 2001 (unpublished));
- *NSW State Groundwater Quality Protection Policy* (DLWC 1998); and
- *NSW State Groundwater Dependent Ecosystem Policy* (DLWC 2002).

The *NSW State Groundwater Policy Framework Document* aims to slow, halt or reverse degradation in groundwater resources, ensure long-term sustainability of the biophysical characteristics of the groundwater system, maintain the full range of beneficial uses of these resources, and maximise the economic benefit to the region and state.

The *NSW State Groundwater Policy Framework Document* will be referenced in the development of the water management plan for the Balranald Project.

2.4.4 Guidelines for the assessment and management of groundwater contamination

The guidelines for the assessment and management of groundwater contamination (DEC 2007) outline best practice framework for assessing and managing contaminated groundwater in NSW.

The guidelines will be referenced in the development of the water management plan for the Balranald Project, and will be referenced for general monitoring frequency and design.

2.5 Commonwealth legislation

2.5.1 Commonwealth Environmental Protection and Biodiversity Conservation Act 1999

The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places which are defined as matters of national environmental significance.

The EPBC Act was amended in June 2013, to ensure that water resources are a matter of national environmental significance, in relation to coal seam gas and large coal mining developments (the ‘water trigger’). The Balranald Project is not subject to the water trigger as it is not a coal mine or coal seam gas development.

2.5.2 The Basin Plan

The MDBA oversees water planning considering the MDB as a whole, rather than state by state. The MDBA has developed the Basin Plan which establishes SDLs for groundwater within the MDB. The limits have been set to ensure the level of use is environmentally sustainable in the long term, and:

- maintains the contribution groundwater make to rivers;
- supports GDEs;
- maintains groundwater systems for productive use; and
- protects against salinity.

The SDLs are consistent with the applicable NSW WSPs.

While the Basin Plan sets the limits it remains the responsibility of the relevant state agencies to decide how the water is used.

2.6 Commonwealth policies and guidelines

2.6.1 Australian Groundwater Modelling Guidelines

The *Australian Groundwater Modelling Guidelines* (NWC 2012) were developed to provide a consistent and sound approach for the development of numerical groundwater flow modelling in Australia. The importance of developing a robust conceptual model is a key aspect of modelling and measured groundwater data is used to conceptualise and describe both quantitatively and qualitatively all observed groundwater behaviour in the region. Groundwater level data is used to calibrate a numerical groundwater model, until there is acceptable agreement between model estimated and actual groundwater levels.

The guidelines provide a confidence-based classification system which defines three different classes of model. Class 1 has limited confidence in model estimates while Class 3 has high confidence. The guidelines provide information on the data requirements for each model class, such as spatial distribution of bores and temporal groundwater level data. Groundwater resource impact assessments at major development sites generally require the use of Class 2 or 3 models.

A Class 2 model developed for the Balranald Project by Jacobs (2015); this has been done so in accordance with the Australian Groundwater Modelling Guidelines.

2.6.2 Australian and New Zealand guidelines for fresh and marine water quality

The *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC/ARMCANZ 2000) set out the framework for the application of water quality guidelines. These guidelines describe requirements over a variety of marine and freshwater environments, aquatic ecosystems, primary industries, recreational water, drinking water and monitoring and assessment. The guidelines provide an authoritative guide for setting water quality objectives for natural and semi-natural water resources in Australian and New Zealand sustaining current or likely future environmental values (uses).

The guidelines were used when assessing the baseline groundwater quality for the Project (Section 6.5.3).

2.6.3 Murray Darling Basin groundwater quality sampling guidelines, technical report no. 3

The *Murray Darling Basin groundwater quality sampling guidelines* (MDBC 1997) provide a set of guidelines for groundwater quality sampling with an emphasis on regional monitoring networks. A uniform, accurate and reliable set of sampling procedures will ensure that comparable data of a known standard is collected throughout the MDB, and will allow for greater confidence in the interpretation of any basin wide data. Groundwater sampling was undertaken in accordance with the provisions outlined in this guideline, as well as the more recent:

- *National Water Quality Management Strategy Australian guidelines for water quality monitoring and reporting*, 2000 (ANZECC/ARMCANZ);
- *Australian Standard 5667.11 water quality sampling Part 11: guidance on sampling of groundwaters*, 1998 Australian/ New Zealand Standard 5667.11:1998; and
- *Groundwater sampling guidelines*, 2000 (Environment Protection Authority – State Government of Victoria).

The guidelines will be referenced in the development of the water management plan.

2.6.4 National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia

The *National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia* (ARMCANZ/ANZECC 1995) provides a framework for protecting groundwater from contamination in Australia. The protection framework involves the identification of specific beneficial uses and values for the major aquifers, and a number of protection strategies which can emerge to protect each aquifer, including monitoring for all aquifers.

The guidelines have been incorporated into the determination of the beneficial use category and the management and mitigation measures for the Balranald Project.

3 Project description

3.1 Project schedule

The Balranald Project will have a life of approximately 15 years, including construction, mining, backfilling of all overburden material, rehabilitation and decommissioning.

Construction of the Balranald Project will commence at the West Balranald mine, and is expected to take about 2.5 years. Operations will commence at the West Balranald mine in Year 1 of the operational phase, which will overlap with approximately the last six months of the construction phase. The operational phase includes mining and associated ore extraction, processing and transport activities, and will be approximately nine years in duration. This will include completion of backfilling overburden into the pits at both the West Balranald and Nepean mines. Construction of infrastructure at the Nepean mine will commence in approximately Year 5 of the operational phase, with mining of ore starting in Year 6 and commencing in approximately Year 8.

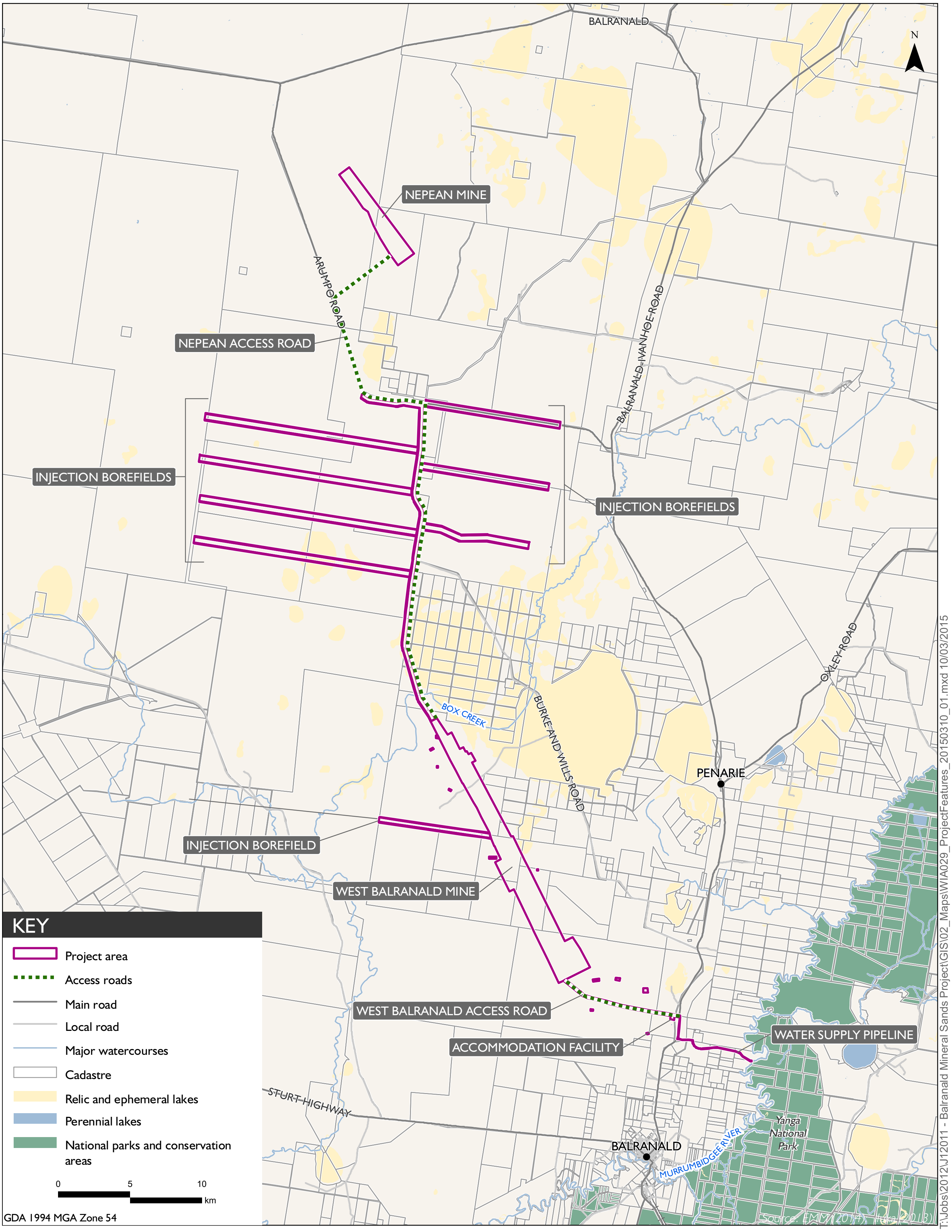
Rehabilitation and decommissioning is expected to take a further two to five years following Year 9 of the operational phase.

3.2 Project area

All development for the Balranald Project that is the subject of the SSD application is within the project area (see Figure 3.1). The project area is approximately 9,964 ha, and includes the following key project elements, described in subsequent sections:

- West Balranald and Nepean mines;
- West Balranald access road;
- Nepean access road;
- injection borefields;
- gravel extraction;
- water supply pipeline (from the Murrumbidgee River); and
- accommodation facility.

Within the project area, the land directly disturbed for the Balranald Project is referred to as the disturbance area. For some project elements in the project area, a larger area has been surveyed than would actually be disturbed. This enables some flexibility to account for changes that may occur during detailed design and mining operations. The project area and disturbance area for each project element are in Table 3.1.



Project features

Balranald Mineral Sands Project

Water Assessment

Figure 3.1

Table 3.1 Project area and disturbance area

Project element	Project area (ha)	Disturbance area (ha)
West Balranald mine	3,059	3,059
Nepean mine	805	805
West Balranald access road	128	52 [1]
Nepean access road	173	156 [2]
Injection borefields	5,721	1,214 [3]
Gravel extraction	42	42
Water supply pipeline	29	11 [4]
Accommodation facility	7	7
Total	**9,964**	**5,346**

Notes: 1. 60 m wide corridor within project area.
2. 40-50 m wide corridor within project area.
3. 100 m wide corridors within project area.
4. 15 m wide corridor within project area.

3.2.1 West Balranald and Nepean mines

The West Balranald and Nepean mines include:

- open cut mining areas (ie pit/mine void) that would be developed using conventional dry mining methods to extract the ore;
- soil and overburden stockpiles;
- ore stockpiles and mining unit plant (MUP) locations;
- a processing area (at the West Balranald mine), including a mineral processing plant, tailings storage facility (TSF), maintenance areas and workshops, product stockpiles, truck load-out area, administration offices and amenities;
- groundwater management infrastructure, including dewatering, injection and monitoring bores and associated pumps and pipelines;
- surface water management infrastructure;
- services and utilities infrastructure (eg electricity infrastructure);
- haul roads for heavy machinery and service roads for light vehicles; and
- other ancillary equipment and infrastructure.

The location of infrastructure at the West Balranald and Nepean mines would vary over the life of the Balranald Project according to the stage of mining.

The mining method proposed is a truck and shovel open cut mining method. This involves excavating and mining an active pit area that advances along the deposit. After ore is removed from an area it is progressively backfilled. The result is a pit that moves from south-east to north-west along the deposits.

To maintain dry mining conditions groundwater abstraction is required, the majority of abstracted groundwater will then be reinjected off path. Dewatering of the Formations overlying and surrounding the ore body would be required ahead of mining operations. Groundwater abstraction and reinjection will occur in the Loxton-Parilla Sands. Abstraction will occur within and adjacent to the pit footprints, while water will be injected off hydraulic gradient, either on path (down gradient at the West Balranald deposit) or in the injection borefield. Prior to reinjection water will be treated with UV light to remove possible bacteria.

It is estimated that dewatering will commence six months in advanced of mining operations and will continue during the mining phase, and while the West Balranald deposit is being backfilled. A dry pit is required at the West Balranald deposit for a further two years after mining whilst the final pit void, located at the northern end of the deposit, is backfilled. The necessary abstraction volumes needed to maintain dry pit conditions during the backfilling of West Balranald and mining at Nepean are substantially reduced when compared to those required during active mining operations at West Balranald.

3.2.2 Access roads

There are two primary access roads within the project area to provide access to the Balranald Project:

- West Balranald access road – a private access road to be constructed from the Balranald Ivanhoe Road to the West Balranald mine; and

- Nepean access road – a route comprising private access roads and existing public roads. A private access road would be constructed from the southern end of the West Balranald mine to the Burke and Wills Road. The middle section of the route would be two public roads, Burke and Wills Road and Arumpo Road. A private access road would be constructed from Arumpo Road to the Nepean mine.

The West Balranald access road would be the primary access point to the project area, and would be used by heavy vehicles transporting HMC and ilmenite. The Nepean access road would primarily be used by heavy vehicles transporting ore mined at the Nepean mine to the processing area at the West Balranald mine.

3.2.3 Accommodation facility

An accommodation facility would be constructed for the Balranald Project workforce. It would operate throughout the construction and operation phases of the project. It would be located adjacent to the West Balranald mine near the intersection of the West Balranald access road with the Balranald Ivanhoe Road.

3.2.4 Gravel extraction

Gravel would be required during the construction and operational phases of the Balranald Project. Local sources of gravel (borrow pits) have been included in the project area to provide gravel during the construction phase. During the construction phase, gravel would be required for the construction of the West Balranald access road, internal haul roads and service roads, and hardstand areas for infrastructure. Processing operations, such as crushing and screening activities (if required) would also be undertaken at the borrow pits. Gravel for the operational phase would be obtained from external sources.

3.3 Site water management

Site water management is necessary during all phases of project operation and will encompass:

- meeting site water demands for mining, processing operations and potable needs;
- providing dry mining conditions via dewatering;
- management of saline groundwater water produced via dewatering;
- storage and containment of runoff from disturbed areas; and
- possible management of water from extreme weather events.

The water management system for the Balranald Project includes the management of both site surface water and extracted groundwater. The surface water management system would be designed to manage surface water flows on site according catchment area and associated water quality. The groundwater management system forms part of the overall site water balance, and inputs into the surface water management system.

3.3.1 Water sources

Water sources would include:

- surface runoff – generated by direct rainfall within the surface water catchment areas in the project area. This would be separated into mine affected water and sediment laden water;
- hypersaline groundwater:
  - groundwater inflow to the pit, although the dewatering system is designed to completely dewater the pit ahead of mining, it is expected that there would be a small volume of groundwater inflow into the pit during the life of the mine;
  - groundwater extracted from the Loxton-Parilla Sands, to dewater the pit prior to mining; and
- fresh water supplied from the Murrumbidgee River by the water supply pipeline (see Figure 3.1).

Site water management is necessary during all phases of project operation. The proposed strategy for the management of water is based on the separation of water from different sources based on anticipated water quality, as follows:

- Saline groundwater dewatered from the Loxton Parilla Sands. Some saline groundwater would be used to satisfy mine water demands, however the majority would be treated with ultra-violet (UV) light and reinjected into the Loxton Parilla Sands.
- Mine affected water, comprising runoff and groundwater inflow to the pit collecting in the active mining area at the West Balranald mine, runoff from saline overburden (SOB) and potentially acid forming (PAF) material stockpiles and runoff from the mining unit plant (MUP) area and processing area (including run of mine (ROM) pad, and tailings and mining by-product stockpiles). Management would include:

- seepage, groundwater and surface runoff inflows to the active mining area would be collected in onsite storages and used preferentially to satisfy mine site water demands; and
- runoff from the MUP area and processing area, and the SOB and PAF stockpiles would also be collected in onsite storages and used to satisfy mine site water demands.

- Sediment laden water, comprising runoff from the active mining area at the Nepean mine, and runoff from non-saline overburden (NSOB), topsoil and subsoil stockpiles. Surface runoff from NSOB stockpiles and the active mining area and ROM pad at the Nepean mine would be captured and treated in sediment dams and used for dust suppression (or released from the site via spillway during certain rainfall events).

Surface water runoff from undisturbed areas would be diverted, wherever possible, around areas disturbed by mining and released from the site, minimising the capture of clean surface runoff.

Raw water for use in dust suppression on NSOB stockpiles, soil stockpiles, rehabilitated areas and haul roads, and to supply filtered water demands would be pumped from the Murrumbidgee River via the water supply pipeline. Potable water would be trucked to the project area and stored.

Sewage at the project area would be managed in two ways:

- for areas with high density of personnel (ie process plant area and accommodation facility), a package waste treatment system would be used, which would require occasional pumping out of sludge; and
- for ablutions located in areas with low or infrequent use, untreated waste would be collected in septic tanks which would be emptied by tanker as required.

3.3.2 Water supply pipeline

A water supply pipeline would be constructed to supply water from the Murrumbidgee River for operation of the Balranald Project. The water supply pipeline will supply fresher, raw water from the Murrumbidgee River that would be filtered and used for plant/domestic purposes. Any remaining water would be utilised for dust suppression in sensitive areas (ie NSOB stockpiles and haul roads). Runoff from the Nepean mining area would also supplement non saline dust suppression.

3.3.3 Dewatering and injection borefields

i Dewatering

Dewatering bores adjacent to the pit will lower the local watertable to enable dry mining. This would involve dewatering of underlying groundwater via a series of dewatering bores installed adjacent to, and in advance of, mining operations at the West Balranald mine.

Based on modelling and in-field trials to date there will be approximately 350 dewatering bores, at a spacing of 100 m, and are expected to be required during dewatering for the West Balranald mine over the course of mining. However this would be optimised based on continued optimisation of the groundwater model and project design. Bores are proposed to be located 50 m from the pit crest in two parallel lines either of the mine void. The dewatering system would be installed progressively over the course of operations, typically several kilometres in advance of the mine void as the mine progresses. The bores would be installed using conventional mud-rotary drilling rigs.

ii Injection

Water reinjection will return saline groundwater abstracted prior to mining at the West Balranald deposits to the original Loxton-Parilla Sands Formation. Two methods of groundwater injection will be undertaken:

- on-path injection: involves the injection of groundwater into bores located along the West Balranald mine pit ahead of mining operations; and

- off-path injection: involves the injection of groundwater into bores located some 5 to 10 km away from mining operations; this will occur in the injection borefield (Figure 3.1).

On-path injection bores will connect to a water transfer main on either side of the mine. These injection bores will be feed directly from this transfer main. Injection bores will be skid mounted. The injection bores will have approximately half the flow rate as that of the dewatering bores and therefore for every dewatering bore, two injection bores are required.

Off-path injection bores will connect to a network of pipeline infrastructure that will extend from the water transfer main at the mine to the off-path injection borefield. Within each borefield, infrastructure is generally located in two 50 m wide corridors (approximately 350 m apart), and typically comprises:

- a network of pipelines with a graded windrow on either side;

- access roads for vehicle access during construction and operation;

- rows of injection bores, with bores spaced at approximately 100 m intervals; and

- a series of water storage dams to store water during bore development.

All bores would be designed and installed to ensure that only the target Loxton-Parilla Sands Formation is utilised. Bore casing would be fully cement sealed to prevent upward migration of injection water.

A telemetry system will be used to monitor the injection infrastructure.

The disposal/reinjection of water from the Nepean mine is currently not considered necessary as the relatively small volume of water abstracted will likely be incorporated into the process water stream.

3.3.4 Water storage infrastructure

Water used in processing operations would be managed by various dams and structures. Water storage infrastructure that would be constructed as part of the water management system are included in Table 3.2. All dams would be lined to prevent leakage.

Table 3.2 Water storage infrastructure

Dam	Description
Settling dam	The settling dam would collect runoff water from the processing area. It allows for settling of solids before transfer to the process water dam and recycling within the processing area.
Process water dam	The process water dam would be the primary water supply for the processing plant. It would receive water from the settling dam and hypersaline groundwater from the dewatering system. The process water pumps are supplied from this dam. Receives overflows from settling dam via gravity. Also supplies saline water dust suppression demand.
MUP dam	The MUP dam would receive dewatering flows from West Balranald mine and transfers of excess water from process water dam. It would supply water to the MUP. The MUP dam would also collect runoff from the ROM pad, stockpile pads containing PAF materials, sand tails stacking pad, which are potentially acid forming. The pH of the MUP dam would be continuously monitored and lime dosing would be done on occasion to maintain a pH > 4.5.
Processing area runoff dam	Captures runoff from the processing area. Water is transferred to the settling dam.
Tailings storage facility	Receives modified co-disposal (ModCod) slurry consisting of sand and thickener underflow mixture (or slimes). It would contain all direct rainfall and resulting runoff that occurs within the TSF area. Water is decanted from the TSF and returned to the settling dam for reuse in the processing plant.
Groundwater retention dams	Two groundwater retention dams would store hypersaline groundwater extracted from the Loxton Parilla Sands by the dewatering bores. Groundwater would be treated with UV light prior to being reinjected.
Non-saline water dam	Constructed to hold imported raw water from the Murrumbidgee pipeline.
Runoff collection drains and dams	Constructed to capture runoff from the NSOB, topsoil and subsoil stockpiles. Will function as sediment basins and would be designed as part of the Erosion and Sediment Control Plan (ESCP) for the Project, which would be developed as part of detailed design.

3.3.5 Water demand

Demands for water would be primarily generated by the processing plant (including MUP, pre-concentrator plant (PCP), wet concentrator plant (WCP) and Illuminate separating plant (ISP), dust suppression and potable requirements for amenities. The ISP also requires potable water which would be sourced from the water supply pipeline from the Murrumbidgee River.

The water demands for the Balranald Project are summarised in Table 3.3.

Table 3.3 Operation phase water demands

Demand	Water type	Average volume (ML/year)	Source
Dust suppression			
Overburden/ore removal Saline overburden rehabilitation Mine access road, haul roads, service roads	Saline	380	Hypersaline groundwater
Topsoil/subsoil and non-saline overburden removal Soil and non-saline rehabilitation Light vehicle roads	Non-saline	310	Water supply pipeline
Process water			
Process plant demand (PCP, WCP, WHIMS)	Saline	15,075	Mine affected water Hypersaline groundwater
MUP demand	Saline	4,160	Mine affected water Hypersaline groundwater
ISP demand	Non-saline	100	Water supply pipeline
Wash down bays	Non-saline	10	Water supply pipeline
Workforce consumption			
Personnel – potable	Potable	5	Truck
Personnel – toilet and non-drinking	Non-saline	10	Water supply pipeline
TOTAL DEMAND	*Saline*	*19,615*	Mine affected water Hypersaline groundwater
	Non-saline	*450*	Water supply pipeline
	Potable	*5*	Truck

4 Impact assessment methodology

4.1 Potential impacts

This water assessment examines the following project-related activities: the construction and use of site infrastructure, dewatering, water reinjection, mining and on-site water storage. Changes to the baseline conditions caused by these activities are termed 'direct impacts'. Eight categories of potential direct impacts were identified in relation to groundwater and surface water, including:

- groundwater quantity including consideration of changes to groundwater levels/pressures and flux;
- groundwater quality including consideration of salinity and concentrations of other important water quality parameters (such as metals, pH, major cations and anions and radionuclides);
- groundwater/surface water interaction including consideration of changes to the interaction between groundwater and surface water systems (such as stream baseflow);
- physical disruption of aquifers including consideration of whether or not there will be permanent disruption of a groundwater system by mining and to what extent;
- surface water quantity including changes to surface water flow and water levels;
- surface water quality including consideration of all water quality parameters;
- watercourse disruption including alterations to watercourses and drainage lines and associated flood risk; and
- groundwater/surface water interaction including changes to the surface water environment that affect groundwater (eg recharge from storages).

4.1.1 Sensitive receptors

The receptors that have been identified as potentially being sensitive to water impacts in the region include:

- ecosystems that rely on groundwater, including groundwater dependant ecosystems (GDEs);
- Murrumbidgee River and ephemeral water courses; and
- private landholder bores, properties and infrastructure.

There are landholder bores in the area that rely on groundwater for stock and domestic use, and these are located throughout the project area.

The Murrumbidgee River is a permanent surface water feature located to the south of the project area. This river is a nationally significant river and is home to many sites of international, national and regional environmental importance. This is a critical water source for the communities that live on and rely on water from the River for predominantly irrigation and potable supply.

Ecosystems that rely on groundwater are important environmental assets and typically occur where groundwater is at or near the land surface. For vegetation to utilise groundwater it must be at an accessible depth and of suitable salinity. The vegetation in the project area are typically hardy, resilient species that periodically rely on groundwater.

4.2 Assessment criteria

The minimal impact thresholds outlined in the AIP will be used to assess the potential impacts to groundwater resulting from the Balranald Project. This is in accordance with the Minister's requirements for approval and administration of the WMA 2000.

The AIPs 'minimal impact considerations' are employed to assess impacts to water table levels, water pressure levels and water quality across a range of different groundwater system types. The AIP divides groundwater sources into 'highly productive' or 'less productive' based on the yield (>5 L/s for high yielding) and water quality (<1,500 mg/L total dissolved solids for high yielding). Thresholds are set in the AIP for the different groundwater sources for the different minimal impact considerations.

The groundwater within the Western Murray Groundwater Source in the MDB Porous Rock WSP in the vicinity of the Balranald Project is classified as 'less productive', based on the very high salinity levels. The categories of less productive groundwater sources include alluvial and, porous rock and fractured rock. The greater water source is classified as a 'porous rock' water source, therefore the minimal considerations for porous rock units of less productive groundwater systems have therefore been adopted for this assessment. The applicable minimal impact considerations are detailed in Table 4.1.

Table 4.1 Less productive groundwater source minimal impact considerations for porous and fractured rock sources (AIP 2012)

Water table	Water pressure	Water quality
1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-WSP" variations, 40 m from any: (a) high priority GDE; or (b) high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the water table, allowing for typical climatic 'post-WSP' variations, 40 m from any: (a) high priority GDE; or (b) high priority culturally significant site listed in the schedule of the relevant WSP if appropriate studies demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem, or significant site. If more than a 2 m decline cumulatively at any water supply work then make good provisions should apply.	1. A cumulative pressure head decline of not more than a 2 m decline, at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1 above then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. 2. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

Notes: 1. "post-WSP" – refers to the period after the commencement of the first WSP in the water source, including the highest pressure head (allowing for typical climatic variations) within the first year after commencement of the first WSP.

5 Environment

5.1 Overview

The project area is located in the geographic centre of the Murray Basin, in south-western NSW, north of Balranald town. The total project area is approximately 9,964 ha (Table 3.1), with the majority of the area having been previously cleared for agricultural uses. Within the project area, only a small area of land is covered by conservation reserves, including Yanga Nature Reserve, east of Balranald town and a small private reserve south of the West Balranald deposit.

5.2 Topography

The topography across the project area is mostly flat with only minor fluctuations in elevation observed. Across the project expanse the elevation rises from 62 m Australian Height Datum (AHD) in the south, at the West Balranald deposit to 100 m AHD in the north, at the Nepean deposit.

The southern half of the West Balranald deposit gently undulates from 62 to 70 m AHD. The terrain of the Nepean mine is slightly more undulating with elevations ranging from 64 m AHD in the south east corner to a maximum height of 100 m AHD in the centre west. The Nepean mine terrain gently slopes to a low of approximately 86 m AHD to the north of the project area. The basement fault structure has a material impact on the topography of the area and the change in elevation at the Nepean deposit is a result of basement faulting.

5.3 Climate

The project area is characterised as semi-arid, with hot dry summers and cold winters. Climatic data from the Bureau of Meteorology's (BoM) weather station at Balranald town (BoM station: 049002) indicates monthly mean minimum temperature ranges from 3.5 degrees Celsius (°C) to 16.4°C and the monthly mean maximum temperature ranges from 15.7°C to 33°C. Temperature data at this station has been collected from 1907 until present.

Rainfall data from the Balranald BoM station reports the average monthly rainfall at 27 mm; the rainfall record commenced in 1879. As seen in Figure 5.1 mean monthly rainfall is evenly distributed throughout the year, with the highest median rainfall over spring and the lowest median rainfall over summer.

WRM (2015) reports that evaporation at Balranald is greater than rainfall for all months, monthly pan evaporation averages 159 mm. Evaporation greatly exceeds rainfall in warmer months, this is highest in January where the maximum monthly mean pan evaporation is 301 mm and the mean monthly rainfall is 22.3 mm. At Mildura Airport (BoM station number 076031) (approximately 160 km north-west), the average, monthly evaporation is 182 mm and the annual evapotranspiration is 350 mm (Jacobs 2015).

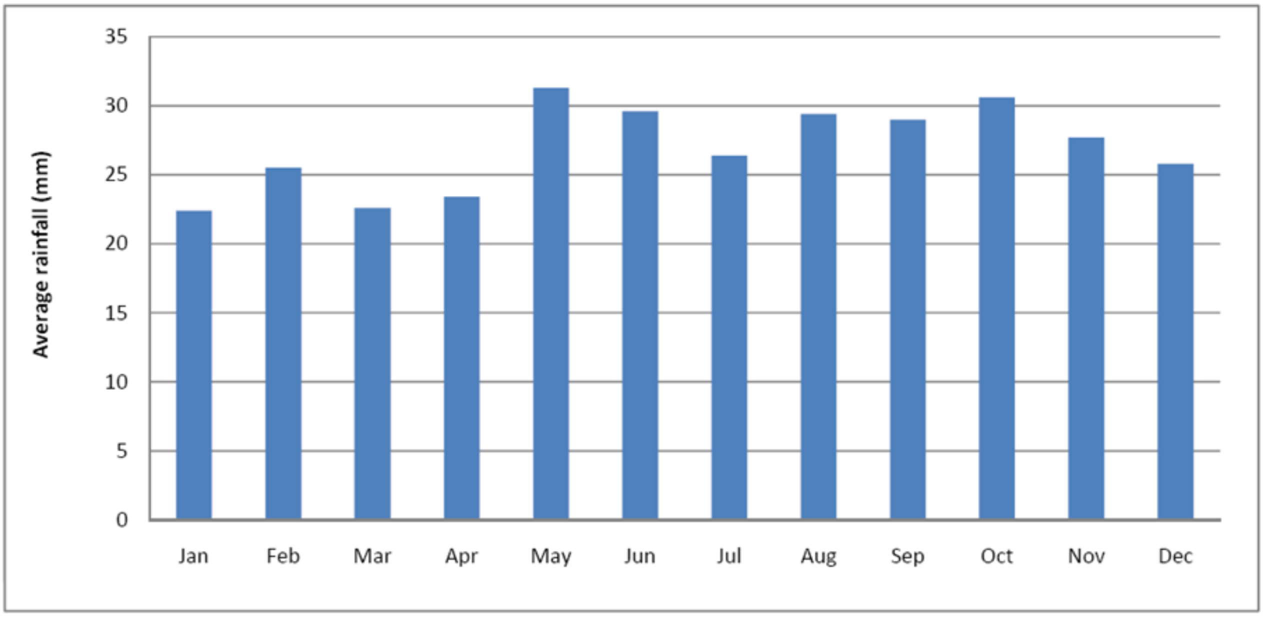


Figure 5.1 Monthly average rainfall at Balranald (BoM 049002)

The monthly cumulative deviation of rainfall from the mean (from 1900 to 2014) is plotted in Figure 5.2. This chart represents discrete rainfall events as a continual trend over time. Periods of below average rainfall plot on a downward trend while periods of above average rainfall plot as upward trending slopes.

The monthly cumulative deviation plot for Balranald shows a period of predominantly below average or average rainfall from 1900 until approximately 1945. Consistent with long term rainfall trends across most of NSW average rainfall since 1950 has overall been higher than rainfall measured between 1900 – 1950 (Hughes 2013). Rainfall from 1980 to 2000 has been average, and recent rainfall, since 2012, has also been mostly comparable to the long term average. Below average rainfall conditions were observed between 2000 and 2010. Major rainfall events and floods in the Murrumbidgee Valley in 1973 and 2010 can be clearly seen in the trends in this chart.

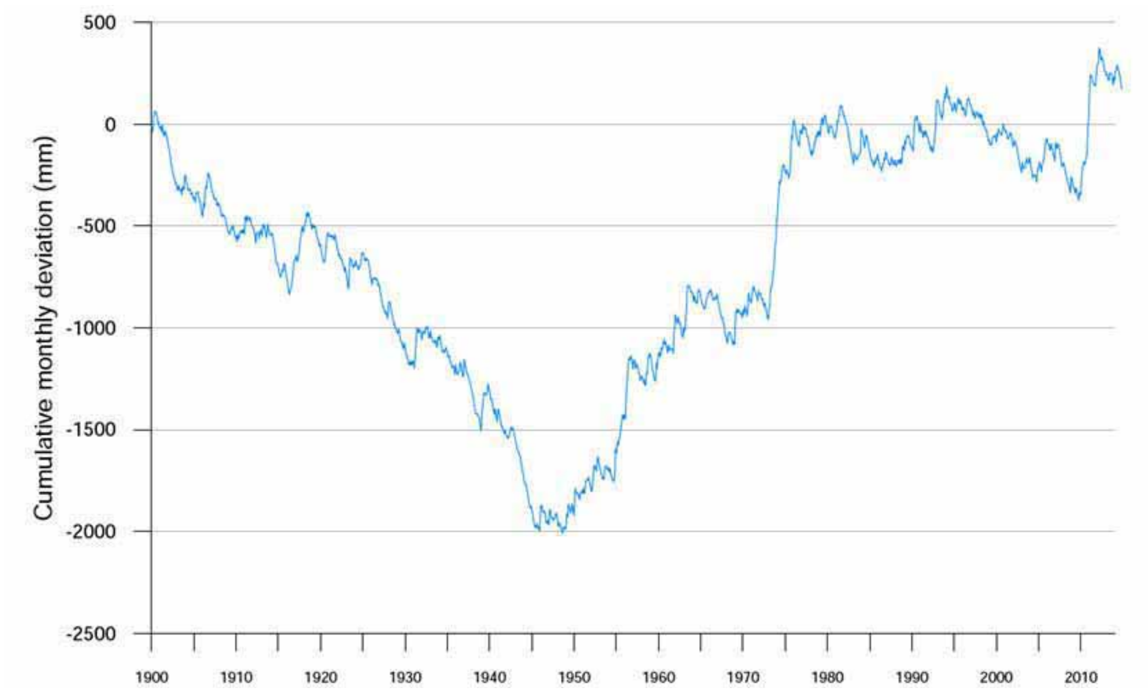


Figure 5.2 Monthly rainfall cumulative deviation for Balranald weather station

5.4 Land use

The project area and surrounding land is zoned for primary production under the *Balranald Local Environment Plan 2010* (Balranald LEP). Land ownership in and near the project area includes Western Lands Leases (WLL), freehold, Crown and other land tenures. Outside Balranald town, properties are typically large rural land holdings, and homesteads and dwellings are sparsely located.

Land uses in and surrounding the project area are primarily agricultural, and include sheep grazing and broadacre grain crops. Dry relic lake beds (Pitarpunga Lake and Tin Tin) occur in the northern half of the West Balranald mine area and are subject to agricultural activities including cropping and grazing.

The Yanga National Park is approximately 10 km south-east of the project area. Mungo National Park and Willandra Lakes World Heritage Area (system of ancient lakes) are approximately 19 km north-west of the northern extent of the project area (Figure 1.2).

Small charcoal farming and gypsum mining operations are undertaken to the east of the project area. No substantial mining land uses currently exist in the Balranald local government area. However approval for a mineral sands mine, known as the Atlas-Campaspe Mineral Sands Project approximately 20 km north of the project area (from Nepean mine), was granted in 2014 (Figure 1.2).

5.5 Surface water

The Murrumbidgee and Murray rivers are the major permanent surface water features in the vicinity of the project area, shown in Figure 2.2. These rivers provide key water resources for large populations within the MDB including town water supplies, agricultural and the environmental supplies. The Murrumbidgee River is about 13 km south-east of the project area, and flows in a south-westerly direction, to its confluence with the Murray River about 40 km to the south-west of Balranald town. A small part of the project area (the water supply pipeline) is located on the western flood plain of the Murrumbidgee River.

The Lachlan River terminates at the Great Cumbung Swamp, approximately 42 km east of the project area, further upstream this is a major permanent surface water feature. During very high flood events the Lachlan River can flow into the Murrumbidgee River. There are a number of non-permanent waterways and lakes within the project area that contribute to the Lachlan and Murrumbidgee River distributor systems. The ephemeral waterways branch off from the main river channels, carrying water away from rivers during high flows and facilitating floodplain inundation.

Flows within the Lachlan, Murrumbidgee and Murray rivers are regulated by major dams in their headwaters, and by local regulating structures such as Balranald Weir and the Paika levee, which divert water for irrigation purposes. A number of ancient lakes that would be otherwise dry (eg Waldaira, Yanga and Paika lakes) are artificially filled from river flows (SKM 2012).

The main surface water feature within the project area is Box Creek, which is an ephemeral watercourse and a distributary of the Lachlan River. Almost all of the project area is located within the Box Creek catchment. However Box Creek only flows during and immediately following heavy local rainfall or large flooding events in the Lachlan River; flow has only occurred in Box Creek on several occasions in the last 60 years (WRM 2015). Permanent surface water flows are confined to the major rivers and their associated backwaters outside of the project area.

5.6 Geomorphology

The project area lies in the Murray Basin, an extensive low lying, intra-cratonic sedimentary basin of Cainozoic age (60 million years before present (BP)) covering part of NSW, Victoria and South Australia (Brown and Stephenson 1991). The Murray Basin forms part of the larger Murray-Darling Basin, which is divided into the northern Basin (Darling system) and the southern Basin (Murray system). Its sits within the continental crust and the stratigraphic sequences are dominated by consolidated sand, silt, clay and lime-rich sediments, formed by marine, deltaic, fluvial and aeolian depositional environments. Landforms in the project area have formed in either the Pleistocene period (approximately 2.5 million to 12,000 years BP) or the Holocene period (approximately 12,000 years to the present).

Parts of the project area contain three dry clay pans which includes Tin Tin, Pitarpunga and Muckee lakes. The lakes have been predominantly dry for at least the last few hundred to thousand years. These lakes functioned as overflow lakes via Box Creek.

In the southern section of the West Balranald mine are longitudinal dune formations. In some places these dunes cover parts of old lake beds. Some of these dunes have also been extensively eroded and now form a series of sand sheets. Sand that has been cemented by calcium carbonate (ie calcrete) can also be found in the dunes.

5.7 Geology

The project area is located in the centre of the Murray Basin, within the centre–west of the Riverine Plain. Subregions within the Murray Basin are defined by surface geomorphology and the presence of the Ivanhoe Block and associated structures. Within the project area the basal unit of the Murray Basin, which directly overlies the basement rocks (comprising Proterozoic and Palaeozoic rocks) is the Olney Formation, deposited from the Paleogene to the mid Miocene periods. The Olney Formation sediments are predominantly continental, but marginal marine units such as the Geera Clay, interfinger through the middle sequence to the east of the project area.

In the eastern end of the Murray Basin, the Olney Formation is overlain by the Calivil Formation which is in turn overlain by the Shepparton Formation. In the west the Olney Formation is overlain by Loxton-Parilla Sands Formation which is in turn overlain by aeolian sands or the Shepparton Formation. The Calivil Formation laterally interfingers and grades into the Loxton-Parilla Sands at the eastern edge of the Riverine Plain.

At the project area, the combined thickness of the Murray Basin sediments ranges from 250 m to 290 m. The Shepparton Formation and Loxton-Parilla Sands range in thickness between 60 to 100 m, while the Geera Clay and Olney Formation have a combined thickness of 190 m. The basement structure has significant impacts on the overlying sedimentary geology and associated groundwater flow in the project area (Kellett 1991 and 1994). The geology of the project area is discussed in more detail in Chapter 8.

5.8 Geochemistry

Earth Systems undertook a geochemistry assessment for the Balranald Project in 2015. This collated data from two geochemical characterisation programs. A preliminary geochemical characterisation focusing on both deposits was conducted by Klohn Crippen Berger (KBC) in 2012. A supplementary program, conducted by Earth Systems in 2014, increased the sampling density for the non-saline, saline and organic overburden materials at the West Balranald deposit to assess the acid and metalliferous drainage potential of the dewatered and sulfidic pit walls and benches (Earth Systems 2015). Samples of product and mining by-product streams were also provided by Iluka for characterisation.

The Nepean deposit does not contain significant quantities of sulfidic minerals and the non saline overburden and ore samples are classified as non acid forming. There was one potentially acid forming sample from the non saline overburden, which was classified as having a low potential for acid generation based on a low sulfide content and low acid neutralising capacity.

The West Balranald non saline overburden and saline overburden is also classified as non-acid forming due to the minimal sulfide content (Earth Systems 2015). However the majority of the organic overburden and ore samples analysed had a low to moderate potentially acid forming classification. Six samples from the organic overburden had a high potential for acid generation, and this material has a relatively higher sulfide-sulfur content and minor acid neutralising capacity.

5.9 Hydrogeology

The Murray Basin is a closed groundwater basin that has regional aquifer systems, confining layers and permeability barriers to groundwater flow. There are three regional groundwater systems within the Basin: Riverine (eastern and southern), Mallee–Limestone (southwestern) and Scotia (northwestern) (Evans and Kellet 1989). The dominant groundwater flow direction is from east to west, although flow tends to converge in the centre of the western boundary of the Riverine province. In the east, the Murray Basin alluvial sediments are targeted for fresh water supplies, with the Lower Lachlan, Lower Murrumbidgee and Lower Murray Groundwater Management areas providing over 550,000 ML of groundwater rights to users in these three areas alone. However, in a westerly direction the water quality becomes increasingly saline, sediments become finer, and average bore yields decline.

Within the project area groundwater resources are too saline for purposes such as irrigation and town water supplies. Extractive water use in the Balranald Project area is typically only for stock watering via groundwater bores. Groundwater in the project area is associated with the Shepparton Formation, Loxton-Parilla Sands and Olney Formation. The Geera clay is an aquitard with low yields and is not targeted for water supply. Hydrogeology is discussed in further detail in Chapter 9.

It should be noted that an aquifer is defined as a rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water. The groundwater underlying the project area is not considered to be sufficiently permeable to transmit economic quantities of water, nor does it have a widespread suitable quality. Other technical studies refer to the groundwater in the Shepparton Formation, Loxton-Parilla Sands and Olney Formation as being aquifers, this terminology has not been adopted in this assessment.

6 Field investigation program

Field investigations at the project area have been ongoing since 2009, and this comprises two years of groundwater quality and level monitoring as per the requirements of the AIP. The understanding of the site specific geological and hydrogeological site characteristics has been progressively developed and refined over time from initial regional published information through a series of drilling programs, and pumping and injection tests, ongoing monitoring and other studies.

6.1 Overview of drilling and hydraulic testing works

During a scoping study for the project URS (2009) undertook a literature review and data assessment to develop an initial conceptual hydrogeological model of the deposits and the surrounding area. Pre-existing geotechnical monitoring bores, were also used during the program to assist with preliminary aquifer characterisation. As part of this assessment a drilling and pumping test program was undertaken which included geological appraisals. Four production bores and two monitoring bores across two sites at the West Balranald deposit were installed. The production bores underwent small-scale pumping tests, and water quality samples were obtained.

During the pre-feasibility study (PFS) in 2011, URS refined their hydrogeological conceptualisation of the groundwater systems at the West Balranald and Nepean deposits, and conducted a hydrological census to capture existing hydrological and hydrogeological data from landholder bores within the proximity of the project area.

In 2011 and 2012, URS supervised a substantial drilling and pumping test program across four locations along the West Balranald deposit and three locations along the Nepean deposit. The program commenced with the installation of the following infrastructure between May 2011 and February 2012:

- seven production bores;
- six injection bores;
- monitoring bores; and
- vibrating wire piezometers.

Following the drilling program small-scale step rate pumping and injection tests (SRTs), and constant rate pumping and injection tests (CRTs) were carried out.

During the detailed feasibility study (DFS) hydrogeological program, Iluka (2015) installed further groundwater infrastructure at locations selected for detailed pumping and injection trials. Production, injection, monitoring bores and vibrating wire piezometers were constructed.

6.2 Iluka monitoring network

A summary of the Iluka groundwater installations are presented in a series of tables:

- monitoring bores (Table 6.1);
- vibrating wire piezometers (Table 6.2);
- production bores (Table 6.3); and

- injection bores (Table 6.4).

The Iluka monitoring installations are shown in Figures 6.1. Figures have also been prepared based on screened formation (Figure 6.2 – 6.6). The monitoring locations included in the formation figures relates only to installations installed by Iluka for the Balranald Project.

Table 6.1 Iluka groundwater monitoring bores

Bore ID	Year installed	Total depth (m)	Screened depth (m bgl)	Formation screened
SHOB03	2009	23	17 - 23	Shepparton
SHOB04	2009	22	16 – 22	Shepparton
WB1	2012	28	22 - 28	Shepparton
WB7	2012	31	15 - 31	LPS
WB8	2012	79	39.8 - 79	LPS
WB17	2012	72	54 - 72	LPS
WB20	2012	21	17 - 20	Shepparton
WB38	2012	22	19 - 22	Shepparton
WB42	2012	27	23 - 27	Shepparton
N21	2012	51	45 - 51	LPS
N28	2012	58	55 - 61	LPS
N12	2012	55	49 - 55	LPS
N23	2011	62	56 - 65	LPS
N29	2011	62	56 - 61	LPS
N27	2011	24	21 - 24	LPS
N7	2012	55.7	50 – 55.5	LPS
WBMW02S	2014	98	43 - 47	LPS (upper)
WBMW02D	2014		84 - 86	LPS (lower)
WBMW03S	2014	82	32 - 35	LPS (upper)
WBMW03D	2014		66 - 70	LPS (lower)
WBMW05S	2014	114	30 - 33	Shepparton
WBMW05D	2014		85 - 86	LPS (lower)
WBMW06S	2014	112	16 - 20	Shepparton
WBMW06D	2014		58 - 64	LPS (lower)
WBMW07S	2014	89	17 - 20	Shepparton
WBMW07D	2014		79 - 82	LPS (lower)
WBMW08D	2014	102	95 - 101	LPS (lower)
WBMW09S	2014	90	27 - 30	LPS (upper) / Shepparton Formation
WBMW09D	2014		69 - 78	LPS (lower)
WBMW10	2014	295	277 - 283	Olney
WBMW11S	2014	119	21 - 23	Shepparton
WBMW11D	2014		85 - 103	LPS (lower)
WBMW12S	2014	96	18 - 21	Shepparton
WBMW12D	2014		69 - 75	LPS (lower)
WBMW13S	2014	114	30 - 36	LPS (upper) / Shepparton Formation
WBMW13D	2014		76 - 79	LPS (lower)

Table 6.1 Iluka groundwater monitoring bores

Bore ID	Year installed	Total depth (m)	Screened depth (m bgl)	Formation screened
WBMW14S	2014	137	34 - 37	LPS (upper)
WBMW14D	2014		75 - 78	LPS (lower)
WBMW15S	2014	137	81 – 83	LPS (lower)
WBMW15D	2014		117 - 120	Olney
WBMW16S	2014	137	29 -32	LPS (upper) / Shepparton
WBMW16D	2014		74 - 77	LPS (lower)
WBMW17S	2014	119	42 - 45	LPS (upper)
WBMW17D	2014		91 - 94	LPS (lower)
WBMW18S	2014	120	16 - 20	Shepparton
WBMW18D	2014		76 - 94	LPS (lower)
WBMW19S	2014	119	39 - 42	LPS (upper)
WBMW19D	2014		72 - 75	LPS (lower)
WBMW22S	2014	120	22 - 25	Shepparton
WBMW22D	2014		89 - 95	LPS (lower)

Notes: m bgl = meters below ground level.
LPS = Loxton-Parilla Sands.
Cluster = nested monitoring site.

Table 6.2 Iluka vibrating wire piezometers

ID	Year installed	Total depth (m)	VWP depth (m bgl)	Formation screened
WB3	2011	200	193	Olney
WB3	2011		145	Geera Clay
WB3	2011		113	LPS (lower)
WB3	2011		80	LPS
WB3	2011		40	Shepparton
WB5	2012	105	unknown	Inconclusive
WB6	2012	80	unknown	Shepparton
WB8	2012	unknown	unknown	Shepparton
WB8	2012		unknown	Inconclusive
WB21	2011	88	19	Shepparton
WB21	2011	88	70	LPS
WB25	2011	84	16	Shepparton
WB28	2011	90	29	Shepparton
WB39	2011	78	45	LPS
WB39	2011		45	Shepparton
WB41	2011	78	22	Shepparton
WB43 (P1)	2011	130	125	Geera Clay
WB43 (P2)	2011		105	LPS (lower)
WB43 (P3)	2011		64	LPS
WB43 (P4)	2011		18	Shepparton
WB100	2011	240	22	Shepparton
WB100	2011		33	LPS

Table 6.2 Iluka vibrating wire piezometers

ID	Year installed	Total depth (m)	VWP depth (m bgl)	Formation screened
WB100	2011		68	LPS (lower)
WB100	2011		108	Geera Clay
WB101	2011	228	210 - 228	Olney
WB102	2011	240	35	Shepparton
WB102	2011		74	LPS
WB102	2011		95	LPS (lower)
WB102	2011		119	Geera Clay
WB103	2011	258	35	Shepparton
WB103	2011		67	LPS
WB103	2011		98	LPS (lower)
WB103	2011		120	Geera Clay
N11	2011	102	16	Shepparton
N11	2011		48	LPS
N11	2011		70	LPS (lower)
N11	2011		97	Geera Clay
N18	2011		48	LPS
N22	2011	87	28	Shepparton
N22	2011		16	Shepparton
N29	2011	102	22	Shepparton
N100	2011	216	52	LPS
N100	2011		80	LPS
N100	2011		120	Geera
N100	2011		22	Shepparton
N101	2011	204	60	LPS
N101	2011		79	LPS (lower)
N101	2011		120	Geera Clay
WBMW02 (P1)	2014	98	25	Shepparton
WBMW02 (P2)	2014	98	65	LPS (lower)
WBMW03 (P1)	2014	82	25	Shepparton
WBMW04 (P1)	2014	264	253	Basement
WBMW04 (P2)	2014		240	Geera
WBMW04 (P3)	2014		180	Olney
WBMW04 (P4)	2014		125	Geera
WBMW04 (P5)	2014		110	Geera
WBMW04 (P6)	2014		85	LPS (lower)
WBMW04 (P7)	2014		60	LPS
WBMW04 (P8)	2014		54	LPS (upper)
WBMW04 (P9)	2014		45	LPS (upper)
WBMW04 (P10)	2014		38	LPS (upper)
WBMW04 (P11)	2014		33	Shepparton
WBMW05 (P1)	2014	114	39	LPS (upper)
WBMW05 (P2)	2014		69	LPS (lower)
WBMW06 (P1)	2014	112	31	Shepparton

Table 6.2 Iluka vibrating wire piezometers

ID	Year installed	Total depth (m)	VWP depth (m bgl)	Formation screened
WBMW06 (P2)	2014		45	LPS (upper)
WBMW07 (P1)	2014	89	44	LPS (upper)
WBMW08 (P1)	2014	102	31	Shepparton
WBMW08 (P2)	2014		38	LPS (upper)
WBMW08 (P3)	2014		79	LPS (lower)
WBMW09 (P1)	2014	90	37	Shepparton
WBMW09 (P2)	2014		15	LPS (upper)
WBMW10 (P1)	2014	295	17	Shepparton
WBMW10 (P2)	2014		23	Shepparton
WBMW10 (P3)	2014		29	Shepparton
WBMW10 (P4)	2014		37	LPS (upper)
WBMW10 (P5)	2014		44	LPS (upper)
WBMW10 (P6)	2014		73	LPS (lower)
WBMW10 (P7)	2014		87	LPS (lower)
WBMW10 (P8)	2014		104	LPS (lower)
WBMW10 (P9)	2014		143	Geera
WBMW10 (P10)	2014		199	Olney
WBMW10 (P11)	2014		241	Geera
WBMW11 (P1)	2014	119	43	LPS (lower)
WBMW11 (P2)	2014		71	LPS (lower)
WBMW12 (P1)	2014	96	49	LPS (upper)
WBMW15 (P1)	2014	137	24	Shepparton
WBMW15 (P2)	2014		34	Shepparton
WBMW17 (P1)	2014	119	19	Shepparton
WBMW17 (P2)	2014		34	Shepparton

Notes: m bgl = meters below ground level.
Loxton-Parilla Sands = Loxton-Parilla Sands.

Table 6.3 Iluka groundwater production bores

Bore ID	Year installed	Total depth (m)	Screened depth (m bgl)	Formation screened
SHPB03	2009	23	17 - 23	Shepparton
LPSPB03	2009	72	60 - 72	LPS
SHPB04	2009	24	18 - 24	Shepparton
LPSPB04	2009	70	58 - 70	LPS
WB100	Unknown	240	222 - 240	Olney
WB103	Unknown	258	238 - 256	Olney
WB6	2012	79	38.6 - 78	LPS
WB25	2012	74.3	32 - 74.3	LPS
WB28	2012	78	48 - 78	LPS
WB41	2012	77	35 - 77	LPS

Table 6.3 Iluka groundwater production bores

Bore ID	Year installed	Total depth (m)	Screened depth (m bgl)	Formation screened
N29	2012	62	32 - 62	LPS
N10	2012	61	25 - 61	LPS
N8	2012	60	30 - 60	LPS
WBPW01	2013	109	37 - 79	LPS upper & lower
WBPW02	2013	91	44 - 80	LPS upper & lower
Karra Homestead	2013	239	218.8 - 230.8	Olney
WBPW04	2014	108	39 - 105	LPS upper & lower
WBPW03A	2014	89	41 - 83	LPS upper & lower

Notes: *m bgl = meters below ground level.*

Loxton-Parilla Sands = Loxton-Parilla Sands.

Cluster = nested monitoring site.

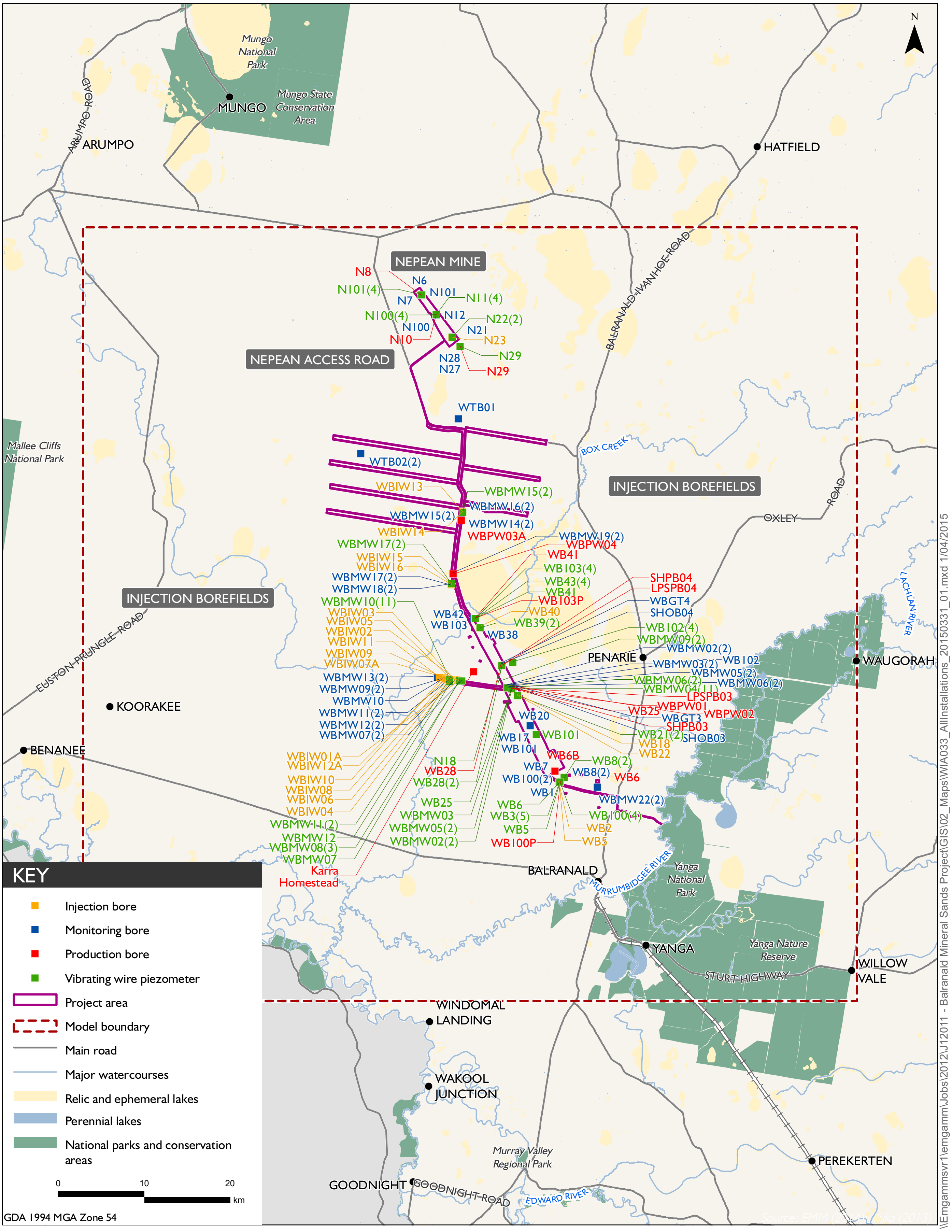
Table 6.4 Iluka groundwater injection bores

Bore ID	Date installed	Total depth (m)	Screened depth (m bgl)	Formation screened
WB2	2012	100	52 - 100	LPS
WB5	2012	102	72 - 102	LPS
WB18	2012	83	29 - 83	LPS
WB22	2012	83	29 - 83	LPS
WB40	2012	77	29 - 77	LPS
N23	2012	62	38 - 62	LPS
WBIW01A	2014	105	57 - 98	LPS
WBIW02	2014	117	53 - 108	LPS upper with minor LPS lower
WBIW03	2014	115	50 - 103	LPS upper with minor LPS lower
WBIW04	2014	113	47 - 107	LPS upper with minor LPS lower
WBIW05	2014	114	60 - 108	LPS upper with minor LPS lower
WBIW06	2014	113	55 -103	LPS upper with minor LPS lower
WBIW07A	2014	112	58 - 110	LPS upper with minor LPS lower and Gerra Clay
WBIW08	2014	119	52 - 104	LPS upper with minor LPS lower
WBIW09	2014	110	59 - 105	LPS upper with minor LPS lower
WBIW10	2014	108	55 - 107	LPS upper with minor LPS lower
WBIW11	2014	126	60 - 102	LPS upper with minor LPS lower
WBIW12A	2014	114	67 - 102	LPS lower
WBIW13	2014	107	46 - 104	LPS upper with minor LPS lower
WBIW14	2014	104	46 - 104	LPS upper with minor LPS lower
WBIW15	2014	101	58 - 98	LPS upper with minor LPS lower
WBIW16	2014	114	71 - 105	LPS lower

Notes: *m bgl = meters below ground level.*

Loxton-Parilla Sands = Loxton-Parilla Sands.

Cluster = nested monitoring site.

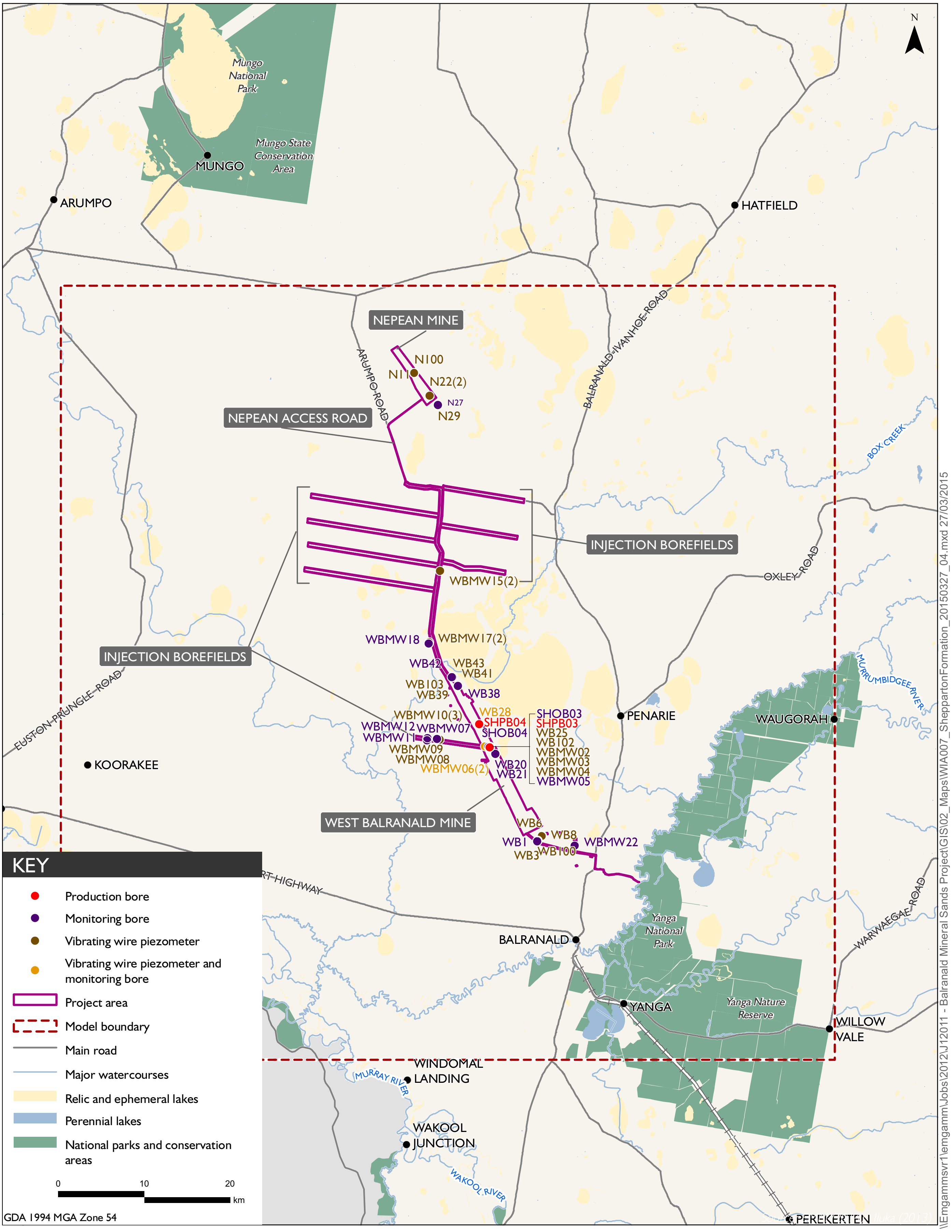


Iluka's groundwater monitoring installations

Balranald Mineral Sands Project

Water Assessment

Figure 6.1

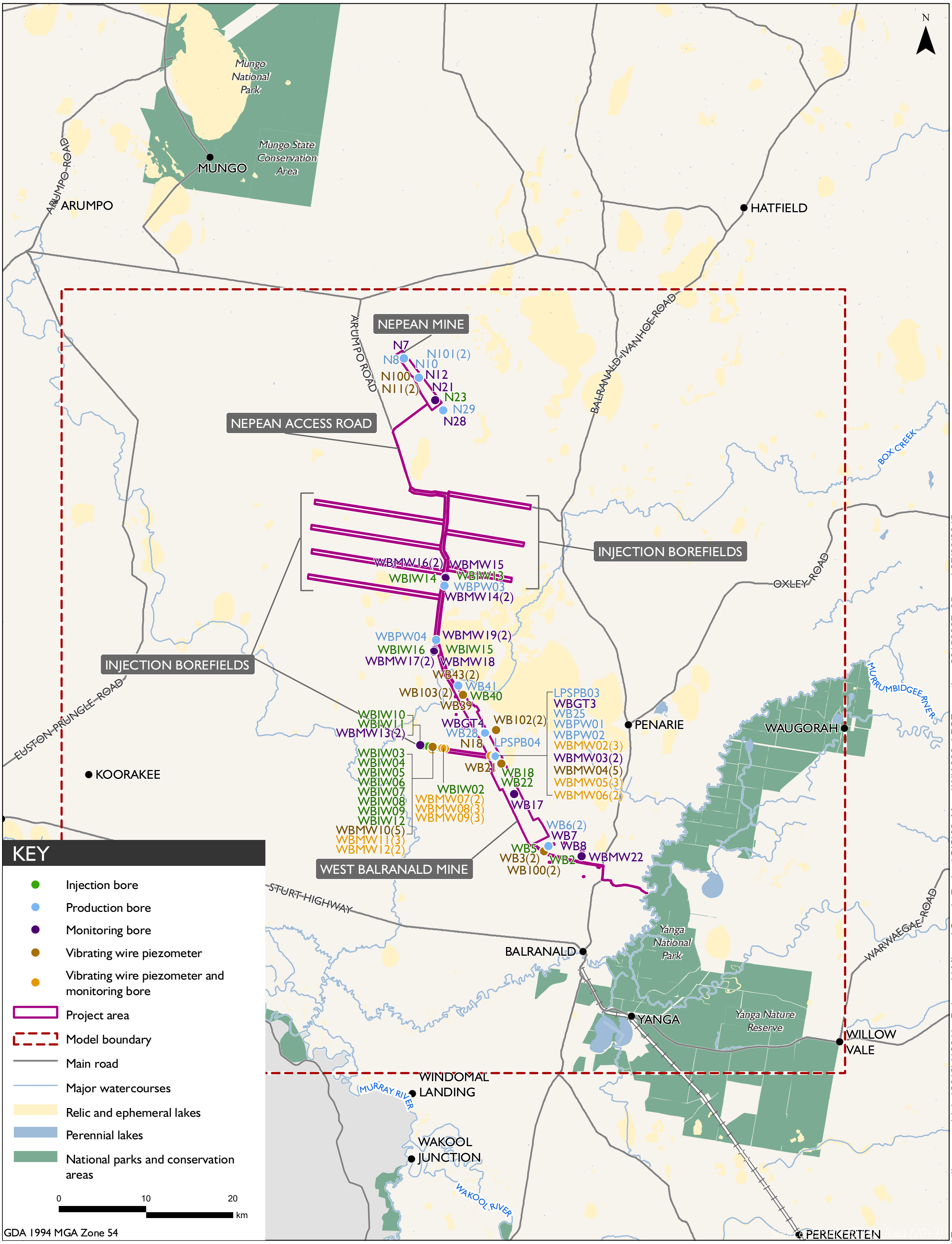


Installations screening the Shepparton Formation

Balranald Mineral Sands Project

Water Assessment

Figure 6.2



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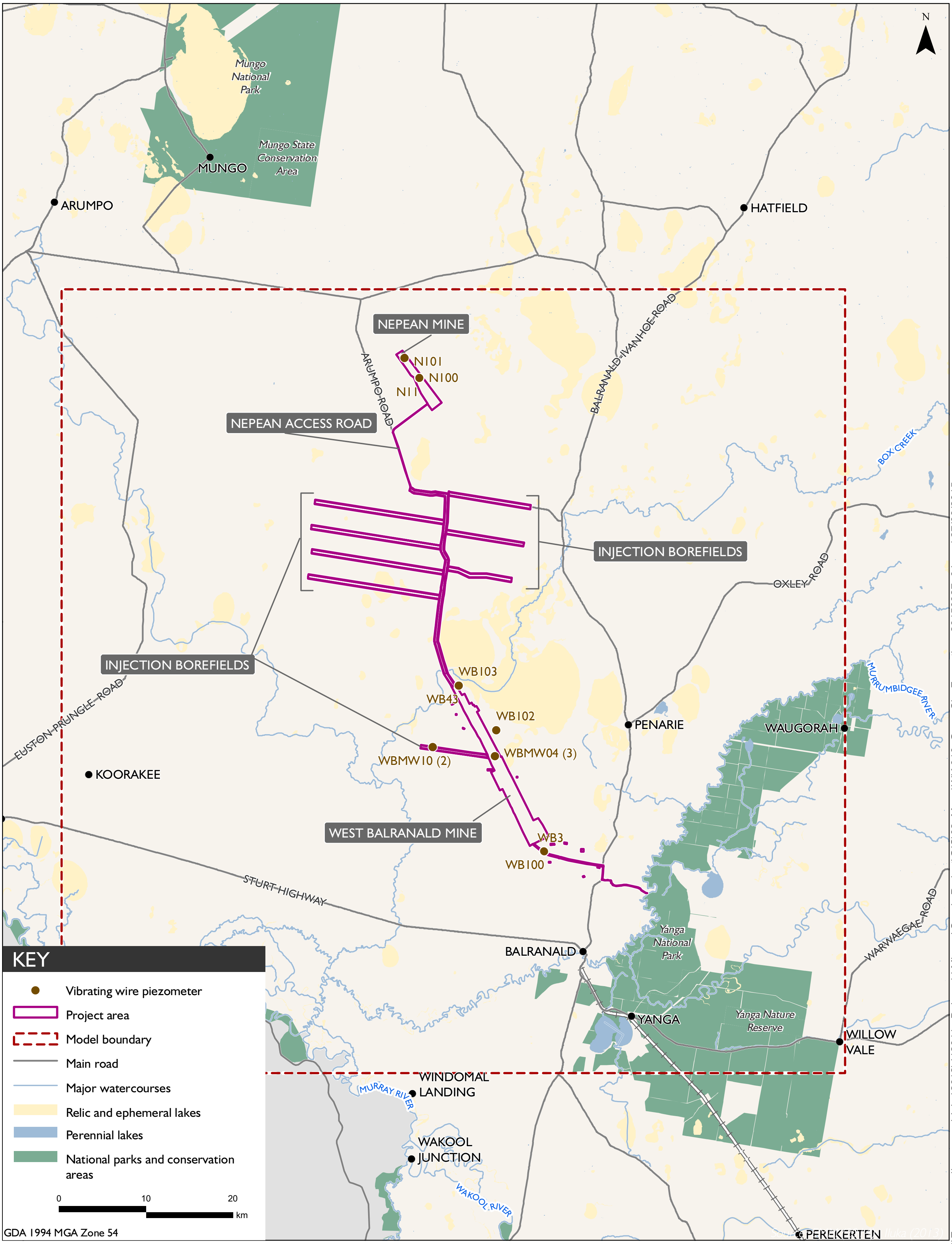
EMM
ILUKA

Installations screening the Loxton-Parilla Sands

Balranald Mineral Sands Project
Water Assessment
Figure 6.3



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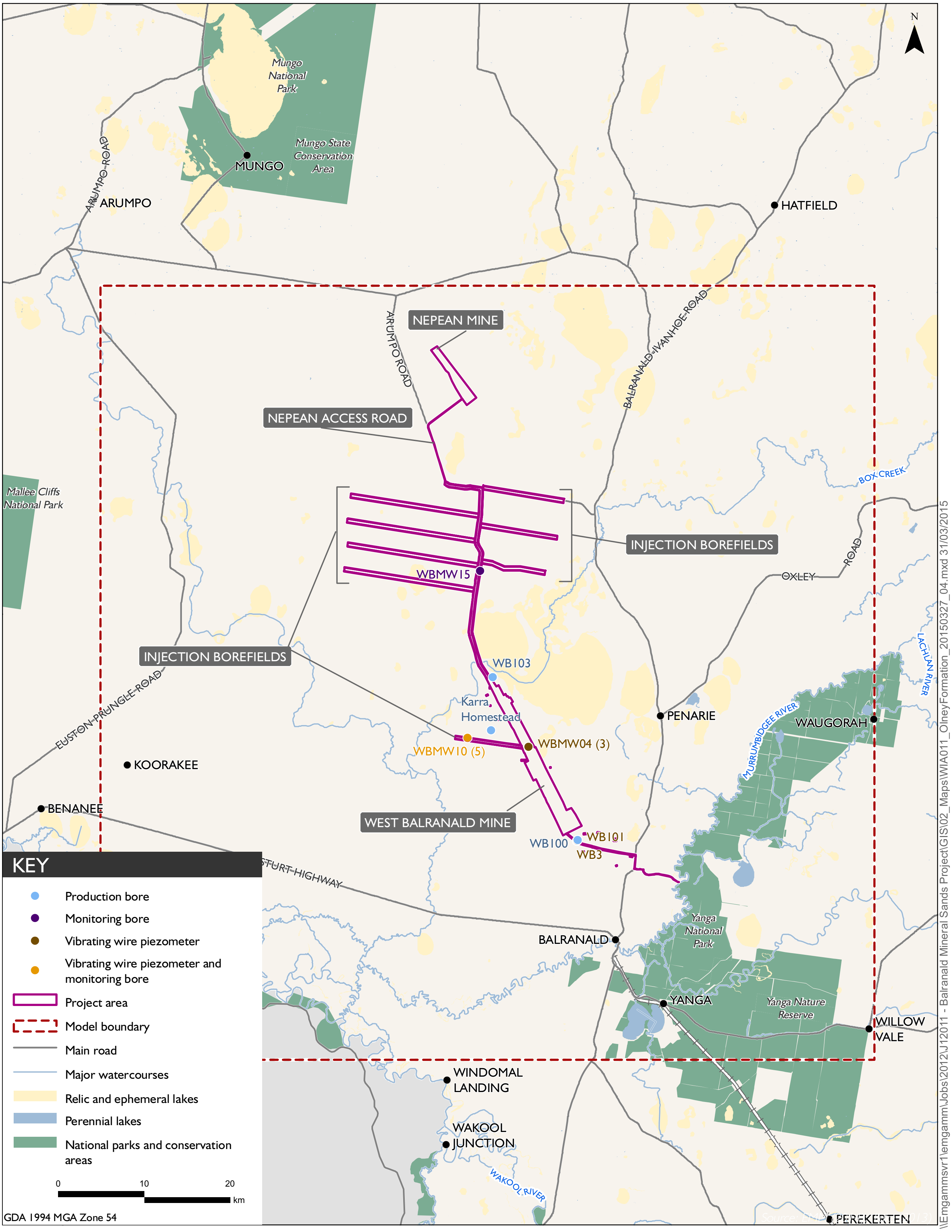
Installations screening the Geera Clay

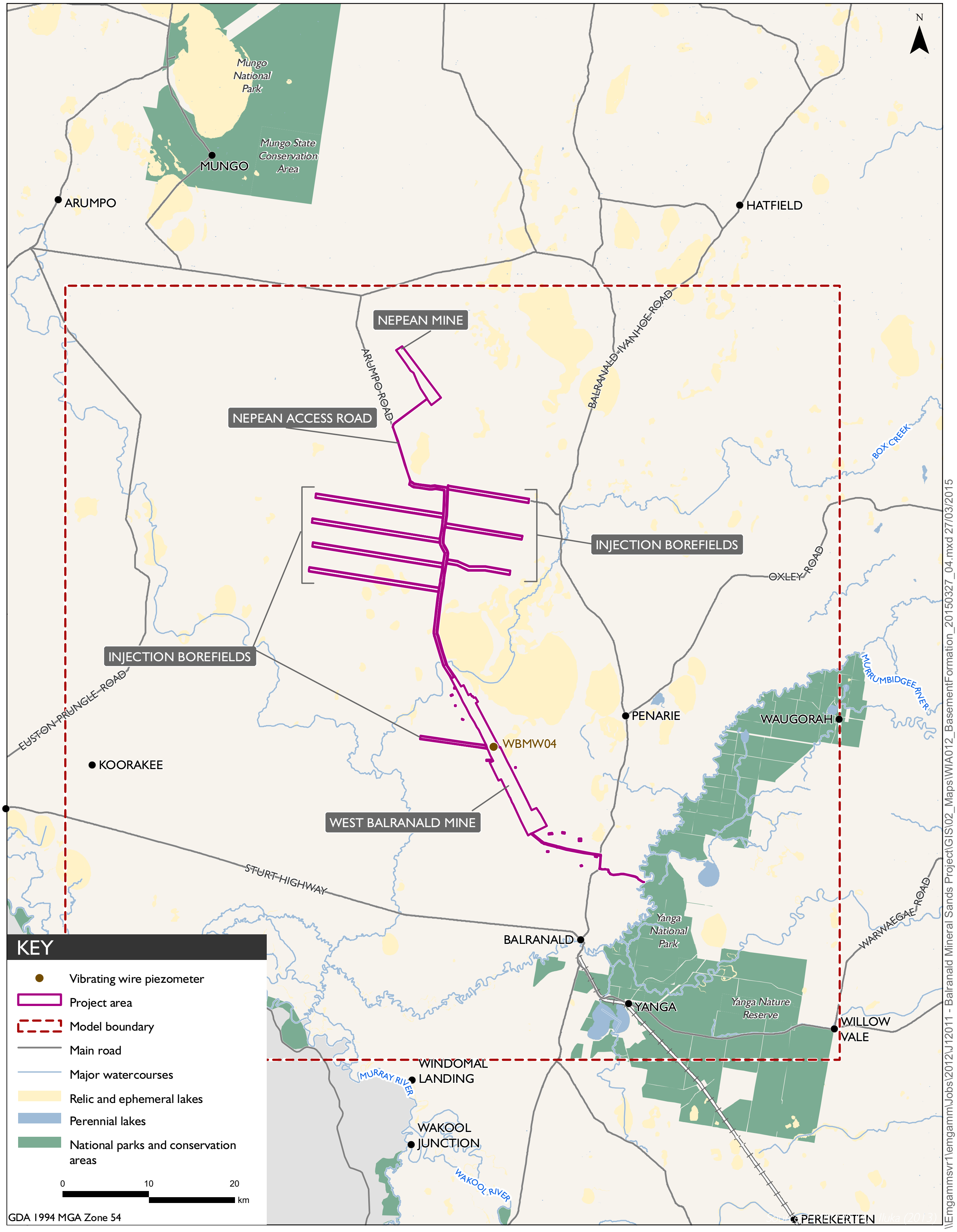
Balranald Mineral Sands Project

Water Assessment

Figure 6.4



Installations screening the Olney Formation
Balranald Mineral Sands Project
Water Assessment
Figure 6.5



EMM
ILUKA

Installations screening basement

Balranald Mineral Sands Project
Water Assessment
Figure 6.6

6.3 Registered bores with the NSW Office of Water

It is a requirement in NSW that once groundwater bores (monitoring, production, injection) are drilled they are registered with the NOW via the submittal of a form ('Form A') which contains details of the bore drilling and construction process. A database is maintained that contains information on all bores, such as location, date drilled, depth drilled, drillers logs, screen interval and type of installation. The database consists of all private landholder bores, private monitoring bores and NOW monitoring bores.

In January 2015, a download of the registered bore database within a 60 km radius of the project area was obtained from the NOW. This database has been used to inform the understanding of the NOW monitoring bores and the private landholder bores.

6.3.1 NSW Office of Water Monitoring bores

The NOW maintains a network of groundwater monitoring bores across the state. The bores are used to monitor groundwater levels and quality, and this data facilitates the assessment of groundwater conditions and informs groundwater management practices. Often the monitoring bores are constructed as 'nested sites' with multiple bores screening different formations.

NOW monitoring installations in the area focus on the Lowbidgee Floodplain, to the east and a salt interception scheme to the south-west. The four NOW monitoring nests in the vicinity of the project area that were assessed for water level fluctuations are tabulated in Table 6.5. A table with all the installations is included in Appendix B of this report and the locations shown in Figure 6.7.

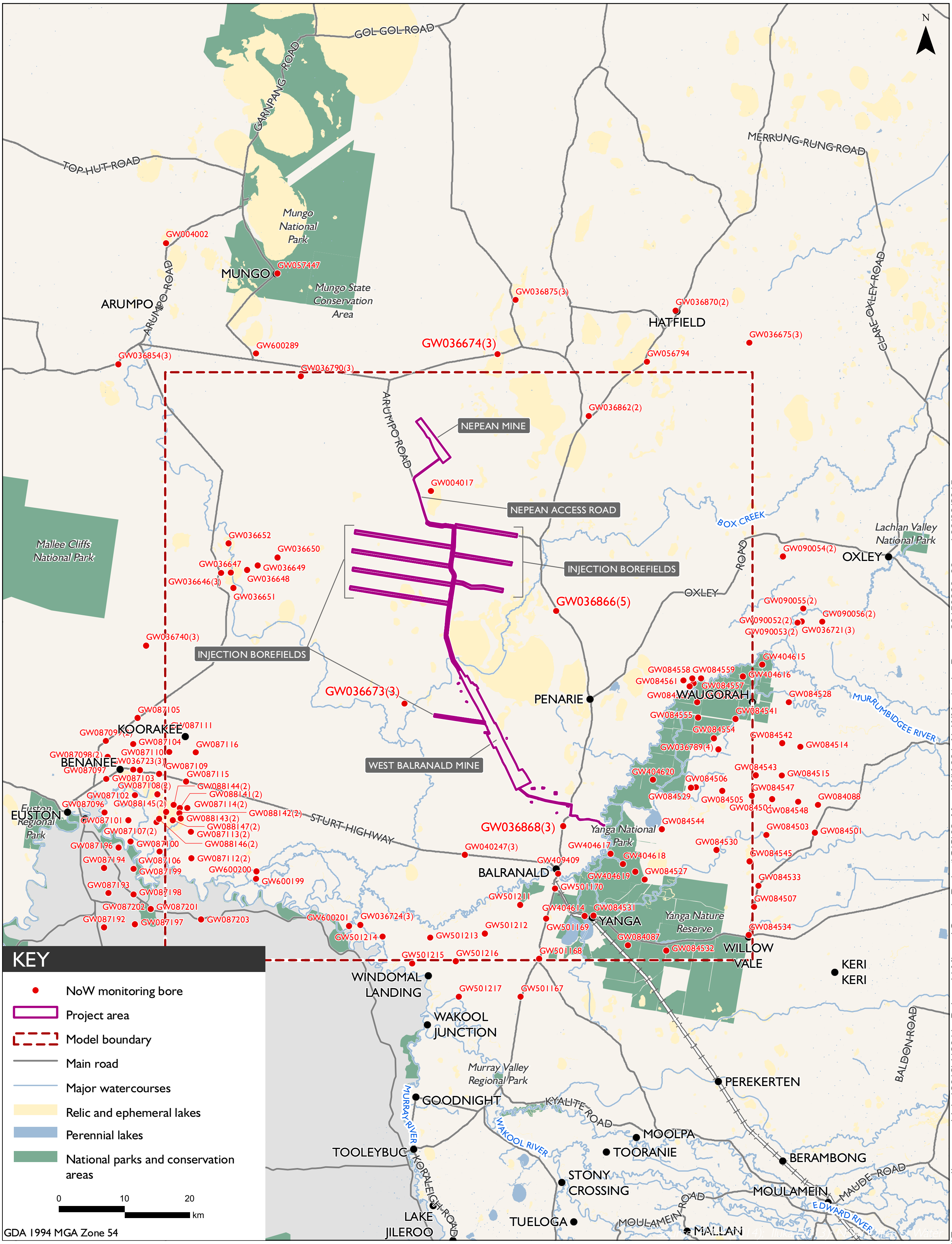
Table 6.5 NSW Office of Water monitoring bores

NOW Id	Year installed	Total depth (m)	Formation screened
GW036866, pipe 1	1990		Shepparton
GW036866, pipe 2	1990		LPS
GW036866, pipe 3	1990		Geera Clay
GW036866, pipe 4	1990	308.4	Olney
GW036866, pipe 5	1990		Olney
GW036868, pipe 1	1990		LPS
GW036868, pipe 2	1990		LPS
GW036868, pipe 3	1990	104	LPS
GW036673, pipe 1	1986		Shepparton
GW036673, pipe 2	1986		LPS
GW036673, pipe 3	1986	300	Olney
GW036674, pipe 1	1986		Shepparton
GW036674, pipe 2	1986		LPS
GW036674, pipe 3	1986	176	Olney

6.3.2 Private landholder bores

The privately owned bores within the vicinity of the project area are predominantly registered for stock or domestic use. The NOW database contains varying level of detail on construction and formation information as this level of detail depends on what was provided by the drillers on their Form A when the bore was initially drilled. For some bores no information was available on the screened formation, and this was inferred by assessing the screen depth, or the total bore depth against the numerical model layers for the site.

The data is tabulated in Table B.2 (Appendix B, of this report), the location of these installations and target formations is shown in Figure 6.8. The majority of the landholder bores were installed into the Shepparton Formation (57), with 35 bores screening the Olney Formation. Nine bores are screened across the Geera Clay, 10 bores are screened across the Loxton-Parilla Sands and one bore is screened across basement.



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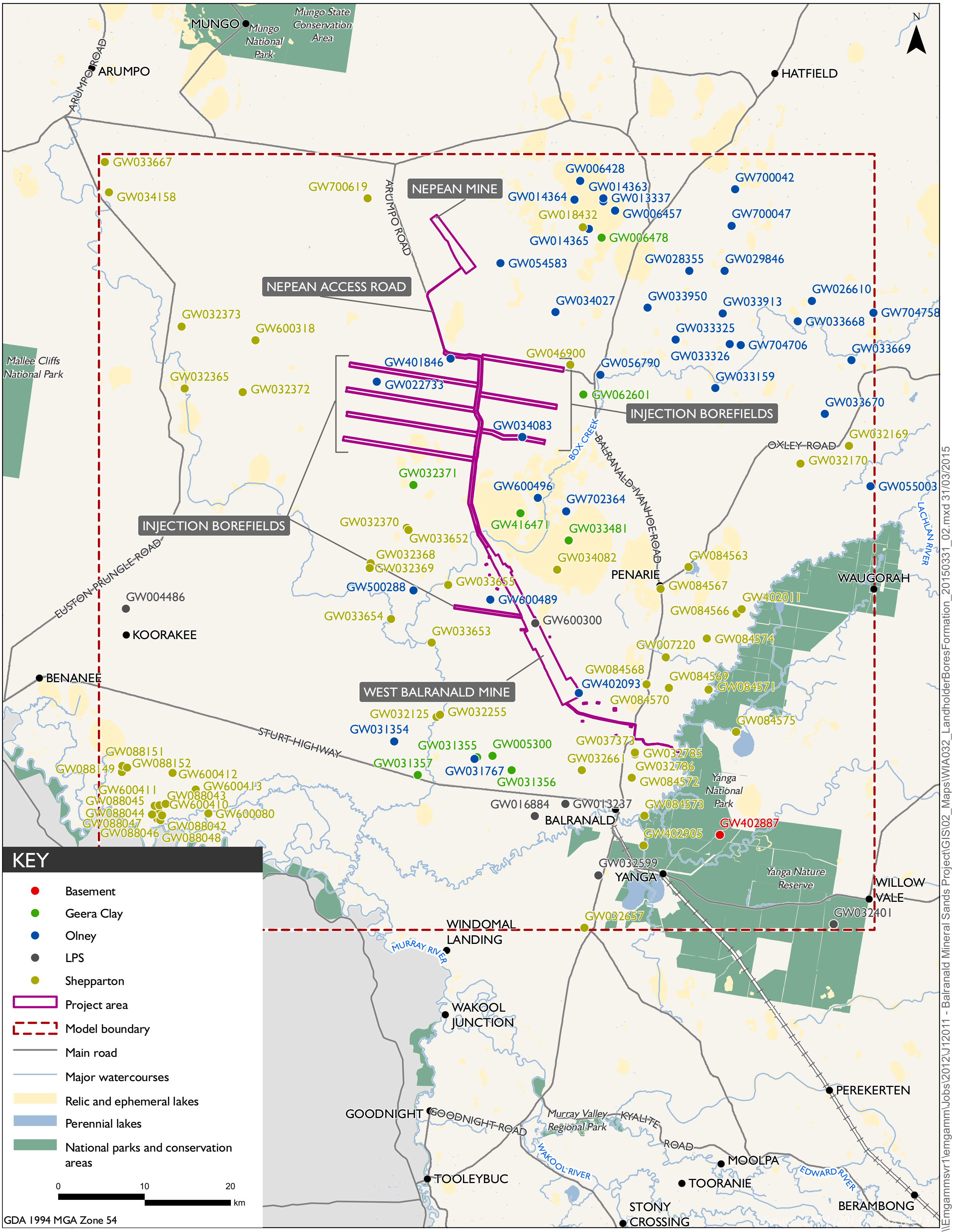
NSW Office of Water monitoring bores

Balranald Mineral Sands Project

Water Assessment

Figure 6.7



Landholder bores and formation screened

Balranald Mineral Sands Project
Water Assessment
Figure 6.8

6.4 Hydraulic testing

Hydraulic conductivity and storativity measurements have been obtained from relevant public domain literature (Kellet 1989), and from short term and long term small-scale step rate pumping and injection tests, and constant rate pumping and injection tests completed during the site investigations (URS 2012).

Short term pumping tests, completed in 2009, were undertaken at four production bores for approximately six hours. The SRTs (undertaken in 2011), are where the flow rate was incrementally increased, and CRTs, were undertaken at four production bores and one injection bore. The constant abstraction flow rates ranged from 8 L/s (Nepean nested monitoring site 1) to 35 L/s (West Balranald nested monitoring sites 1 and 4), (URS 2012). Two nested monitoring sites at the Nepean deposit were not sufficiently transmissive to facilitate longer term hydraulic testing.

SKM (2013) later reanalysed the field results and the reported measurements of hydraulic conductivities for different stratigraphic units from both URS (2012) and SKM (2013) are provided below in Table 6.6.

Table 6.6 Historic hydraulic conductivity and storativity measurements

Hydrostatigraphic unit	Bulk K (m/d) Kellet (1989)	Bulk K (m/d) URS (2012)	Bulk S URS (2012)	Bulk K (m/d) SKM (2013)	Bulk S SKM (2013)
Shepparton Formation	1 - 2				
LPS	4				
LPS – WB nested monitoring site1		0.5 – 3.1	$2.4 \times 10^{-6} - 4 \times 10^{-4}$	7.3	$2 \times 10^{-4} - 6 \times 10^{-4}$
LPS – WB nested monitoring site 3		0.7 – 2.3	$1.94 \times 10^{-5} - 3.2 \times 10^{-3}$	1.9	1×10^{-3}
LPS – WB nested monitoring site 4		1.4	2.4×10^{-3}	2.7	8×10^{-4}
LPS – WB nested monitoring site 5		1.6 – 2.2	$2.3 \times 10^{-7} - 5.4 - 10^{-5}$	4	1.3×10^{-4}
LPS – N nested monitoring site 1		0.4 – 0.8	$4.8 \times 10^{-3} - 9 \times 10^{-3}$		
Upper Renmark Group	1 – 2				
Middle Renmark Group	0.5 – 1				
Lower Renmark Group	1 - 5				

Notes: WB = West Balranald, N – Nepean. K = hydraulic conductivity, S = Storativity, LPS = Loxton-Parilla Sands

There is a large range of results between different Formations, as well as variation within the Loxton-Parilla Sands. These differences generally arise from different assumptions and interpretations included in the aquifer test analyses, and illustrates typical levels of uncertainty inherent in the methods used to analyse aquifer pumping test results.

6.5 Groundwater monitoring program

Groundwater quality and level monitoring has been undertaken at the Iluka groundwater monitoring bores since 2012. In April 2013 Land & Water Consulting commenced quarterly groundwater quality sampling from a number of Iluka monitoring bores, with a minor number of sampling events undertaken from the landholder and NOW monitoring bores. The greatest number of samples was collected from the Loxton-Parilla Sands, consistent with there being the largest number of monitoring installations in this Formation.

6.5.1 Groundwater levels monitored by Iluka

Monitoring of groundwater levels undertaken by Iluka typically commenced in January 2012 and focused on bores targeting the Shepparton Formation and Loxton-Parilla Sands. Bores are monitored via manual dips approximately every six weeks, which are made via electronic dip meters. Hydrographs showing groundwater level trends have been plotted against cumulative deviation rainfall data for West Balranald deposit (north and south) and the Nepean deposit in Figures 6.9 – 6.11.

Vertical scales on these graphs are different to ensure that groundwater level trends can be clearly seen, however a 2 m interval is consistent across each of the graphs.

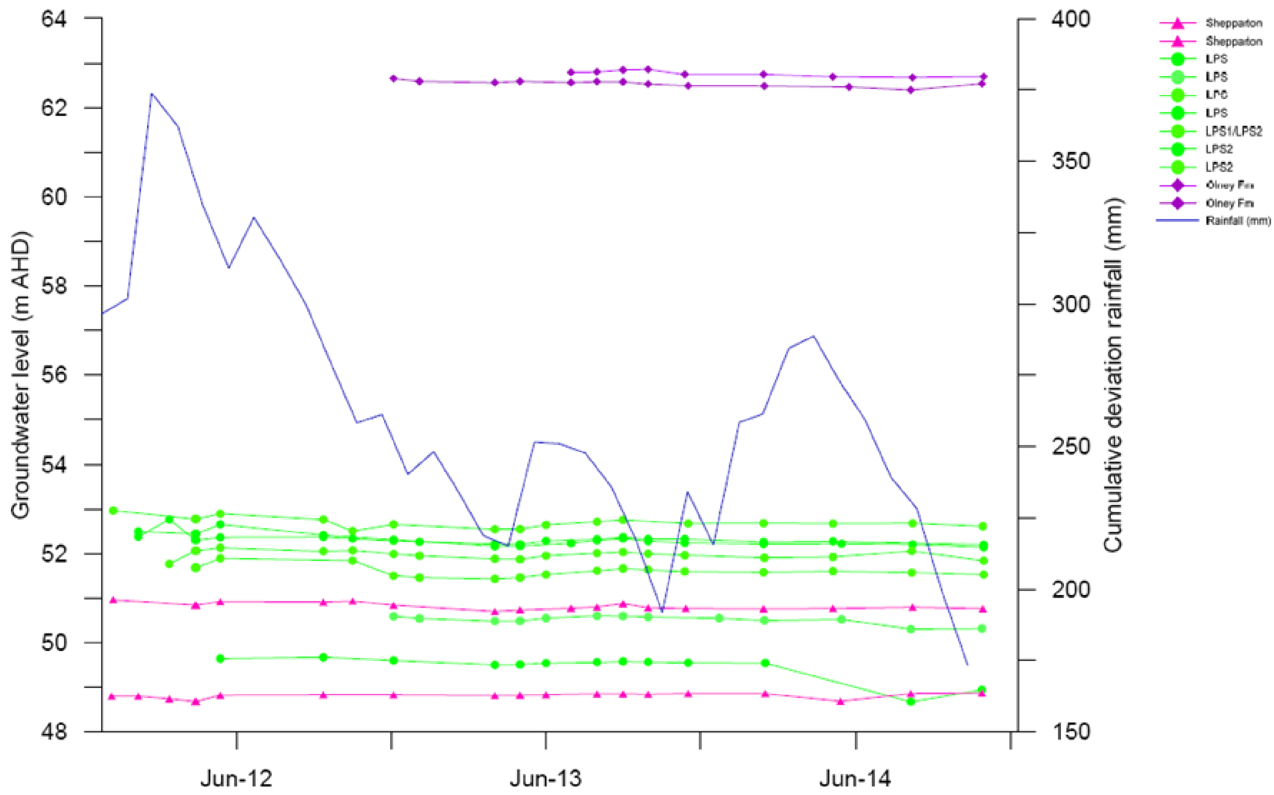


Figure 6.9 West Balranald deposit south hydrograph with cumulative deviation rainfall

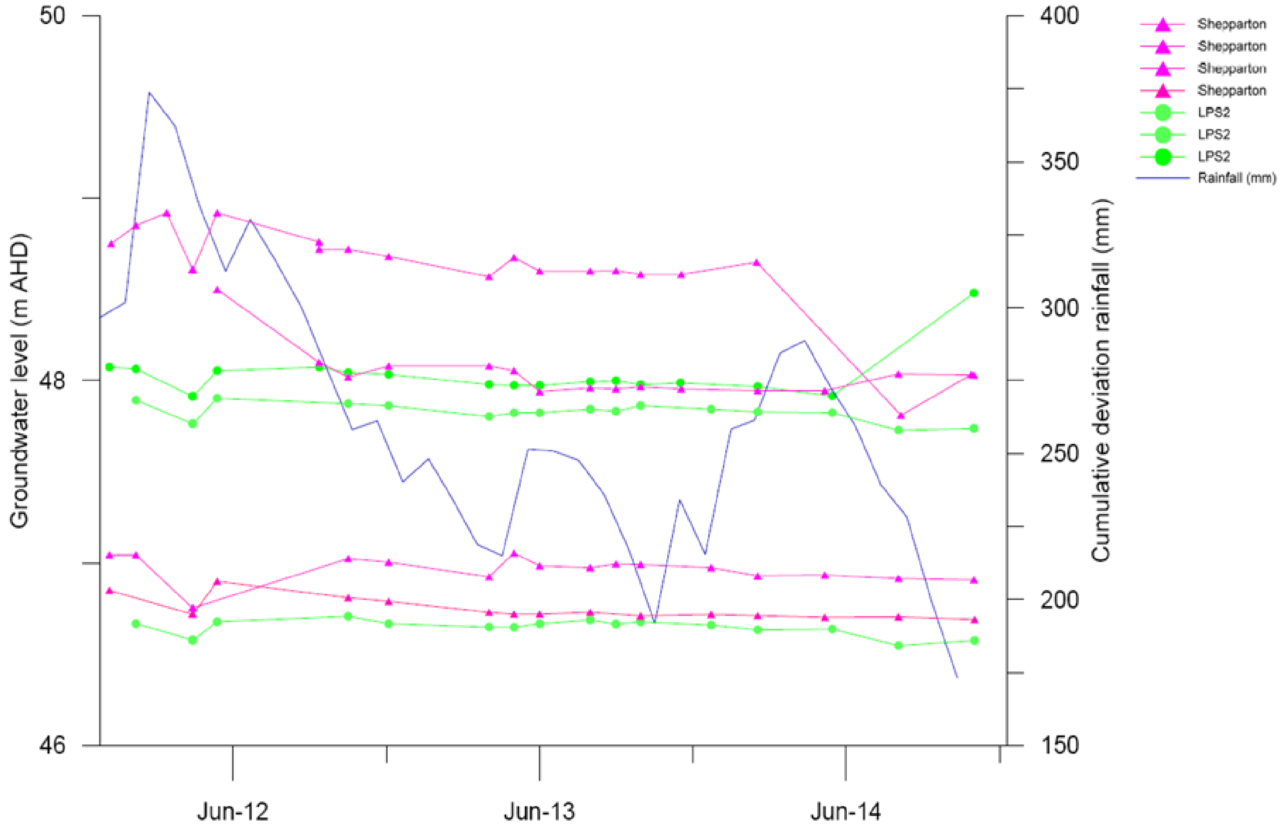


Figure 6.10 West Balranald deposit north hydrograph with cumulative deviation rainfall

Groundwater level monitoring at the West Balranald deposit, at both the northern and southern ends shows the groundwater level in the Shepparton Formation is comparable to the potentiometric elevation in the Loxton-Parilla Sands. There is no notable response to rainfall events. The Olney Formation is monitored at the southern end of the West Balranald deposit. There is an approximate 10 m head difference between the shallower Shepparton Formation and Loxton-Parilla Sands, and the Olney Formation, indicating an upward vertical hydraulic gradient and therefore potential for upwards vertical flow from the Olney Formation.

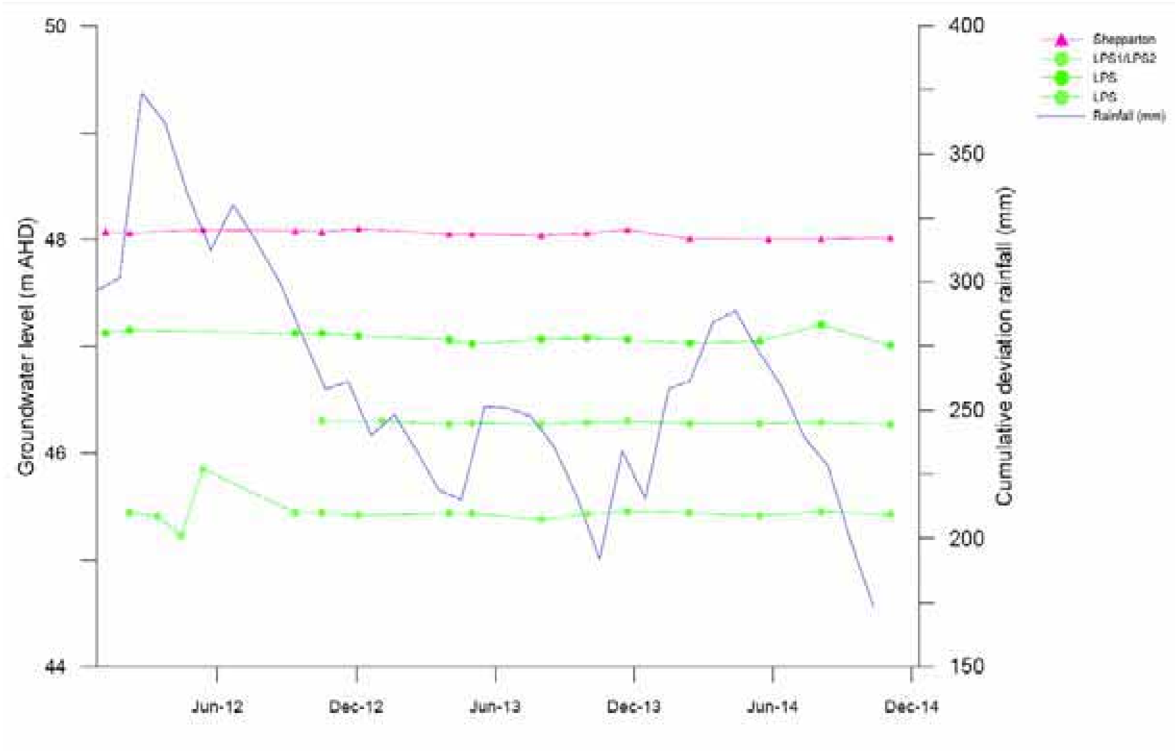


Figure 6.11 Nepean deposit south hydrograph with cumulative deviation rainfall

Groundwater level monitoring at the Nepean deposit shows stable groundwater levels in the Loxton-Parilla Sands and Shepparton Formation. The water table is in the Shepparton Formation, and there is a slight downward vertical gradient between the Shepparton Formation and the Loxton-Parilla Sands.

The monitoring period of record (two years) does not lend itself to capturing longer term climatic trends. Reference to the longer term monitoring undertaken in NOW monitoring bores within the model domain allows comparison to longer term climatic data (28 years).

6.5.2 NSW Office of Water long term groundwater level monitoring

Long term groundwater level data was obtained from the following four NOW nested monitoring sites:

- GW036868, approximately 6.5 km north of Balranald town;
- GW036673, approximately 35 km north west of Balranald town;
- GW036866, approximately 40 km north of Balranald town; and
- GW036674, approximately 68 km north of Balranald town.

The location of these monitoring bores is shown in Figure 6.7. Hydrographs, showing groundwater level trend and cumulative deviation rainfall data (from Balranald Town BoM Station: 049002) are shown in Figures 6.12 – 6.15.

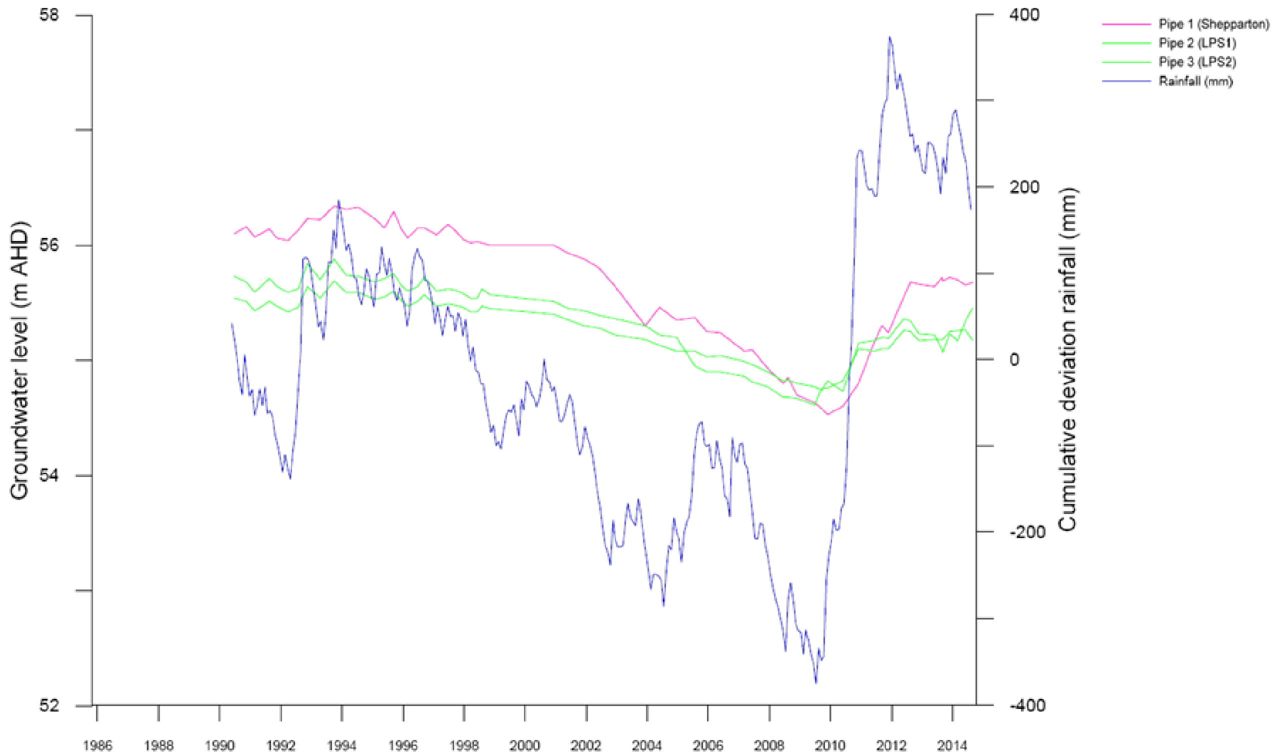


Figure 6.12 GW036868 hydrograph with cumulative deviation rainfall

Groundwater levels at GW036868 (Shepparton Formation, Loxton-Parilla Sands upper and Loxton-Parilla Sands lower are comparable and show a very downward trend since monitoring commenced in 1990 until 2010, consistent with overall declining cumulative rainfall deviation over that same time. High rainfall and large floods in 2010/2011 are clearly seen in the rainfall trends, and are also noted as groundwater levels increases at that same time. The greatest increase is observed in the shallower Shepparton Formation, approximately 1 m increase. There is minimal vertical gradient between the Shepparton Formation and the Loxton-Parilla Sands at this location, but it can be seen to be slightly downward for most of the time.

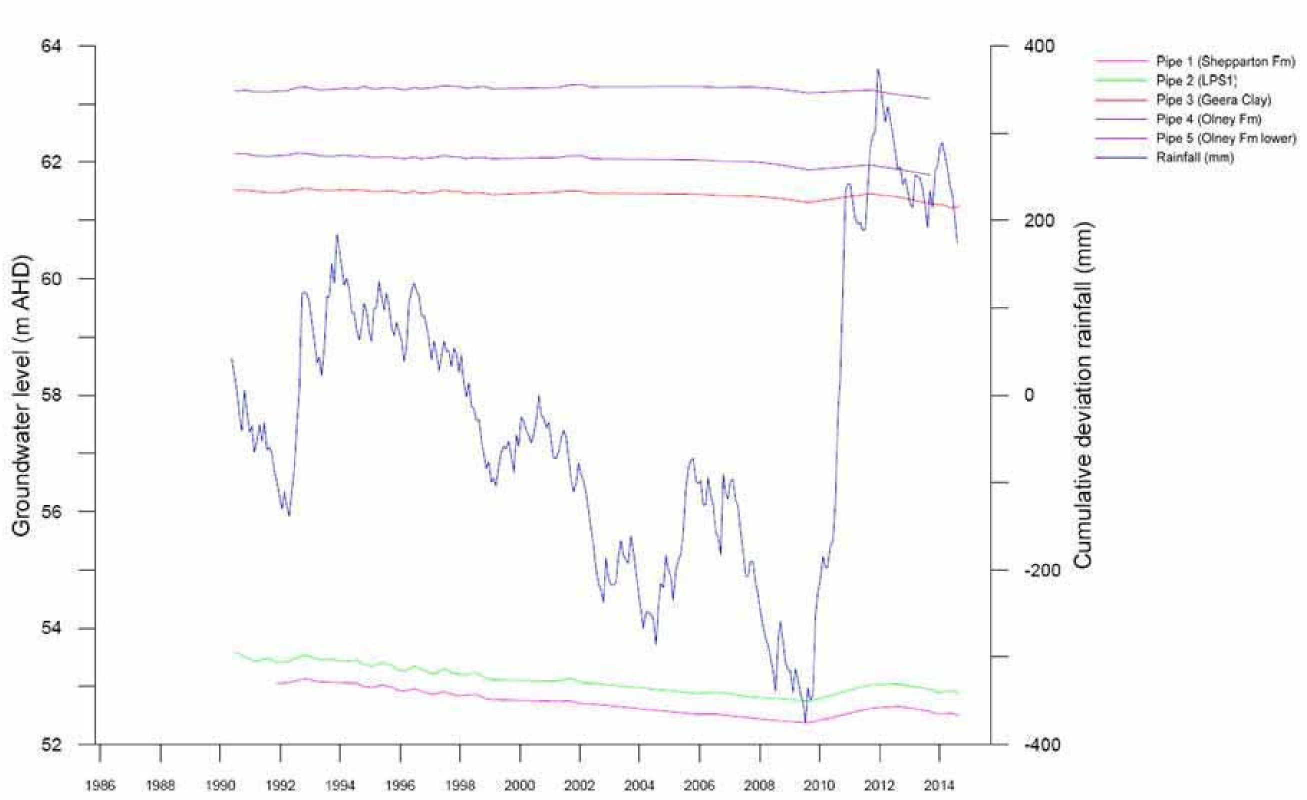


Figure 6.13 GW036866 hydrograph with cumulative deviation rainfall

The groundwater level at the three deeper bores (intersecting the Geera Clay, and different depths of the Olney Formation) at the NOW nested site GW036866 do not fluctuate for the period of monitoring (1990 – 2014), with the exception of a very slight (~0.05 m increase) and following heavy rainfall and flooding in 2010.

Within the shallower Shepparton Formation and Loxton Parilla Sands a very gentle decline in groundwater level is observed, likely associated with prolonged dry conditions. There is a slight increase in levels (~0.2 m increase) in 2010 following heavy rainfall and flooding (NOW 2011).

There is also an approximate 9 m head difference between the deeper Olney Formation and Geera Clay, and the Loxton Parilla Sands, indicating an upwards vertical head gradient and potential for upward vertical flow.

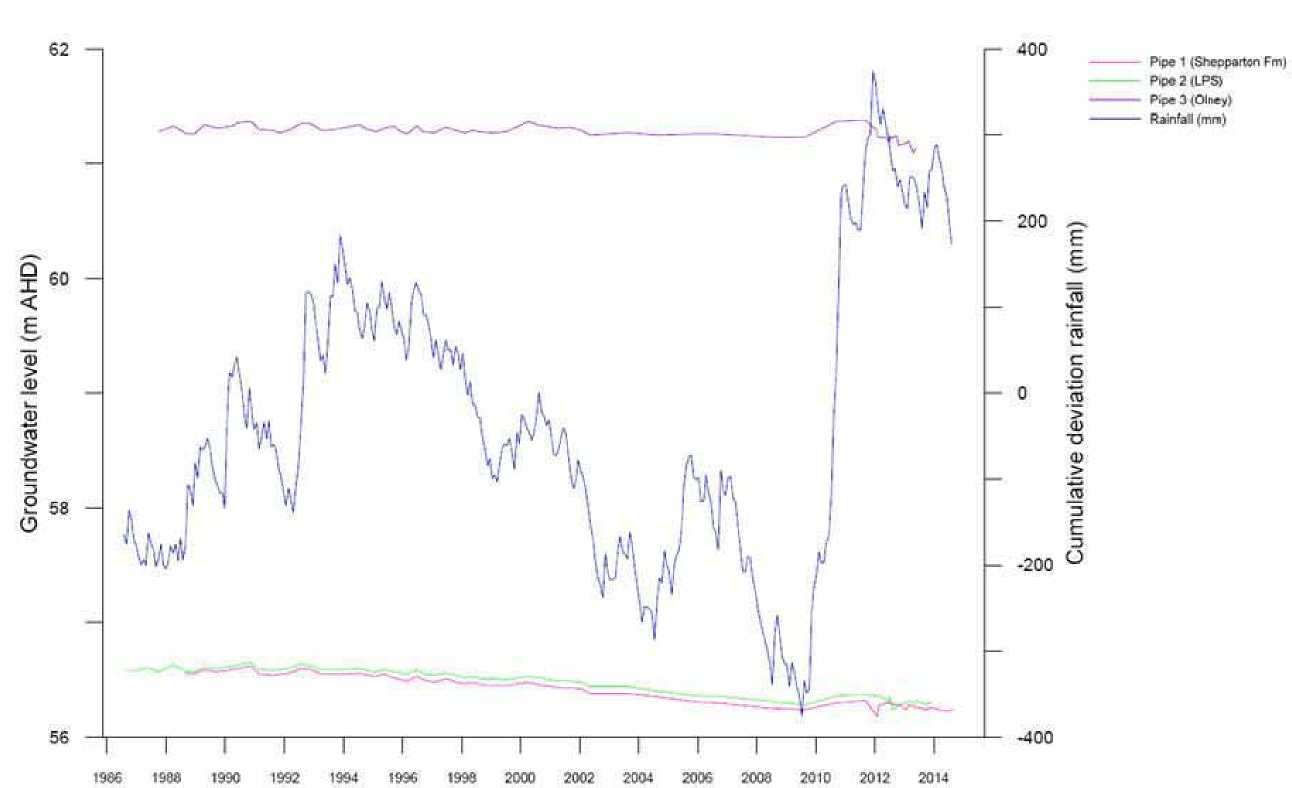


Figure 6.14 GW036674 hydrograph with cumulative deviation rainfall

Groundwater level monitoring at GW036674 shows a very slight correlation to rainfall in the shallower Shepparton Formation and Loxton-Parilla Sands. The hydrograph shows a very slight declining trend from 1992 to 2010 (when rainfall is largely below average) and then an approximately (~0.05 m increase), following heavy rain and flooding in 2010.

Between the shallow and deep there is an approximate 6 m head difference, indicating an upwards vertical head gradient and potential for upward flow.

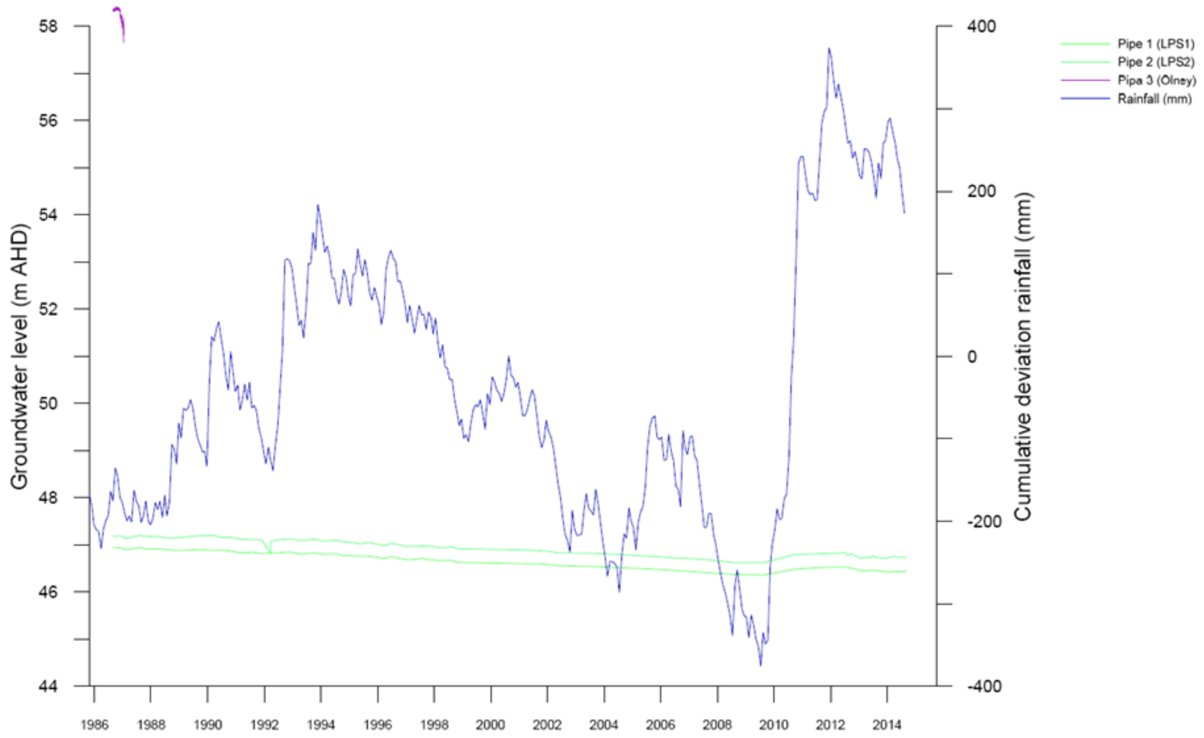


Figure 6.15 GW036673 hydrograph with cumulative deviation rainfall

Groundwater level monitoring at GW036673 show a slight downwards trend consistent with below average rainfall from 1990 until 2010. Groundwater levels increase slightly in 2010 in response to higher rainfall and flooding (~0.05 m increase).

The one year monitoring period in the bore within the Olney Formation indicates that there is an approximate 11 m head gradient between the Olney Formation and the shallower formations. This indicates an upward hydraulic gradient and the potential for upwards vertical flow.

6.5.3 Groundwater quality

Key groundwater quality results have been collated and organised according to formation. An overview groundwater quality parameters is provided in Table 6.7 to 6.11 below. The data set spans 2012 – 2014.

Table 6.7 Overview of key groundwater quality parameters in the Shepparton Formation

Analyte	Units	Minimum	Maximum	Mean	Median	Count
Shepparton Formation						
pH	pH units	6.1	8.6	7.11	7	105
TDS	mg/L	15	45,000	14,982.9	37,91.9	70
EC	mS/cm	0.83	98.8	47.9	52.9	72
Suspended solids	mg/L	28	295	101.2	66.5	24
Sulfate	mg/L	5	4,630	951.41	477	41
Calcium	mg/L	9.9	832	453.3	556	41
Chloride	mg/L	17	21,000	13,984.2	16,300	13
Magnesium	mg/L	476	1,320	1004	1,100	11
Sodium	mg/L	2	12,000	27,00.8	137	41
Potassium	mg/L	1	116	40.1	34	39
Total alkalinity	mg/L	56	417	261.8	253	24
Aluminium*	mg/L	0.1	13.9	1.9	0.3	31
Arsenic*	mg/L	0.005	0.05	0.03	0.02	21
Cadmium*	mg/L	0.0001	0.2	0.1	0.1	4
Chromium*	mg/L	0.001	0.02	0.01	0.01	4
Copper*	mg/L	0.01	0.2	0.05	0.01	11
Lead*	mg/L	0.014	0.01	0.01	0.01	1
Manganese*	mg/L	0.115	255	77.8	18.5	54
Nickel*	mg/L	0.012	0.089	0.03	0.03	13
Strontium*	mg/L	8.35	17	13.6	13.9	24
Zinc*	mg/L	0.009	0.616	0.2	0.02	12
Iron*	mg/L	0.15	16	5.9	6.2	21

*Notes: * = dissolved metal, EC = electrical conductivity, TDS = total dissolved solids.*

Table 6.8 Overview of key groundwater quality parameters in the Loxton-Parilla Sands

Analyte	Units	Minimum	Maximum	Mean	Median	Count
Loxton-Parilla Sands						
pH	pH units	2.1	9.58	6.9	6.8	423
TDS	mg/L	2	54,000	13,104.4	2,549.2	244
EC	mS/cm	2.27	5,158	56	38.2	255
Suspended solids	mg/L	19	7,500	402.9	93	85
Sulfate	mg/L	2	999	271.9	242	101
Calcium	mg/L	2	5,410	1,364.5	678	198
Chloride	mg/L	1	978	111.6	48	185
Magnesium	mg/L	5	29,000	8,670.7	774	198

Table 6.8 Overview of key groundwater quality parameters in the Loxton-Parilla Sands

Analyte	Units	Minimum	Maximum	Mean	Median	Count
Sodium	mg/L	1	983	383.8	452	198
Potassium	mg/L	3	1820	580.3	77.5	198
Total alkalinity	mg/L	12.4	530	100	22.9	97
Aluminium*	mg/L	0.03	52.9	1.4	0.2	123
Arsenic*	mg/L	0.004	0.2	0.02	0.02	64
Cadmium*	mg/L	0.0001	0.004	0.04	0.0001	15
Chromium*	mg/L	0.001	0.2	0.02	0.01	22
Copper*	mg/L	0.003	0.08	0.03	0.01	43
Lead*	mg/L	0.002	0.02	0.01	0.01	4
Manganese*	mg/L	0.025	7.5	0.8	0.6	85
Nickel*	mg/L	0.001	0.09	0.02	0.02	26
Strontium*	mg/L	5.03	17	12.9	13	85
Zinc*	mg/L	0.006	0.92	0.2	0.1	62
Iron*	mg/L	0.12	43	4.1	2.6	122

*Notes: * = dissolved metal, EC = electrical conductivity, TDS = total dissolved solids.*

Table 6.9 Overview of key groundwater quality parameters in the Olney Formation

Analyte	Units	Minimum	Maximum	Mean	Median	Count
Olney Formation						
pH	pH units	6.4	9.26	7.5	7.5	173
TDS	mg/L	4	7,114	1,447.4	419	99
EC	mS/cm	0.9	87	9.3	6.9	118
Sulfate	mg/L	1	45	2.8	1	56
Calcium	mg/L	1.9	85	38.9	38	58
Chloride	mg/L	2	392	158.9	165	50
Magnesium	mg/L	5	135	50.2	55.5	58
Sodium	mg/L	11	972	195.9	125.5	58
Potassium	mg/L	2.	29	21.6	24.5	58
Aluminium*	mg/L	0.1	0.8	0.3	0.2	43
Manganese*	mg/L	0.1	9	1.8	0.3	48
Iron*	mg/L	0.1	9	0.9	0.6	40

*Notes: * = dissolved metal, EC = electrical conductivity, TDS = total dissolved solids.*

Table 6.10 Overview of key groundwater quality parameters in the Geera Clay

Analyte	Units	Minimum	Maximum	Mean	Median	Count
Geera Clay						
pH	pH units	7	9.86	7.73	7.3	11
EC	mS/cm	1.6	15.4	10.3	12.4	8
Suspended solids	mg/L	92	297	194.5	194.5	2
Sulfate	mg/L	3	294	99	49.5	4
Calcium	mg/L	14	459	209.5	182.5	4
Chloride	mg/L	51	483	163.8	60.5	4
Magnesium	mg/L	11	119	56.5	48	4
Sodium	mg/L	12	868	333.5	227	4
Potassium	mg/L	29	97	48.8	34.5	4
Total alkalinity	mg/L	39	422	230.5	230.5	2
Aluminium*	mg/L	0.16	0.34	0.23	0.2	4
Arsenic*	mg/L	0.13	0.19	0.16	0.2	2
Chromium*	mg/L	0.2	0.2	0.20	0.2	1
Copper*	mg/L	0.11	0.11	0.11	0.1	1
Manganese*	mg/L	0.25	1.2	0.64	0.6	6
Nickel*	mg/L	0.16	0.16	0.16	0.2	1
Strontium*	mg/L	11.8	16	13.90	13.9	2
Zinc*	mg/L	0.14	0.25	0.20	0.2	2
Iron*	mg/L	1	9.28	5.21	5.2	6

*Notes: * = dissolved metal, EC = electrical conductivity.*

Table 6.11 Overview of key groundwater quality parameters in the basement

Analyte	Units	Minimum	Maximum	Mean	Median	Count
Basement						
pH	pH units	7.4	7.71	7.5	7.4	3
TDS	mg/L	5500	6,900	6,153.3	6,060	3
Suspended solids	mg/L	7.9	26	16.6	16	3
Sulfate	mg/L	5	16	7.3	11	3
Calcium	mg/L	70	81	75	74	5
Chloride	mg/L	3,400	3,840	3,588	3,500	5
Magnesium	mg/L	86	104	97.4	99	5
Sodium	mg/L	1,800	2,200	1,980	2,000	5
Potassium	mg/L	32	37	34.2	34	5
Total alkalinity	mg/L	230	290	261.3	262.5	4
Aluminium*	mg/L	0.01	0.01	0.01	0.01	1

Table 6.11 Overview of key groundwater quality parameters in the basement

Analyte	Units	Minimum	Maximum	Mean	Median	Count
Arsenic*	mg/L	0.072	0.13	0.1	0.1	3
Cadmium*	mg/L	0.0002	0.0002	0.0002	0.0002	1
Copper*	mg/L	0.002	0.002	0.002	0.002	1
Manganese*	mg/L	0.018	0.025	0.02	0.02	3
Nickel*	mg/L	0.001	0.001	0.001	0.001	1
Strontium*	mg/L	2.6	3.1	2.8	2.6	3
Zinc*	mg/L	0.009	0.009	0.009	0.009	1
Iron*	mg/L	0.44	2.7	1.5	1.4	4

*Notes: * = dissolved metal, EC = electrical conductivity, TDS = total dissolved solids.*

i Field parameters

The average pH measurements are similar and are circum neutral at all formations, with the exception of the Geera Clay which was very slightly alkaline (average 7.73 pH units). Overall the lowest pH measurements are observed in the Loxton-Parilla Sands (average 6.9 pH units). The pH is considered acceptable for human drinking water, livestock drinking water and irrigation (ANZECC/ARMCAZ 2000 and NHMRC 2011).

Groundwater salinity, represented by electrical conductivity (EC) is variable and a decreasing trend with depth is observed. The salinity of the Shepparton Formation and Loxton-Parilla Sands are similar, and these formations have the highest EC measurements. The average EC measurement for the Shepparton Formation is 48 milliSiemens per centimetre (mS/cm), and is 56 mS/cm for the Loxton-Parilla Sands. The salinity measurements within the Shepparton Formation and Loxton-Parilla Formations arise through high evaporation rates concentrating salts in recharge zones, which are mobilised during recharge events and transported to this region (Jacobs 2015).

The EC of sea water is 53-60 mS/cm (Australian Water Resources Council 1998). An EC between 0 and 0.5 mS/cm is considered to be good drinking water for humans. Beef cattle and adult sheep can tolerate water with an EC up to 6 and 7 mS/cm. Water below 3 mS/cm is generally suitable for irrigation. Water with an EC up to between 5 to 12 mS/cm can be used for irrigation, however this requires consideration of the crop and plant salt tolerance (ANZECC/NRMHC 2011). The average EC values for the Shepparton and Loxton-Parilla Sands precludes this water for human drinking water, livestock drinking water and irrigation (ANZECC/ARMCAZ 2000 and NHMRC 2011). There may be areas where the EC is fresher and thus suitable for stock and domestic use.

The EC is lower in the Olney Formation with an average EC of 9.3 mS/cm. The Geera clay EC is comparable to the EC of the Olney Formation, the average EC result was 10.3 mS/cm, and this is likely a result of sampling at the edge of the Geera Clay where the potential for mixing is highest.

Suspended solids measurements were variable amongst the formations and the highest result was observed in the Loxton-Parilla Sands (403 mg/L). Measurements of suspended solids were also elevated in the Geera Clay (195 mg/L), however this result is from two sampling events only. The suspended solids measurements were lower (101 mg/L) in the Loxton-Parilla Sands.

ii Major cations and anions

Jacobs (2015) report that groundwater sampled from all formations was rich in major ions and was Na-Cl dominant, although the Loxton-Parilla Sands and Shepparton Formation have moderate magnesium dominance and the Shepparton Formation also has moderate sulfate dominance. The deeper, Olney Formation, is consistently low in sulphate and has elevated bicarbonate compared to other groundwaters.

Major ion concentrations from the Loxton-Parilla Sands and the Shepparton Formation are typically one order of magnitude higher than the other deeper formations, consistent with the elevated salinity in these uppermost formations.

The Olney Formation groundwater has the lowest salinities and their signature presents as a subdued sodium chloride-dominated groundwater composition in comparison to the overlying formations. Sulfate concentrations are particularly (and characteristically) low compared to the shallower aquifers.

iii Dissolved metals

Dissolved metal measurements are typically low amongst the formations, especially within the few samples collected from the basement. The following dissolved metals results were similar and elevated at the shallower Formations (Shepparton and Loxton-Parilla Sands): aluminium, strontium and iron, while manganese was high in the Shepparton Formation only (mean result of 78 mg/L).

A reduced dissolved metal sampling suite was applied to the Olney Formation, however aluminium, iron and manganese measurements were an order of magnitude lower than the Shepparton Formation.

The dissolved strontium and iron measurements in the Geera Clay were similar to the upper Formations (Shepparton and Loxton-Parilla Sands), however the aluminium result was lower. Although still low the arsenic, chromium, copper and nickel measurements were an order of magnitude higher than the upper Formations.

iv Radionuclide monitoring

Land and Water Consulting conducted a pre-mining groundwater radionuclide monitoring event in June 2014 to provide a baseline background understanding of radionuclide distribution. Groundwater and soil samples were collected within and up gradient of both the West Balranald and Nepean deposits, as well as down hydraulic gradient of the West Balranald deposit and in the vicinity of the Nepean deposit.

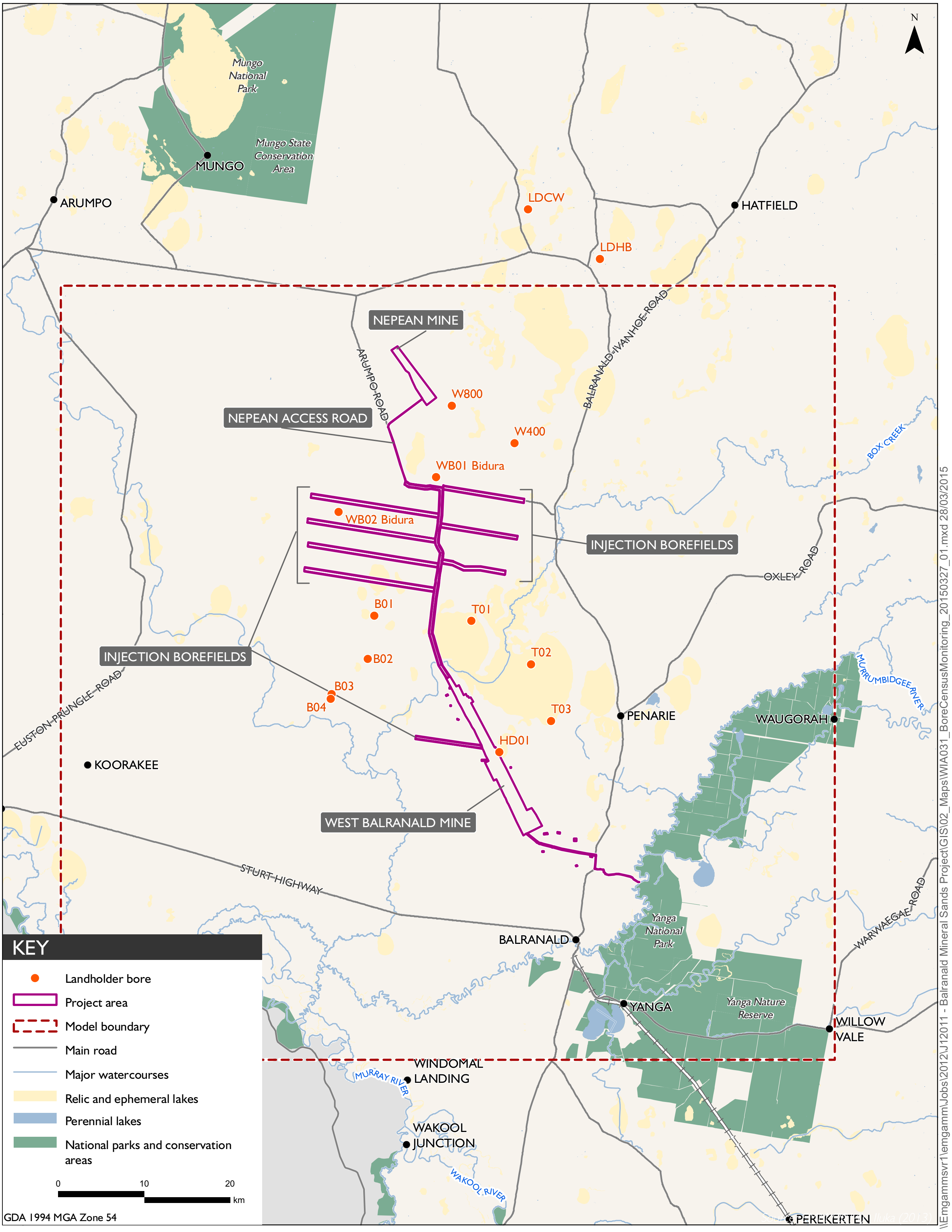
During the pre-mining groundwater radionuclide monitoring one water sample (from WB20) exceeded the Australian Drinking Water Guideline criteria threshold and three samples were in the 'watching brief' threshold. Monitoring bore WB20 has historically reported naturally elevated uranium results; WB20 is within the West Balranald deposit. The bore intersects both the Shepparton Formation and the Loxton-Parilla Sands. None of the mine materials were classified as 'radioactive ore' or as 'radioactive substance.'

Radium 228 results were typically elevated in all water sampled, and were somewhat higher in waters sampled down hydraulic gradient of the West Balranald deposit. Lead 210 exceeded the conservative screening criteria (World Health Organisation levels), although levels are not considered to be high. Refer to the Radiation Risk Assessment (Iluka 2015, Appendix S of the EIS report) for further details.

6.6 Bore census

Land and Water Consulting (2014) undertook a groundwater use study within the project area (Appendix A of this report). This comprised interviewing available landholders on the status and use of any bores on their property. The majority of the registered landholder bores in the project area are registered for stock or domestic use. In most cases, bore water is the only source of stock water with the exception of intermittent surface water runoff.

All the bores utilised by the landholders interviewed (16 bores) are used for stock water, with one bore used for stock and domestic (Land and Water Consulting 2014). Ten of the landholder bores identified were screened in the lower Olney Formation, five bores were screened in the Shepparton Formation and the screen depth of one bore was unknown. Artesian conditions were observed in four bores screened in the Olney Formation. Salinity conditions were variable (ranging between 350 mg/L to 5,300 mg/L TDS) and were comparable between the bores intersecting the Olney Formation and the Shepparton Formation. The bores were mostly low yielding, typically around 0.4 L/s.



EMM
ILUKA

Bore census monitoring locations

Balranald Mineral Sands Project
Water Assessment
Figure 6.16

7 Surface water

7.1 Regional setting

The southern end of the West Balranald deposit is approximately 10 km to the north of the Murrumbidgee River. The confluence of the Murrumbidgee and the Murray rivers is approximately 30 km to the south-west of the deposit. The proximity of the West Balranald deposit to the Murrumbidgee and Murray rivers necessitates the water assessment considers these significant water bodies. The Lachlan River meets the Murrumbidgee River approximately 42 km north-east of Balranald (at the Great Cumbung Swamp), although it contributes flows only periodically in very high flow events.

7.1.1 Riparian environments

The Great Cumbung Swamp Area, a 16,000 ha swamp, is listed in the *Directory of Important Wetlands in Australia* (Department of the Environment, Water, Heritage and the Arts 2001). The Swamp Area is a series of dry lakes and associated lunettes that supports large areas of reeds and riverine woodland species on the surrounding floodplain. The reed bed, the core of the Great Cumbung Swamp, provides drought refuge and supports a large number of waterbirds, some of which are considered vulnerable at State level (MDBA 2012). The Great Cumbung Swamp joins the Murrumbidgee River to the south and becomes part of the Lower Murrumbidgee (Lowbidgee) Floodplain.

The Lowbidgee floodplain, on the lower reaches of the Murrumbidgee River catchment to the south-west of the Cumbung Swamp, comprises permanent and intermittent rivers, streams and creeks as well as saline to brackish lakes and marshes. These surface water features support freshwater marshes and ponds, and shrub and tree dominated wetlands (Hardwick and Maqiure 2012). The wetlands support some of the largest water bird breeding colonies in Australia. The Lowbidgee floodplain is listed as a Nationally Important Wetland in the Directory of Important Wetlands of Australia; subsequently it is subject to a number of national and international agreements to protect its ecological assets.

7.1.2 Surface water quality

The Murrumbidgee and Murray Rivers in the vicinity of the project area contain fresh water supplies that are frequently used for purposes such as town water supply and irrigation. NOW reports that the recent salinity of the Murrumbidgee River at the Balranald weir is fresh, with an average EC of 0.2 mS/cm (in February 2015). Background water quality data is available for the Lachlan, Murrumbidgee and Murray rivers; however this is not relevant to the Balranald Project as no water will be discharged to these rivers.

7.2 Surface water within the project area

7.2.1 Surface water features and mine infrastructure

The relationship between mine infrastructure in the project area and local surface water features is as follows:

- the Nepean access road passes through the western edge of Tin Tin Lake;
- a small section of the eastern side of the West Balranald mine is adjacent to the south western edge of Muckee Lake;

- the southern end of the injection borefield area where it extends to within approximately 500 m of the north-western edge of Tin Tin Lake and 3 km of Box Creek; and
- a small part of the project area associated with the water supply pipeline that extends to the Murrumbidgee River.

7.2.2 Surface water flow

Box Creek flow characteristics have been determined based on observations with landholders and are reported in WRM (2015) as follows:

- there was sufficient flow in Box Creek to cause Pitarpunga and Tin Tin Lakes to fill and overflow in 1956 with flow originating from flooding in the Lachlan River;
- flooding was observed several times in the 1970s, although it is unclear if this was as severe as the 1956 flood, or if the lakes filled and overflowed; and
- flooding occurred in the project area and surrounds in 2010/2011, however it is thought this was due to heavy, localised rainfall in the Box Creek catchment area rather than overflow from the Lachlan River (via Merrowie and Middle Creeks). There was insufficient volume to cause Tin Tin and Pitarpunga Lakes to fill and overflow into Box Creek in the vicinity of the project area.

The 2010/2011 flood event recorded an estimated peak discharge in Box Creek downstream of the Balranald Ivanhoe Road of 150 m^3/s. This was the result of a two day rainfall event that exceeded 1 in 100 annual exceedance probability (AEP) (WRM 2015; Appendix H, EIS report). The AEP is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year (BoM 2014).

Although not mentioned by landholders, the Lachlan River as flooded in 1990 as detailed in the *Lachlan River – Hillston Floodplain Management Plan Lake Brewster to Whealbah* (WRM 2015). The 1990 flood event in the Lachlan River had an AEP of between 1 in 60 to 1 in 70, and a flow rate of 3,000 ML/day (WRM 2015). This flood did not result in sufficient flows in Box Creek, and Pitarpunga and Tin Tin Lakes, despite high flows in Middle and Merrowie Creeks. The annual exceedance probability refers to the probability that a given rainfall total will accumulate over a given duration will be exceeded in any one year (BoM 2014). Peak flow rates in the Lachlan River during the 1990 and 1956 flood events were comparable, however the duration of the 1956 event was approximately three months longer (totalling nine months) than the later flood. This suggests that for flooding in the project area to occur, flooding of the Lachlan River in excess of six months is required.

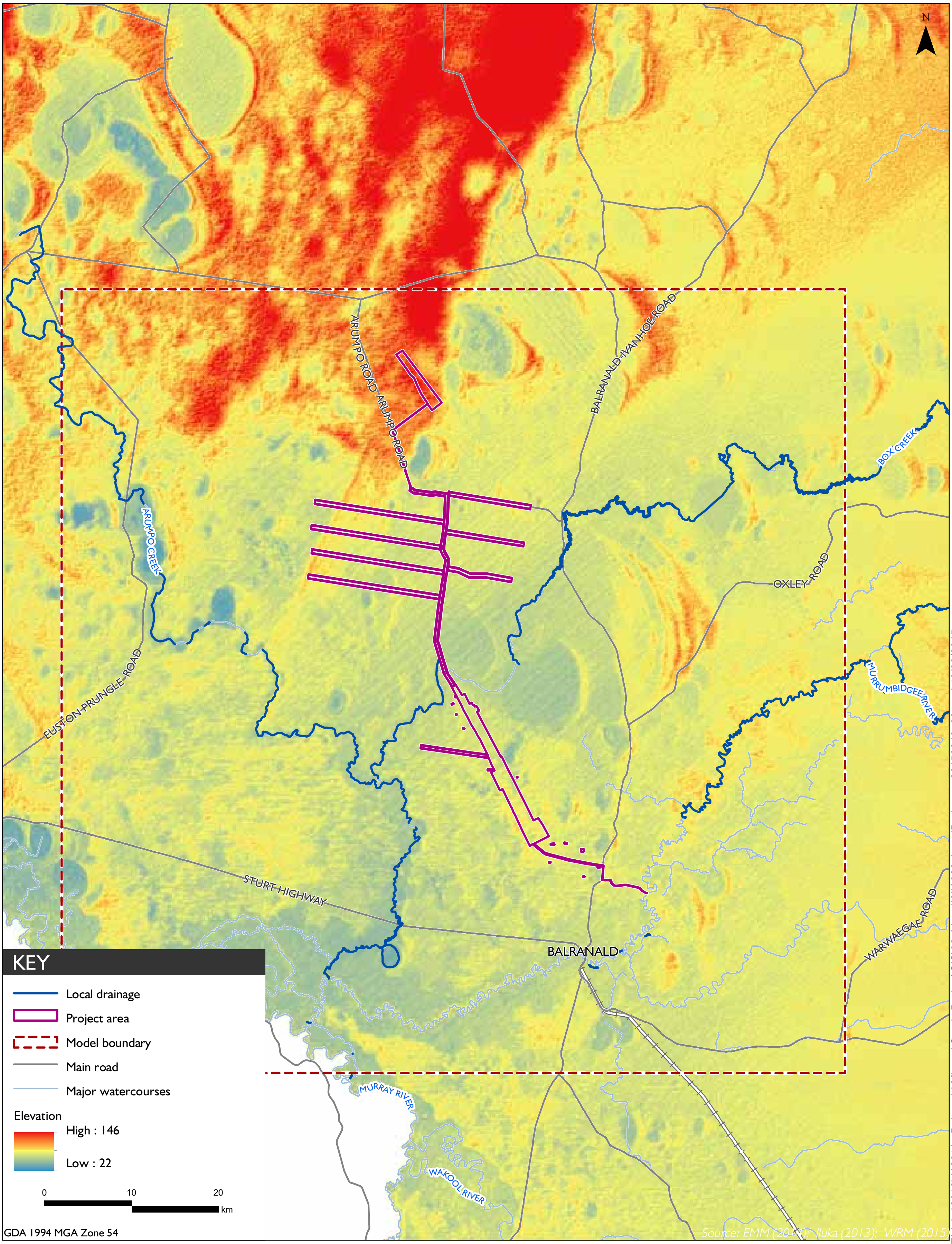
7.2.3 Site drainage

Due to the dry climate, flat landscape, and large areas of permeable soils, there is little locally derived runoff in the project area and no permanent surface water sources. Extremely heavy local rainfall events are capable of filling local depressions, including dry relic beds and creating temporary flow in drainage features, such as Box Creek.

To the far north-east of the project area, Merrowie and Middle creeks, overflow distributaries of the Lachlan River, drain into Box Creek. However only if the flood levels are high enough and sustained for a long enough period will flood water from Middle and Merrowie Creeks drain into Box Creek. Muckee, Pitarpunga and Tin Tin Lakes are on the eastern side of the project area, and Box Creek drains into these lakes. If these lake become full (they are typically dry) flow will drain into Box Creek downstream of the lakes, to the west of the project area. After merging with Arumpo Creek, Box Creek flows into the Murrumbidgee River, approximately 30 km south-west of the project area.

In the vicinity of the project area, Box Creek has no defined beds or channels, and is typically indistinguishable from the surrounding salt bush flats (WRM 2015). The vast majority of the Box Creek catchment area drains into dry lakes or depressions; very little to no local runoff enters Box Creek. Under pre mining conditions it is likely that any runoff from the project area would drain via shallow overland sheet flow towards dry lakes or minor depressions (WRM 2015).

Run off in the vicinity of West Balranald mine typically drains north into Muckee, Pitarpunga and Tin Tin Lakes, which when full drains into Box Creek. The Nepean mine is located on a ridge of slightly elevated ground that forms the western boundary of the Box Creek catchment area. Run off in the vicinity of the Nepean mine flows into a dry lake at the eastern toe of the ridge, overflow then flows south through the edge of the proposed injection borefield towards Tin Tin Lake (WRM 2015) (Figure 7.1).



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Local drainage

Balranald Mineral Sands Project
Water Assessment
Figure 7.1

8 Geology

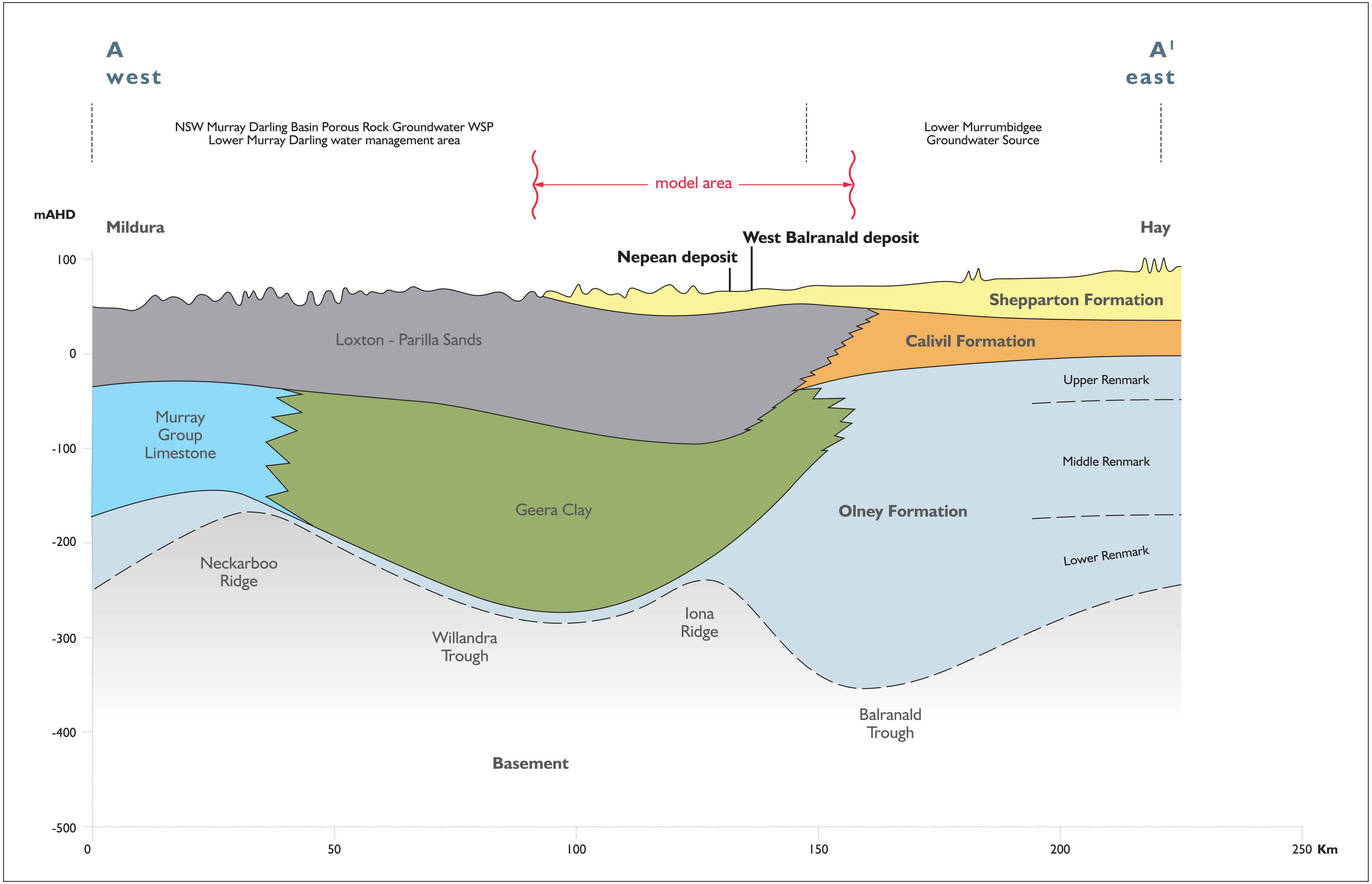
8.1 Stratigraphy

The Murray Basin stratigraphy is shown in Figure 8.1. At the project area the Shepparton Formation and Loxton-Parilla Sands is underlain by the Geera Clay and Olney Formation. Basement consists of rocks associated with the Palaeozoic Lachlan Fold Belt. The Coonambidgal Formation is a Quaternary unit associated with late stage alluvial activity and is restricted to areas in the immediate vicinity of the Murray and Murrumbidgee Rivers.

The project and regional geology, in a west – east cross section is shown in Figure 8.2. The regional cross section does not specify the detail of the Balranald Project deposits.

<table>
<tr><th>Period</th><th>Epoch</th><th>Group</th><th>Formation</th></tr>
<tr><td rowspan="2">Quaternary</td><td rowspan="2"></td><td rowspan="2"></td><td>Coonambidgal</td></tr>
<tr><td>Shepparton Formation</td></tr>
<tr><td rowspan="9">Tertiary</td><td rowspan="3">Pliocene</td><td rowspan="3"></td><td>Loxton-Parilla Sands</td></tr>
<tr><td>Bookpurnong beds</td></tr>
<tr><td>Calivil Formation</td></tr>
<tr><td rowspan="4">Miocene - Oligocene</td><td rowspan="4">Murray Group</td><td>Geera Clay</td></tr>
<tr><td>Murray Group Limestones</td></tr>
<tr><td>Winnambool Formation</td></tr>
<tr><td>Ettrick Formation</td></tr>
<tr><td>Eocene</td><td rowspan="2">Renmark Group</td><td>Olney Formation</td></tr>
<tr><td>Paleocene</td><td>Warina Sand</td></tr>
</table>

Figure 8.1 Murray Basin stratigraphy



Conceptual geology of the Murray Basin

Balranald Miner Sands Project
Water Assessment

Figure 8.2

8.2 Basement controls

The Palaeozoic rocks of the Lachlan Fold Belt underlie the Murray Basin sediments and form the basement to the basin. The basement contains structures such as ridges and troughs that have influenced deposition of the sediments, and therefore also influence the hydrogeology and hydrology of the Murray Basin. The Ivanhoe Block is a north-northeast to south-westerly treading faulted and uplifted (throws of greater than 100 m) concealed basement ridge complex to the north-west of the project area (Kellett 1989). The Olney Formation is truncated by the Iona Ridge, and all overlying formations are thinned by this basement ridge.

At the southern end of the Ivanhoe Block is the Tyrrell Fault Block, which is approximately 10 km south west of the project area. To the east of the Tyrrell Fault lies the Tyrrell Trough. From a low at the Tyrrell Fault, the basement rises eastward towards the West Balranald deposit and Pitarpunga Granite High, which aligns roughly with the Iona Ridge to the north. East of the Iona Ridge and Pitarpunga Granite High is the Balranald Trough (Jacobs 2015). The Balranald Trough represents the Cainozoic depocentre for the Western Riverine Plain. The Balranald Trough is a closed sub-basin, completely enclosed by rising basement.

URS (2012) suggest the West Balranald and Nepean deposits are located in the Balranald Trough. However, comparison of the site locations with structural information provided by Kellett (1991 and 1994) indicates that the Nepean deposit is located on the southern end of the Iona Ridge and the West Balranald deposit is located on the eastern side of the Pitarpunga Granite High.

8.3 Murray Basin formations

8.3.1 Shepparton Formation

The late Pliocene to Pleistocene Shepparton Formation outcrops across the project area. The Shepparton Formation is a complex assemblage of fluvio-lacustrine, unconsolidated to poorly consolidated sediments comprising red and grey clays and silts, with lenses of sand and gravel (Geoscience Australia 2014). The proportion of sand is highly variable and ranges between about 20-30% (NOW 2009). Iluka (2013) undertook a study of the Shepparton Formation in the broader area of the West Balranald and Nepean deposits and concluded that clay rich layers exist throughout the formation, and while this is not a universally continuous interval, a 2 - 3 m thick clay layer is observed in the base of many of Iluka's bore logs.

URS (2012) describes the thickness of the Shepparton Formation as ranging from 20 to 40 m thick in the vicinity of the West Balranald deposit, decreasing to around 25 m at Nepean. The unit thickens to the east and does not exist on the Iona Ridge to the west.

8.3.2 Pliocene Sands

The Pliocene Sands are a composite of two sand-dominated sequences; the fluvial Calivil Formation of the Riverine Plain and the marginal marine Loxton-Parilla Sands of the Riverine Plain and Mallee Province (Lewis *et al* 2008). To the east of the project area, the Calivil Formation grades laterally into the Lower-Parilla Sands, which becomes the dominant Pliocene Sands aquifer.

i Loxton-Parilla Sands Formation

The Loxton-Parilla Sands forms a thick sequence of marine sands which were deposited during two marine regressions. The Loxton-Parilla Sands consist of approximately 50 - 80 m of fine to medium, unconsolidated to weakly cemented, well sorted quartz sand with minor clay and silt. Clay layers are indicated to be less prevalent in the Loxton-Parilla Sands than in the overlying Shepparton Formation. Iluka (2009) reports a geological model for the Loxton-Parilla Sands that divides into repeating cycles of a facies stack that moves upwards from offshore to lower shore to surf zone to foreshore facies.

The Loxton-Parilla Sands were deposited during an extensive regressive period of marine and fluvial environments, which has resulted in the deposition of a layer of quartz sand over the Murray Basin. The Loxton-Parilla Sands rulite rich deposits are the mineralised target zones for mining. The heavy mineral deposits are associated with periods of multiple sea level fluctuations deposited during the early Pliocene (NOW 2011). The north-south boundary of the Loxton-Parilla Sands represents the second major Tertiary marine transgression.

8.3.3 Geera Clay Formation

The Geera Clay represents the maximum extent of the Late Oligocene-Miocene marine transgression into the Murray Basin. This unit is a massive estuarine clay and muds that comprises major carbonaceous silts and minor carbonates. The average thickness of the Geera Clay at the project area is around 90 m and the clay is dark greenish grey to black. The boundary of the Geera Clay represents the limit of a major Tertiary marine transgression; further east and north-east of the project area the Geera Clay grades laterally into the Olney Formation.

The Balranald 1:250,000 scale hydrogeological map (Australian Geological Survey Organisation 1994) illustrates that the eastern boundary of the Geera Clay cuts through the southern end of the West Balranald deposit. Contrary to this, (Brown and Stephenson 1991) provide isopachs for the Geera Clay that indicate it is present for the entire length of the West Balranald deposit with a thickness between 50 - 100 m, and extends further east than indicated by the hydrogeological map (Kellet 1991).

Iluka carried out drilling along the length of the West Balranald deposit and confirmed the presence of the Geera Clay along the strike of the proposed mine, including the area at the southern end where the hydrogeological map (Kellett 1994) indicates that Geera Clay is not present (AquaGeo, pers. comm. in Jacobs 2015). On that basis the isopachs presented by (Brown and Stephenson 1991) combined with the recent drilling carried out by Iluka have been used as the conceptual basis for the distribution of the Geera Clay indicating its presence along the West Balranald deposit and extending some distance to the east.

8.3.4 Olney Formation

The Renmark Group has historically been referred to as the Lower, Middle and Upper Renmark Group (Kellett 1994), however this subdivision is a hydrostatigraphic grouping and has no formal stratigraphic meaning. The Renmark Group terminology is most commonly used to describe deep Murray Basin sediment further east (ie within the Lower Murrumbidgee). Site drilling investigations have concluded that the correct stratigraphic naming for this unit is the Olney Formation within the Renmark Group, as per (Brown and Stephenson 1991). The difference is shown in Figure 8.3, notably the Olney Group is not subdivided.

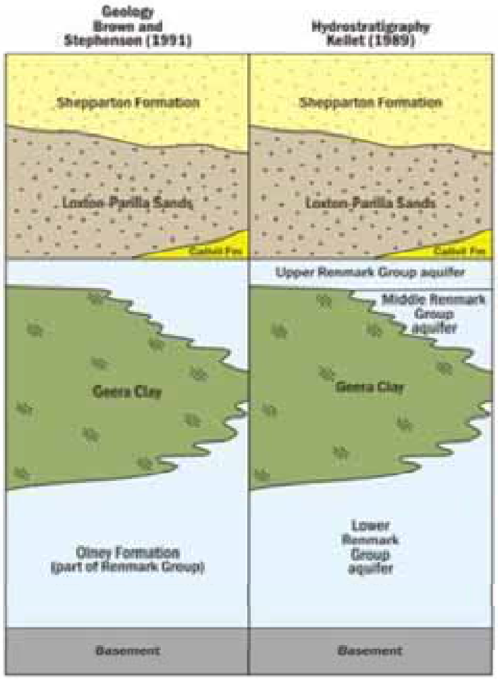


Figure 8.3 Comparison of the geological models of the study area

The Olney Formation overlies the basement and comprising fluvial clay, silt, coarse lithic sand and minor, fine gravel with ubiquitous carbonaceous/lignitic deposits. This unit can be up to 400 m thick in the western Riverine Plain, at the project area the thickness is approximately 100 m. Sediments within this unit to the west of the project area become weakly cemented and are therefore included in the MDB Porous Rock WSP (NSW Office of Water 2011).

The base of the Olney Formation comprises sand, coarse and fine grained gravels, and silty, sandy clay; it is not present across the whole project area (Evans and Kellet 1989). Moving upwards finer grained silty sands that were deposited in a low energy environment are observed. The top of the Olney Formation comprises predominantly fine to medium grained sand with minor silt interbeds, and which is generally micaceous and carbonaceous, but not as rich in lignitic material as deeper Olney Formation sediments (URS 2012; Evans 2014). The uppermost Olney Group is comparable and interchangeable with the Lower Loxton-Parilla Sands Formation.

8.3.5 West Balranald deposit

At the West Balranald deposit, the Shepparton Formation consists of a thick layer of unconsolidated to poorly consolidated clays and silty clays with inter-bedded sand lenses. The strata unit is highly variable across the West Balranald deposit and drilling has defined two dense clay layers (locally up to 4 - 6 m thick). Moderately to strongly indurated iron cemented rock layers are also present within the sand-dominant lenses between the clay layers. The thickness of the unit varies from approximately 19 m at the northern end to more than 36 m through central and southern areas of the deposit. The strata strikes in a north west – south east direction.

The upper Loxton-Parilla Sands marine sequence (Loxton-Parilla Sands 1) varies in thickness along the strike of the deposit from 16 - 20 m in the north to more than 60 m at the southern end. The sequence typically consists of three upper beach facies: foreshore, surf zone and lower shore. A marine transgression marks the boundary between the Loxton-Parilla Sands 1 and the lower (older) marine sequence Loxton-Parilla Sands 2. At the southern end of the West Balranald deposit there is a lagoonal deposit consisting of black carbonaceous clays and sands.

The lower marine sequence (Loxton-Parilla Sands 2) is host to the West Balranald deposit and consists of three facies (foreshore, surf zone and lower shore), with the mineral sands deposit lying within the foreshore facies of Loxton-Parilla Sands 2. These sands comprise well to very well sorted medium grained sands. Below the Loxton-Parilla Sands 2 at the West Balranald deposit is the Geera Clay unit. The boundary between the Geera Clay and the overlying Loxton-Parilla Sands is difficult to identify in drill cuttings. Iluka field staff have suggested that there is a transition layer that interfaces between the two units, suggesting some form of reworking or a regressive unit (Evans 2014). Explorative drilling along the length of the West Balranald deposit confirmed the presence of Geera Clay underlying the Loxton-Parilla Sands 2 along the strike of the West Balranald mine.

i Stratigraphic conceptualisation of West Balranald

A review of materials and consideration of the sequence stratigraphic conceptual model for the Loxton-Parilla Sands sequence was undertaken by Evans (2014) to assess whether the uppermost Olney Formation has either not been identified by Iluka or has been assigned to a different layer in their conceptual stratigraphic model of the area. Given Kellett's conceptual stratigraphic model for the area, there is conjecture as to where the base of the offshore facies of lower Loxton-Parilla Sands exists.

Kellett's evidence of both a weathering break consistent with a Late Miocene depositional hiatus, and palynological data assigning a thick sequence of sediment above the Geera Clay to the Late Miocene is compelling evidence that an upper Olney Group unit does exist in the broader region. Descriptions of both the lower Loxton-Parilla Sands and the upper Olney Group are similar. It would appear that the only difference between the two is the finer grained nature of the offshore facies in the Iluka drillholes and the fact that the grainsize is constant (monotonous) over a large thickness. There is little evidence of any interbedding of different grainsize in the Iluka cuttings as might be expected within Olney Formation sediments given its environment of deposition.

Where borehole information is available the sediments in question are underlain by Geera Clay. Thus there is a consistent relationship between the coarser materials at the top of the overall sedimentary sequence, the fine-grained layer of Geera Clay and the deeper Olney Formation unit. Therefore regardless of the age of the unit immediately overlying the Geera Clay the relationship does not change, and this unit can be unambiguously included in any conceptualisation of groundwater flow without recourse to assigning a stratigraphic name. In addition, the MDBC combined the upper Olney Formation with the overlying Pliocene sands aquifer because of the reasonable degree of hydraulic continuity for reporting purposes (Lewis *et al* 2008).

8.3.6 Nepean deposit

The Nepean deposit has the same stratigraphic units and strike as the West Balranald deposit, with differing local features. The Shepparton Formation across the extent of the Nepean deposit consists of an upper layer which contains the consistently high clay contents of the typical Shepparton Formation. Underlying this at the northern and southern ends of the deposit are additional fluvio-lacustrine sediments of the Shepparton Formation. These additional units have highly variable clay contents relative to what is typically seen in the region. These sediments are interpreted to be derived from material eroded from the uplifted Iona Ridge and a broad paleo-channel immediately adjacent to the southern edge of the Iona Ridge. In the south, this unit is 80 m thick including up to 60 m of the highly variable sediments beneath the typical Shepparton Formation sediments.

Within the Loxton-Parilla Sands unit, unlike the West Balranald deposit, the contact between the Loxton-Parilla Sands 2 and the overlying Loxton-Parilla Sands 1 regressive sequence is impossible to delineate as the Loxton-Parilla Sands 1 sequence is incomplete. The Loxton-Parilla Sands 1 foreshore facies sediments sit unconformably above Loxton-Parilla Sands 2 foreshore sediments. Similar to West Balranald the lower marine sequence (Loxton-Parilla Sands 2) is host to the Nepean deposit and is also located within the foreshore facies, often immediately above the poorly sorted coarser surf zone sands. The foreshore sands comprise well to very well sorted medium grained sands. Below the Loxton-Parilla Sands 2 at Nepean is the Geera Clay unit, however in parts the Olney Formation underlies the lower Loxton-Parilla Sands and overlies the Geera Clay.

9 Groundwater

9.1 Hydrogeological units

9.1.1 Shepparton Formation

The Shepparton Formation is a composite aquifer-aquitard system comprising unconsolidated clays, sandy clays and fine grained sand. The Shepparton Formation hosts the superficial water table in most of the project area, although the bulk of the Shepparton Formation at the Nepean deposit is unsaturated (Jacobs 2015; Appendix I, EIS report). The saturated aquifer thickness of the Shepparton Formation aquifer at the West Balranald deposit ranges from 10 to 25 m in thickness from north to south.

The Shepparton Formation is relatively heterogeneous compared to the underlying Tertiary sequences. Within this unit there are fine to coarse channel sands that are poorly graded and sub rounded, and these allow partial water flow as they are discontinuous in nature. High bore yields from this aquifer are dependent on the intersection of coarse sand channels. Groundwater yield from clay rich areas are typically much lower. Clay lenses may constrain both vertical and horizontal flow. Overall groundwater flow is anisotropic with the highest possible flow observed along bands of higher sand content.

The Shepparton Formation is unconfined, with some local areas of confinement associated with thicker clay lenses. Jacobs (2015) note there is a shallow perched watertable at the West Balranald deposit within the Shepparton Formation. A stiff clay lens (4-6 m thick) at the base of the Shepparton Formation separates the groundwater within the Shepparton Formation from the groundwater within the Loxton-Parilla Sands at the West Balranald deposit. Iluka (2013) confirmed clay rich layers are not universally continuous. Hydraulic testing carried out by Iluka (2015) indicates the Shepparton Formation typically displays a poor hydraulic connection to the underlying Loxton-Parilla Sands, a consequence of clay layers at the base on the formation.

Within the project area, the Shepparton Formation does not produce significant volumes of groundwater due to the discontinuous nature of its sands.

9.1.2 Loxton-Parilla Sands Formation

The Loxton-Parilla Sands comprises well sorted quartz sand and sandstone, with minor clay, silt and pebble conglomerate. This unit is relatively conductive and can be unconfined, semi-confined and confined based on the thickness of the clay in the base of the overlying Shepparton. The Loxton-Parilla Sands is saturated at the West Balranald deposit and partially saturated at Nepean deposit.

Jacobs (2015) divide the Loxton-Parilla Sands into repeating cycles of a facies stack moving upwards from offshore, to lower shore, to surf zone and then foreshore facies. These different depositional zones have varying hydraulic conductivities. At the West Balranald deposit the surf zone has the highest hydraulic conductivity (15 – 25 m/d) and can be several meters thick, while the offshore facies, consisting of finer units, are conceptualised as a lower permeability layer (hydraulic conductivity between 1 – 3 m/d). The other facies have hydraulic properties between these two extremities, and estimates of bulk horizontal hydraulic conductivity range between 2 m/d and 5 m/d.

9.1.3 Geera Clay Formation

The Geera Clay is a massive esturine clay (with silt), that has a very low permeability and is thus considered an aquitard. The Geera Clay laterally interfingers the Olney Formation below the eastern boundary of the Ivanhoe Block. This unit acts as a low permeability barrier to groundwater movement, both within the Olney Formation, and between the Loxton-Parilla Sands and Olney Formation, and has a profound effect on pressure distribution and water chemistry of the Olney Formation.

9.1.4 Olney Formation

The Olney Formation is the basal unit overlying the basement rocks of the Murray Basin. The Olney Formation consists of different grades and proportions of sand and gravel, and salinity concentrations vary considerably. The Olney Formation is confined where overlain by Geera Clay, in the west, however further east the formation is considered semi-confined where Calivil Formation and the Shepparton Formation are overlying (Kellett 1989). Above the Ivanhoe Block the mid Olney Formation is largely replaced by the Geera Clay and the lower Olney Formation is truncated by the basement rocks.

9.1.5 Lachlan Fold Belt basement

The Palaeozoic rocks of the Lachlan Fold Belt underlie the Murray Basin sediments and form the basement to the basin. The basement contains structures such as ridges and troughs that have influenced deposition of the sediments and therefore also influence the hydrogeology of the Murray Basin. It is noted that there are some minor groundwater chemistry influences in deep Murray Basin sediments that potentially are derived from the basement rock. However, this does not represent a significant volumetric flux across this boundary and therefore the boundary between the basement rocks of the Lachlan Fold Belt and the Murray Basin is considered to be a no flow boundary.

9.2 Groundwater recharge

Regionally, recharge to the Murray Basin sediments within NSW primarily occurs along the basin margins to the east, with groundwater then flowing in general westerly direction. Recharge from these easterly areas is largely a combination of river leakage (particularly during overbank flood events) and direct rainfall recharge. Localised recharge also occurs across the Murray Basin, particularly adjacent to major rivers and during high flow or flood events.

The Western Porous Rock SDL estimates recharge under native vegetation to be 0.1 mm/yr, while recharge under cleared, grazed and cropped land uses is estimated to be 7 mm/yr (MDBA 2012).

Locally in the project area there is limited recharge from direct rainfall, with most recharge to the area occurring via throughflow from the east. While minor direct rainfall recharge may occur locally, the low rainfall and high evaporation means this volume would be minimal and the presence of stratified low permeability clays and silts in the Shepparton Formation often results in this water entering perched systems. The Loxton-Parilla Sands and the Olney Formation is recharged via through flow from areas to the east of the project area.

In the Lower Murrumbidgee, the connectivity between the Murrumbidgee River and the underlying Murray Basin sediments is considered to be seasonably variable (MDBA 2012). Locally within the project area, Jacobs (2015) reports that the monitoring bores screening the Shepparton Formation and Loxton Parilla Sands in close proximity to the Murrumbidgee and Murray rivers have a lower groundwater table elevation than the river stage, and this therefore supports the concept that rivers in this local area are of loosing type.

9.3 Groundwater discharge

The Western Riverine Plain is the regional groundwater discharge zone for the eastern Murray Basin in NSW. The rising basement of the adjacent Ivanhoe Block causes aquifer thinning and along with the decrease in permeability associated with the Geera Clay aquitard the potential for upward vertical discharge is created (Kellet 1989).

The ancient and dry lakes in the vicinity of the West Balranald deposit (ie Tin Tin, Pitarpunga and Muckee lakes) with relatively lower topography and apparent surface salinisation form localised groundwater discharge features experiencing evaporative losses from the watertable.

9.4 Groundwater levels and flows

Groundwater flow at the project area is generally from east to west (see Figures in Appendix C of this report showing model generated contours in m AHD, developed by Jacobs (2015)). In the deeper Olney Formation groundwater flows to the west-northwest as a result of the basement structure in the area.

The Shepparton Formation hosts the water table for the majority of the study area, although the water table is within the Loxton-Parilla Sands at Nepean (Jacobs 2015).

There is a general decrease in the depth to water moving north and north-west from the Murray and Murrumbidgee rivers. The deepest water table depth is observed at the Nepean deposit (~48 m AHD), compared to the southern end of the West Balranald deposit (~53 m AHD) and the northern end of the West Balranald deposit (~48.8 m AHD).

9.5 Horizontal groundwater pressures

Consistent with topographic gradients, hydraulic gradients are very gentle in the central and western Murray Basin, and the broad flow direction in all aquifers is from east to west. In the project area, especially on the western side of the West Balranald deposit, the Shepparton Formation, Loxton-Parilla Sands and Olney Formation, the groundwater flow direction curves slightly northwest. In the shallow aquifers, a component of this northward flow may be attributed to leakage from the Murrumbidgee and Murray rivers. However, given this flow direction is most pronounced in the deeper Olney Formation it appears that basement structural features are likely the primary influence on groundwater flow direction.

The Ivanhoe Block impedes westerly through flow in the Riverine Plain as the regional aquifer either thins out over the rising basement block or is truncated by it. At the boundary of the Ivanhoe Block flow lines in the deeper aquifers are deflected north and south, and flow lines in the shallower aquifers on top of the ridge line are forced to converge. The Geera Clay also forms a hydraulic barrier to lateral flow to the middle Olney Formation, forcing westerly groundwater flow lines in the middle and upper Olney Formation to converge.

9.6 Vertical groundwater pressures

Kellett (1991 and 1994) indicates artesian conditions in the east of the study area and URS (2012) reports a measured head at West Balranald (WB3 P1 screening the Olney Formation, seen in Figure 6.2), 3.1 m above the ground surface. Iluka have identified two artesian Olney Formation landholder bores (HD1 and T02) (and suspect artesian conditions at T03), in the vicinity of the West Balranald deposit (Figure 6.16).

A strong vertical upwards gradient is pronounced at GW036866 (40 km north of Balranald) and GW036674 (68 km north of Balranald) where there is approximately 9 m and 5 m difference, respectively, in head pressure between the Loxton-Parilla Sands, and the Geera Clay and Olney Formation. It is likely that Geera Clay prevents artesian pressures in the Olney Formation from equilibrating with the shallower units. Upward vertical head gradients are consistent with the monitoring sites being at the discharge end of the Balranald trough and near where basement rises, causing upward groundwater flow.

Groundwater density differences associated with variable groundwater salinity may contribute to groundwater flow patterns. From the surface downwards salinity decreases. On the vertical scale the potentiometric heads at depth may represent higher equivalent fresh water head, although due to the relative homogeneity in groundwater salinity within hydrostatigraphic units it is likely that density does not have a significant impact on horizontal groundwater flows.

Although heads in the Shepparton Formation and Loxton-Parilla Sands are very similar, the results of pumping and injection trials indicate that the two units are poorly connected (Iluka 2015) and that significant head differences may be created when water is extracted from or injected into one or other of these units. This is likely to be associated with clay lens throughout the Shepparton Formation, particularly near its base, at the locations tested.

Comparison of heads in the Shepparton Formation and Loxton-Parilla Sands at NOW monitoring nested site GW036866 demonstrates the potential for a small upward gradient from the Loxton-Parilla Sands to the Shepparton Formation. This would tend to suggest that, away from the rivers, groundwater has the potential to move upward in the uppermost Formations. If this is the case then rainfall recharge cannot be significant, otherwise a downward gradient would be observed, and it is likely evapotranspiration may be intercepting seepage of rainfall that does penetrate to the water table.

9.7 Hydraulic conductivity

Hydraulic conductivity in the Shepparton Formation is highly variable, due to the heterogeneous nature of this formation with sand and clay lenses throughout. Continual lateral flow through formations is not common. A range of bulk hydraulic conductivity is observed in the Loxton-Parilla Sands and this is due to the differences in the hydraulic conductivities of the surf and offshore zones. The stratification in this unit is likely to cause considerable vertical anisotropy in hydraulic conductivity measurements.

Horizontal hydraulic conductivity in the Olney Formation decreases proportionally with distance from the eastern to western Riverine Plain (Kellet 1994). Typically the vertical hydraulic conductivity is at least an order of magnitude lower than horizontal hydraulic conductivity (Evans and Kellet 1989). The Geera Clay creates a steeper hydraulic gradient in the Olney Formation in response to the notable decrease in permeability.

9.8 Hydrochemistry

Groundwater quality within the Murray Basin is variable, and (Evans and Kellet 1989) report that one-third of the resource is highly saline with salts originating from the marine depositional environment. The cycle of low precipitation and high evaporation is also likely to enhance the salinity within the shallow geological formations. The high occurrence of groundwater abstraction and irrigation in the eastern areas of the Murray Basin has enhanced shallow and mid groundwater interaction, contributed to the mixing of saline waters and has remobilised salts from previously unsaturated zones. Ancient and dry lakes in the western areas are indicative of groundwater discharge zones and the formations are likely associated with saline conditions in the upper aquifers (Kellet 1989).

There is a general trend of salinity concentrations in all water bearing units to increase linearly from east to west within the Murray Basin, in line with groundwater flow direction. The salinity trend is proportional to distance along a flow line and this indicates mixing between groundwater and additional water inputs via stream leakage and rainfall infiltration. Groundwater mixing influences the water quality and reduces the degree of difference between water quality of different formations.

Site monitoring indicates that almost all groundwater samples have been significantly altered from the original rainfall source and local rainfall is generally not seen as a direct input to local groundwater composition, in accord with the very low recharge rates expected in the area (Jacobs 2015).

Water quality in the Shepparton Formation is highly variable and related to permeability, depth to water table and anthropogenic influences. There are local areas in the Shepparton Formation where pockets of fresher groundwater lenses are identified to be floating on regional saline groundwater (SKM 2013). Site salinity measurements support the conceptual model of the Olney Formation being separate from all overlying formations in the region. The salinity within the Geera Clay is comparable to the Olney Formation and sampling is thought to be conducted at the edge of the clay unit, where there is potential for mixing with the adjacent Olney Formation.

The Balranald 1:250,000 scale hydrogeological map (Australian Geological Survey Organisation 1994) indicates that moving west across the project area salinity in the Olney Formation increases. To the east of the project area salinity is vertically stratified and the most saline water (maximum TDS of 14,000 mg/L) is in the upper three units (Shepparton Formation, Loxton-Parilla Sands). Nearer to the Ivanhoe Block, and at the mineral deposits, the salinity profile becomes more comparable across all water bearing units and there is minimal distinction in groundwater salinity with increasing depth.

The current hydrogeochemical understanding does not indicate whether discrete alterations to the hydro geochemistry of the groundwater would have the potential to increase the annual radionuclide concentration based on hydrogeochemical interactions (phase partitioning, dissolution etc). Equally discrete and localised occurrences of increased activity may occur in the vicinity of operational extraction or injection bores associated with hydrogeochemical interactions (ie the formation and dissolution of ferric oxyhydroxides) (Land and Water Consulting 2014).

9.9 Ecosystems that rely on groundwater

9.9.1 High priority groundwater dependent ecosystems

NSW WSPs include schedules with lists of high priority GDEs which are required to be assessed using the minimal impact criteria outlined in the AIP. Groundwater WSPs (outlined in Section 2.2.1) were reviewed for reference to GDEs and only the Lower Murrumbidgee Groundwater WSP identified high potential groundwater dependent ecosystems. There were no high priority groundwater dependent ecosystems identified in the Western Murray Porous Rock Groundwater Source of the MDB Porous Rock WSP.

The Lower Murrumbidgee Groundwater Source, which covers the western Murrumbidgee floodplain to the north of Balranald, identified two high priority GDEs in the area:

- terrestrial vegetation along the floodplains and prior streams, these occur to the south and west of the Murrumbidgee River; and
- the Great Cumbung Swamp, which, as previously discussed, is a known ecological asset, which is about 42 km to the east of the West Balranald deposit.

9.9.2 Ecosystems that potentially rely on groundwater

The baseline investigations (SKM 2011), undertaken as part of the PFS, identified the occurrence of ecosystems that potentially rely on groundwater in the vicinity of the project area. This investigation mapped and characterised ecosystems that potentially rely on groundwater into to two broad categories:

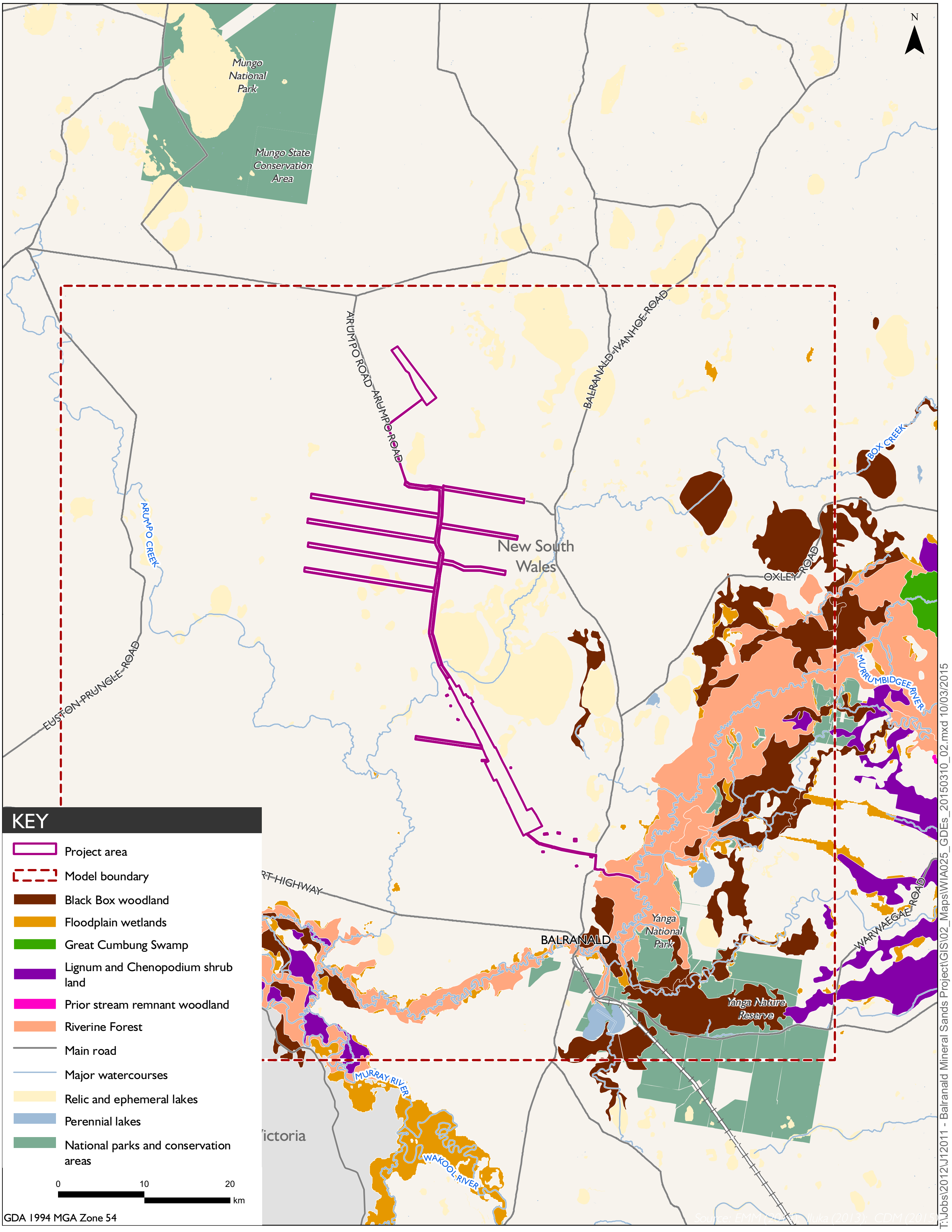
- wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments, as per the Lower Murrumbidgee Groundwater WSP for the vegetation to the south and west of the Murrumbidgee River; and
- vegetation (primarily Black Box woodland) outside the floodplain and permanent streams, in topographic depressions where the water table may be shallow enough and not too saline.

The study found that potential groundwater reliance associated with both of these environments is likely to be only partial, if at all. Groundwater use of vegetation in the region is influenced by two main factors: the depth of the water table and groundwater salinity. The ecosystems that potentially rely on groundwater associated with the floodplain environments include the high value River Red Gum forests and the Great Cumbung Swamp (which, as discussed previously, has already been identified as a high priority GDE by NOW). The Black Box woodlands away from the floodplain are less significant assets, in terms of their ecological value, they provide locally valuable shade and shelter for fauna (and stock) in a landscape sparsely populated by trees.

Rainfall and the periodic flooding of the Murrumbidgee River are more likely sources of water for vegetation (URS 2012). Thus floodplain environments are considered to have a low susceptibility to altered groundwater conditions due to the close presence of the Murrumbidgee River, a regular flow regulated water source. Further from floodplains, vegetation may have a greater reliance on groundwater as there are no permanent water sources in these environments.

In 2014, an investigation was undertaken to establish where the Black Box vegetation was accessing water from the Shepparton Formation (CDM Smith 2015; Appendix J, EIS report). This study found that rainfall and episodic surface water (irregular flooding and/or pooling from heavy rainfall) provided the dominant water source for Black Box, although there was some potential for these trees to use groundwater opportunistically to supplement their water needs. Previous studies have shown Black Box to be a hardy, resilient species capable of sustaining droughts and quite saline conditions (up to 60 mS/cm). The River Red Gum is more tolerate to water logging than the Black Box.

Figure 9.1 shows the spatial distribution of ecosystems that rely on groundwater, updated from the baseline investigation to include the areas of Black Box that were mapped in 2014 (prepared by CDM Smith 2015; Appendix J, EIS report).



GDE distribution

Balranald Mineral Sands Project

Water Assessment

Figure 9.1

10 Site conceptual model

10.1 Introduction

A site conceptual model is a simplified representation of the physical hydrologic and hydrogeological setting and understanding, including the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic frameworks, recharge to the system, groundwater flow dynamics and surface-groundwater interaction processes.

10.2 Surface water systems

The Murrumbidgee and Murray rivers located to the south-east and south of the Balranald Project are permanent water features that provide key water resources for large populations within the MDB, including town water, agriculture and the environment water.

Within the project area is Box Creek, an ephemeral watercourse that receives distributary flows from the Lachlan River. Box Creek has no defined beds and flow has only occurred in Box Creek on several occasions in the last 60 years. The vast majority of the Box Creek catchment area, which covers most of the project area, drains into dry lakes or depressions; significant and sustained rainfall is needed for Box Creek to flow (WRM 2015; Appendix H, EIS report).

Due to the climatic conditions (ie low rainfall and high evaporation), flat landscape, and large areas of permeable soils, there is little locally derived runoff in the project area and no permanent surface water sources.

10.3 Groundwater systems

The project area is within the alluvial sediments of the Murray Basin, which is a large closed groundwater basin with regional aquifer systems, confining layers and permeability barriers to groundwater flow. The basal unit overlying the basement rocks is the Olney Formation, comprising predominantly continental clay, silt and sand sediments. A marginal marine unit, the Geera Clay, interfingers through the middle and upper sequence. Overlying the Geera Clay and Olney Formation is the Loxton-Parilla Sands, a thick sequence of marine sands that contains the target mineral deposits. Overlying the Loxton-Parilla Sands is the Shepparton Formation, comprising fluio-lacustrine unconsolidated clays and silts.

Locally in the vicinity of the project area, there is limited recharge from direct rainfall and some limited recharge from surface water systems, with most recharge to the area occurring via throughflow from the east. Minor direct rainfall recharge may occur locally, but the low rainfall and high evaporation means this volume would be minimal and the presence of stratified low permeability clays and silts in the Shepparton Formation often results in this water entering perched systems. The Loxton-Parilla Sands and the Olney Formation is recharged via through flow from areas to the east of the project area.

The Balranald Project monitoring bores screening the Shepparton Formation and Loxton Parilla Sands in close proximity to the Murrumbidgee and Murray rivers have a lower groundwater table elevation than the river stage, and this therefore indicates the loosing nature of these rivers in this local area (Jacobs 2015).

Consistent with topographic gradients, hydraulic gradients are very gentle in the central and western Murray Basin, and the broad flow direction in all aquifers is from east to west. However, the basement structure influences the groundwater flow direction in the project area causing a slightly northwest trend in flow. This is most pronounced in the deeper Olney Formation, and is conceptualised in the cross section in Figure 10.1.

The horizontal hydraulic conductivity in both the Shepparton Formation and Loxton-Parilla Sands is variable, due to the depositional environments and volume of clay; continual lateral flow through Formations is not common.

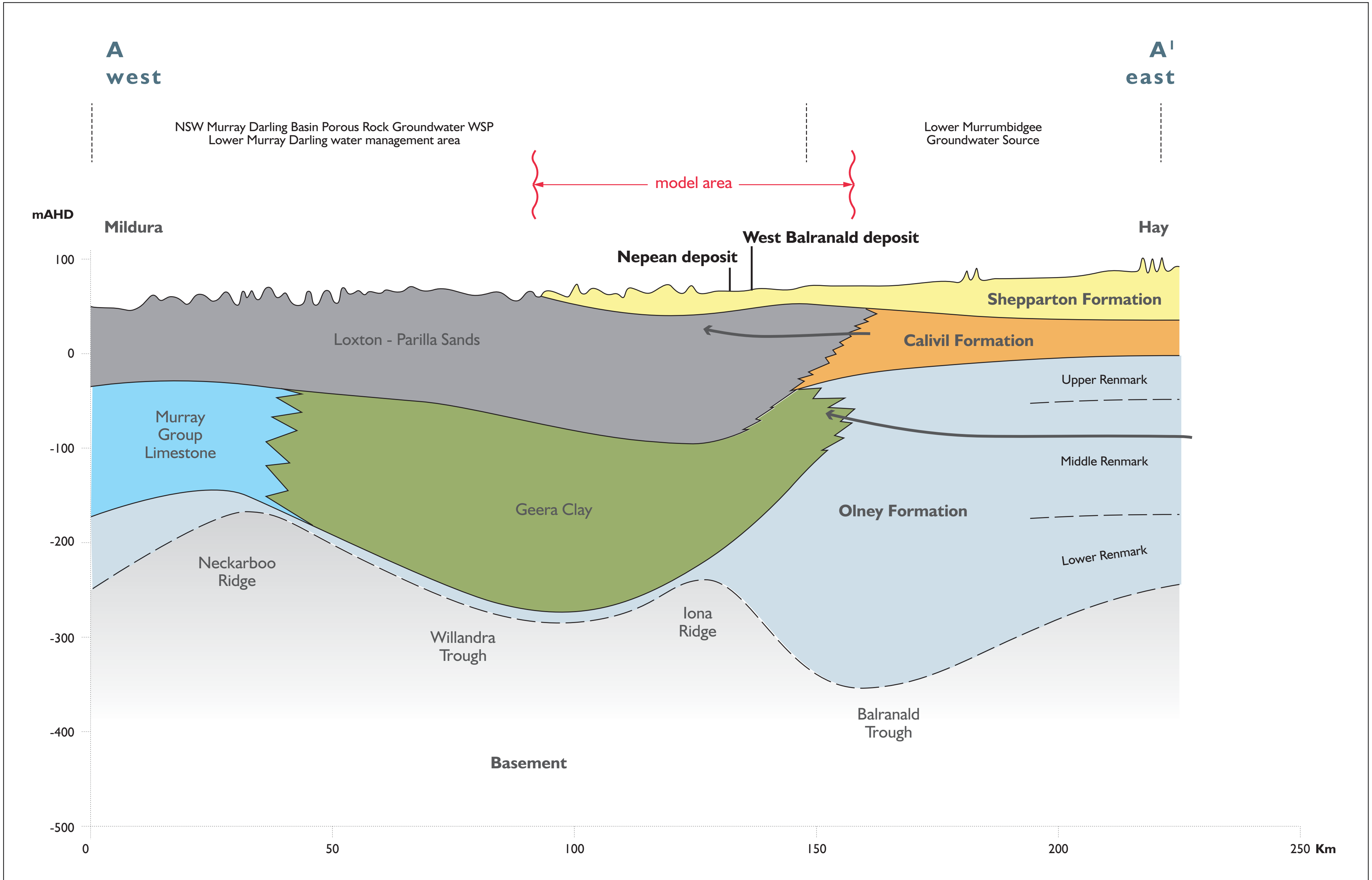
There is an upwards hydraulic gradient from the Olney Formation and Geera Clay to the Loxton-Parilla Sands and Shepparton Formation based on pressure head differences observed on site and reported in the literature. Heads in the Shepparton Formation and Loxton-Parilla Sands are mostly similar, although results of pumping and injection trials indicate that the two units are poorly connected (Iluka 2015) and therefore vertical flow is limited. Thus significant head differences may be created when water is extracted from or injected into one of these units. This is likely associated with clay lens at the base of the Shepparton Formation.

Groundwater quality within the Murray Basin is variable, with fresher water near the basin margins to the east. Quality becomes poorer in a westerly direction (downgradient). Within the project area water quality is typically equivalent to seawater in the Loxton-Parilla Sands and is moderately saline in the underlying Formations. Salts originate from the marine depositional environment, and are enhanced by low precipitation and high evaporation rates as well as long groundwater residence times. The water quality of the Shepparton Formation and Loxton-Parilla Sands is comparable, and is characterised by high salinity, neutral pH, low dissolved metals and Na-Cl type dominance.

10.4 Surface water and groundwater connectivity

The widespread absence of permanent surface water features across the project area means that groundwater and surface water connectivity can only be considered to the south, near the Murray and Murrumbidgee rivers.

Jacobs (2015) reports that the monitoring bores screening the Shepparton Formation and Loxton Parilla Sands in close proximity to the Murrumbidgee and Murray rivers have a lower groundwater table elevation than the river stage, and this therefore indicates the loosing nature of these rivers in this local area. The conceptualisation of the river as a losing system is supported by work undertaken by the MDBA (MDBA 2012) where the lower section of the Murrumbidgee River was classified as transitional between gaining and losing and the Murray River in this area being classified as losing. It is also supported by NOW monitoring bore hydrographs (GW036868 - located close to the Murrumbidgee River) which display a downward gradient between the Shepparton Formation and the Loxton Parilla Sands, and a response to major flooding in 2010/2011.



Conceptual groundwater flow direction in the Murray Basin

Balranald Miner Sands Project
Water Assessment

Figure 10.1

11 Hydrogeological numerical model

11.1 Model overview

A regional groundwater model (BAL2.0) was developed by Jacobs (2015) to simulate groundwater behaviour under the proposed mining conditions, including dewatering abstraction and reinjection conditions. This was used to inform the design of the dewatering systems and to quantify impacts to the groundwater regime. The model was built in the Groundwater Vistas 6 graphical user interface and was run using the MODFLOW-SURFACT 4 numerical modelling code. Local scale 'sub-models' were calibrated to site production and injection trials, and this was extrapolated across the full BAL2.0 model domain to calibrate the regional model.

The numerical model is constructed based on the data collected from extensive site investigations undertaken over a number of years, comprising data used to describe the hydrostratigraphy, recharge and discharge features and groundwater flow directions, and a sound conceptual hydrogeological model. The model domain includes the West Balranald and Nepean deposits, and part of the Murrumbidgee and Murray rivers, and measures 90 km east-west and 90 km north-south.

The model has been established as a Class 2 model as per the Australian modelling guidelines (refer to Section 2.5.1) and has been designed to consider the hydrogeological impacts of the Balranald Project.

11.1.1 Model objectives

The specific objectives of the groundwater model are to:

- determine indicative dewatering rates necessary to undertake a dry mining operation at both West Balranald and Nepean mines;
- optimise a dewatering strategy using operational constraints provided by Iluka;
- determine the area required to operate an off-path injection borefield such that groundwater produced from dewatering activities can be disposed of into the Loxton-Parilla Sands;
- optimise an injection strategy using operational constraints provided by Iluka; and
- provide estimates of regional drawdown/mounding and water balance impacts resulting from operation of the proposed groundwater management scheme.

11.1.2 Calibration

The approach adopted to calibrate the regional model involved using a combination of local-scale 'sub-models' to calibrate aquifer parameters locally to transient production and injection tests, followed by the extrapolation of the calibrated parameter values regionally across the full BAL2.0 model domain. The regional model was calibrated in steady state to regional groundwater head data, and has been informed by the transient calibration of sub-models. Five locale scale transient sub models were developed, these enable much finer spatial discretisation around their respective features of interest.

The calibration sensitivity analysis was completed whereby multiple local-scale models were used to calibrate aquifer parameters by matching modelled and measured drawdown responses to pumping and injection trials. The first step in the analysis involves carrying out individual sensitivity analyses to key aquifer parameters on each of the individual local-scale models. This provides a calibration sensitivity analysis for each of the local-scale models. The scaled root mean square values returned from each of the models were then averaged to provide an indicative quantification of the calibration sensitivity of the regional BAL2.0 model. The calibration process considered a sufficient range of parameter values such that those adopted are close to optimum, from a statistical measure of calibration performance.

11.1.3 Model layers

The model is discretised vertically into nine model layers, which align with key hydrostatigraphic layers and varying horizontal hydraulic conductivities. The model layers are:

- Shepparton Formation, shallow;
- Shepparton Formation, deep;
- Loxton-Parilla Sands 1 foreshore;
- Loxton-Parilla Sands 1 surf zone;
- Loxton-Parilla Sands 1 lower shores/Loxton-Parilla Sands 2 foreshore;
- Loxton-Parilla Sands 2 surf zone;
- Loxton-Parilla Sands 2 lower shore;
- Geera Clay; and
- Olney Formation.

The model layers Loxton-Parilla Sands 1 lower shore and Loxton-Parilla Sands 2 foreshore were combined into a single model layer due to their adjacent stratigraphic position and similar hydraulic properties. The basement was not included in the model due to its relatively impermeable nature and lack of hydraulic interaction with the overlying groundwater system. The basement surface was set as the base of the model.

The genetic sequence stratigraphic model developed by Iluka's exploration team is internally consistent and is supported by sedimentology based on environment of deposition. There was no need to introduce a further unit below the Loxton-Parilla Sands 2 package of sediments and the fine grained basal unit is consistent with the pervading model of the evolution of the Pliocene package of sediments in the Murray Basin (Evans 2014). The relationship between geological descriptions and the model layers is shown in Figure 11.1.

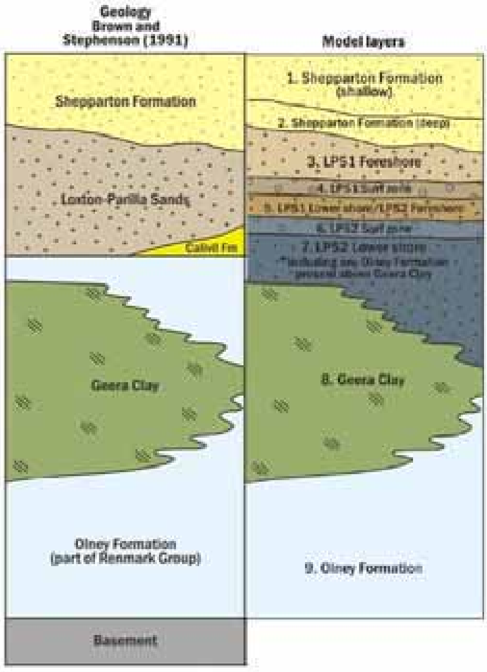


Figure 11.1 Relationship between geology and model layers

11.1.4 Model parameters

Specific yield and specific storage values have been adopted from other Iluka models developed in similar environments in northern Victoria. The specific yield was set to 0.15 and the specific storage was $3x10^{-5}$.

A uniform recharge value of 0.0365 mm/y was applied across the model domain. The recharge and groundwater evapotranspiration fluxes within the mining area are expected to be relatively small in comparison to the dewatering and reinjection requirements of the Balranald Project.

Evapotranspiration from groundwater occurs where the water table was shallower than 3 m below the surface, and this, was set at 2,000 mm/y. Below the 3 m ‘extinction depth’ modelled evapotranspiration from groundwater was zero.

The aquifer parameter values determined through calibration to transient drawdown data in the local-scale models are presented in Table 11.1. Where uniform parameter values were not obtained for a model layer, the values obtained at the local-scale trial sites were interpolated and extrapolated across the BAL2.0 model domain via a series of zones.

The horizontal hydraulic conductivity was always, at a minimum, one order of magnitude higher than the vertical hydraulic conductivity.

Table 11.1 Modelled hydraulic conductivity values

Hydrostatigraphic unit	Kh (m/d) – Jacobs (2015)	Kv (m/d) – Jacobs (2015)
Shepparton Formation	1	0.001
Loxton-Parilla Sands 1 foreshore	0.9	0.001
Loxton-Parilla Sands 1 surf zone	16 / 20 / 24	0.1
Loxton-Parilla Sands 1 lower shore/Loxton-Parilla Sands 2 foreshore	0.9	0.001
Loxton-Parilla Sands 2 surf zone	16 / 20 / 24 / 10 / 40 / 17	0.1
Loxton-Parilla Sands 2 lower shore	0.9	0.001
Geera Clay	0.0001	0.00001
Olney Formation	3	0.3

Source: Jacobs 2015.

11.1.5 Limitations

There is not a great deal of knowledge regarding the interaction between the Murrumbidgee and Murray rivers and the groundwater system in the project area, except for the understanding that the river is generally losing in the vicinity of Balranald town. This limits the models ability to represent spatially detailed surface-groundwater interaction. However impacts to not extent towards the Rivers.

11.2 Scenario modelling

Groundwater management for the proposed mining scenario was simulated in model run BAL2.0_TS2_opt29. This scenario included the groundwater supply for pre-mining construction, dewatering of the West Balranald and Nepean deposits during 'truck and shovel' open cut mining, and disposal of all dewatering water via reinjection into the Loxton-Parilla Sands. A saline groundwater supply is operated from the Loxton-Parilla Sands for a period during which dewatering rates alone do not meet requirements for plant make-up water and dust suppression. There is also some minor injection on-path at West Balranald in the modelled scenario.

The different model stresses, or activities that could potentially impact groundwater, are included in Table 11.2.

Table 11.2 BAL2.0 model stresses

Stress period	Mining year	Start date	End date	Stress length	Project activities that may impact groundwater
1	n/a	1-Jan-1914	1-Jan-2014	100 yr	None (equilibration)
2	-3.0 to -1.5	1-Jan-2014	1-Jul-2015	1.5 yr	Water supply: wellfield 3
3	-1.5 to -0.5	1-Jul-2015	1-Jul-2016	1 yr	Water supply: wellfield 7 and plant bore
4	-0.5 to 0.0	1-Jul-2016	1-Jan-2017	0.5 yr	Water supply: plant bore
5	0.0 to 0.25	1-Jan-2017	1-Apr-2017	0.25 yr	West Balranald mining above water table
6-141	0.25 to 5.9	1-Apr-2017	1-Dec-2022	14 d	West Balranald (mining) dewatering and injection
142	5.9 to 6.0	1-Dec-2022	1-Jan-2023	30 d	West Balranald (backfilling) dewatering and Nepean (mining) dewatering
143-146	6.0 to 6.3	1-Jan-2023	1-May-2023	30 d	West Balranald (backfilling) dewatering, West Balranald make-up water supply (56 L/s) and Nepean (mining) dewatering
147-154	6.3 to 7.0	1-May-2023	1-Jan-2024	30 d	West Balranald (backfilling) dewatering, West Balranald make-up water supply (12 L/s) and Nepean (mining) dewatering
155-159	7.0 to 7.5	1-Jan-2024	1-Jul-2024	30 d	West Balranald (backfilling) dewatering and Nepean (mining) dewatering
160-166	7.5 to 8.0	1-Jul-2024	1-Jan-2025	30 d	West Balranald (backfilling) dewatering
167	n/a	1-Jan-2025	1-Jan-2125	100 yr	None (recovery)

Source: Jacobs 2015.

11.2.1 Construction water supply

Construction phase water supply, sourced from the Olney Formation will be abstracted via:

- Wellfield 3: 75 ML/yr (2.4 L/s) supply for the construction of the injection borefield between 3 and 1.5 years before mining;
- Wellfield 7: 75 ML/yr (2.4 L/s) supply for the construction of the injection borefield between 1.5 and 0.5 years before mining; and
- Plant bore: 75 ML/yr (2.4 L/s) supply for construction at the West Balranald deposit from 1.5 years before mining to commencement of mining.

The exact locations of these bores is yet been determined. The volume of abstracted water is 75 ML/yr for the first 1.5 years before mining commences, this volume increases to 150 ML/yr for a further 1 year, when two bores are operational. For the final half year of pre-mining construction the volume reduces back to 75 ML/yr. The total volume taken is 300 ML over 3 years.

The residual drawdown at abstraction bores at Wellfield 3 and Wellfield 7 is less than 0.2 m. Groundwater extraction from the plant bore creates a localised drawdown impact, with the 0.2 m drawdown contour constrained to a small area within the footprint of the West Balranald disturbance area.

11.2.2 West Balranald dewatering

Model results demonstrate the pit can be effectively dewatered to enable dry mining conditions. The modelled potentiometric surface of the Loxton-Parilla Sands was maintained at approximately 5 m below Fthe pit floor at the advancing face and the centre of the West Balranald pit. At the toe of the backfill the potentiometric surface oscillates around the elevation of the pit floor, which is thought to be a function of the model grid resolution. There is an expectation, however, that the low vertical conductivity in the Shepparton Formation will act as a barrier between the water table and the dewatering bores that are screened in the underlying Loxton-Parilla Sands. This is expected to result in residual waterlogging in the Shepparton Formation and potentially a perched water table in the vicinity of dewatering operations.

The model predicts an average dewatering rate of 746 L/s for the six years of mining and an average of 95 L/s during the two years of backfilling. The predicted peak fortnightly dewatering rate is 1,309 L/s. It is anticipated that, even for the most difficult yet plausible set of aquifer parameter values, the West Balranald deposit could be dewatered with infrastructure capable of operating at a peak capacity of approximately 50% more than the base case predicted rate of 1,309 L/s (Jacobs 2015).

Dewatering rates are predicted to increase over the life of the West Balranald mining operation. The primary reason for this is that the pit deepens over time as it advances northward. The pit floor at the commencement of ore production is 9.5 m AHD. This is 22 m higher than the final pit floor elevation of -12.5 m AHD (in 2022).

A drawdown cone extends the length of the West Balranald deposit during mining and the whole duration of post mining modelling (ie 100 years). In the Shepparton Formation, the 0.2 m groundwater drawdown curve extends to approximately 10 km laterally from the strike of the deposit. In the more transmissive Loxton-Parilla Sands, the 0.2 m drawdown curve extends to approximately 15 km laterally from the deposit. The 0.2 m drawdown cone does not extend to the Murray or Murrumbidgee rivers, and therefore does no induce additional inflow from these surface water systems.

An uncertainty analysis, where both plausible higher and lower dewatering properties from the base case are modelled, was undertaken (Jacobs 2015). Predicted drawdown impacts in the Olney Formation at the end of mining at Year 6, 8 and 100 are evident only for the high dewatering case. In the base case and low dewatering case the Geera Clay acts as a sufficient barrier that restricts modelled impacts in the Olney Formation to less than 0.2 m. In the high dewatering case the vertical hydraulic conductivity of the Geera Clay base increases 100 times (which is much higher than is reasonably expected), and drawdown and mounding are relatively localised to the West Balranald mine and off-path injection areas and at levels not much more than 2 m in years 6 and 8. There are no 2 m drawdown or mounding curves in the Olney Formation under high dewatering cases at year 100.

Model predicted drawdown in the Shepparton Formation and Loxton-Parilla Sands 100 years after cessation of groundwater-affecting activities are similar and some residual drawdown remains. While the magnitude of drawdown reduced following the ceasing of groundwater abstraction the extent of the 0.2 m drawdown contour continues to expand outward during the 100 year modelling period.

11.2.3 West Balranald backfilling

During the backfilling of the West Balranald deposit the potentiometric surface rises slower than the assumed backfilling operation. Hence, the latter part of the backfilling operation requires no dewatering to maintain a dry pit. It should be noted that, should the increase in pit floor elevation not follow the simple linear assumption made, then the temporal dewatering requirements during backfilling may vary.

Iluka has identified that the final elevation of the West Balranald deposit base will be 52 m AHD following backfilling. This will provide a fill cover of a maximum 3 m above the pre-mining, potentiometric surface, ~ 49 m AHD, in the Loxton-Parilla Sands and 3.5 m above the water table depth, ~ 48.5 m AHD, in the Shepparton Formation. The modelled groundwater level drawdown at the mine void is between 1.2 m lower than the pre-mining water level after 100 years of recovery (ie post mining). Therefore the depth to water at the final West Balranald void will more likely be 4.7 m below ground level 100 years after mining.

11.2.4 Nepean dewatering

The modelled potentiometric surface of the Loxton-Parilla Sands was maintained approximately 5 m below the pit floor of the Nepean deposit. The model predicts an average dewatering rate of 100 L/s for the 1.5 years of mining, with a peak monthly dewatering rate of 186 L/s. Dewatering rates are predicted to increase over the life of the Nepean mining operation, due to the pit deepening further below the pre-mining water table as it advances northward. At the commencement of the extraction of ore, the pit floor is at 49 m AHD and progressively deepens to 36 m AHD by the end of the mining.

The model predicted dewatering rates are likely to be conservative (ie the model predicts dewatering rates much higher than is expected) as the model was populated with hydraulic properties obtained from production and injection trials carried out near West Balranald, where the aquifers are more transmissive.

Model predicted groundwater 0.2 m drawdown in the Shepparton Formation and Loxton-Parilla Sands at the end of mining the Nepean deposit (Year 7.5) is localised, extending no more than 2 km from the mine in both units. These small predicted impacts are consistent with expectations given the shallow depth of the mine below the water table. No residual impact of dewatering (ie drawdown) is evident at the Nepean deposit 100 year after mining has commenced.

The will be no void remaining at the Nepean mine following mining.

11.2.5 Injection

Iluka plans to inject water produced from dewatering operations back into the Loxton-Parilla Sands principally to the north-west of the West Balranald mine (ie off-path reinjection). Whilst some abstracted water will be consumed in mining, processing and for dust suppression, this is expected to constitute a minimal proportion of the dewatering volume. Injection bores will be located along the proposed Nepean access road and in borefields coming off this road. Injection trials at the “Nanda” and “Upson Downs” sites have suggested a highly transmissive aquifer in this region.

Injected water will be distributed equally amongst all off-path bores. Therefore, transmissive parts of the aquifer to receive greater volumes of water are not targeted. This adds to the conservative nature of the impact assessment. Injection peaks at about 1,300 L/s. The off-path borefield has been sized such that injection is spread over a large area. This is done to ensure that mounding of the water table and potentiometric surface within the Shepparton Formation (unconfined) and Loxton-Parilla Sands (semi-confined) remains a minimum of 3 m below the ground surface to avoid potential waterlogging and salinisation of surface sediments.

Modelling indicates that piezometric pressure heads in the Loxton-Parilla Sands increase by more than 5 m above the pre-mining levels. However the impact in the overlying Shepparton Formation is lower, in the order of 2 m, due to the poor hydraulic connection between the two aquifers.

Whilst localised elevated heads can be seen along the Nepean access road and borefields coming off it, the mounding creates a large 'bubble' of regional elevated heads. This occurs as a result of two factors. Firstly, the borefield is operated using a pressure head constraint of 3 m below ground surface. This necessitates a borefield covering a large area (around 25 km x 20 km) that injects water in a diffuse manner. Secondly, the Loxton-Parilla Sands in the region is highly transmissive, enabling rapid disbursement of injected water to the surrounding groundwater system.

Model predicted mounding in the Shepparton Formation and Loxton-Parilla Sands 100 years after cessation of groundwater-affecting indicates mounding of up to 1 m at the off-path borefield. After ceasing reinjection the 0.2 m mounding curve continued to expand, predominantly to the north and east during the 100 year modelling period.

12 Water balance

12.1 Introduction

The water balance for the Balranald Project incorporates both the groundwater numerical modelling and mine water balance and water management system modelling. A water balance involves the estimation of the storage and flow of water in a defined area, during a given timeframe. A mass balance equation is used in which the change of water stored within an open (natural) hydrological system, is equal to the inputs to the system minus the outputs from the system (Todd and Mays 2005):

$$\text{Change in storage } (\Delta S) = \text{Inflows} - \text{Outflows}$$

12.2 Groundwater model water balance

A modelled groundwater balance for the study area (Jacobs 2015; Appendix I, EIS report) is included in Table 12.1. Under pre mining conditions recharge and evapotranspiration are both minor components, indicating that local climate has little effect on the groundwater system. River leakage into the groundwater system is greater than leakage out of the groundwater system. However, the greatest component of the water balance is regional throughflow via the model boundaries, and this dominates both modelled inflow and outflow.

Prior to mining a total of 300 ML will be abstracted from the Olney Formation for construction water. This has been represented as abstraction from the West Balranald deposit.

Upon commencement of mining at the West Balranald mine, dewatering and injection dominate the water balance, along with the associated storage changes. When dewatering and injection reduce and then cease, the water balance rapidly approaches the pre-development conditions. Throughout the period of mining, no significant change is evident in flows through the boundary conditions.

Importantly, no significant change in river leakage in or out is evident, indicating that mine dewatering and injection activities are predicted not to affect the Murrumbidgee and Murray Rivers. The lack of significant changes in other components of the water balance suggests that dewatering and injection are balanced almost entirely by changes in storage in their respective locations.

Model estimates suggest that project related abstracted from, and reinjected into the Western Murray Porous Rock Groundwater Source, will not induce flow into or from adjacent water sources.

Table 12.1 Groundwater balance at key pre mining, mining and post mining years

Period	Storage		Recharge		EVT		River leakage		Through flow		WB dewatering		Nepean dewatering		Injection		Water supply		Total	
	In	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Pre development	325	236	296	-	-	607	1,512	97	7,831	9,127	-	-	-	-	-	-	-	-	**9,964**	**10,067**
Construction yr 3	263	176	296	-	-	613	1,457	99	7,789	8,987	-	300	-	-	-	-	-	125	**9,804**	**10,300**
Mining yr 1	22,679	22,481	296	-	-	611	1,456	99	7,783	8,978	-	19,546	-	-	19,532	-	-	-	**51,744**	**51,715**
Mining yr 2	29,755	29,514	296	-	-	599	1,456	99	7,779	8,966	-	20,435	-	-	20,447	-	-	-	**51,715**	**59,732**
Mining yr 3	32,623	32,442	296	-	-	573	1,456	98	7,775	8,958	-	21,329	-	-	21,329	-	-	-	**63,479**	**63,417**
Mining yr 4	33,416	33,836	296	-	-	555	1,456	98	7,772	8,952	-	22,421	-	-	22,418	-	-	-	**65,358**	**65,862**
Mining yr 5	40,057	40,219	296	-	-	551	1,456	98	7,770	8,946	-	27,004	-	-	27,144	-	-	-	**76,722**	**76,818**
Mining yr 6	43,775	44,573	296	-	-	547	1,456	98	7,769	8,944	-	29,461	-	76	29,616	-	-	-	**82,912**	**83,700**
Mining yr 7	24,205	23,375	296	-	-	545	1,456	98	7,767	8,524	-	4,730	-	2,300	6,269	-	-	841	**39,993**	**40,414**
Mining yr 8	14,799	14,561	296	-	-	534	1,456	98	7,768	8,923	-	183	-	2,295	2,065	-	-	-	**26,384**	**26,603**
Recovery yr 1	7,084	7,054	286	-	-	524	1,407	95	7,513	8,627	-	-	-	-	-	-	-	-	**16,290**	**16,300**
Recovery yr 100	439	477	286	-	-	495	1,401	92	7,491	8,589	-	-	-	-	-	-	-	-	**9,617**	**9,653**

Notes: *WB = West Balranald, EVT = evapotranspiration*

All units = ML/year

12.3 Mine operation water balance

WRM (2015; Appendix H, EIS report) undertook mine water balance and water management system modelling for Years 1, 4 and 8 of the mine life (Table 12.2). These times reflect changes in catchments caused by the different mine infrastructure areas and configurations. For each year of the mine life that is modelled, the model was run for a 125 year period using a synthetic climatic dataset (January 1889 – January 2014). This is called a static simulation. It provides an indication of the water balance at each year of mine life and allows for a comparison of worst case inflows and outflows between each of the modelled years.

The groundwater inflow to the pit is an approximate value to account for seepage into the pits that is not captured as part of the groundwater abstraction program. This seepage is a result of interception of shallow perched groundwater systems that cause water to collect in the base of the mine pit. The mine operation water balance assessment does not consider groundwater abstraction and reinjection volumes, (as per Table 12.1).

Table 12.2 Annual site water balance summary

Inflow/outflow (ML)	Average rainfall year			Wet rainfall year			Dry rainfall year		
	Year 1	Year 4	Year 8	Year 1	Year 4	Year 8	Year 1	Year 4	Year 8
Inflows to water management system									
Groundwater inflow to pit	1,577	1,577	0	1,577	1,577	0	1,577	1,577	0
Catchment runoff	34.9	32.5	37.7	186.7	172.5	195	2.6	2.2	2.0
Direct rainfall on water storages	11.2	12.1	4.8	13.0	14.9	5.4	6.0	6.5	2.0
Total inflows	1,623	1,621	42.5	1,777	1,764	200.4	1,586	1,586	4.0
Outflows from water management system									
Net site demand supplied	1,558	1,553	27.3	1,688	1,672	183.6	1,528	1,525	0.0
Uncontrolled releases	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Evaporation	68.0	71.0	27.7	74.5	80.0	30.2	66.9	70.0	24.7
Total outflows	1,628	1,624	55.0	1,762	1,752	213.8	1,595	1,595	24.7
Change in site water inventory									
Net change in total site water inventory	-2.8	-2.9	-12.5	14.3	12.2	-13.4	-9.8	-9.8	-20.7
Required makeup water volume									
Total makeup water required	207.2	211.7	1,738	77.3	83.1	1,581	236.8	239.7	1,765

The water management system maximises the capture and reuse of mine affected water. The predicted long term average volume of required makeup water ranges from 207 ML/year (Year one) to 1,737 ML/year (Year eight) (average rainfall years). Water balance modelling indicates that the Balranald Project would source the majority of the required water from dewatered groundwater with make-up water supplied via on-site sources (ie rainfall runoff, and groundwater inflow to the pit). Mine affected water will be reused to supply the MUP, processing plant and saline water dust suppression demands. The dewatering borefield production rates are predicted to exceed the net makeup water demands at all stages of mine life.

12.4 Water balance

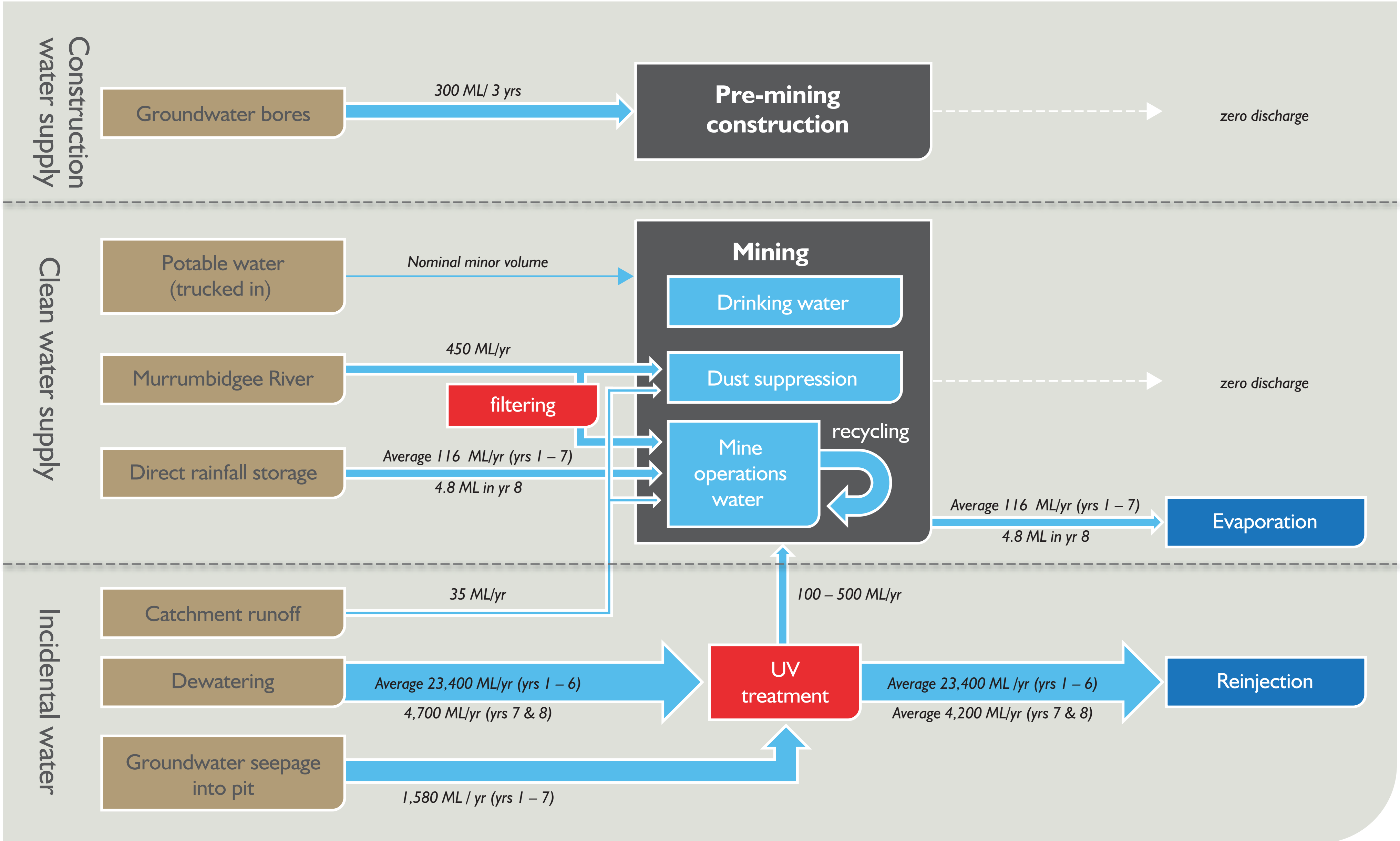
A water balance combining the mine affected water management system, hypersaline groundwater and reinjection volumes has been prepared for pre-mining, and years one, four and eight of the conceptual mine plan. This is presented in Table 12.3 and indicates marginal net change in total site water inventory during the operation phase. A representative water schematic is also shown in Figure 12.1.

Table 12.3 Water balance (average rainfall year)

Parameter	Construction (total*)	Year 1 ML/ yr (operational)	Year 4 ML/yr (operational)	Year 8 ML/yr (operational)
Inflows to water management system				
Groundwater inflow to pit	-	1,577	1,577	0
Catchment runoff	-	34.9	32.5	37.7
Direct rainfall on water storages	-	11.2	12.1	4.8
Dewatering borefield	-	19,532	22,421	1,239
Hypersaline water supply to processing plant	-	-	-	841
Water supply bores – Olney Formation	300			
Total inflows	**300**	**21,155**	**24,043**	**2,123**
Outflows from water management system				
Net site water management system	-	1,558	1,553	27.3
Uncontrolled releases	-	0	0	0
Evaporation	-	68	71	27.7
Reinjection	-	19,532	22,418	2,065
Total outflows	**-**	**21,158**	**24,042**	**2,120**
Net change in total site water inventory	**-300**	**-3**	**1**	**3**

Notes: Taken from Jacobs 2015 and WRM 2015.

** Total water usage has been provided for 3 years as the rate of abstraction is variable during this period.*



EMM EMGA Mitchell McLennan

Water balance schematic

Balranald Mineral Sands Project
Water Assessment

Figure 12.1

13 Surface water impact assessment

13.1 Introduction

Potential surface water impacts of the Balranald Project are discussed and assessed in this chapter. Although the Balranald Project is located in the MDB and proximate to the major inland rivers of the Murrumbidgee, Murray and Lachlan, there are no direct surface water impacts to these rivers due to these Rivers being located outside the area of potential impacts.

Within the project area itself there is an absence of permanent surface water sources, there are no surface water users, and no surface water related infrastructure. The exception is the project area where the water supply pipeline runs from the Murrumbidgee River to provide freshwater during construction and operation.

13.2 Surface water impacts

The potential impacts to the surface water environment resulting from the Balranald Project include:

- loss of catchment area that drains into Box Creek, Pitarpunga and Tin Tin lakes due to capture of run off within onsite storages and the pit;
- interference with flood flows along Box Creek, Pitarpunga and Tin Tin lakes and their tributaries;
- potential for runoff from the project area to become contaminated with either of the following: elevated salinity, low pH, heavy metals, and fuels, oils and grease due to interaction with either:
  - saline groundwater (at West Balranald mine in particular);
  - stockpiles, overburden or acid forming materials;
  - MUP area and processing areas; and
  - mine voids.
- overflow of the mine water management system during large rainfall events resulting in the release of sediment laden water or saline water; and
- depletion of regional water availability associated with abstraction of water from the Murrumbidgee River and potential use from other external sources.

Each of these potential impacts is addressed below.

13.2.1 Loss of catchment area

During the operational phase of the Balranald Project, the maximum catchment area draining to the mine water management system would be 194.3 ha. This is less than 1% of the total Box Creek catchment area (WRM 2015; Appendix H, EIS report). The loss of 1% of the catchment area is considered insignificant, especially considering the ephemeral nature of Box Creek and the lack of reliance by environmental and human users on this system.

Upon completion of operations, the final void remaining at the West Balranald mine will have a contributing catchment area of 52.1 ha (WRM 2015), consisting of the surface area of the void itself. The invert level of the final void will be above the pre mining depth to groundwater, in the Loxton Parilla Sands. The amount of runoff that could be potentially captured within the final void will be limited by diversion works. The small volume of runoff expected to collect in the void will either evaporate or will infiltrate through the floor of the void into the Loxton Parilla Sands. The maximum volume of water predicted to accumulate in the West Balranald mine final void is 34 ML (WRM 2015). Following an average rainfall event it is estimated that the void would take approximately two weeks to evaporate under average evaporation rates.

There will be no void at the Nepean mine, therefore there would be no loss of catchment area from Box Creek following rehabilitation.

13.2.2 Interference with flooding

The majority of the mine infrastructure for both the West Balranald and Nepean mines are located outside the predicted Box Creek and associated lakes flood extent area. A small part of the West Balranald mine could be inundated by floodwater originating from Muckee Lake. Parts of the Nepean access road and injection borefields are located within the flood extent of Box Creek and Tin Tin Lake. For the access road and reinjection field to be inundated there would need to be a flood well in excess of a 1 in 100 AEP (WRM 2015).

Mine infrastructure located in areas subject to flooding are not expected to impact on flooding. The access road will be constructed at the existing ground level and is not expected to impact predicted flood levels, velocities or flow distributions. The injection bores have a small diameter and likely present an insignificant obstruction to any flood flows, and these bores would not be damaged by flood flows. If a major flood event occurred (comparable to a 1 in 100 AEP) then the Nepean access road and borefield may be temporarily inundated with water. A small bund wall would be sufficient to protect the West Balranald mine from flooding, if required.

13.2.3 Impacts to receiving environments from potentially contaminated runoff

There is the potential for runoff water quality to be affected by chemicals, natural elements or undergo physiochemical changes (ie increased EC or lowered pH), and cause contamination to possible receptors, including groundwater, soils and vegetation. However for this to occur surface water needs to be present and in contact with a contaminating agent, and the surface water then needs come into contact with a receptor. This is considered an unlikely scenario due to the lack of surface water in the project area and the implementation of a water management plan which will control all project water.

Surface water runoff from undisturbed areas will be diverted, where possible, around areas disturbed by mining and released from the site before it has the potential to become contaminated. Surface water runoff from disturbed areas has the potential to be contaminated, and this water will be captured, stored and treated as part of the mine water management program. No run off from disturbed areas will be released from the site.

The organic overburden, and more so the heavy mineral concentrate, ilmenite stockpiles and mining by-products will be potential sources of acid and metalliferous drainage. In the event of a heavy rainfall event sulfuric acid or metals (including: zinc, cobalt, chromium, cadmium, boron, arsenic and nickel) have the potential to become mobilised, causing acidification of soils, groundwater or process water (Earth Systems 2015; Appendix Q, EIS report). In addition acidic seepage from stockpiles could also cause acidified ponding. However the appropriate management of stockpiles will greatly reduce the volume of potential acidity generated from stockpiles.

There will be no surface releases of saline groundwater abstracted from dewatering. Saline water will be reinjected downgradient or off path back into the Loxton-Parilla Sands.

If run off is contaminated with chemicals (ie fuels, oils, lubricants) from a spill event this will be treated in accordance with proposed water management plan.

An incident or accident resulting in the loss of containment of HMC, mineral concentrates or process waste could potentially result in local contamination of land or surface waters with radiological material. However, the mine material is not classified as radioactive ore, and the heavy nature and insolubility of the material limits contamination potential. Refer to the Radiation Risk Assessment (Iluka 2015, Appendix S of the EIS report) for further details.

13.2.4 Mine water management overflow

The area has a dynamic flooding history and historic flooding has resulted in the inundation of the entire Box Creek floodplain, (Section 7.2). Flooding in Box Creek can be the result of heavy rain fall events in the local catchment area (such as the 2010/2011 flood event), floodwater overflowing from the Lachlan River and draining into Box Creek via Merrowie and Middle creeks (such as the 1956 and 1974 flood events) or a combination of the two scenarios.

WRM (2015) simulated flood flow behaviour in Box Creek and its floodplain, including Muckee, Pitarpunga and Tin Tin lakes using TUFLOW hydrodynamic modelling software to investigate the possibility of the West Balranald mine and subsequent final void becoming inundated by floodwater overflowing from Box Creek or the nearby lakes. A constant discharge of 300 m^3/s was applied to Box Creek, this discharge was applied to represent a conservative flood event greater than 1 in 100 AEP, and was twice the estimated February 2011 peak discharge in Box Creek prior to entering Pitarpunga and Tin Tin lakes. The Nepean deposit is located outside of the predicted Box Creek and Tin Tin Lake flood extent, although parts of the Nepean access road and injection borefields are located within the flood extent.

Modelling indicates that the West Balranald mine and subsequent void are not predicted to be completely inundated by flooding from Box Creek, while parts of the Nepean access roads and the reinjection borefields may be subject to inundation (shown in Figure 13.1). Parts of the West Balranald mine could be potentially inundated by floodwater that backs up into the Muckee Lake from Pitarpunga Lake. The greatest inundation (~6.5 m) is expected at Muckee Lake adjacent to West Balranald mine, although at Pitarpunga Lake, also adjacent to West Balranald Mine, the height of the maximum possible inundation is only 0.36 m. The flooded area coincides with the limits of the alluvium located in low lying areas.

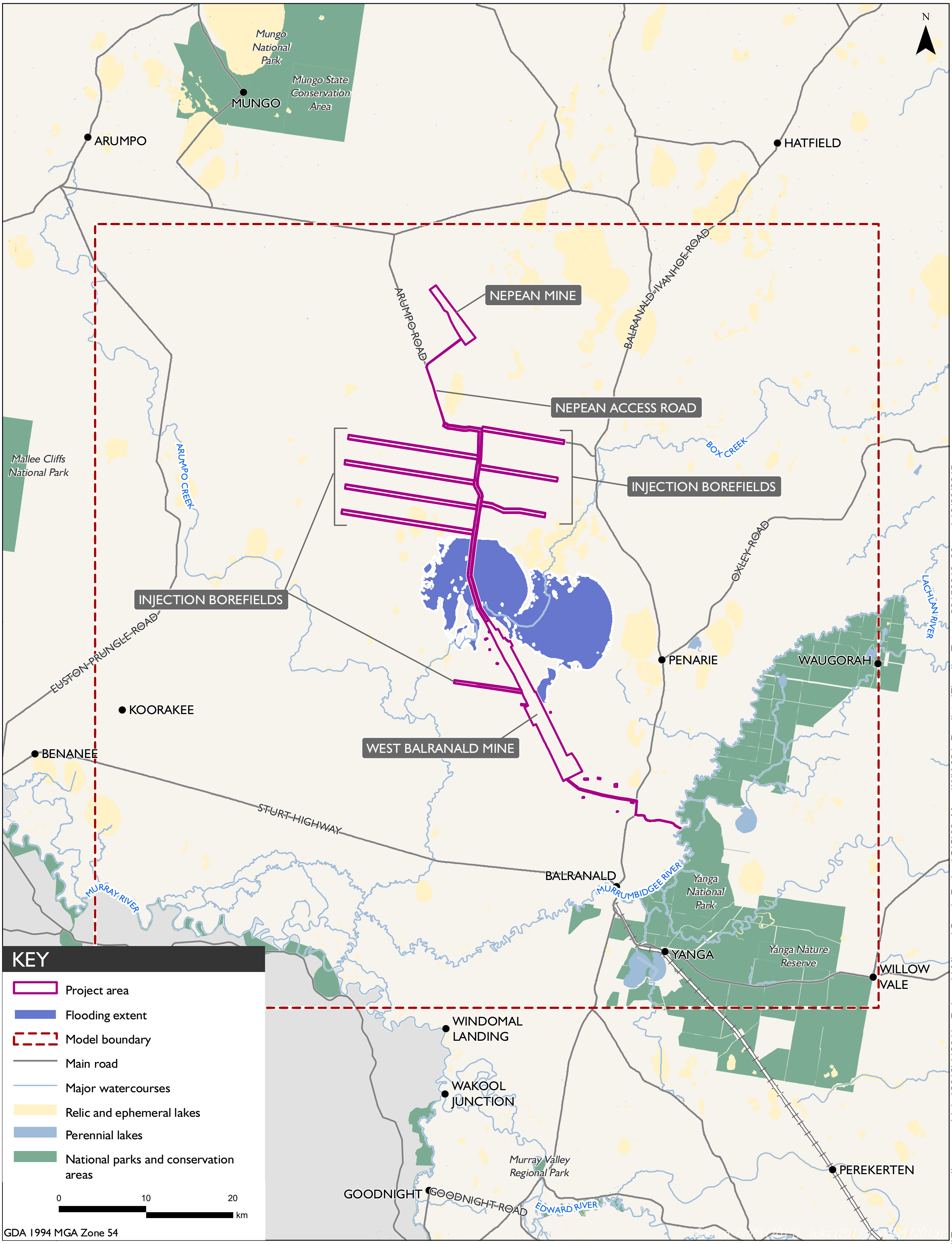
The proposed water management system is adequately configured and designed to prevent long term inundation of the West Balranald mine pit and surrounding project area (WRM 2015). Long term catchment modelling undertaken by WRM (2015), incorporating the mine water management system, indicates that this system is capable of handling both the wettest and driest periods on record at the project area for each of the selected years of mine life.

WRM (2015) concludes there is a less than a 1% chance of uncontrolled release of mine affected water during any year of mine life during Year 1 and 4. All predicted uncontrolled releases of water from mine affected water storages simulated in modelling were associated with the same rainfall event (February 2011), which had some 72-hour rainfall intensities that were 34% greater than estimated 1 in 100 AEP rainfalls. If a rainfall event of this nature occurred, the predicted volume of uncontrolled releases would be small and diluted with large amounts of clean runoff. No uncontrolled releases of mine affected water are predicted for Year 8, due to the volume and configuration of the mine water.

13.2.5 Regional surface water availability

The use of external water will be minimised by sourcing all processing water from the mine water management system and saline water extracted from the dewatering borefield. No external water will be required to supply these demands, and hence these demands will have no impact on regional water availability.

Raw water for use in dust suppression of sensitive areas and to supply filtered water demands will be pumped from the Murrumbidgee River. The required WAL will be purchased from the registered water license market under the Murrumbidgee River WSP and is therefore within the sustainable limits of this system and this will have no net impact on regional water availability. The only other source of external water will be potable drinking water trucked into the project area.



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Predicted flooding extent

Balranald Mineral Sands Project

Water Assessment

Figure 13.1

14 Groundwater impact assessment

14.1 Introduction

Potential groundwater impacts of the Balranald Project are discussed and assessed in this chapter. Changes to groundwater levels, groundwater chemistry and the hydrogeology itself are considered in respect of the sensitive receptors that were identified in Chapter 4. Specifically, the degree of change and subsequent impact is considered.

14.2 Groundwater levels

The abstraction and injection of groundwater will result in changes to the pre mining groundwater levels and potentiometric pressures. The numerical model, described in Chapter 11, has predicted changes in groundwater levels as a result of the Balranald Project generally across the project area and locally at identified sensitive receptors.

14.2.1 Construction phase abstraction

Construction phase abstraction consists of the abstraction of between 75 to 150 ML /yr of groundwater from the Olney Formation to supply water for construction ahead of mining commencing. The numerical model concluded that abstraction from the Olney Formation for construction purposes resulted in very localised drawdown, with the 0.2 m drawdown contour constrained to a small area (ie less than 10 m) at the Plant Well. Residual drawdown from wells at Wellfield 3 and Wellfield 7 was less than 0.2 m.

The relatively minor drawdown associated with construction abstraction over this short three year period will not cause any impacts of concern and is not explored further as a potential impact.

14.2.2 Mining

i Dewatering

Dewatering from the Loxton-Parilla Sands will result in a decrease in the potentiometric pressure in this Formation, and to a lesser degree the overlying Shepparton Formation. The numerical model predicts an average dewatering rate at the West Balranald mine of 746 L/s for the six years of mining and an average of 95 L/s during the two years of backfilling, totalling 145,109 ML over 8 years. The model predicted average dewatering rate at the Nepean mine is 100 L/s (comprising a total of 4,671 ML) for the 1.5 years of mining. Dewatering aims to maintain the potentiometric surface of the Loxton-Parilla Sands at a depth 5 m below the pit floor.

Drawdown cones, representing reductions in potentiometric pressures, at the West Balranald mine extend in the Loxton-Parilla Sands and Shepparton Formation for the length of the deposit during mining. The extent of the 2 m drawdown cone extends approximately 5 km in the Loxton-Parilla Sands from the mining area at its maximum extent. The 0.2 m drawdown cones continue to spread laterally (by up to 15 km in the Loxton-Parilla Sands and 10 km in the Shepparton Formation) during the 100 year duration when post mining conditions are modelled. Drawdown in the Loxton-Parilla Sands as a result of dewatering will increase the vertical hydraulic gradient with the Shepparton Formation, but actual flow between these units is governed by the presence, thickness and continuity of clay layers within the Shepparton Formation.

The model predicted 0.2 m drawdown in the Shepparton Formation and Loxton-Parilla Sands at the end of mining the Nepean deposit (mining year 7.5) is localised, extending no more than 2 km from the deposit in both units. No residual impact of dewatering (ie drawdown) is evident at the Nepean deposit 100 year after mining has commenced.

ii Reinjection

Iluka will inject water produced from dewatering operations back into the Loxton-Parilla Sands. Injection continues once mining at the West Balranald mine ceases, but the necessary volumes to maintain dry pit conditions for backfilling of West Balranald and mining at Nepean mine are substantially reduced when compared to those required during active mining operations at West Balranald. Injection rates peak at around 1,300 L/s during mining and the total modelled injected volume (148,820 ML) is comparable to the total volume of abstracted groundwater (149,780 ML).

Modelled predicted mounding (increase in potentiometric pressures) are observed in the target Loxton-Parilla Sands and overlying Shepparton Formation. At the injection borefield heads in the Loxton Parilla sands increase by more than 5 m above the pre-mining pressures, while heads in the Shepparton increase by 2 m. During the 100 years of post mining numerical modelling in both the Loxton-Parilla Sands and Shepparton Formation indicates that the 0.2 m mounding contours continue to expand (to approximately 12 km from the edge of the injection borefields) and a 1 m mounding contour remains at the centre of the borefields. Injection into the Loxton-Parilla Sands will increase the vertical hydraulic gradient with the Shepparton Formation, but upward flow is governed by the presence, thickness and continuity of clay layers within the Shepparton Formation.

During injection Iluka have committed to maintaining a 3 m constraint on the adopted groundwater head elevation from surface in the Loxton-Parilla Sands. Essentially injection will be managed so that the pressure in the Loxton-Parilla Sands is less than 3 m below the surface at all times. The threshold is a compromise between the unsaturated zone thickness (which is minimal at some locations), the off-path injection borefield footprint and the risk of preferential flow through the more permeable part of the Shepparton Formation. This is a conservative approach and even where the clay lens that act as an aquitard is absent across the project area, the water table does not rise within 3 m of the site surface.

iii Impacts to private landholder bores

Registered private landholder bore details were obtained from NOW in January 2015. Within a 60 km radius of the project area there are 112 private landholder bores, predominantly utilising groundwater for stock and domestic purposes. Appendix B of this report includes the bore details. The majority of the bores are screened in the Shepparton Formation (Figure 6.8).

Groundwater level fluctuations at the private bore locations were predicted using the numerical model (Jacobs 2015). The predictions were made for the entire modelling period, ie during mining and for 100 years of recovery. Table 14.1 provides a summary of the predicted levels of change, while Appendix D of this report includes details about the pre mining groundwater elevation (as m AHD), the maximum or minimum groundwater elevation following the commencement of mining and the level of change (as meters). Hydrographs showing pre mining groundwater levels and the predicted future groundwater level changes are also included in Appendix D.

Table 14.1 Overview of predicted groundwater level changes in private landholder bores

Formation	Number of landholder bores	Maximum pressure mounding (m)	Maximum pressure drawdown (m)
Shepparton	57	0.55	1.63
Loxton-Parilla Sands 1 (upper)	2	0	0.0
Loxton-Parilla Sands 2 (lower)	8	0.02	0.06
Geera Clay	9	0.40	0.39
Olney	35	0.04	0.07

Notes: The one bore screening the basement could not be included in the assessment as the model does not include a basement layer.

The greatest change in groundwater level is observed as mounding in the Shepparton Formation (1.63 m), which is observed at GW034082, ~6 km east of the West Balranald deposit. There is one location, GW600300, where the observed drawdown is approximately 59.5 m, however this bore is located within the West Balranald deposit and will be decommissioned as part of the mining works. GW600300 has subsequently not been included in Table 14.1.

This assessment indicates that there are no instances where the maximum change in pre mining groundwater level exceeds 2 m. Therefore there is no requirement for 'make good' provisions in accordance with the AIP.

iv Groundwater dependent ecosystems

There are no high priority GDEs within the zones of drawdown and mounding, including the Great Cumbung Swamp and terrestrial vegetation along the Lower Murrumbidgee floodplains. There is the potential for low to moderate impacts to Black Box vegetation proximate to the project area, however, these are considered to be ecosystems that rely on groundwater (see section 14.4 for further discussion).

14.3 Groundwater quality

14.3.1 Mining

i Dewatering and reinjection

The Balranald Project comprises the abstraction of groundwater from predominantly the Loxton-Parilla Sands, and the injection of this water back into the Loxton-Parilla Sands, down hydraulic gradient. Modelling undertaken by Jacobs (2015) indicates drawdown and mounding in both the Loxton-Parilla Sands and the Shepparton Formation. Incidental dewatering of the Shepparton Formation will also occur locally. Groundwater abstraction and injection will therefore enhance both vertical and horizontal hydraulic gradients. There is potential for localised groundwater mixing and exchange between the Loxton-Parilla Sands and the Shepparton Formation. Vertical groundwater flow however, is dependent on the nature of clay aquitards within the Shepparton Formation and is likely to be localised.

The abstracted groundwater will be predominantly Loxton-Parilla Sands but will also contain groundwater from the Shepparton Formation. The receiving environment is primarily the Loxton-Parilla Sands, but where vertical flow occurs this will also include the Shepparton Formation (but this will be to a much lesser degree). Assessment of the pre mining groundwater quality data for both the Loxton-Parilla Sands and the Shepparton Formation indicates similar conditions. The Loxton-Parilla Sands is of slightly poorer water quality with a higher EC (average of 56 mS/cm in the Loxton-Parilla Sands and average of 48 mS/cm in the Shepparton Formation, refer to Table 6.8). The major cations and anions are the same (Na-Cl), while magnesium is also dominant in the Shepparton Formation.

Preliminary assessment of the project site water quality suggests there will be no negative change in the water quality of the receiving environments. Ultra violet treatment of injected water will reduce the possibility of introducing bacteria.

The beneficial use of the groundwater systems is governed by the very high salinity of the Shepparton Formation and Loxton-Parilla Sands, and this water is unsuitable for the following beneficial uses: human drinking water, livestock drinking water and irrigation (ANZECC/ARMCAZ 2000 and NHMRC 2011). The only beneficial use of this water is therefore considered to be for emergency supply for stock, and for industrial and mining purposes where use of poor quality water is not a constraint.

In accordance with the AIP, there will not be any change to the water quality that would change the beneficial use category of the water in either the Loxton Parilla Sands or the Shepparton Formation as a direct result of the Balranald Project.

14.3.2 Backfilling

Iluka plan to isolate the top 5 m of non-saline overburden and replace it during the rehabilitation process. Given this material is currently, and will be replaced, above the water table, it is not expected to significantly alter the groundwater quality.

14.3.3 Reinjection clogging

A preliminary analysis of groundwater chemistry suggests that, provided reinjection bores are screened in the Loxton-Parilla Sands only, clogging will not be a problem, or can be readily managed (Jacobs 2015). Poor well development is likely to have the greatest impact on injection well performance, this is an operational management concern and is not of concern to clogging within the formation itself.

14.4 Mine void

Iluka has identified that the final elevation of the West Balranald pit void (at the northern end of the deposit) will be 52 m AHD based on backfilling. The pre mining measured water level in the Shepparton Formation at the void is approximately 48.5 m AHD, and the potentiometric surface of the Loxton-Parilla Sands is approximately 49 m AHD.

Backfilling will provide a fill cover of at least 3 m above the pre-mining potentiometric surface and 3.5 m above the pre-mining water table elevation. The pre mining potentiometric surfaces are also likely to be conservative (ie higher) compared to the expected post mining elevations due to the sediment pile stratigraphy being replaced with more homogeneous backfill, with potentially larger porosity.

The modelled groundwater level drawdown at the mine void is between 1.2 m lower than the pre-mining water level after 100 years of recovery (ie post mining). Therefore the depth to water at the final West Balranald void will more likely be 4.7 m below ground level 100 years after mining. Full recovery to pre-mining water level is expected approximately 110 years after mining.

Given the planned final backfill level is approximately 13 m below the initial and surrounding ground surface elevation of approximately 65 m AHD, any rainfall runoff is likely to collect within the remaining depression. This is likely to lead to increased recharge to the water table below the remaining depression and, therefore, slight mounding of the water table at this point. Given the void will overlie an area of reduced groundwater levels this enhanced recharge will assist with the overall predicted timeframe for recovery of groundwater levels in the area.

The maximum volume of water predicated to accumulate in the West Balranald final void is 34 ML (WRM 2015). The final void is predicted to behave in a similar hydrologic manner to the nearby dry lakes and surface depressions. The small volume of runoff expected to collect in the void will either evaporate or will infiltrate through the floor of the void into the Loxton-Parilla Sands. WRM note that between a 1 in 50 and 1 in 100 rainfall event (with ongoing rainfall) the final void would take approximately 5.5 weeks to completely dry out. Under average rainfall conditions the final void would take approximately 2 weeks to dry out.

Although the daily evaporation exceeds the adopted infiltration rate the height of capillary rise in unconsolidated units occurs at depths of less than 0.75 m (most conservative measurement for unconsolidated sediments) (Fetter 1994). Therefore there is enough cover to avoid the creation of an artificial salina, ie an accumulation of salts via evaporation. The maximum EC of water in the final void is not expected to exceed the existing average EC conditions for the Loxton-Parilla Sands (56 mS/cm).

14.5 Ecosystems that rely on groundwater

14.5.1 Groundwater dependent ecosystems

No high priority GDEs have been identified in the MDB Porous Rock WSP. The Lower Murrumbidgee Groundwater WSP, identified two high priority GDEs, the Great Cumbung Swamp and terrestrial vegetation along the Lower Murrumbidgee floodplains and prior streams. The Great Cumbung Swamp will not be impacted by the Balranald Project due to the distance of this ecosystem from project area, and the fact that it is hydraulically upgradient of the project area. Predicted groundwater impacts do not extend to this ecosystem.

Terrestrial vegetation along the Lower Murrumbidgee floodplains and prior streams will not be impacted by the Balranald Project given their distance from the project area, and the fact that predicted groundwater impacts do not extend to these ecosystems.

Supporting documentation for the Lower Murrumbidgee Groundwater WSP speculates that the groundwater dependence of the terrestrial vegetation along the floodplains and prior streams is minimal, noting they are dependent mainly on surface water flows (CDM Smith 2015). This conclusion is derived mainly from observations on health of the vegetation communities during prolonged periods of dry weather, and salinity differences between surface water and groundwater (Braaten and Gates 2003). Thus these GDEs are considered to be ecosystems that rely on groundwater.

14.5.2 Ecosystems that rely on groundwater

An assessment of the ecosystems that rely on groundwater was undertaken by CDM Smith in 2015. This assessment concluded the predicted effects to surface runoff are confined to the immediate project disturbance area and do not reach the areas with ecosystems that rely on groundwater. Although where water table fluctuations are predicted (ie in Shepparton Formation or the Loxton-Parilla Sands at the Nepean deposit) there may be a reduced water availability (associated with drawdown) or water logging (associated with mounding).

A classification system for the indicative level of groundwater use was developed based on groundwater salinity and the depth of the water table. This derived groundwater use classes from very high or sensitive (Class 1) to negligible or insensitive (Class 5). No class 1 ecosystems were identified.

Class 2 and 3 ecosystems that rely on groundwater were identified along the Lachlan, Murrumbidgee and Murray floodplains, where the water table is relatively shallow and less saline. Further away from surface waters, class 4 ecosystems, which are less sensitive to drawdown, were identified in the vicinity of the West Balranald and Nepean deposits. Jacobs (2015) undertook predictive water level simulations using the numerical model at the locations where ecosystems potentially rely on groundwater. The major findings concluded that:

- no impacts have been identified for the wetlands associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments (due to their distance from the project area, and the stabilising influence of regulated watercourses on the water table aquifer);

- predicted drawdown impacts are constrained to areas of Black Box vegetation near the West Balranald mine, but the extent of drawdown is such that predicted impacts are rated as low (ie there will be no significant change in distribution); and

- predicted mounding impacts are constrained to areas of Black Box vegetation near the injection borefield. A moderate rating was assigned to some areas of Black Box vegetation in these areas (ie there could be some evidence of changing distribution of species and disturbance).

14.6 Geochemistry

Earth Systems undertook a geochemistry assessment for the Balranald Project in 2015 (Appendix Q, EIS report). The dewatering and excavation of the deposits will expose sulfidic materials within the ore, overburden, pit wall sediments and process water streams to atmospheric oxygen. This can result in sulfide oxidation and the subsequent generation of acid and metalliferous drainage. The oxidation of sulfide mineral within mine materials is governed by the availability and flux of oxygen, a requirement of oxidation. Grain size, compaction, moisture content and the surface area to volume ratio will affect the degree of oxygen diffusion. Therefore, the overall oxidation of the dewatered sulfide minerals within the pit walls and the ore stockpiles is limited by the diffusion of oxygen into the pit walls and stockpiles via the exposed face (Earth Systems 2015).

The Nepean deposit does not contain significant quantities of sulfidic minerals and is classified as non acid forming. In addition the Nepean deposit is closer to the surface and considerably smaller than the West Balranald deposit and therefore the extent of disturbance and duration of mining at Nepean will be less than at West Balranald. The Nepean deposit is likely to represent a lower acid and metalliferous drainage risk than the West Balranald deposit.

The West Balranald non saline overburden and saline overburden is also classified as non-acid forming (Earth Systems 2015), while the majority of the organic overburden and ore samples analysed had a low to moderate potentially acid forming classification. There is a pronounced increase in the risk profile of the acid and metalliferous drainage risk classification, with the top of the organic overburden materials defining the upper boundary of the potentially acid forming materials.

Dewatering of the West Balranald deposit will result in the desaturation of large volumes of in-situ organic overburden within the pit walls. This will expose susceptible sulfides, mainly in the ore and organic overburden, to oxidation with the subsequent risk of acid and metalliferous drainage generation. Should heavy rainfall occur, acid and metalliferous drainage could be transported below the pit floor to the natural groundwater level, causing acidification of groundwater. The organic overburden within mining and backfill lags, and the pit walls represents with largest acid and metalliferous drainage risk area (Earth Systems 2015).

Lime dosing may be undertaken to neutralise acid and metalliferous drainage generation, this will raise the pH of the overburden and pit walls. It is expected that the overburden and pit walls will remain predominantly dry during mining, however there is the potential for enhanced alkaline conditions to be mobilised via groundwater flow one the pits are backfilled if there is a low groundwater buffering capacity. Modelling indicates that the groundwater flow direction will be towards the centre of the pit voids for well over 100 years post mining, and therefore potential alkaline conditions will be localised for a very long period of time and will not contribute to the wide scale mobilisation of alkaline conditions.

14.7 Hydrostratigraphy

The mining and backfilling process will result in localised alteration to the physical structure and distribution (ie stratigraphy) of the Loxton-Parilla Sands and Shepparton Formation. On a regional scale the current hydrostratigraphy and associated aquifer properties are not expected to change. However, along the West Balranald and Nepean mine paths, the Shepparton Formation and the Loxton-Parilla Sands will be excavated to the base of the ore body and backfilled following mining. Iluka have indicated that these units will not be replaced with the same stratification.

While backfill will be compacted to some degree this will not be undertaken with the specific aim of replicating pre-mining porosity and specific yield properties. The resulting localised porosity and associated specific yield of backfill material is expected to be elevated from current levels.

Along the mine paths, where the degree of stratification is reduced by the mining and backfilling process, it is expected that post-mining hydraulic conductivity will differ from current conditions. Generally, it is expected that, due to the reduction in stratification, vertical hydraulic conductivity will increase while the mixing of higher and lower conductivity material could potentially reduce localised horizontal hydraulic conductivity. Under such conditions localised perched water tables are less likely to occur with recharge more readily percolating down to the regional water table, enhancing the rate of groundwater level recovery.

14.8 Cumulative impacts

Regionally cumulative impacts at the water source scale are considered within the process of preparing WSPs where sustainable limits are assessed. Within the Western Murray Porous Rock Groundwater Source of the MDB Porous Rock WSP, NOW has established the long term average annual recharge to the system, and then set aside 52% of this annual recharge for the environment. Of the remaining 48% of water that recharges to the system each year, 2% is reserved for landholder rights, 1% is allocated to salinity interception schemes and 2% is currently allocated to other licensed users. This leaves 42% (or 467,377 ML/yr) available to be allocated to other extractive uses.

The Balranald Project is seeking to take groundwater for the project over 10 years, but with a peak take spanning over six years. Over this six year peak take they are seeking to take between 19,546 and 29,461 ML/year. These volumes are well within the sustainable limits of the Western Murray Porous Rock Groundwater Source and constitute only 6% of the current level of unallocated water within this groundwater source.

Iluka will be seeking credits for all injected water under the return flow regulation once it is enacted. This regulation was scheduled for enactment in late 2014, but is yet to commence. Under this regulation Iluka are only required to hold the license volume for the difference between the net and gross take of groundwater. Over the mining period the difference between the annual volume extracted and injected has an average of 120 ML/yr, with a peak of 761 ML in year 7. Once the return flow regulation commences this will reduce the required license volume from the Western Murray Porous Rock Groundwater Source to 761 ML, which represents 0.16% of the current level of unallocated water within this groundwater source.

14.8.1 Atlas-Campaspe mineral sands project

There are a number of mining tenements (exploration licenses (ELs) and mining lease applications (MLAs) for mineral sands deposits in the Murray Basin in NSW. One of these is relates to Cristal's Atlas-Campaspe Mineral Sands Project (the Atlas-Campaspe Project), which received development consent under the EP&A Act in 2014. The Atlas-Campaspe Project is located approximately 20 km to the north of the Nepean deposit and will comprise the extraction of mineral sands from the Loxton-Parilla Sands. At this location the mineral deposits are located predominantly above the existing regional groundwater table. However groundwater abstraction would be undertaken to supply mine water and for localised dewatering; this water also falls under the Wester Murray Porous Rock Groundwater Source within the MDB Porous Rock WSP.

Numerical groundwater modelling for the Atlas-Campaspe Project was undertaken to assess impacts associated with groundwater abstraction. The model extent incorporated the Nepean mine, and has been considered as part of a cumulative impact assessment. The predicted 1 m drawdown cone extends a maximum 2 km from the southernmost part of the Atlas-Campaspe deposit (which is closest to the Nepean deposit), wand this does not overlap with the drawdown from the Nepean deposit (Resource Strategies 2013). There is approximately 17 km between the predicted 1 m drawdown cones of the two mines.

Cristal Mining currently holds a combined total of 21,442 share components (which are included in the MDB Porous Rock WSP for the Ginkgo and Snapper Mines, authorised by the following WALs:

- WAL 27918 (60AL582836) – 14,000 shares;
- WAL 27915 (60AL582832) – 7,402 shares; and
- WAL 27912 (60AL582834) – 40 shares.

The very poor water quality of the groundwater in the Western Murray Porous Rock Groundwater Source limits the beneficial use of the water in the system, and this is represented by the dominant purpose of water being for mining and industrial purposes, and for stock supplies. There is no significant demand for water from this source in the region.

There are a number of operational gypsum projects to the north of the Murray River, including a mine located immediately to the east of the West Balranald deposit; these projects comprise shallow works that do not comprise groundwater abstraction. Therefore gypsum operations are unlikely to contribute to cumulative hydrogeological impacts.

The cumulative impacts have been considered thoroughly, and no cumulative impact is expected as a result of the Balranald Project.

15 Management, mitigation and monitoring measures

15.1 Introduction

Water management for the Balranald Project combines site surface water management, and the management of abstracted and injected groundwater. A key to successful water management for this project will be the separation and control of water from different sources and of different water qualities. In addition, a water monitoring program to assess impacts and ensure the functioning of the site water management system will be implemented. The proposed mine site water management strategy and infrastructure will be designed to ensure that the Balranald Project has a negligible impact on the quality of surface runoff and potential receiving environments.

15.2 Water management

A water management system will be designed to:

- segregate different water sources and different water qualities, (ie mine affected water, and raw water from the Murrumbidgee River, sediment-laden water);
- capture and contain mine affected water and prevent discharge to receiving water environments;
- ensure unused abstracted, saline groundwater is contained and injected rather than discharged to the surface;
- capture and segregate runoff from the following locations:
    - MUP area, processing area, and the saline overburden stockpiles;
    - the non saline overburden, topsoil and subsoil stockpiles; and
    - other disturbed areas.
- divert clean runoff away from areas disturbed by mining activities to minimise the volume of mine affected water;
- manage sediment laden water in accordance with an erosion and sediment control plan that would be part of the water management plan, which will include the capture and treatment of sediment laden water in sediment dams;
- reuse and recycle water in mining operations;
- include contingency measures to accommodate either a surplus or deficit of site water; and
- communicate with key stakeholders (ie NOW, landholders, other users).

Some abstracted groundwater will be used to satisfy mine water demands although the majority will be treated with ultra-violet light and injected into the Loxton-Parilla Sands. Saline groundwater will be contained and there will be no releases of groundwater from the project area, merely groundwater will be temporarily relocated. Groundwater seepage and surface runoff inflows to the open cut mining area at the West Balranald mine will be collected in onsite storages, and will be used for mine operations and water supply.

15.3 Flooding

The possible inundation at the West Balranald mine resulting from overflow from Muckee Lake during a greater than 1 in 100 AEP flood in Box Creek would be managed via the construction of a small bund within the project area to prevent floodwater interacting with operations.

15.4 Contamination

Due to the segregation of mine affected water and clean run off, broad contamination of surface waters is not expected. In addition the recycling and reuse of mine affected water will minimise the volume of water used by the project.

Any water contaminated from industrial areas will be collected for treatment in an oil and grease separator prior to recycling in the mine water management system. The waste products from the oil and grease separator will be disposed of offsite at a registered waste facility.

Responses to spill events will be detailed in a water management plan, and spill response equipment will be kept on site.

Sewage is not considered to be a potential source of contamination as both the package waste treatment system and septic tanks are above ground systems that comprise off site disposal at a licensed facility.

15.5 Acid and metalliferous drainage

The risk of acid and metalliferous drainage is greatest from stockpiles, and exposed (and desaturated) organic overburden and ore material (ie pit walls, working face) within the West Balranald pit. In the event of heavy rainfall acidity can become mobilised and can lower soil, surface water, process water or groundwater pH. While some residual acid and metalliferous drainage from the in-situ and backfilled organic overburden is likely to be unavoidable, alkaline amendments and management practices can lower the overall acid volume generated. The management measures employed to prevent the acidification of surface water and groundwater focus on preventing the generation of acid, this includes:

- routine, visual inspections of stockpiles for possible drainage and the construction of bund walls to channel and collect drainage;
- not disposing of mining by products in the Nepean mine;
- optimising stockpile dimensions, such that the surface area to volume ratio is minimised;
- covering any long term stockpiles with conventional agricultural stockpile covers or calcium carbonate, and compact to limit oxidisation;
- installing a low permeability or limestone liner beneath potentially acid and metalliferous drainage producing stockpiles;
- minimising the exposed surface area and time of the pit organic overburden and ore;
- where the exposure of high risk material cannot be avoided amend the material/air interface with an oxygen consuming or limiting layer;
- dumping and spreading ultra fine grained limestone in the pit floor and backfill material to neutralise acid and metalliferous drainage generation; and

- in the event of pit acid metalliferous drainage generation backfill with sufficient limestone and possibly compost to neutralise the acid and promote reducing conditions (Earth Systems 2015).

Should any acid and metalliferous drainage be generated and transported into the surface or groundwater systems active segregation and treatment of this water may be required.

Since the generation of acid and metalliferous drainage from sulfidic materials at West Balranald is considered to be largely controlled by exposed surface area and air entry, management options should focus on minimising surface exposures of organic over burden and ore, and further minimising air entry via the surface exposures using material compaction and application of air-entry-barrier materials.

15.6 Water Management Plan

A water management plan will detail management measures to mitigate impacts to water resources during construction and operation of the Balranald Project. This plan will include details on how Iluka will undertake the following:

- establish a program for monitoring flow events in Box Creek to collect baseline water quality and flow data;
- use rainfall forecasting and the development of site water balances to identify when storages may be vulnerable to overtopping;
- establish a procedure for maintenance and inspection of on-site water management structures such as drains, culverts, bunds, sediment dams, dewatering bores, re-injection borefield and the TSF;
- monitoring and management of abstracted and reinjected groundwater volumes in real time;
- respond to any spill or contamination events;
- monitor water levels in water storages in parallel with monitoring of forecast weather conditions to ensure that adequate storage capacity is available; and
- undertake controlled discharge from sediment dams and the conditions for this, notably that suspended solids concentration is lower than the ANZECC (2000) aquatic ecosystem guideline value.

15.7 Monitoring

15.7.1 Surface water

Surface water monitoring includes sampling from key storages within the mine affected water management system and possible surface water flows (when present). The monitoring parameters are based on the expected water quality of the sampled water, while the frequency of monitoring is related to the climatic conditions. Specifically, water quality monitoring in surface water flows will comprise physiochemical parameters when there is sufficient volume. Water quality monitoring comprising physiochemical parameters and chemical analytes is proposed at the sediment dams following run off events, and at the MUP and process water dams during uncontrolled releases.

Regular inspection of surface drainage infrastructure will be a crucial component of the surface water monitoring program. All drains will be regularly inspected to identify actual or potential problems, including erosion or sediment depositions. Dam lining and stock pile bund walls will also be inspected to verify their integrity.

Metering and quality monitoring of all water volumes pumped from in pit sumps will be undertaken.

15.7.2 Groundwater

Groundwater quality and groundwater level monitoring has been carried out on the existing network of monitoring bores on an intermittent basis since their installation and quarterly since 2013 for the purpose of baseline data collection. The established monitoring network will be used for ongoing monitoring during construction and operation to assess groundwater level and quality trends. Monitoring data will be used to verify the model predictions and assess the degree of inter aquifer mixing. Specifically monitoring data will be used to assess changes to groundwater level and pressure against the modelled predictions. Groundwater quality monitoring will ensure early detection of any change in groundwater quality or possible groundwater contamination.

It is recommended that groundwater level and quality monitoring continue as agreed with NOW, and this includes:

- monitoring of targeted groundwater elevations on at least a quarterly basis up to and including September 2015; and
- continued targeted groundwater quality sampling on a quarterly basis up to and including September 2015, with the analytical suite being based on baseline investigations.

The groundwater level and quality monitoring frequency will be revised in conjunction with the NOW, via the water management plan during the pre-mining, construction, mining and post-mining phases.

Additional monitoring locations may be required to monitor drawdown extent during mining at key locations between active groundwater users (including the environment) and the mine areas such as:

- monitoring site/s between the mine and the Murrumbidgee River; and
- monitoring site/s between the mine and active groundwater users.

Additional shallow monitoring bores will be installed adjacent to mine water dams and overburden stockpiles that could potentially produce acid and metalliferous drainage so that groundwater quality can be monitored.

Field based physiochemical water quality monitoring of the dewatered groundwater prior to reinjection will occur on a daily basis. Real time metering of all dewatering and reinjection volumes will be recorded using telemetry systems. This monitoring data will also be used to record take and injection volumes.

The water management plan will contain the details for the groundwater monitoring program and will also include the establishment of groundwater level and quality triggers, actions and contingencies that will be implemented in the event that monitoring indicates an impact. This process would also comprise the ongoing evaluation of monitoring data and the redefinition of triggers, actions and contingencies if required. Triggers specific to groundwater reliant ecosystems will also be developed, these will be designed to indicated substantial deviation from expected or predicted impacts or to provide an early warning of an impact that has not been predicted.

16 Conclusions

Iluka's Balranald Project comprises the mining of two mineral sands deposits within the Murray Basin. This water assessment has been prepared to address specific requirements relating to groundwater and surface water in the SEARs. Specifically, the water assessment has taken into account project activities associated with the Balranald Project that could impact on groundwater and surface water receptors in the region.

16.1 Surface water systems

Due to the climatic conditions (ie low rainfall and high evaporation), flat landscape, and large areas of permeable soils, there is little locally derived runoff in the project area and no permanent surface water sources. The Murrumbidgee and Murray rivers are located outside the project area to the south-east and south, although the pipeline extends to the Murrumbidgee River.

Within the project area is Box Creek, an ephemeral watercourse that receives distributary flows from the Lachlan River. Box Creek has no defined beds and flow has only occurred in Box Creek on several occasions in the last 60 years.

16.2 Groundwater systems

The basal unit overlying the basement rocks is the Olney Formation, comprising predominantly continental clay, silt and sand sediments. A marginal marine unit, the Geera Clay, interfingers through the middle and upper sequence. Overlying the Geera Clay and Olney Formation is the Loxton-Parilla Sands, a thick sequence of marine sands that contains the target mineral deposits. Overlying the Loxton-Parilla Sands is the Shepparton Formation, comprising fluio-lacustrine unconsolidated to poorly consolidated clays and silts.

Locally in the project area there is limited recharge from direct rainfall, with most recharge to the area occurring via throughflow from the east. Minor direct rainfall recharge may occur locally, but the low rainfall and high evaporation means this volume would be minimal and the presence of stratified low permeability clays and silts in the Shepparton Formation often results in this water entering perched systems. The Loxton-Parilla Sands and the Olney Formation is recharged via through flow from areas to the east of the project area.

Monitoring bores screening the Shepparton Formation and Loxton Parilla Sands in close proximity to the Murrumbidgee and Murray rivers have a lower groundwater table elevation than the river stage, and this therefore indicates the loosing nature of these rivers in this local area (Jacobs 2015). The conceptualisation of the river as a losing system is supported by work undertaken by the MDBA (MDBA 2012) where the lower section of the Murrumbidgee River was classified as transitional between gaining and losing and the Murray River in this area being classified as losing.

Consistent with topographic gradients, hydraulic gradients are very gentle in the central and western Murray Basin, and the broad flow direction in all aquifers is from east to west. However, the basement structure influences the groundwater flow direction in the project area causing a slightly north northwest trend in flow. This is most pronounced in the deeper Olney Formation.

The horizontal hydraulic conductivity in both the Shepparton Formation and Loxton-Parilla Sands is variable, due to the depositional environments and volume of clay; continual lateral flow through Formations is not common.

There is the potential for vertical upwards flow from the Olney Formation and Geera Clay to the Loxton-Parilla Sands and Shepparton Formation based on pressure head differences observed on site and reported in the literature. Heads in the Shepparton Formation and Loxton-Parilla Sands are mostly similar, although results of pumping and injection trials indicate that the two units are poorly connected (Iluka 2015) and that significant head differences may be created when water is extracted from or injected into either of these units. This is likely associated with clay lens at the base of the Shepparton.

Groundwater quality within the Murray Basin is variable, and within the vicinity of the project area is typically seawater quality in the Loxton-Parilla Sands and Shepparton Formation. Salts originate from the marine depositional environment and are enhanced by low precipitation and high evaporation rates as well as long groundwater residence times. The water quality of the Shepparton Formation and Loxton-Parilla Sands is comparable, and is characterised by high salinity, neutral pH, low dissolved metals and Na-Cl type dominance.

16.3 Water utilisation and management

Water will be utilised and managed in the following ways:

- groundwater from the Loxton-Parilla Sands will be abstracted from the pits, and at the West Balranald mine ex-pit bores, to create dry mining conditions;
- groundwater abstracted will mostly be injected back into the Loxton-Parilla Sands down hydraulic gradient of mining, a small amount of this water will be used in mine operations;
- surface water will be taken from the Murrumbidgee River to the south of the project area for plant and domestic use, and for dust suppression at sensitive areas; and
- during the pre mining phase construction water will be abstracted from the Olney Formation.

The abstraction and reinjection of groundwater represents the largest volume of water taken; the combined total volume of abstracted groundwater from both the Nepean and West Balranald deposits is 149,780 ML. Of this volume 148,820 ML will be reinjected as some of this water will be utilised for mining and processing. The total volume of groundwater abstracted during the construction phase is 300 ML.

16.4 Sensitive receptors

The receptors that have been identified as potentially being sensitive to water impacts in the region include:

- ecosystems that rely on groundwater, including GDEs;
- Murrumbidgee River and ephemeral water courses; and
- private landholder bores, properties and infrastructure.

Within a 60 km radius of project area there are 112 private landholder bores registered on the NOW groundwater database (as extracted in January 2015), predominantly utilising groundwater for stock and domestic purposes. The majority of the bores are screened in the Shepparton Formation.

Ecosystems that rely on groundwater are important environmental assets and typically occur where groundwater is at or near the land surface. The vegetation in the project area are typically hardy, resilient species that periodically rely on groundwater and are not considered to be GDEs. The MDB Porous Rock WSP does not list any high priority GDEs within the Western Murray Porous Rock Groundwater Source.

16.5 Assessment criteria

The SEARS were used to inform the water assessment for the Balranald Project.

The minimal impact thresholds outlined in the AIP was used to assess the potential impacts to groundwater resulting from the Balranald Project. This is in accordance with the Minister’s requirements for approval and administration of the WMA 2000. The groundwater within the Western Murray Porous Rock Groundwater Source is classified as 'less productive', based on the very high salinity levels. The minimal considerations for porous rock units of less productive groundwater systems have been adopted for this assessment.

16.6 Numerical model

A regional groundwater model (BAL2.0) was developed by Jacobs (2015) to simulate groundwater behaviour under the proposed mining conditions, including dewatering abstraction and reinjection conditions. This was used to inform the design of the dewatering systems and to quantify impacts to the groundwater regime. The numerical model is based on extensive site investigations undertaken over a number of years. A good compilation of data was used to describe the hydrostratigraphy, recharge and discharge features and groundwater flow directions; the model provides a good regional scale representation of the groundwater system.

16.6.1 Construction supply

The total volume abstracted from the Olney Formation is 300 ML, over a 3 year period during the construction phase. The residual drawdown at abstraction bores at Wellfield 3 and Wellfield 7 is less than 0.2 m. Groundwater extraction from the plant bore creates a localised drawdown impact, with the 0.2 m drawdown contour constrained to a small area within the footprint of the West Balranald disturbance area.

16.6.2 West Balranald dewatering

The model predicts an average dewatering rate of 746 L/s for the six years of mining at West Balranald and an average of 95 L/s during the two years of backfilling. Drawdown cones extend the length of the West Balranald mine during mining and the whole duration of post mining modelling (ie 100 years). In the Shepparton Formation the 0.2 m groundwater drawdown curve extends to approximately 10 km laterally from the strike of the deposit. In the more transmissive Loxton-Parilla Sands the 0.2 m drawdown curve extends to approximately 15 km laterally from the deposit. The 0.2 m drawdown cone does not extend to the Murray or Murrumbidgee rivers, and therefore does no induce additional inflow from these surface water systems. Predicted drawdown impacts in the Olney Formation at the end of mining are evident only for the high dewatering case.

Model predicted drawdown in the Shepparton Formation and Loxton-Parilla Sands 100 years after cessation of groundwater-affecting activities are similar and some residual drawdown remains. While the magnitude of drawdown reduced following the ceasing of abstraction the extent of the 0.2 m drawdown contour continues to expand outward.

16.6.3 West Balranald backfilling

The final elevation of the West Balranald mine (52 m AHD) is based on backfilling to provide a fill of 3.5 m above the pre-mining potentiometric surface in the Loxton-Parilla Sands and 3 m above the water table depth, in the Shepparton Formation. However due to mine induced drawdown the depth to water at the final West Balranald void will more likely be 4.7 m below ground level 100 years after mining.

16.6.4 Nepean dewatering

The model predicts an average dewatering rate of 100 L/s for the 1.5 years of mining at the Nepean deposit, with a peak monthly dewatering rate of 186 L/s. Dewatering rates are predicted to increase over the life of the Nepean mining operation, due to the pit deepening further below the pre-mining water table as it advances northward. At the commencement of ore production the pit floor is at 49 m AHD and this progressively deepens to 36 m AHD by the end of the mining.

Model predicted groundwater drawdown in the Shepparton Formation and Loxton-Parilla Sands at the end of mining the Nepean deposit is localised, with the 0.2 m drawdown cone extending no more than 2 km from the mine in both units. These small predicted impacts are consistent with expectations given the shallow depth of the mine below the water table. No residual impact of dewatering (ie drawdown) is evident at the Nepean deposit 100 year after mining has commenced.

The will be no void remaining at the Nepean mine following mining.

16.6.5 Reinjection

Iluka plans to inject water produced from dewatering operations back into the Loxton-Parilla Sands to the north-west of the pit area (ie off-path reinjection). Injection rates peak at about 1,300 L/s. Modelling indicates that piezometric pressure heads in the Loxton-Parilla Sands increase by more than 5 m above the pre-mining levels. The impact of this on the overlying Shepparton Formation is managed by ensuring water pressures remain 3 m below ground surface. In addition, clay layers and relatively poor hydraulic connection between the two aquifers will also minimise potential water level mounding within the Shepparton Formation.

The water quality of the injected water is similar to the groundwater within the receiving environment in both the Loxton Parilla Sands and overlying Shepparton Formation (should upward leakage occur).

Model predicted mounding in the Shepparton Formation and Loxton-Parilla Sands 100 years after cessation of groundwater-affecting activities indicates mounding of up to 1 m at the off-path borefield. Following the ceasing of reinjection the 0.2 mounding curve continues to expand, predominantly to the north and east.

16.7 Surface water assessment

Although the Balranald Project is located in the MDB and nearby to the major inland rivers of the Murrumbidgee, Murray and Lachlan, there are no direct surface water impacts to these major rivers. Within the project area itself there is an absence of permanent surface water sources, there are no surface water users, and no surface water related infrastructure. The impacts associated with surface water are mostly related to extreme rainfall events, but the implementation of the mitigation measures would reduce risks to acceptable levels.

The proposed water management system is adequately configured and designed to prevent long term inundation of the West Balranald mine pit and surrounding project area (WRM 2015). Long term catchment modelling undertaken by WRM (2015), incorporating the mine water management system, indicates that this system is capable of handling both the wettest and driest periods on record at the project area for each of the selected years of mine life. WRM (2015) concludes there is a less than a 1% chance of uncontrolled release of mine affected water during any year of mine life during Year 1 and 4.

The use of external water will be minimised by sourcing all processing water from the mine water management system and saline water extracted from the dewatering borefield. No external water will be required to supply these demands, and hence these demands will have no impact on regional water availability.

Water balance modelling indicates that the Balranald Project would source the majority of the required water from dewatered groundwater with make-up water supplied via on-site sources (ie rainfall runoff, and groundwater inflow to the pit). Mine affected water will be reused to supply the MUP, processing plant and saline water dust suppression demands. The dewatering borefield production rates are predicted to exceed the net makeup water demands at all stages of mine life.

Raw water for use in dust suppression of sensitive areas and to supply filtered water demands will be pumped from the Murrumbidgee River. The required WAL will be purchased from the registered water license market under the Murrumbidgee River WSP and is therefore within the sustainable limits of this system and therefore no net impact on regional water availability. The only other source of external water will be potable drinking water trucked into the project area.

16.8 Groundwater assessment

The Balranald Project will cause localised changes to the groundwater conditions due to dewatering and injection requirements. The numerical model has been used to predict changes in groundwater levels as a result of mining generally across the project area and locally at identified sensitive receptors. While Iluka will abstract and inject groundwater from/to the Loxton-Parilla Sands, modelling indicates drawdown and mounding will occur in both the Loxton-Parilla Sands and the Shepparton Formation. Thus, groundwater abstraction and injection will enhance vertical hydraulic gradients between these formations.

The abstracted groundwater will be a mix of both the Loxton-Parilla Sands and Shepparton Formation groundwaters, and the receiving environment is both the Loxton-Parilla Sands and the Shepparton Formation. Due to the high salinity the only beneficial use of this water is considered to be for emergency supply for stock, and for industrial and mining purposes where use of poor quality water is not a constraint. In accordance with the AIP, there will not be any change to the water quality that would change the beneficial use category of the water in either the Loxton Parilla Sands or the Shepparton Formation as a direct result of the Balranald Project.

Assessment of the predicted groundwater level fluctuations indicates that there are no instances where the maximum change in pre mining groundwater level exceeds 2 m in any nearby registered landholder bore, therefore there is no requirement for 'make good' provisions in accordance with the AIP. There is one landholder bore, GW600300, where the observed drawdown is approximately 59.5 m, however this bore is located within the West Balranald deposit and will be decommissioned as part of the mining works.

The Lower Murrumbidgee Groundwater WSP, identified two high potential GDEs, the Great Cumbung Swamp and terrestrial vegetation along the Lower Murrumbidgee floodplains and prior streams. Neither the Great Cumbung Swamp or the terrestrial vegetation along the Lower Murrumbidgee floodplains and prior streams considered to be vulnerable to project-related impacts due to the distance of these ecosystems from the project area. The Great Cumbung Swamp is also hydraulically upgradient from the project area.

Supporting documentation for the Lower Murrumbidgee Groundwater WSP speculates that the groundwater dependence of the terrestrial vegetation along the floodplains and prior streams is minimal, noting they are dependent mainly on surface water flows (CDM Smith 2015). Thus these GDEs are considered to be ecosystems that rely on groundwater.

16.8.1 Mine void

Iluka identified that final elevation of the West Balranald mine of 52 m AHD is based on backfilling to provide a fill cover of 3 – 3.5 m above the pre-mining potentiometric surface and water table. However due to mine induced drawdown the depth to water at the final West Balranald void will more likely be 4.7 m below ground level 100 years after mining.

Given the planned final backfill level is approximately 13 m below the initial and surrounding ground surface elevation of approximately 65 m AHD, any rainfall runoff is likely to collect within the remaining depression. This is likely to lead to increased recharge to the water table below the remaining depression and, therefore, mounding of the water table at this point. The final void is predicted to behave in a similar hydrologic manner to the nearby dry lakes and surface depressions.

The small volume of runoff expected to collect in the void will either evaporate or will infiltrate through the floor of the void into the Loxton Parilla Sands. There is enough cover to avoid the creation of an artificial salina, ie an accumulation of salts. The maximum EC of water in the final void is not expected to exceed the existing average EC conditions for the Loxton-Parilla Sands.

16.8.2 Geochemistry

The excavation and dewatering of the West Balranald sand deposits will expose sulfidic materials within the ore, overburden, pit wall sediments and process water streams to atmospheric oxygen which can result in sulfide oxidation and the subsequent generation of acid and metalliferous drainage. The overall oxidation of the dewatered sulfide minerals within the pit walls and the ore stockpiles is limited by the diffusion of oxygen into the pit walls and stockpiles via the exposed face (Earth Systems 2015).

The non saline overburden and saline overburden were classified as unlikely to be acid generating at both deposits. At the West Balranald deposit the desaturation of in-situ organic overburden within the pit walls will expose susceptible sulfides, mainly in the ore and organic overburden, to oxidation with the subsequent risk of acid and metalliferous drainage generation. The ore at the Nepean deposit does not contain significant quantities of sulfidic minerals and is classified as non acid forming.

Lime dosing may be undertaken to neutralise acid and metalliferous drainage generation, this will raise the pH of the overburden and pit walls. It is expected that the overburden and pit walls will remain predominantly dry during mining, however there is the potential for enhanced alkaline conditions to be mobilised via groundwater flow one the pits are backfilled if the neutralising capacity of the groundwater is low. Modelling indicates that drawdown curves continue to expand during the 100 years post mining suggesting that groundwater will flow towards the centre of the pit voids, and will not contribute to the wide scale mobilisation of alkaline conditions.

16.8.3 Hydrostratigraphy

The mining and backfilling process will result in localised alteration to the physical structure and distribution (ie stratigraphy) of the Loxton-Parilla Sands and Shepparton Formation. On a regional scale the current hydrostratigraphy and associated aquifer properties are not expected to change. While backfill will be compacted to some degree this will not be undertaken with the specific aim of replicating pre-mining porosity and specific yield properties. The resulting localised porosity and associated specific yield of backfill material is expected to be elevated from current levels.

Along the mine paths, where the degree of stratification is reduced by the mining and backfilling process, it is expected that post-mining hydraulic conductivity will differ from current conditions. Generally, it is expected that, due to the reduction in stratification, vertical hydraulic conductivity will increase while the mixing of higher and lower conductivity material could potentially reduce localised horizontal hydraulic conductivity. Under such conditions localised perched water tables are less likely to occur with recharge more readily percolating down to the regional water table.

16.9 Cumulative impacts

There are a number of mining tenements for mineral sand deposits in the Murray Basin in NSW. One of these is the Atlas-Campaspe Project, which received development consent under the EP&A Act in 2014. The Atlas-Campaspe Project is approximately 20 km to the north of the Nepean deposit and will comprise the extraction of mineral sands from the Loxton-Parilla Sands. Groundwater abstraction would be undertaken to supply mine water and for localised dewatering; this water falls under the Wester Murray Porous Rock Groundwater Source in the MDB Porous Rock WSP.

The predicted 1 m drawdown cone extends a maximum 2 km from the southernmost part of the Atlas-Campaspe deposit (which is closest to the Nepean deposit), which is approximately 17 km from the predicted drawdown from the Nepean deposit (Resource Strategies 2013).

Cristal Mining currently holds a combined total of 21,442 share components (units or million litres in the Western Murray Porous Rock Groundwater Source for the Ginkgo and Snapper Mines.

The very poor water quality of the groundwater in the Western Murray Porous Rock Groundwater Source limits the beneficial use of the water in the system, and this is represented by the dominant purpose of water being for mining and industrial purposes, and for stock supplies. There is no significant demand for water from this source in the region.

There are also a few operational gypsum projects to the north of the Murray River, including a mine located immediately to the east of the West Balranald deposit; these projects comprise shallow works that do not comprise groundwater abstraction. Therefore gypsum operations are unlikely to contribute to cumulative hydrogeological impacts.

16.10 Summary

A water assessment was undertaken in accordance with the SEARs. Water investigations, focusing on the hydrogeological regime, have spanned three years and comprise the collection of site data and the development of a numerical model. The receptors identified as potentially being sensitive to water impacts in the region included:

- ecosystems that rely on groundwater, including GDEs;
- Murrumbidgee River and ephemeral water courses; and
- private landholder bores, properties and infrastructure.

Based on the assessment criteria contained in the AIP impacts from groundwater abstraction and reinjection are likely to be minimal. Overall there are few water related impacts as a result of the Balranald Project due to:

- groundwater quality of the target units for abstraction and injection (Loxton-Parilla Sands and Shepparton Formation) already being highly saline, and not suitable for beneficial uses (human drinking water, livestock drinking water and irrigation) without treatment;
- the absence of landholder bores in areas where 2 m or greater drawdown or mounding is predicted;
- the absence of GDEs; and
- compliance with the Water Act and WM Act, and the rules within the relevant WSPs.

In regards to criteria not included in the AIP the following impacts are possible:

- Predicted mounding impacts which are constrained to areas of Black Box vegetation near the dedicated injection borefield. There could be some evidence of changing distribution of species and disturbance;
- Localised alteration to the physical structure and distribution (ie stratigraphy) of the Loxton-Parilla Sands and Shepparton Formation. Along the mine paths it is expected that post-mining hydraulic conductivity will differ from current conditions; and
- Generation of acid and metalliferous mine drainage associated with the desaturation of mine pit walls and overburden, and oxidation of sulfides.

Preliminary assessment of the project site water quality suggests there will be no negative change in the water quality receiving environments. In addition the proposed mine site water management strategy and infrastructure will be designed to ensure that the Balranald Project has a negligible impact on the quality of surface runoff.

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Glossary of Terms

Acidity	Base neutralising capacity.
Alkalinity	Acid neutralising capacity.
Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on river beds, floodplains, and alluvial fans.
Alluvial aquifer	Permeable zones that store and produce groundwater from unconsolidated alluvial sediments. Shallow alluvial aquifers are generally unconfined aquifers.
Anion	An ion with a negative charge.
Anthropogenic	Occurring because of, or influenced by, human activity.
Annual exceedance probability	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Aquatic ecosystem	The stream channel, lake or estuary bed, water, and (or) biotic communities and the habitat features that occur therein.
Aquitard	A very low-permeability unit that forms either the upper or lower boundary of a groundwater flow system and does not transmit water or allow water to migrate from upper and lower horizons.
Aquifer	Rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water.
Aquitard	A low permeability unit that can store groundwater and also transmit it slowly from one formation to another. Aquitards retard but do not prevent the movement of water to or from adjacent aquifers.
Artesian water	Groundwater that is under pressure when tapped by a bore and is able to rise above the level at which it is first encountered. It may or may not flow at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is a confined aquifer.
Baseflow	The part of stream discharge that originates from groundwater seeping into the stream.
Beneficial formation	An aquifer with a water resource of sufficient quality and quantity to provide either ecosystem protection, raw water for drinking water supply, and agricultural or industrial water.
Bore	A structure drilled below the surface to obtain water from an aquifer or series of aquifers.
Boundary	A lateral discontinuity or change in the formation resulting in a significant change in hydraulic conductivity, storativity or recharge.
Capillary rise	The upward drawing of liquids in the unsaturated zone, due to intermolecular forces between the liquid and surrounding solid surface.
Cation	An ion with a positive charge – usually metal ions when disassociated and dissolved in water.
Confined formation	An aquifer that is overlain by low permeability strata. The hydraulic conductivity of the confining bed is significantly lower than that of the aquifer.
Concentration	The amount or mass of a substance present in a given volume or mass of sample, usually expressed as microgram per litre (water sample) or micrograms per kilogram (sediment sample).
Conceptual model	A simplified and idealised representation (usually graphical) of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.

Cone of depression	A depression of the water table or potentiometric surface that has the shape of an inverted cone, which develops around a production bore/gas well from which water is being drawn. It defines the radius of influence of a pumping test.
Confining layer	Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients.
Contamination	Contamination is the presence of a non-natural compound in soil or water, or unwanted compound in chemicals or other mixtures.
Discharge	The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.
Discharge area	An area in which there are upward or lateral components of flow in an aquifer.
Drawdown	A lowering of the water table in an unconfined aquifer or the pressure surface of a confined aquifer caused by pumping of groundwater from bores and wells.
Electrical conductivity (EC)	A measure of a fluid's ability to conduct an electrical current and is an estimation of the total ions dissolved. It is often used as a measure of water salinity.
Fault	A fracture in rock along which there has been an observable amount of displacement. Faults are rarely single planar units; normally they occur as parallel to sub-parallel sets of planes along which movement has taken place to a greater or lesser extent. Such sets are called fault or fracture zones.
Fluvial	Pertaining to a river or stream.
Fluvial deposit	A sedimentary deposit consisting of material transported by suspension or laid down by a river or stream.
Fracture	Breakage in a rock or mineral along a direction or directions that are not cleavage or fissility directions.
Fractured rock aquifer	These occur in sedimentary, igneous and metamorphosed rocks which have been subjected to disturbance, deformation, or weathering, and which allow water to move through joints, bedding planes, fractures and faults. Although fractured rock aquifers are found over a wide area, they generally contain much less groundwater than alluvial and porous sedimentary rock aquifers.
Groundwater	The water contained in interconnected pores or fractures located below the water table in the saturated zone.
Groundwater dependent ecosystems (GDEs)	Groundwater dependent ecosystems are communities of plants, animals and other organisms whose extent and life processes are dependent (or partially dependent) on groundwater.
Groundwater flow	The movement of water through openings in sediment and rock within the zone of saturation.
Groundwater system	A system that is hydrogeologically more similar than different in regard to geological province, hydraulic characteristics and water quality, and may consist of one or more geological formations.
Hydraulic conductivity	The rate at which water of a specified density and kinematic viscosity can move through a permeable medium (notionally equivalent to the permeability of an aquifer to fresh water).
Hydraulic gradient	The change in total hydraulic head with a change in distance in a given direction.
Hydraulic head	Is a specific measurement of water pressure above a datum. It is usually measured as a water surface elevation, expressed in units of length. In an aquifer, it can be calculated from the depth to water in a monitoring bore. The hydraulic head can be used to determine a hydraulic gradient between two or more points.
Hydrochemistry	Chemical characterisation of water (both surface water and groundwater).
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrology	The study of the occurrence, distribution, and chemistry of all surface waters.
Infiltration	The flow of water downward from the land surface into and through the upper soil layers.

Major ions	Constituents commonly present in concentrations exceeding 10 milligram per litre. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulphate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate.
MilliSiemens per centimetre (mS/cm)	A measure of water salinity commonly referred to as EC (see also electrical conductivity). Most commonly measured in the field with calibrated water quality meter.
Monitoring bore	A non-pumping bore, is generally of small diameter that is used to measure the elevation of the water table and/or water quality. Bores generally have a short well screen against a single aquifer through which water can enter.
Nested monitoring site	Multiple monitoring bores screening different formations in close proximity.
Numerical model	A model of groundwater flow in which the aquifer is described by numerical equations (with specified values for boundary conditions) that are usually solved in a computer program. In this approach, the continuous differential terms in the governing hydraulic flow equation are replaced by finite quantities. Computational power is used to solve the resulting algebraic equations by matrix arithmetic. In this way, problems with complex geometry, dynamic response effects and spatial and temporal variability may be solved accurately. This approach must be used in cases where the essential aquifer features form a complex system (ie high complexity models).
Permeability	The property or capacity of a porous rock, sediment, clay or soil to transmit a fluid. It is a measure of the relative ease of fluid flow under unequal pressure. The hydraulic conductivity is the permeability of a material for water at the prevailing temperature.
Permeable material	Material that permits water to move through it at perceptible rates under the hydraulic gradients normally present.
pH	Potential of hydrogen; the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per litre; provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral, greater than 7 is alkaline and less than 7 is acidic).
Piezometer	See monitoring bore.
Piezometric surface	In a confined aquifer this is the surface representation of the level to which water will rise in a bore.
Porosity	The proportion of open space within an aquifer, comprised of intergranular space, pores, vesicles and fractures.
Porous rock	Consolidated sedimentary rock containing voids, pores or other openings (joints, cleats, fractures) which are interconnected in the rock mass and may be capable of storing and transmitting water.
Potentiometric surface	See piezometric surface.
Precipitation	(1) in meteorology and hydrology, rain, snow and other forms of water falling from the sky (2) the formation of a suspension of an insoluble compound by mixing two solutions. Positive values of saturation index (SI) indicate supersaturation and the tendency of the water to precipitate that mineral.
Pumping test	A test made by pumping a bore for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the bore and the hydraulic characteristics of the aquifer.
Quaternary	The most recent geological period extending from approximately 2.5 million years ago to the present day.
Recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the water table and by river water reaching the water table or exposed aquifers. The addition of water to an aquifer.
Recharge area	A geographic area that directly receives infiltrated water from surface and in which there are downward components of hydraulic head in the aquifer. Recharge generally moves downward from the water table into the deeper parts of an aquifer then moves laterally and vertically to recharge other parts of the aquifer or

	deeper aquifer zones.
Recovery	The difference between the observed water level during the recovery period after cessation of pumping and the water level measured immediately before pumping stopped.
Residence time	The time that groundwater spends in storage before moving to a different part of the hydrological cycle (ie it could be argued it is a rate of replenishment).
Riparian	Relating to the banks of a natural waterway.
Salina	An artificial pond whereby evaporation of saline water eventually results in the accumulation of salts.
Salinity	The concentration of dissolved salts in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L TDS).
Salinity classification (Australia Water Resources s Council 1988)	Fresh water quality – water with a salinity <800 µS/cm. Marginal water quality – water that is more saline than freshwater and generally waters between 800 and 1,600 µS/cm. Brackish quality – water that is more saline than freshwater and generally waters between 1,600 and 4,800 µS/cm. Slightly saline quality – water that is more saline than brackish water and generally waters with a salinity between 4,800 and 10,000 µS/cm. Moderately saline quality – water that is more saline than brackish water and generally waters between 10,000 and 20,000 µS/cm. Saline quality – water that is almost as saline as seawater and generally waters with a salinity greater than 20,000 µS/cm. Seawater quality – water that is generally around 55,000 µS/cm.
Saturated zone	The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric pressure. The water table is the top of the saturated zone in an unconfined aquifer.
Screen	A type of bore lining or casing of special construction, with apertures designed to permit the flow of water into a bore while preventing the entry of aquifer or filter pack material.
Semi-confined formation	An aquifer overlain by a low-permeability layer that permits water to slowly flow through it. During pumping, recharge to the aquifer can occur across the leaky confining layer – also known as a leaky artesian or leaky confined aquifer.
Specific storage	Relating to the volume of water that is released from an aquifer following a unit change in the hydraulic head. Specific storage normally relates to confined aquifers.
Specific yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Specific yield generally relates to unconfined aquifers. Gravity drainage may take many months to occur.
Standing water level (SWL)	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to specific yield.
Stratigraphy	The depositional order of sedimentary rocks in layers.
Surface water-groundwater interaction	This occurs in two ways: (1) streams gain water from groundwater through the streambed when the elevation of the water table adjacent to the streambed is greater than the water level in the stream; and (2) streams lose water to groundwater through streambeds when the elevation of the water table is lower than the water level in the stream.
Tertiary	Geologic time at the beginning of the Cainozoic era, 65 to 2.5 million years ago, after the Cretaceous and before the Quaternary.

Total Dissolved Solids (TDS)	A measure of the salinity of water, usually expressed in milligrams per litre (mg/L). See also EC.
Transmissivity	The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.
Unconfined formation	Also known as a water table aquifer. An aquifer in which there are no confining beds between the zone of saturation and the surface. The water table is the upper boundary of an unconfined aquifer.
Unsaturated zone	That part of an aquifer between the land surface and water table. It includes the root zone, intermediate zone and capillary fringe.
Vibrating wire piezometer	Piezometer with a vibrating wire pressure gauge permanently installed, this converts water pressure to an electrical signal.
Water quality	Term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Water quality data	Chemical, biological, and physical measurements or observations of the characteristics of surface and ground waters, atmospheric deposition, potable water, treated effluents, and waste water and of the immediate environment in which the water exists.
Water table	The top of an unconfined aquifer. It is at atmospheric pressure and indicates the level below which soil and rock are saturated with water.
Well	Pertaining to a gas exploration well or gas production well.

List of units

°C	degrees Celsius
L/s	litres per second
m	metres
m AHD	metres Australian Height Datum
m bgl	metres below ground level
m btoc	metres below top of casing
m/d	metres per day
m3/d	cubic metres per day
mm/yr	millimetres per year
m/y	metres per year
ML	megalitres
ML/y	megalitres per year
mS/cm	milliSiemens per centimetre
mg/L	milligrams per litre

Abbreviations

ANZECC/ARMCANZ	Australian and New Zealand guidelines for fresh and marine water quality
BoM	Bureau of Meteorology
BP	Before Present
CRT	Constant Rate Test
DEC	Department for Environment and Conservation
DFS	Detailed feasibility study
DLWC	Department of Land and Water Conservation
EC	Electrical conductivity
EIS	Environmental Impact statement
EP&A Act	Environmental Protection & Assessment Act
EPBC Act	Environment Protection and Biodiversity Conservation Act
K	Hydraulic conductivity
LEP	Local Environment Plan
MDBA	Murray Darling Basin Authority
MDBC	Murray Darling Basin Commission
NSW	The Australian state of New South Wales
NoW	NSW Office of Water
NWC	National Water Commission
NHMRC	National Health and Medical Research Council
PFS	Pre-feasibility study
SDLs	Sustainable Diversion Limits
SEARs	Secretary's environmental assessment requirements
SSD	State Significant Development
TDS	Total Dissolved Solids
WA	Water Act
WAL	Water access license
WMA	Water Management Act
WSP	Water Sharing Plan

Appendix A

Land and Water Consulting 2014, Summary of Landholder Discussions as part of the Beneficial Use Assessment

30 June 2014

Julieanne Goode
Senior Environment & Community Specialist
Iluka Resources Limited
11 Dequetteville Terrace
Kent Town SA 5067

RE: Summary of Landholder Discussions as part of Beneficial Use Assessment

Dear Julieanne,

Land and Water Consulting Pty Ltd (LWC) is pleased to provide Iluka Resources Limited (Iluka) the following letter report summarising discussions with landholders in regard to beneficial use of groundwater within the West Balranald Deposit area and surrounds.

1. SCOPE OF WORKS

As part of the Pre-Mining Groundwater Monitoring Plan a Beneficial Use Assessment was completed. A component of this assessment involved a field review (which was partially completed at time of issue of the draft Pre-Mining Monitoring Plan) involving discussion with individual land owners within the area of interest to identify (1) location of existing/former and/or proposed groundwater extraction points (2) purpose/use of groundwater (3) any relevant information on aquifers targeted for use and any specific conditions (i.e. whether groundwater is being extracted from multiple aquifers).

Iluka provided a mud map (see attached as Appendix A) which was utilised to identify which landholders to contact as part of the review (also refer to Table 2.1). A select number within close proximity of proposed mine operations were identified by Iluka where information should be sought. The discussions with relevant landholders were proposed to occur as part of implementation of the quarterly groundwater monitoring works.

2. OBJECTIVE

The purpose of the beneficial use assessment was to document the location and nature of existing groundwater users within the project area and to identify users rights in regard to access/extraction of groundwater. In accordance with the NEPM, beneficial uses of groundwater are those uses that could be supported by the background groundwater quality and is based on the inherent ability of the aquifer to support those uses.

Table 2.1 *Relevant Land Owner and Property Details*

Land Owner	Property Reference	Proximity to West Balranald Deposit
Craig Williams	Upson Downs	North West
Bruce Williams	Karra	Central and West
Dianne Williams	Nanda and Paika	North and East
Salvatore Lanteria	Hughdale	Central
Ron Hoare	Tin Tin	Central, North East
Peter and Suzanne Morton	Pine Lodge	Central/South
Balranald Local Aboriginal Land Council	-	South
Leonard Dalton	Coogee	South West
Michael and Anne Headon	North Waldaira	South West
Paul Gillbee	Carinya	West
Mr Shearman	Cringadale	West
Henry Weaver	Bramah	North West
Philip and Alexandra Pippin	Wintong	North

3. LIMITATIONS

A key limitation to the scope of works was that landholders were not readily available during the times assigned for the quarterly monitoring events. In addition, a number of land holders were not able to be contacted (as advised by Iluka during review). A number of land holders were contacted multiple times (i.e. Dianne Williams and Mr Sherman) however, a meeting could not be arranged to obtain relevant information. The main limitation was that the budget allocated to discussion with landholders was associated with the quarterly field program, thus if land holders were not available during 1-2 days extent of the quarterly monitoring event (when the LWC project manager was on-site), the review was delayed until the next quarterly program. Initially face to face meetings were sought with land holders.

At the inception of the discussion process, a proforma/questionnaire was established to collect relevant information from the land holders. During discussions with the land holders the level of detail to complete the proforma/questionnaire was for the most part not provided as their understanding of the hydrogeological conditions was generally limited.

4. LAND HOLDER DISCUSSIONS

A summary of the review is provided in Table 4.1.

Table 4.1 Relevant Land Owner and Property Details

Land Owner	Property Reference	Make Contact	Source Relevant Information
Craig Williams	Upson Downs	✓	No - Could not arrange to meet in person
Bruce Williams	Karra	*	
Dianne Williams	Nanda and Paika	✓	Incomplete - Could not arrange for meeting in person
Salvatore Lanteri	Hughdale	✓	Yes – Met in person
Peter and Suzanne Morton	Pine Lodge	✓	Yes – Phone conversation
Ron Hoare	Tin Tin	✓	Yes – Phone conversation
Balranald Local Aboriginal Land Council	-	*	
Lenoard Dalton	Coogee	✓	Yes – Met in person
Michael and Anne Headon	North Waldaira	✓	Yes – Phone conversation
Paul Gillbee	Carinya	X	
Mr Shearman	Cringadale	✓	No - Could not arrange for meeting in person
Henry Weaver	Bramah	*	
Philip and Alexandra Pippin	Wintong	✓	Yes – Met in person

***advised by Iluka not to contact at initial time of review**

Ron Hoare – Tin Tin Station

A phone discussion occurred with Ron Hoare which identified the following:

- Within current property boundary of Tin Tin Station, Iluka are currently monitoring the operational stock watering bores (T01 to T03 – as illustrated in Figure 1).
- Existing information is available for the T01 to T03 bores with these installed within the lower Renmark System.
- The three stockwatering bores (T01 to T03) are the only source of stock water on the property with the exception of surface water run-off. No specific detail was able to be provided in regard to when the bores were installed and/or yield. However field observation identified the yield in all three bores as generally low being utilised to infill into open water body areas.
- Reliance on the bores for stock watering purposes was continual. At the time of discussion, there was no intent to install any further groundwater well infrastructure on the property.
- Historically a number of open wells (hand dug) were present on the property but have not recently been utilised.

Ron Hoare did not readily volunteer additional information nor was interested in meeting to discuss the review. Ron requested that all further requests for information be provided in a formal letter.

Philip Pippin – Wintong Station

A face to face meeting with Philip Pippin from Wintong Station occurred which identified:

- Within current property boundary of Wintong, Iluka are currently monitoring the primary operational stock watering bores (W400 and W800 – as illustrated in Figure 1).
- Existing information is available for the W400 and W800 stock watering bores. While yield information was not specifically provided, it is understood to be generally low. No details were able to be provided in regard to when these bores were installed. The two bores are relied upon continuously for source of stock water with surface water run-off the only other intermittent water supply.
- Philip Pippin did indicate there was a single windmill stock water bore on the southern portion of his Station which was installed within a shallower aquifer unit. Based on discussion with Philip, it was considered this well may have been installed within a shallow perched aquifer and/or Shepparton Formation. While the windmill was sighted in the field, no additional information was able to be obtained from the bore.
- Philip did indicate that an additional stock watering bore may be installed in the future however no further detail was provided.

Philip Pippin presented no issue providing relevant information in regard to existing groundwater use on his property.

Lanteri – Hughdale

A face to face meeting with the Hughdale property owners occurred which identified the following:

- Within current property boundary of Hughdale, Iluka are currently monitoring the only operational stock watering bore (HD01 – as illustrated in Figure 1).
- Existing information (in Iluka's possession) is available for the HD01 with the Lanteri's providing a copy of the well installation records which confirmed the bore is located within the Lower Renmark Aquifer unit.
- The single bore is relied upon continuously for source of stock water with surface water run-off the only other intermittent water supply.

No issue was presented to obtaining information from the Lanteri Family in regard to existing use of groundwater within their property boundary.

Morton – Pine Lodge

A phone discussion occurred with the Pine Lodge owners which identified the following:

- No current or historical stock watering/groundwater bores are present on the Pine Lodge property based on their knowledge.

No issue was presented to obtaining information from the Morton Family in regard to existing use of groundwater within their property boundary.

Dalton – Coogee

A discussion occurred with the Coogee owner which identified the following:

- A single stock watering bore is potentially present on the northern portion of the property, however further specific details were not obtained.
- No specific details on the stock watering bore were provided, however it was indicated there were no proposal at the time of discussion to install any further bores on the property.
- While it was proposed that a field event occur to identify the stock bore located on the northern portion of the Coogee property, this was not completed due to limited time in the field and contact issues with the landholder (not on property at time of monitoring works).

No issue was presented by the Dalton family at the time of discussion in regard to obtaining information on existing groundwater use across their property.

Headon – North Waldaira

A discussion occurred with the Headon owners which identified the following:

- A number bores are located on the property. It was the understanding of the Headons that the information in regard to the bores was available on the NSW Government data base.

Dianne Williams – Nanda/Paika

Verbal contact was made with Dianne Williams however no site specific information was able to be obtained. Field observations suggest the presence of groundwater wells (for stock) on the Nanda property (to the north of the West Balranald Deposit);

Remaining landholders:

- Bruce Williams – At the time of the assessment, advice was provided not to make contact.
- Craig Williams – Verbal contact made but was not able to obtain any site specific information.
- Ian & Kate Weaver – At the time of the assessment, advice was provided not to make contact.
- Mr Shearman - Verbal contact made but did was not able to obtain any site specific information
- Paul Gillbee - Verbal contact made but was not able to obtain any site specific information
- Balranald Aboriginal Land Council - At the time of the assessment, advice was provided not to make contact.

5. NSW Government Office of Water

As part of preparing the Groundwater Monitoring Plan for the Balranald project, a review of existing information including NSW Government Office of Water records was undertaken. It is noted that the records reviewed were collected as previous groundwater investigation for the Balranald project with information not obtained specific from the Office of Water.

A recently acquired database obtained from the NSW Governmnet (Refer to Appendix B) provides a detailed summary of registered wells within the Balranald West region. It is recommended that this database be further reviewed to obtain relevant information to specific areas of interest subject to further discussion with Iluka.

6. SUMMARY

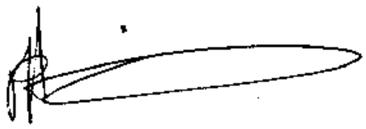
The primary limitation to completing the review of existing groundwater use across the relevant properties was associated with the timing of the quarterly sampling events and landholder availability. It is considered that an appropriate means to collect the remaining data may be through issuing a letter in a first instance which outlines the information that is being requested, then if any relevant detail is identified, standalone field events are organised to visit the areas of interest.

Based on the information obtained to-date, further assessment of the following may be warranted:

- Philip Pippin/Wintong – locating and identifying the nature of the shallow bore utilised on the southern portion of the property for stock watering purposes.
- Dalton/Coogee – locating and identifying the nature of the stock water bore located on the northern portion of the property.
- Obtaining the site specific detail from the Headons' (North wildaira) regarding the groundwater use on their property.

In addition, it is recommended that the most recent information obtained from the NSW Government Office of Water in regard to registered groundwater wells across the property areas is further reviewed specific to areas of interest. This information could potentially be provided to the landholders (where information is yet to be collected) in the first instance to initiate discussion and ascertain whether the Office of Water records are accurate or otherwise.

Yours sincerely
Land & Water Consulting Pty Ltd



Peter Howieson
Senior Environmental Scientist
Mobile: 0418 966 722

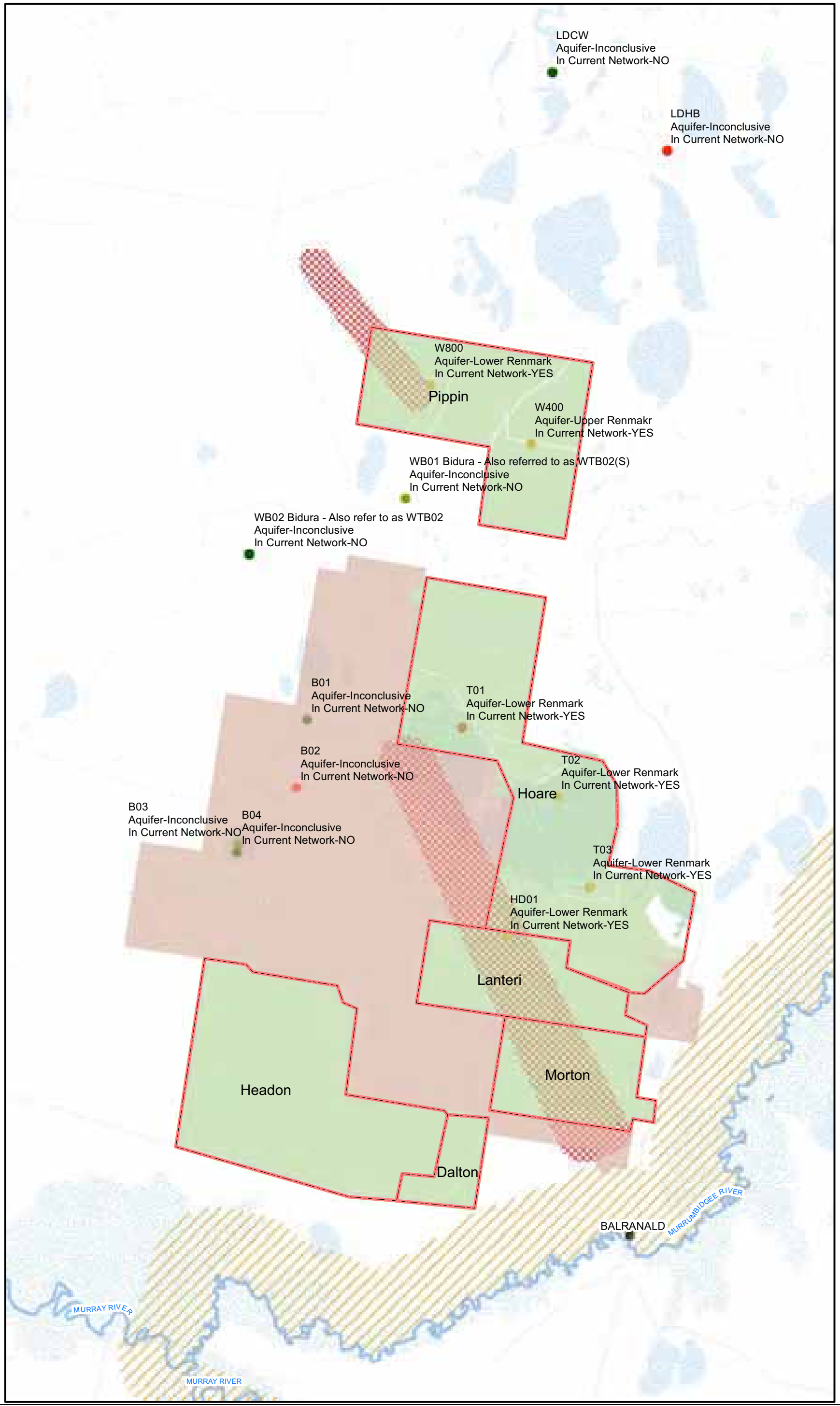
<u>FIGURES</u>

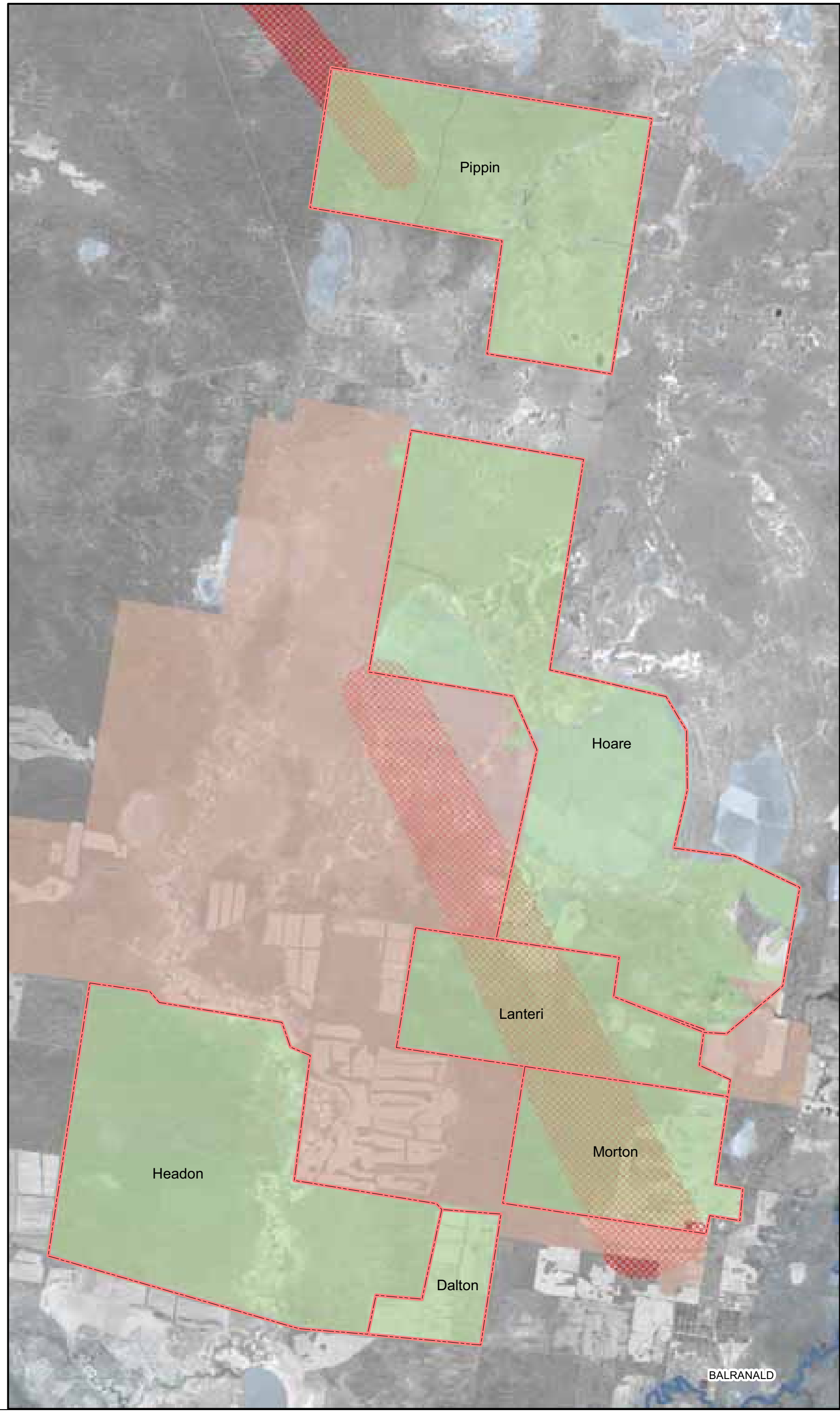
Figure 1 Existing Groundwater Use Review

<u>APPENDIX</u>

Appendix A Iluka Provided Landholder Plan
Appendix B Registered Groundwater Well Review

FIGURES





Legend

Extent of Target Ore Bodies

Water Course

Non-Perennial/Intermittent/Fluctuating

Perennial/Permanent

5km Buffer of River

Groundwater Use Review (EC range us/CM)

- 0 - 1000
- 1001 - 2500
- 2501 - 5000
- 5001 - 7500
- 7501 - 10000

Land Owner Groundwater Review Complete*

Land Owner Groundwater Review Incomplete

*area of enquiry based on consent provided by Iluka to contact relevant landholders

Land & Water Consulting Pty Ltd
Email: enquiries@lwconsulting.com.au
Web: www.lwconsulting.com.au

0 0.5 1 2 3 4 Kilometers

Date: JUNE 2014

NA

Project:

Balranald Groundwater Review

Site Address:

Balranald NSW

Figure Title:

Existing Groundwater Use Review

Figures in Set 1 of 1

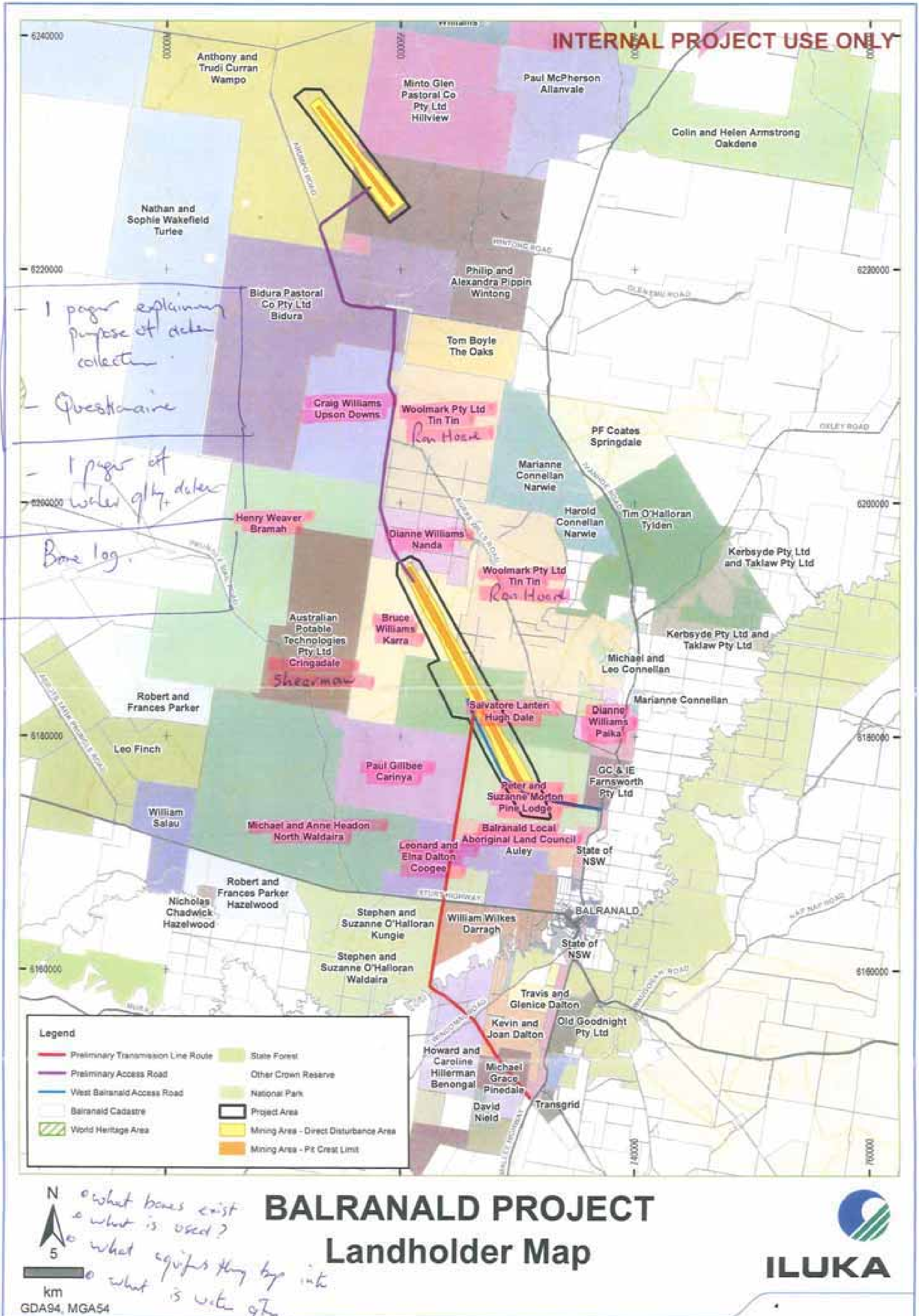
Figure 1

Scale:

Drawing Reference AAAA

Revision A

APPENDIX A



BALRANALD PROJECT
Landholder Map

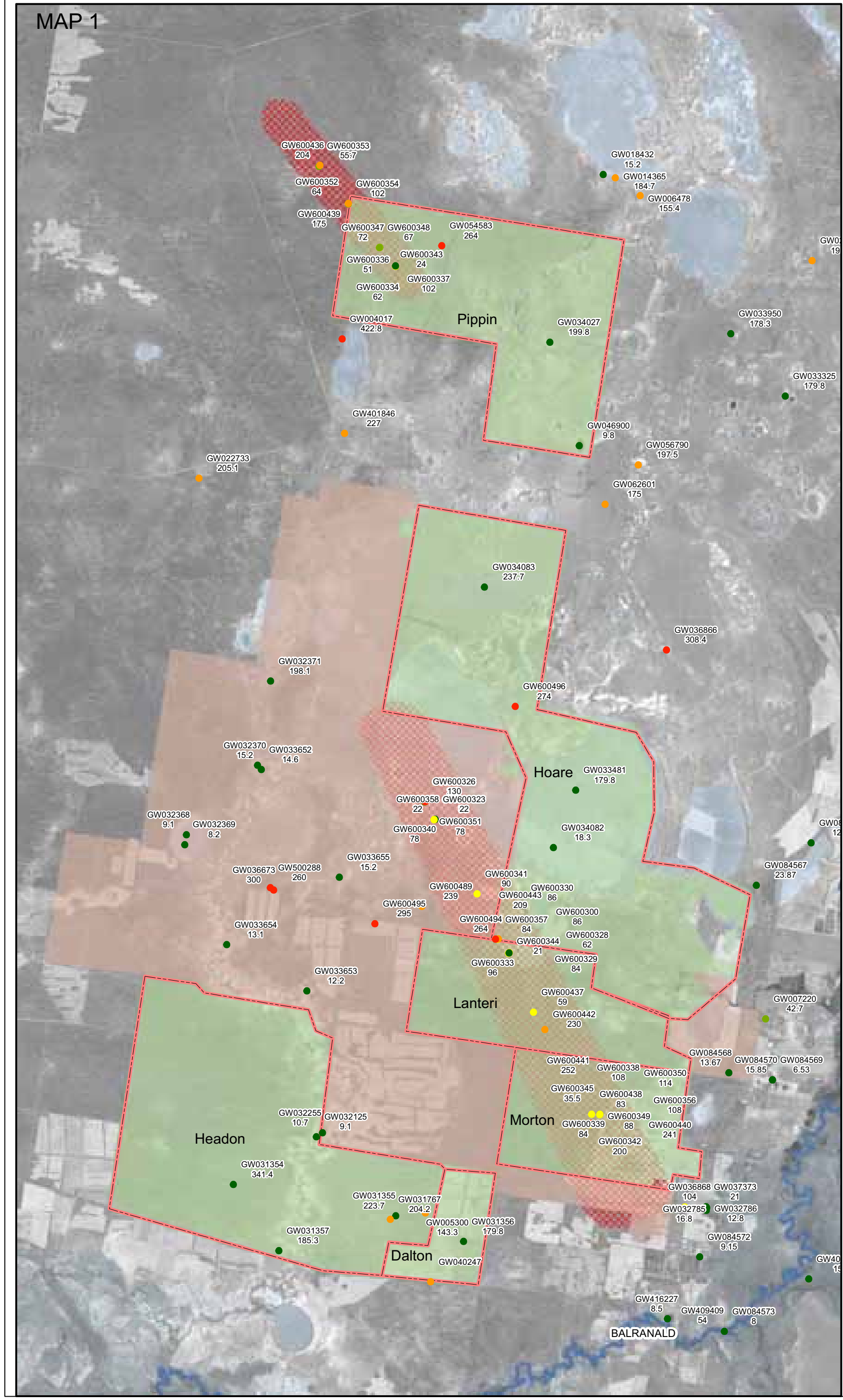
ILUKA

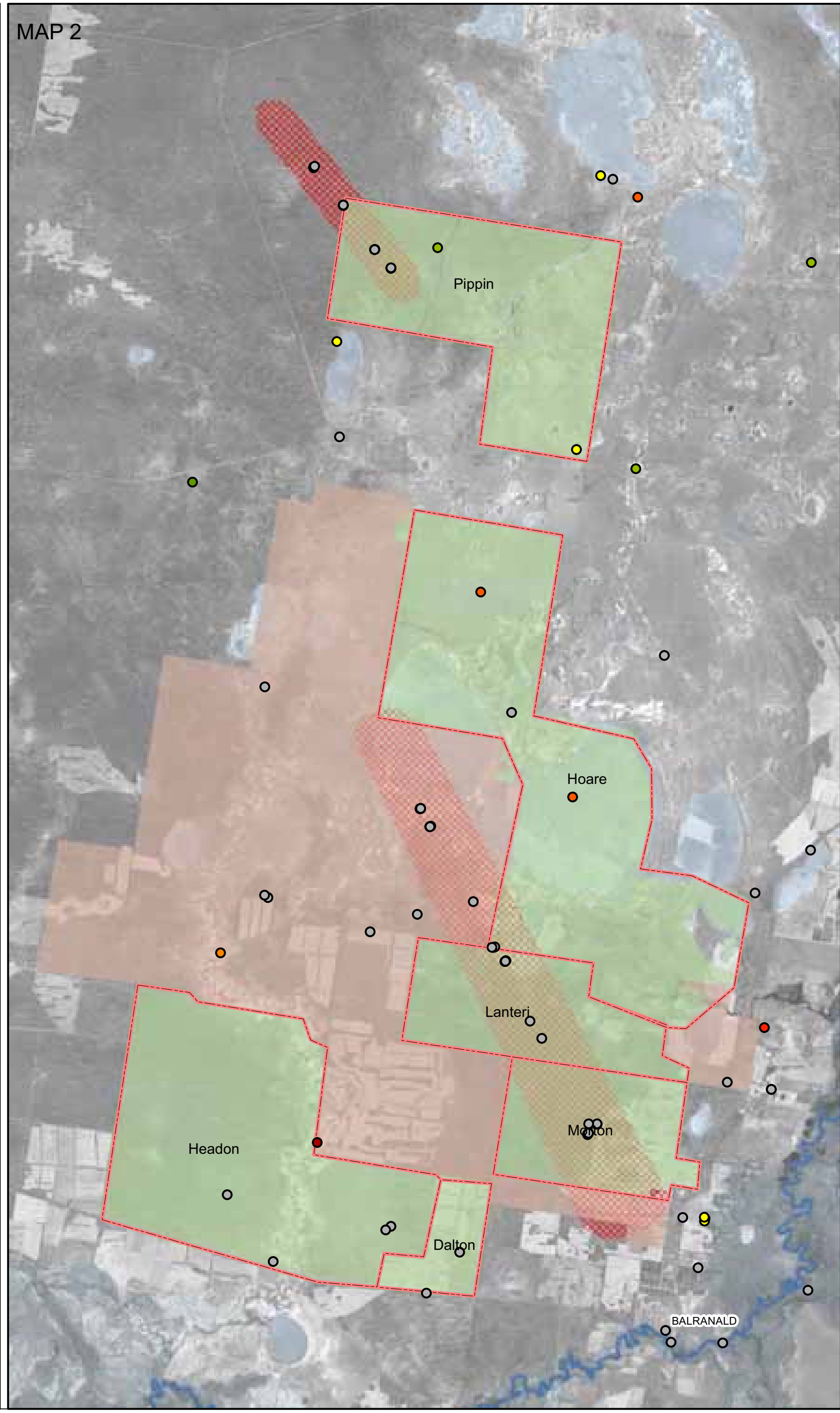
FIGURE: 4

ORIG: RP DRAWN: RP SCALE: 1:300,000 (A3) DATE: 8/01/2013 DWG No: Bal004v03

Bal004_PFS_Landholders_v03.mxd

APPENDIX B





Legend

Extent of Target Ore Bodies

Water Course
- Non-Perennial/Intermittent/Fluctuating
- Perennial/Permanent

5km Buffer of River

Land Owner Groundwater Review Complete*

Land Owner Groundwater Review Incomplete

*area of enquiry based on consent provided by Iluka to contact relevant landholders

MAP 1

DRILLED_DEPTH
- 0-30m
- 30-70m
- 70-150m
- 150-250m
- 250-450m

MAP 2

Salinity Description
- 10001-14000 ppm
- 3001-7000 ppm
- 7001-10000 ppm
- <Null>; (Unknown)
- Fresh
- Salty
- Stock
- V.Salty

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Land & Water Consulting Pty Ltd
Email: enquiries@lwconsulting.com.au
Web: www.lwconsulting.com.au

0 1 2 4 6 8 Kilometers

Date: JUNE 2014

NA

Project:

Balranald Groundwater Review

Site Address:

Balranald NSW

Figure Title:

Registered Groundwater Well Review

Figures in Set 1 of 1

Figure 1

Scale:

Drawing Reference: AAAA

Revision: A

Appendix B

NSW Office of Water registered monitoring bores and private landholder bores

Table B.1 NSW Office of Water monitoring bores

NOW Id	Year installed	Total depth (m)	Screen depth (m bgl)	Formation screened
GW004002	1900	609.6		Basement
GW004017	1902	422.8		Basement
GW036646, pipe 1	1985	346.4		Basement
GW036646, pipe 2	1985			
GW036646, pipe 3	1985			
GW036647	1985	20	2 - 20	Shepparton
GW036648	1985	51	45 - 51	LPS
GW036649	1985	30	24 - 30	LPS
GW036650	1985	24	20 - 24	LPS
GW036651	1986	20	14 - 17	LPS
GW036652	1986	20	14 - 17	LPS
GW036673, pipe 1	1986	300		Shepparton
GW036673, pipe 2	1986			LPS
GW036673, pipe 3	1986			Olney
GW036674, pipe 1	1986	176		Shepparton
GW036674, pipe 2	1986			LPS
GW036674, pipe 3	1986			Olney
GW036675, pipe 1	1987	408		Olney
GW036675, pipe 2	1987			
GW036675, pipe 3	1987			
GW036721, pipe 1	1987	428		Olney
GW036721, pipe 2	1987			
GW036721, pipe 3	1987			
GW036723, pipe 1	1987	339		Olney
GW036723, pipe 2	1987			
GW036723, pipe 3	1987			
GW036724, pipe 1	1987	72		LPS
GW036724, pipe 2	1987			
GW036724, pipe 3	1987			
GW036740, pipe 1	1987	286		Geera
GW036740, pipe 2	1987			
GW036740, pipe 3	1987			
GW036789, pipe 1	1989	373		Olney
GW036789, pipe 2	1989			
GW036789, pipe 3	1989			
GW036789, pipe 4	1989			
GW036790, pipe 1	1988	204		Geera
GW036790, pipe 2	1988			
GW036790, pipe 3	1988			
GW036854, pipe 1	1990	286		Geera
GW036854, pipe 2	1990			
GW036854, pipe 3	1990			

Table B.1 NSW Office of Water monitoring bores

NOW Id	Year installed	Total depth (m)	Screen depth (m bgl)	Formation screened
GW036862, pipe 1	1990	73		LPS
GW036862, pipe 2	1990			
GW036866, pipe 1	1990	308.4		Shepparton
GW036866, pipe 2	1990			LPS
GW036866, pipe 3	1990			Geera Clay
GW036866, pipe 4	1990			Olney
GW036866, pipe 5	1990			Olney
GW036868, pipe 1	1990	104		LPS
GW036868, pipe 2	1990			LPS
GW036868, pipe 3	1990			LPS
GW036870, pipe 1	1990	76		LPS
GW036870, pipe 2	1990			
GW036875, pipe 1	1990	109		LPS
GW036875, pipe 2	1990			
GW036875, pipe 3	1990			
GW040247, pipe 1	2005			Shepparton
GW040247, pipe 2	2005			LPS
GW040247, pipe 3	2005			LPS
GW056794	1983	163	145 - 163	LPS
GW057447	1983			
GW084087	2001	12.35	10.85 - 12.35	Shepparton
GW084088	2001	11.5	10 - 11.5	Shepparton
GW084501		15		Shepparton
GW084502		15.5		Shepparton
GW084503		10.5		Shepparton
GW084504		12.5		Shepparton
GW084505		8		Shepparton
GW084506		10		Shepparton
GW084507		15		Shepparton
GW084508		10.5		Shepparton
GW084509		11.8		Shepparton
GW084514		10		Shepparton
GW084515		13		Shepparton
GW084527		12		Shepparton
GW084528		26		Shepparton
GW084529		19.3		Shepparton
GW084530		22		Shepparton
GW084531		16.5		Shepparton
GW084532		12.9		Shepparton
GW084533		17		Shepparton
GW084534		15.1		Shepparton
GW084535		13.5		Shepparton

Table B.1 NSW Office of Water monitoring bores

NOW Id	Year installed	Total depth (m)	Screen depth (m bgl)	Formation screened
GW084540		18.25		Shepparton
GW084541		18.2		Shepparton
GW084542		19.8		Shepparton
GW084543		13.6		Shepparton
GW084544		17.2		Shepparton
GW084545		20.5		Shepparton
GW084547		13.5		Shepparton
GW084548		18		Shepparton
GW084549		11.4		Shepparton
GW084553		17.7		Shepparton
GW084554		21.1		Shepparton
GW084555		17.4		Shepparton
GW084556		24		LPS
GW084557		17.8		Shepparton
GW084558		18.5		Shepparton
GW084559		11.6		Shepparton
GW084560		15.5		Shepparton
GW084561		11.3		Shepparton
GW087096	1975	8	7.24 - 7.84	LPS
GW087097	1975	13	12.22 - 12.82	LPS
GW087098, pipe 1	1975			
GW087098, pipe 2	1975	23.3		LPS
GW087099, pipe 1	1975	26		LPS
GW087099, pipe 2	1975			
GW087100	1975	10	9.2 - 9.8	LPS
GW087101	1975	10	9.19 - 9.79	LPS
GW087102	1975	13.7	12.89 - 13.49	LPS
GW087103	1975	12.5	11.72 - 12.32	LPS
GW087104	1975	28	27.23 - 27.83	LPS
GW087105	1975	20	19.22 - 19.82	LPS
GW087106	1975	8	7.19 - 7.79	LPS
GW087107, pipe 1	1975	10.3		LPS
GW087107, pipe 2	1975			
GW087108, pipe 1	1975	14.3		LPS
GW087108, pipe 2	1975			
GW087109	1975	18.3	17.58 - 18.18	LPS
GW087110	1975	18	17.19 - 17.79	LPS
GW087111	1975	28	27.24 - 27.84	LPS
GW087112, pipe 1	1975	13		Shepparton
GW087112, pipe 2	1975			
GW087113, pipe 1	1975	20		LPS
GW087113, pipe 2	1975			

Table B.1 NSW Office of Water monitoring bores

NOW Id	Year installed	Total depth (m)	Screen depth (m bgl)	Formation screened
GW087114, pipe 1	1975			
GW087114, pipe 2	1975	20		LPS
GW087115	1975	20	19.24 - 19.84	LPS
GW087116	1975	23.3	22.51 - 23.11	LPS
GW087192	1976	20	17.85 - 19.85	LPS
GW087193	1975	15	12.81 - 14.81	LPS
GW087194	1975	20	17.81 - 19.81	LPS
GW087196	1976	10	7.95 - 9.95	LPS
GW087197	1976	16	13.79 - 15.79	LPS
GW087198	1975	17.7	15.5 - 17.5	LPS
GW087199	1975	11	8.75 - 10.75	LPS
GW087201	1976	10	8.83 - 9.83	LPS
GW087202	1976	10	9.07 - 10.07	LPS
GW087203	1976	8.7	7.54 - 8.54	Shepparton
GW088141	1999	12	10 - 11	LPS
GW088141	1999		11 - 11	LPS
GW088142	1999	8.5	7 - 7.5	Shepparton
GW088142	1999		7 - 7.5	Shepparton
GW088143	1999	9	7 - 8	Shepparton
GW088143	1999		7 - 8	Shepparton
GW088144	1999	5.5	3.5 - 4.5	LPS
GW088144	1999		3.5 - 4.5	LPS
GW088145	1999	9	7 - 8	LPS
GW088145	1999		7 - 8	LPS
GW088146	1999	12	10 - 11	LPS
GW088146	1999		10 - 11	LPS
GW088147	1999	10.8	8.8 - 9.8	Shepparton
GW088147	1999			
GW090048, pipe 1	2001	10		Shepparton
GW090048, pipe 2	2001			
GW090052, pipe 1	2001	10		Shepparton
GW090052, pipe 2	2001			
GW090053, pipe 1	2001	10		Shepparton
GW090053, pipe 2	2001			
GW090054, pipe 1	2001	10		Shepparton
GW090054, pipe 2	2001			
GW090055, pipe 1	2001	10		Shepparton
GW090055, pipe 2	2001			
GW090056, pipe 1	2002	16.5		Shepparton
GW090056, pipe 2	1992	227		Shepparton
GW404614	2008	12	5.5 - 9	Shepparton
GW404615	2008	15	6 - 11	Shepparton

Table B.1 NSW Office of Water monitoring bores

NOW Id	Year installed	Total depth (m)	Screen depth (m bgl)	Formation screened
GW404616	2008	13.5	8 - 12.5	Shepparton
GW404617	2008	15	10 - 11.5	Shepparton
GW404618	2008	15	8 - 11	Shepparton
GW404619	2008	14	9 - 12	Shepparton
GW404620	2008	12	7.5 - 10	Shepparton
GW409409	2009	54		LPS
GW501167	1999	18.2	17.2 - 18.2	Shepparton
GW501168	1999	12	11 - 12	Shepparton
GW501169	1999	18.2	17.2 - 18.2	Shepparton
GW501170	1999	18.2	17.2 - 18.2	Shepparton
GW501211	1999	9	8 - 9	Shepparton
GW501212	1999	12.5	11.5 - 12.5	Shepparton
GW501213	1999	18	17 - 18	Shepparton
GW501214	1999	12	11 - 12	Shepparton
GW501215	1999	12	12 - 12	Shepparton
GW501216	1999	23	22 - 23	Shepparton
GW501217	1999	20	19 - 20	Shepparton
GW600199	2007	43	12-14	Shepparton
GW600200	2007	54	25 - 27	LPS
GW600201	2007	52.3	36 - 38	LPS
GW600289	2012	53	49. 52 - 52.53	LPS

Notes: *m bgl = meters below ground level.*
Loxton-Parilla Sands = Loxton-Parilla Sands.
NOW = NSW Office of Water.

Table B.2 Private landholder bores

NOW Id	Year installed	Total depth (m)	Screen interval(m bgl)	Formation screened
GW004486		54.9		Loxton-Parilla Sands1
GW005300	1959	143.3		Geera Clay
GW006428	1938	243.8		Olney
GW006457		143.8	140.8 - 143.8	Geera Clay / Olney
GW006478	1939	155.4		Geera Clay
GW007220	1946	42.7		Shepparton
GW013237	1957	66.4		Loxton-Parilla Sands2
GW013337	1957	184.4	181.4 - 184.4	Olney*
GW014363	1958	137.2		Olney
GW014364		138.7		Olney
GW014365	1960	184.7		Olney*
GW016884	1958	94.8		Loxton-Parilla Sands2
GW018432	1961	15.2		Shepparton
GW022733	1964	205.1		Olney*
GW026610	1965	181.1		Olney*
GW028355		195.1		Olney*
GW029846	1968	295		Olney*
GW031354		341.4		Olney
GW031355		223.7		Geera Clay
GW031356		179.8		Geera Clay
GW031357		185.3		Geera Clay
GW031767		204.2		Olney*
GW032125	1/01/1935	9.1		Shepparton
GW032169		21.3		Shepparton
GW032170		22.9		Shepparton
GW032255	1945	10.7		Shepparton
GW032365		10.7		Shepparton
GW032368		9.1		Shepparton
GW032369	1966	8.2		Shepparton
GW032370	1929	15.2		Shepparton
GW032371	1965	198.1		Geera Clay
GW032372		10.7		Shepparton
GW032373		13.7		Shepparton
GW032401		103.6		Loxton-Parilla Sands2
GW032599		121.9		Loxton-Parilla Sands2
GW032657		54.9		Shepparton
GW032661		30.5		Shepparton
GW032785		16.8		Shepparton
GW032786		12.8		Shepparton
GW032884		36.6		Shepparton
GW033159		176.8		Olney
GW033325		179.8		Olney

Table B.2 Private landholder bores

NOW Id	Year installed	Total depth (m)	Screen interval(m bgl)	Formation screened
GW033326		189		Olney
GW033481		179.8		Geera Clay
GW033652	1940	14.6		Shepparton
GW033653	1939	12.2		Shepparton
GW033654		13.1		Shepparton
GW033655		15.2		Shepparton
GW033667	1966	24.4	0 - 46	Shepparton / Loxton-Parilla Sands1
GW033668		207.3		Olney
GW033669		158.5		Olney
GW033670		201.2		Olney
GW033913		185		Olney
GW033950		178.3		Olney
GW034027	1964	199.8		Olney
GW034082		18.3		Shepparton
GW034083		237.7		Olney
GW034158		18.3		Shepparton
GW037373		21		Shepparton
GW046900	1977	9.8	6.8 - 9.8	Shepparton
GW054583	1981	264	257 - 264	Olney*
GW055003	1982	0		Olney*
GW056790	1983	197.5		Olney*
GW062601	1986	175	169.8 - 175	Geera Clay
GW084563	1999	12.7	11.2 - 12.7	Shepparton
GW084566	1999	13.25	11.75 - 13.25	Shepparton
GW084567	1999	23.87	22.37 - 23.87	Shepparton
GW084568	1999	13.67	12.17 - 13.67	Shepparton
GW084569	1999	6.53	5.03 - 6.53	Shepparton
GW084570	1999	15.85	14.35 - 15.85	Shepparton
GW084571	1999	8.48	6.98 - 8.48	Shepparton
GW084572	1999	9.15	7.65 - 9.15	Shepparton
GW084573	1999	8	6.5 - 8	Shepparton
GW084574	1999	11.72	10.22 - 11.72	Shepparton
GW084575	1999	11.4	9.9 - 11.4	Shepparton
GW088042	1998	12	10.5 - 11.5	Shepparton
GW088043	1998	27	25 - 26	Shepparton
GW088044	1998	26	24 - 25	Shepparton
GW088045	1998	27.5	25.5 - 26.5	Shepparton
GW088046	1998	12	10.3 - 11.3	Shepparton
GW088047	1998	11.5	10-Nov	Shepparton
GW088048	1998	12	10.5 - 11.5	Shepparton
GW088149	1999	3	2.5 - 3	Shepparton

Table B.2 Private landholder bores

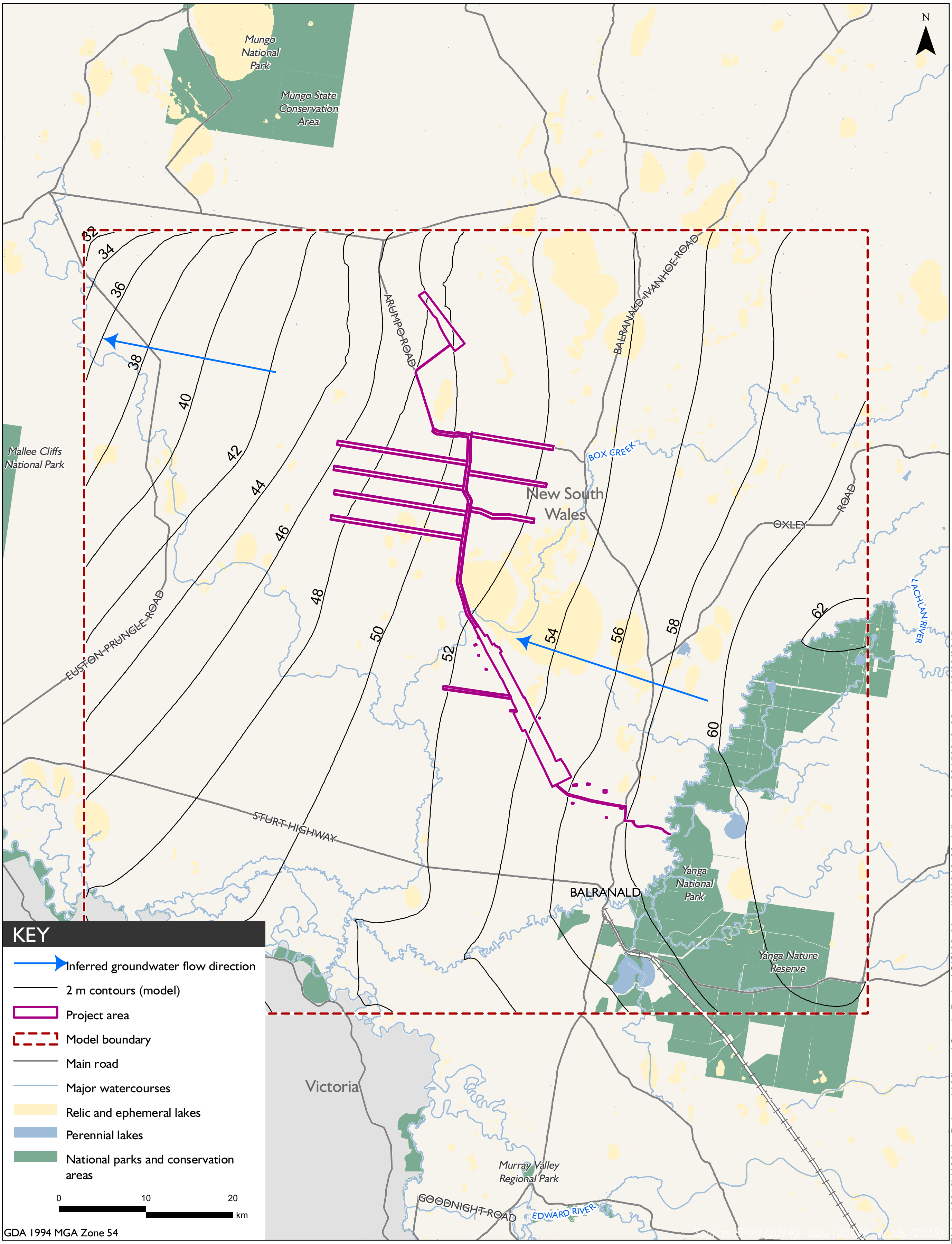
NOW Id	Year installed	Total depth (m)	Screen interval(m bgl)	Formation screened
GW088149			2 - 2.5	Shepparton
GW088151	1999	3.5	2 - 3	Shepparton
GW088151			2 - 3	Shepparton
GW088152	1999	3.5	2 - 3	Shepparton
GW088152			2 - 3	Shepparton
GW401846	1992	227	220 - 226	Olney
GW402011	2002	5.7	3.7 - 5.7	Shepparton
GW402093	2002	373	364 - 370	Olney
GW402578	2003	58	44 - 46	Shepparton
GW402578			48 - 54	Loxton-Parilla Sands2
GW402887	2004	407		Basement
GW402905	2004	30		Shepparton
GW416471	1992	180		Geera Clay
GW500288	1998	260		Olney*
GW600080	2004	17	11.3 - 12.5	Shepparton
GW600300	2011	86		Loxton-Parilla Sands2
GW600318	2001	66	50 - 60	Shepparton
GW600410	2012	14.5	12 - 14.5	Shepparton
GW600411	2012	22	19.5 - 22	Shepparton
GW600412	2012	25.5	23 - 25.5	Shepparton
GW600413	2013	24.5	22 - 24.5	Shepparton
GW600489	2014	239	216 - 229	Olney*
GW600496	2014	274	232 - 234	Olney*
GW700042	1992	178	168.5 - 170.5	Olney
GW700042		178	176 - 178	Olney
GW700047	1992	188	180.5 - 185	Olney
GW700619	1998	37		Shepparton
GW702364	2004	248	241 - 247	Olney
GW704706	2014	206	191 - 197	Olney*
GW704758	2014	234.5	224.5 - 230.5	Olney*

Notes: m bgl = meters below ground level, Loxton-Parilla Sands = Loxton-Parilla Sands.

* Formation provided by NSW Office of Water.

Appendix C

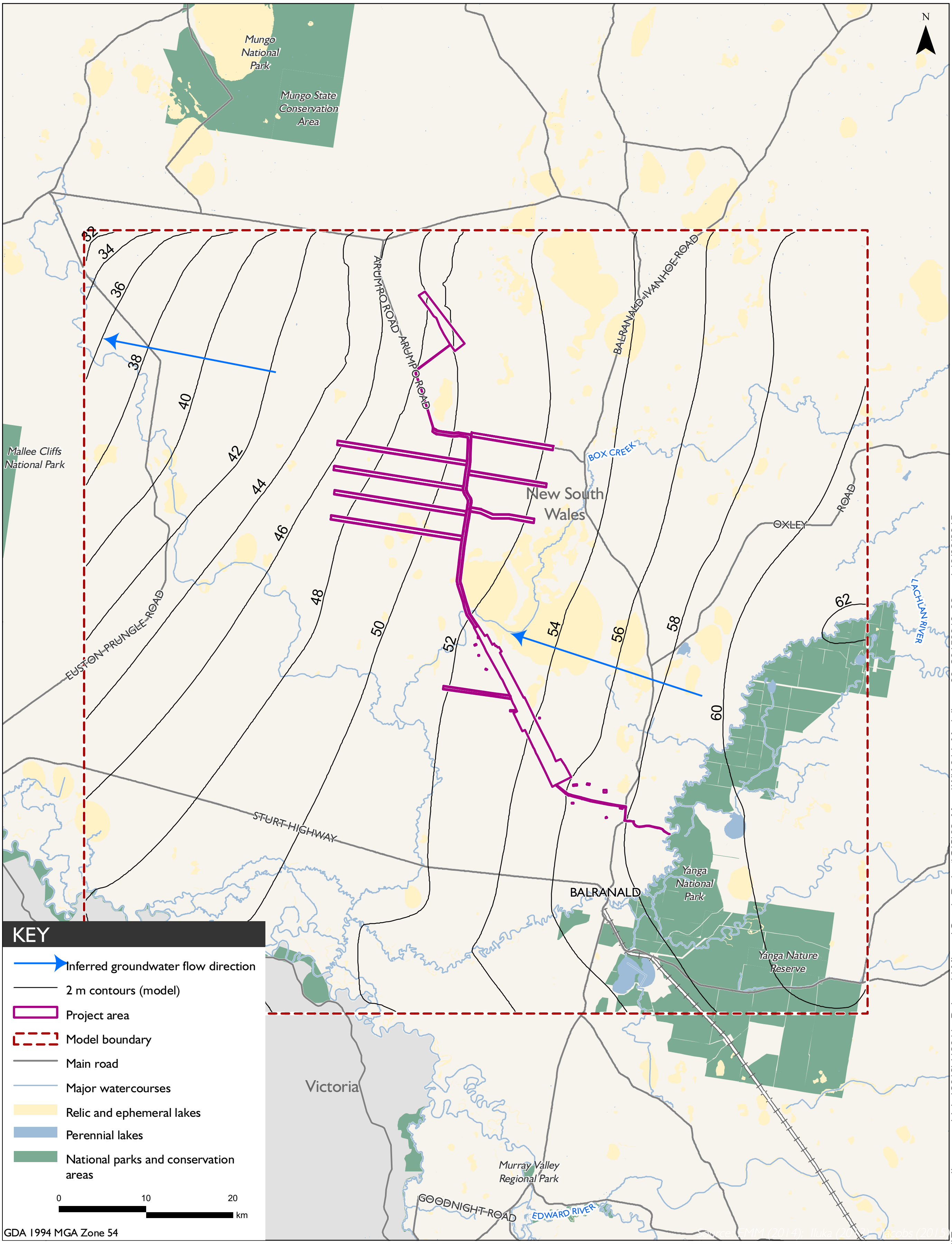
Pre mining groundwater flow directions



T:\Jobs\2012\J12011 - Balranald Mineral Sands Project\GIS\02_Maps\WIA013_ModelLayer02_20150310_02.mxd 10/03/2015

Steady state heads in model layer 2: Shepparton Formation (deep)

Balranald Mineral Sands Project
Water Assessment
Figure C.1

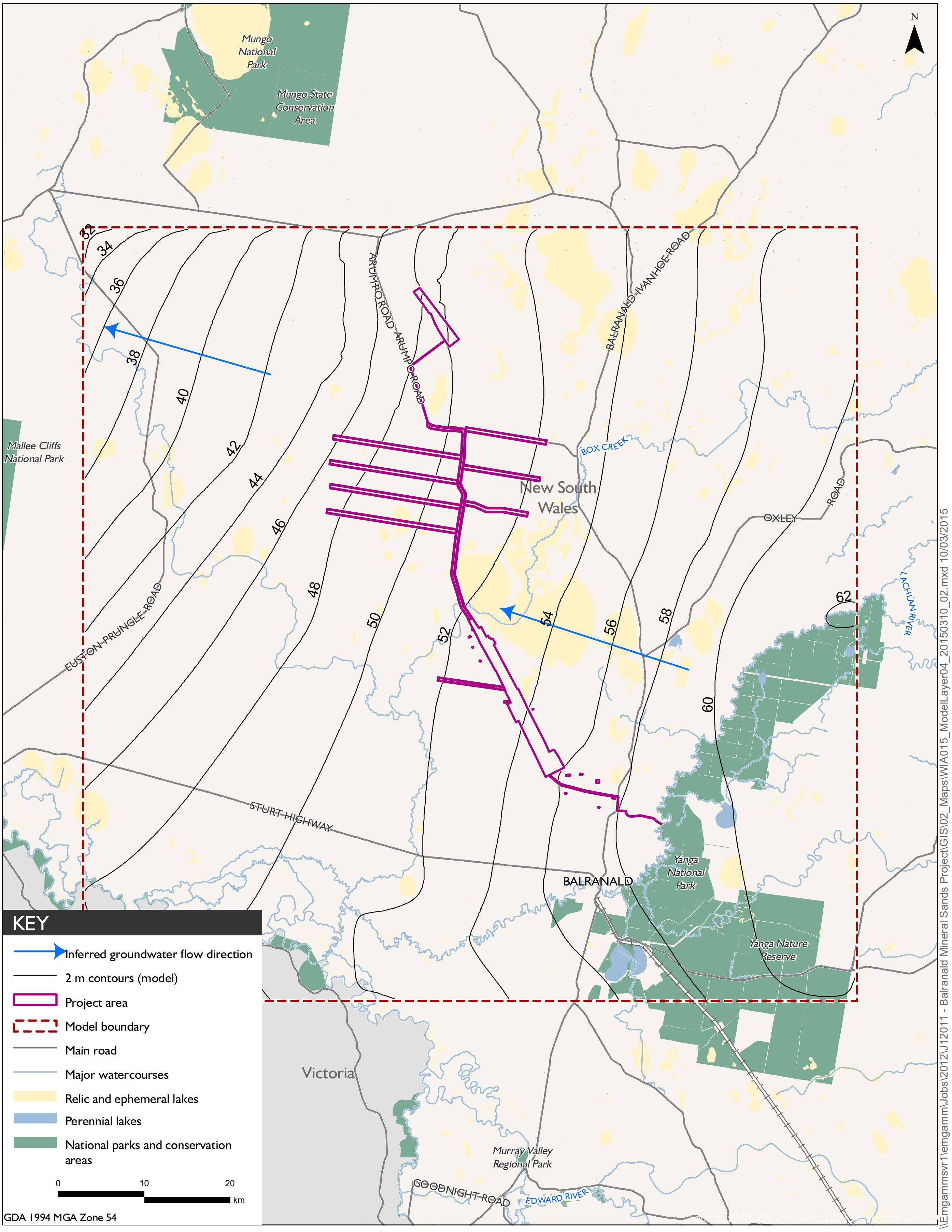


\\Emgammsvr1\emgamm\Jobs\2012\J12011 - Balranald Mineral Sands Project\GIS\02_Maps\WIA014_ModelLayer03_20150310_02.mxd 10/03/2015

Steady state heads in model layer 3: LPS1 foreshore

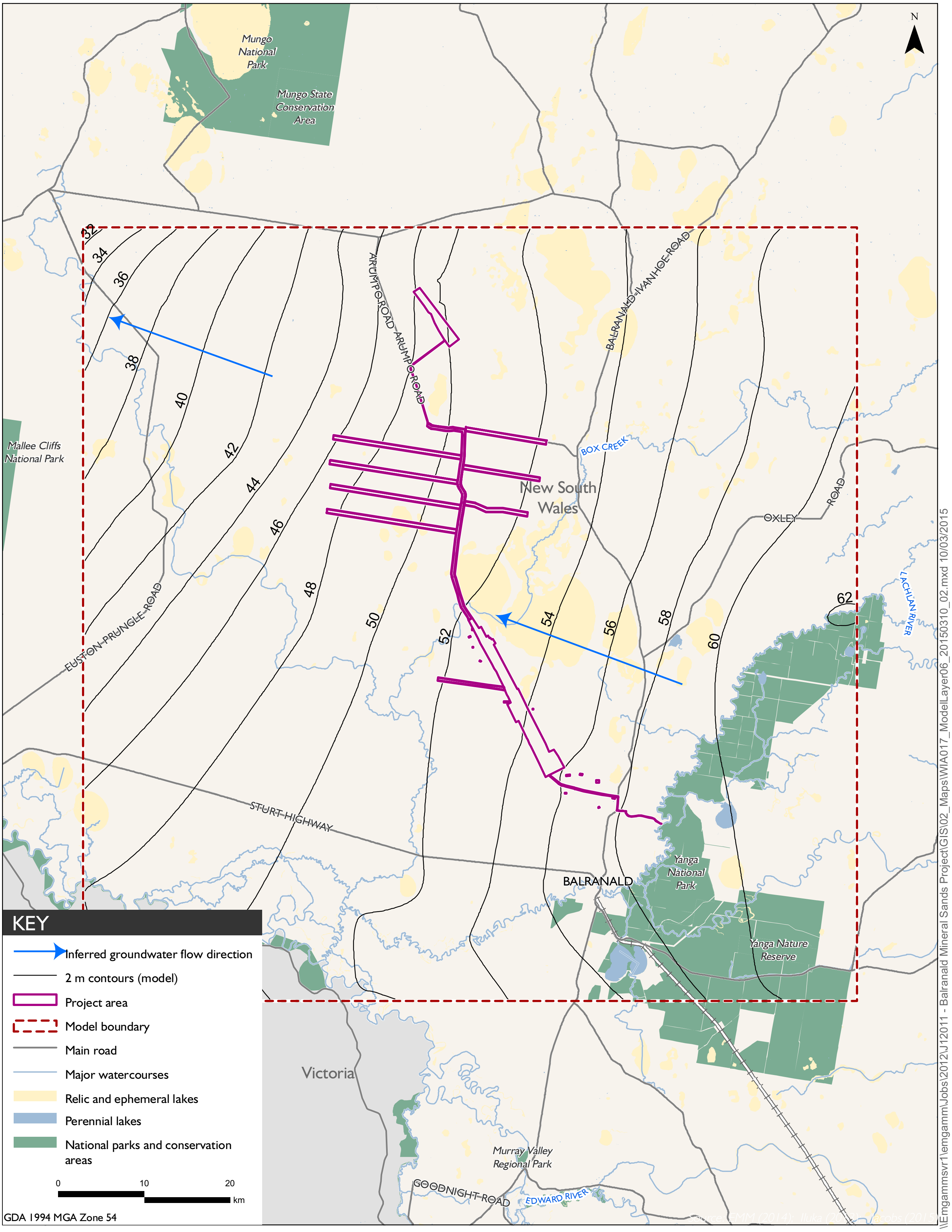
Balranald Mineral Sands Project
Water Assessment

Figure C.2



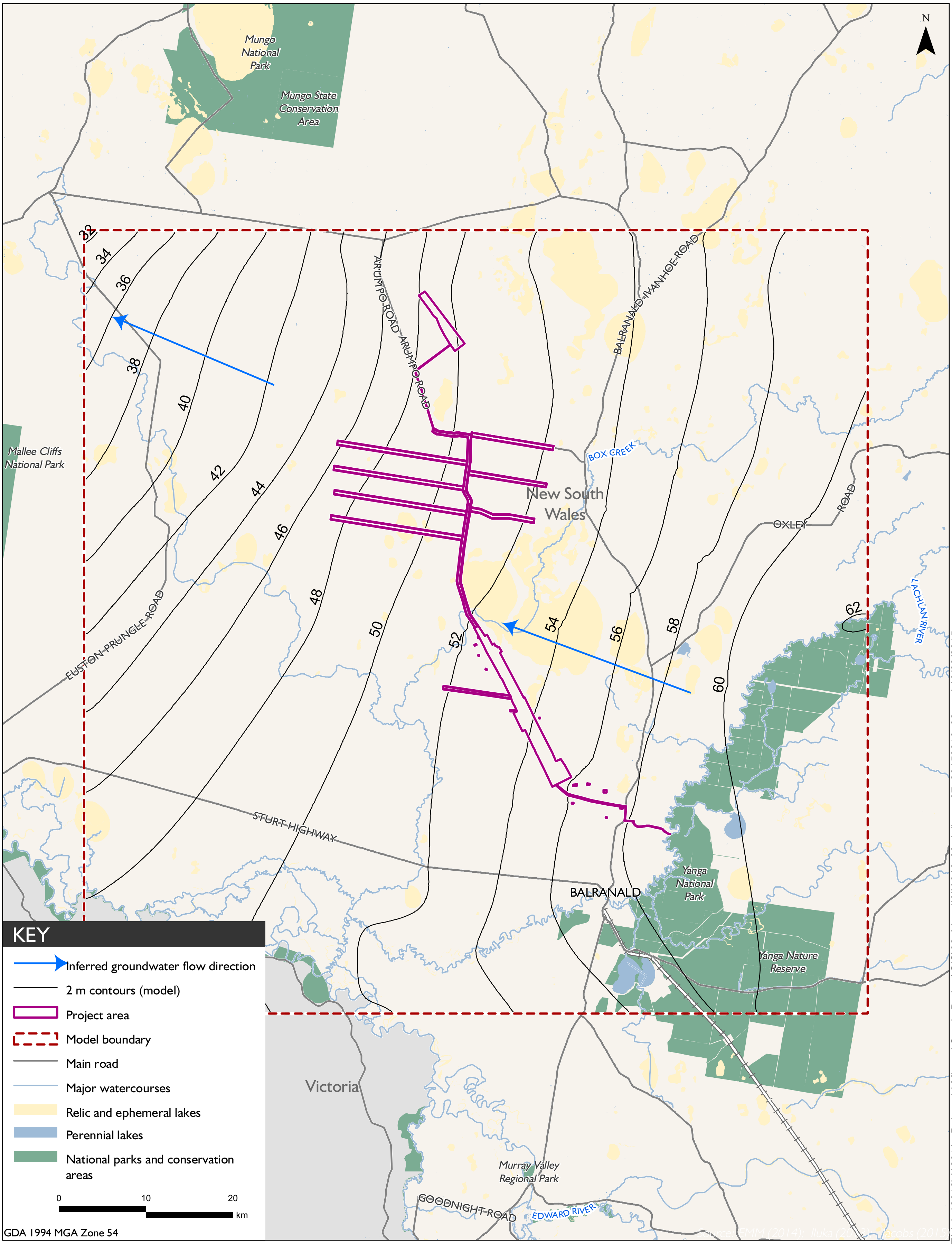
Steady state heads in model layer 4: LPS1 surf zone

Balranald Mineral Sands Project
Water Assessment
Figure C.3



Steady state heads in model layer 6: LPS2 surf zone

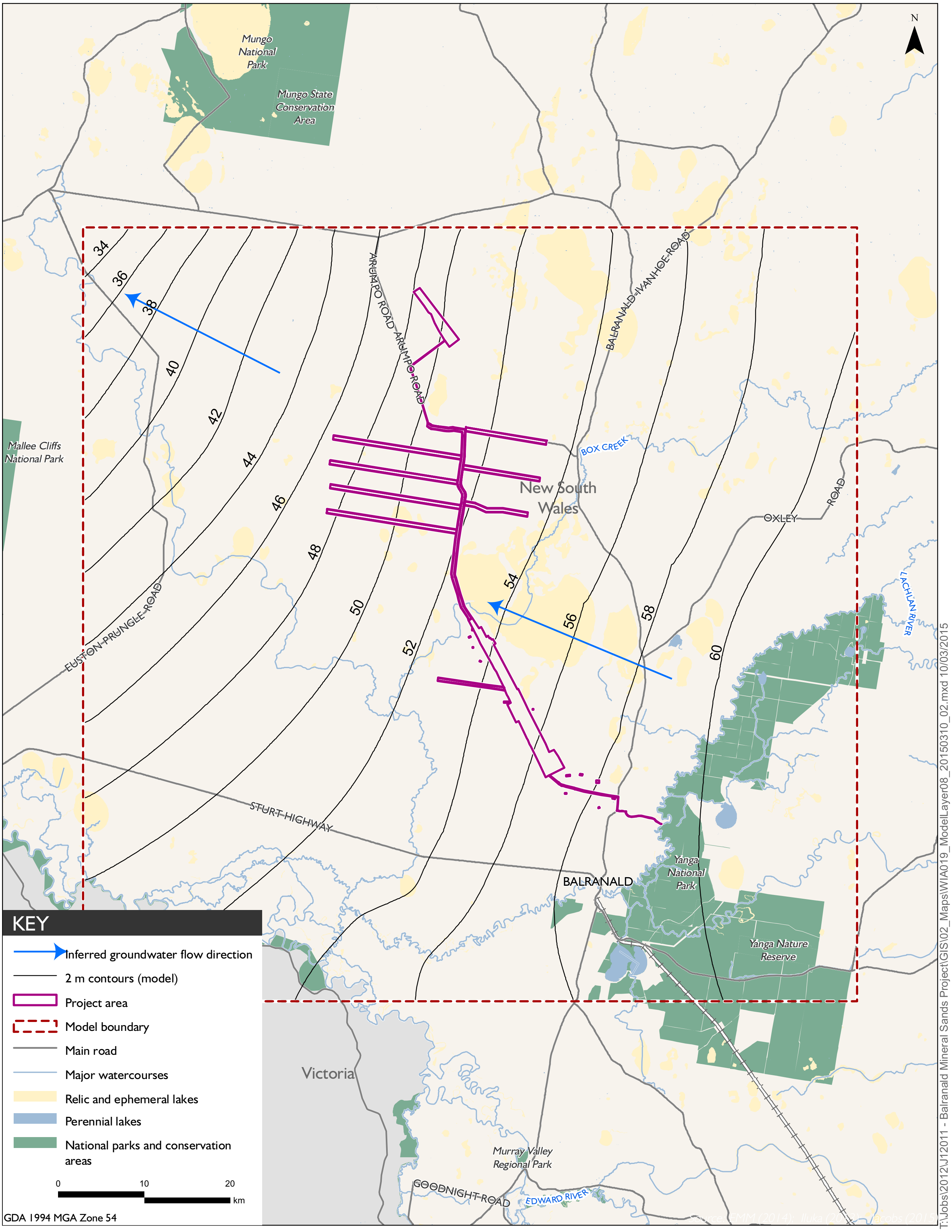
Balranald Mineral Sands Project
Water Assessment
Figure C.4



T:\Jobs\2012\J12011 - Balranald Mineral Sands Project\GIS\02_Maps\WIA018_ModelLayer07_20150310_02.mxd 10/03/2015

Steady state heads in model layer 7: LPS2 lower shore

Balranald Mineral Sands Project
Water Assessment
Figure C.5

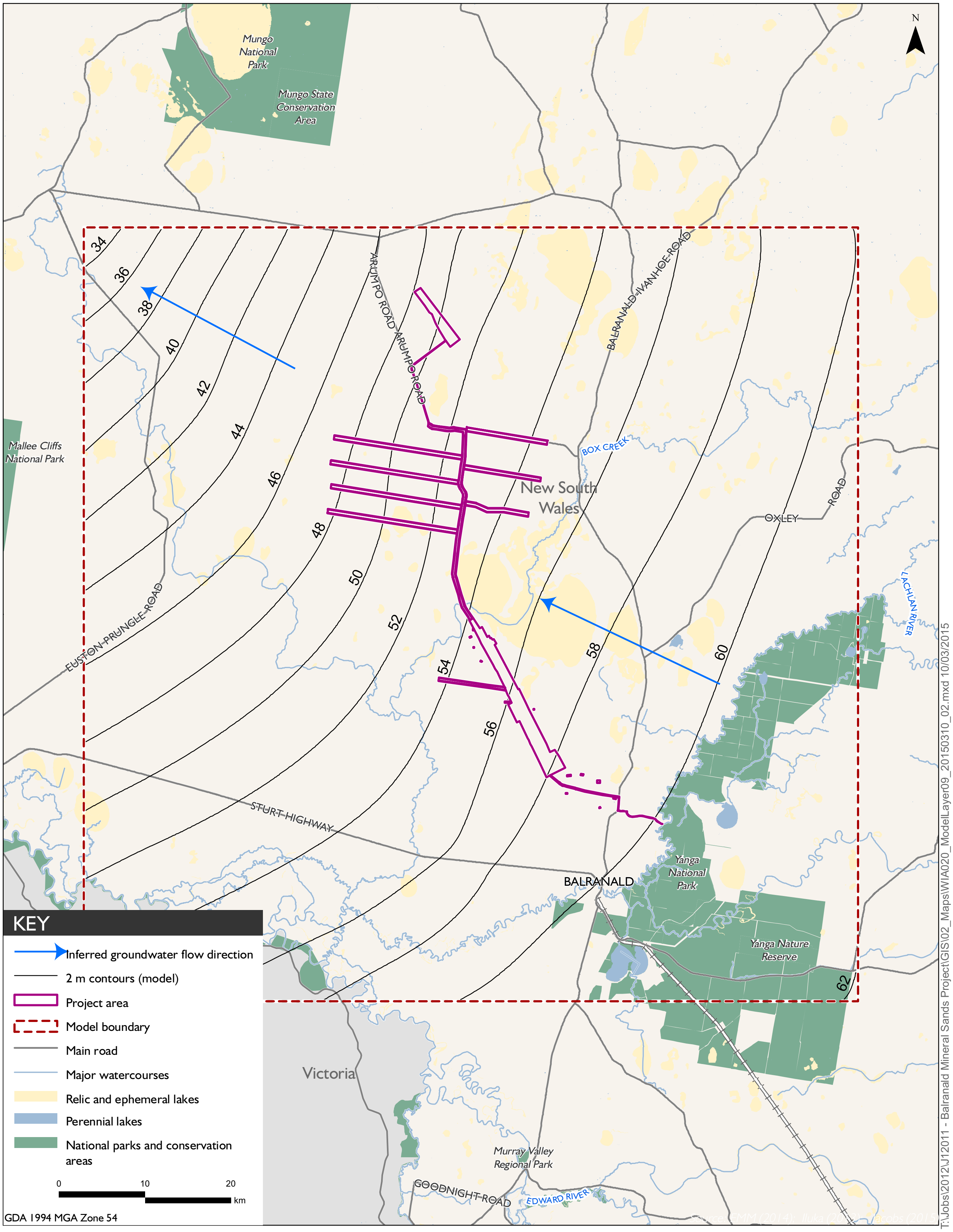


Steady state heads in model layer 8: Geera Clay

Balranald Mineral Sands Project

Water Assessment

Figure C.6



Steady state heads in model layer 9: Olney formation

Balranald Mineral Sands Project

Water Assessment

Figure C.7

Appendix D

Predicted impacts to landholder bores

Table D.1 Predicted groundwater level impact on landholder bores

NOW ID	Formation	Pre mining level (m AHD)	Maximum or minimum level (m AHD)	Predicted change (m)
GW004486	Loxton-Parilla Sands1	46.32	46.54	-0.09
GW005300	Geera Clay	54.87	54.77	-0.1
GW006428	Olney	53.03	53.01	-0.01
GW006457	Geera Clay / Olney	54.17	54.16	-0.01
GW006478	Geera Clay	53.36	53.53	0.01
GW007220	Shepparton	58.36	58.22	-0.1
GW013237	Loxton-Parilla Sands2	56.17	56.11	-0.06
GW013337	Olney*	53.81	53.79	-0.01
GW014363	Olney	53.78	53.77	-0.01
GW014364	Olney	53.06	53.04	-0.02
GW014365	Olney*	53.69	53.67	-0.02
GW016884	Loxton-Parilla Sands2	54.96	54.92	-0.04
GW018432	Shepparton	52.58	52.6	0.02
GW022733	Olney*	48.44	48.38	-0.06
GW026610	Olney*	59.37	59.37	0.00
GW028355	Olney*	56.44	56.44	0.00
GW029846	Olney*	57.27	57.27	0.00
GW031354	Olney	54.3	54.28	-0.03
GW031355	Geera Clay	54.45	54.36	-0.09
GW031356	Geera Clay	55.73	55.67	-0.07
GW031357	Geera Clay	53.41	53.39	-0.03
GW031767	Olney*	56.03	56.04	- / + 0.01
GW032125	Shepparton	51.89	51.61	-0.27
GW032169	Shepparton	60.76	60.79	0.03
GW032170	Shepparton	60.09	60.16	0.06
GW032255	Shepparton	51.95	51.65	-0.3
GW032365	Shepparton	40.12	40.06	-0.06
GW032368	Shepparton	49.41	49.45	0.05
GW032369	Shepparton	49.44	49.46	0.02
GW032370	Shepparton	49.98	50.28	0.30
GW032371	Geera Clay	50.36	50.76	0.4
GW032372	Shepparton	41.97	42.00	0.03
GW032373	Shepparton	39.29	39.28	-0.01
GW032401	Loxton-Parilla Sands2	60.39	60.39	0.00
GW032599	Loxton-Parilla Sands2	56.14	56.13	-0.01
GW032657	Shepparton	54.93	54.93	0.00
GW032661	Shepparton	56.54	56.34	-0.19
GW032785	Shepparton	58.03	57.9	-0.12
GW032786	Shepparton	58.02	57.89	-0.12
GW032884	Shepparton	56.16	55.83	-0.34
GW033159	Olney	58.08	58.10	0.01

Table D.1 Predicted groundwater level impact on landholder bores

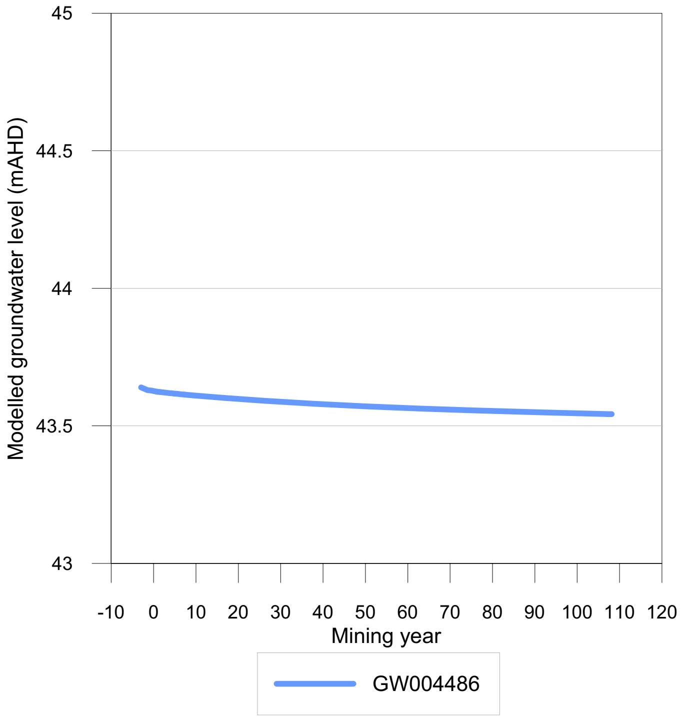
NOW ID	Formation	Pre mining level (m AHD)	Maximum or minimum level (m AHD)	Predicted change (m)
GW033325	Olney			
GW033326	Olney	57.98	57.99	0.01
GW033481	Geera Clay	55.21	54.82	-0.39
GW033652	Shepparton	50.04	50.32	0.28
GW033653	Shepparton	51.55	51.05	-0.49
GW033654	Shepparton	50.44	50.27	-0.18
GW033655	Shepparton	51.58	50.93	-0.65
GW033667	Shepparton / Loxton-Parilla Sands1	31.56	31.56	0.00
GW033668	Olney	59.22	59.23	0.01
GW033669	Olney	60.54	60.54	0.00
GW033670	Olney	60.50	60.51	0.01
GW033913	Olney	57.56	57.57	0.01
GW033950	Olney	55.8	55.8	0.00
GW034027	Olney	53.71	53.70	-0.01
GW034082	Shepparton	53.83	52.2	-1.63
GW034083	Olney	54.1	54.09	-0.01
GW034158	Shepparton	33.60	33.60	-0.01
GW037373	Shepparton	58.01	57.89	-0.13
GW046900	Shepparton	52.42	52.97	0.55
GW054583	Olney*	52.08	52.03	-0.04
GW055003	Olney*	61.7	61.7	0.00
GW056790	Olney*	55.34	55.36	0.02
GW062601	Geera Clay	54.03	54.33	0.30
GW084563	Shepparton	58.28	58.22	-0.06
GW084566	Shepparton	60.29	60.32	0.02
GW084567	Shepparton	57.38	57.18	-0.20
GW084568	Shepparton	57.80	57.62	-0.19
GW084569	Shepparton	58.72	58.62	-0.10
GW084570	Shepparton	58.72	58.62	-0.1
GW084571	Shepparton	59.91	59.90	0.01
GW084572	Shepparton	57.91	57.84	-0.07
GW084573	Shepparton	57.80	57.80	0.00
GW084574	Shepparton	59.51	59.49	-0.02
GW084575	Shepparton	59.49	59.50	0.01
GW088042	Shepparton	48.51	48.50	-0.01
GW088043	Shepparton	48.46	45.45	-0.01
GW088044	Shepparton	48.36	48.35	-0.01
GW088045	Shepparton	48.41	48.40	-0.01
GW088046	Shepparton	48.60	48.59	-0.01
GW088047	Shepparton	48.44	48.43	-0.01

Table D.1 Predicted groundwater level impact on landholder bores

NOW ID	Formation	Pre mining level (m AHD)	Maximum or minimum level (m AHD)	Predicted change (m)
GW088048	Shepparton	48.70	48.69	-0.01
GW088149	Shepparton	47.50	47.48	-0.02
GW088149	Shepparton	47.50	47.48	-0.02
GW088151	Shepparton	47.39	47.36	-0.02
GW088152	Shepparton	47.48	47.46	-0.02
GW401846	Olney	51.60	51.58 / 51.62	+ & - 0.02
GW402011	Shepparton	60.48	60.50	0.02
GW402093	Olney	58.33	58.36	0.03
GW402578	Shepparton	56.17	56.12	-0.05
GW402578	Loxton-Parilla Sands1	56.24	56.19	-0.06
GW402887	Basement	NA	NA	NA
GW402905	Shepparton	57.51	57.50	-0.01
GW416471	Geera Clay	53.70	53.57	-0.13
GW500288	Olney*	52.38	52.31	-0.07
GW600080	Shepparton	49.07	49.07	0.00
GW600300	Loxton-Parilla Sands2	53.66	-5.83	-59.5
GW600318	Shepparton	41.54	41.65	0.08
GW600410	Shepparton	48.57	48.56	-0.01
GW600411	Shepparton	48.45	48.44	-0.01
GW600412	Shepparton	48.15	48.13	-0.02
GW600413	Shepparton	48.66	48.66	-0.01
GW600489	Olney*	54.68	54.65	0.03
GW600496	Olney*	55.24	55.65	-0.03
GW700042	Olney	55.23	55.27	0.04
GW700042	Olney	57.05	57.05	0.00
GW700047	Olney	57.14	57.14	0.00
GW700619	Shepparton	44.42	44.43	-0.03
GW702364	Olney	56.15	56.18	0.04
GW704706	Olney*	58.22	58.23	0.01
GW704758	Olney*	60.63	60.63	0.00

Notes: ** inferred Formation, based on model layers.*
Unable to predict change in basement as this is not included in the model layers.

The base case begins with a 100 year equilibration period, such that modelled heads and flows at the commencement of groundwater affecting activities are essentially in equilibrium. Consequently, impacts predicted by the model are attributed to the simulated mining activities. Minor variations are attributed to further equilibration after the 100 year equilibration period.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44
43.5
43
Modelled groundwater level (mAHD)
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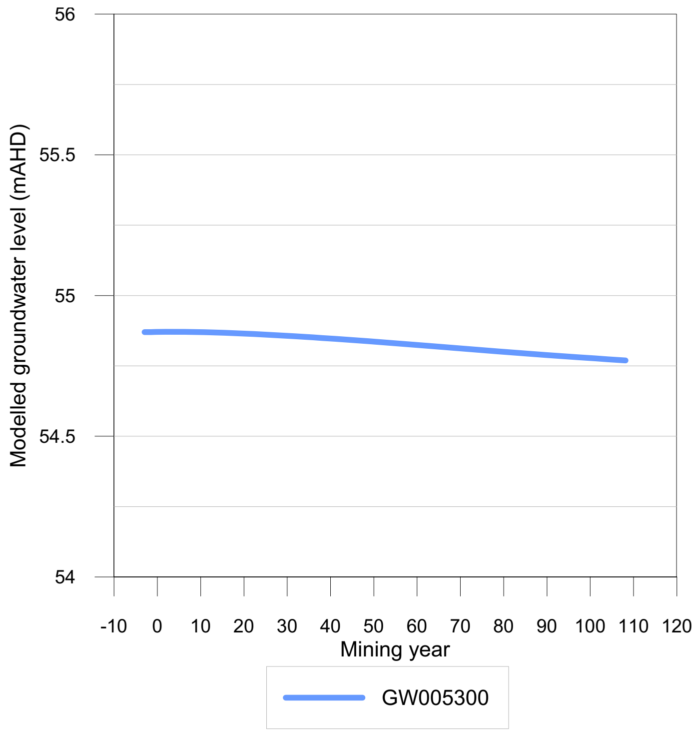
Mining year
GW004486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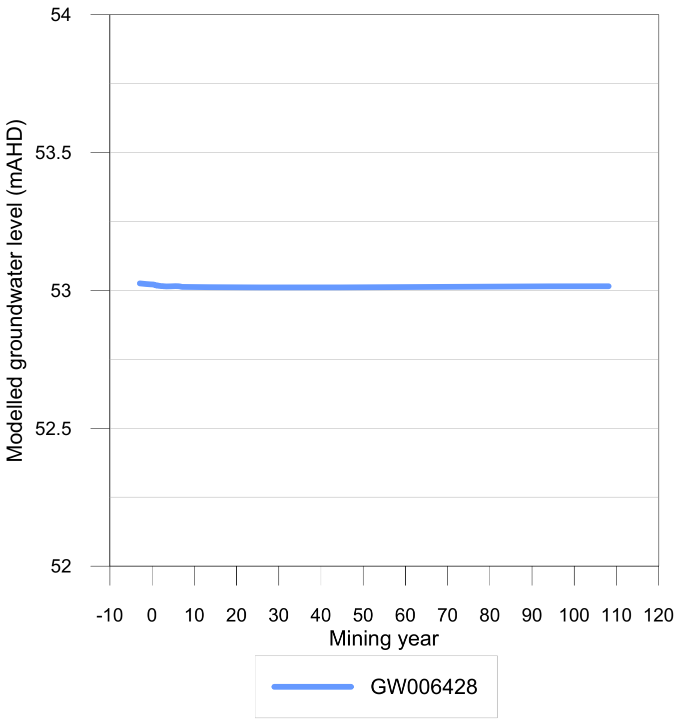
Mining year
GW005300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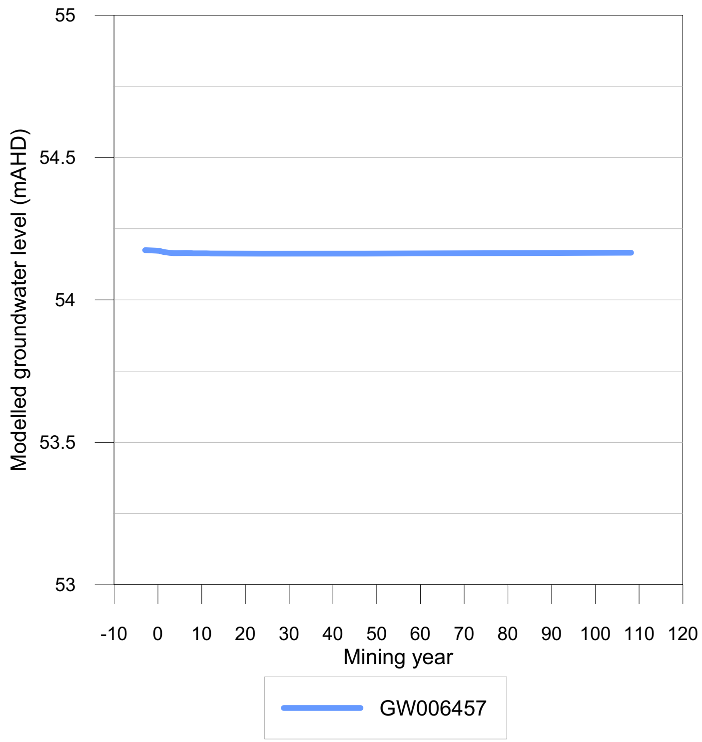
Mining year
GW006428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54
53.5
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Mining year
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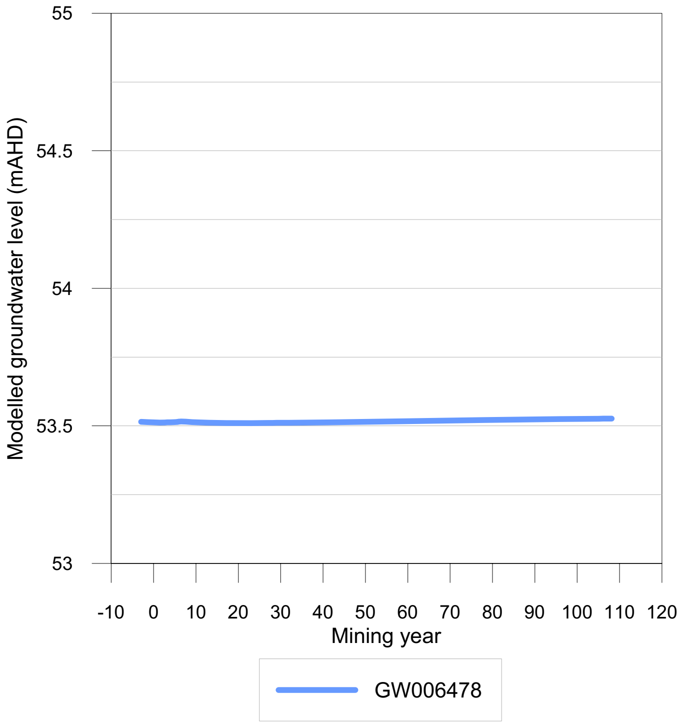

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54.5
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53.5
53
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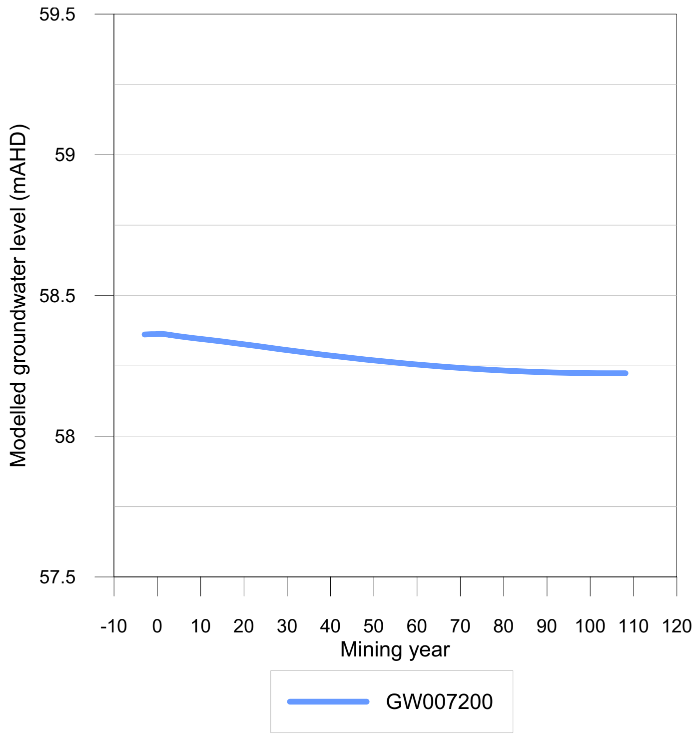
Mining year
GW006478



59.5
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58.5
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57.5
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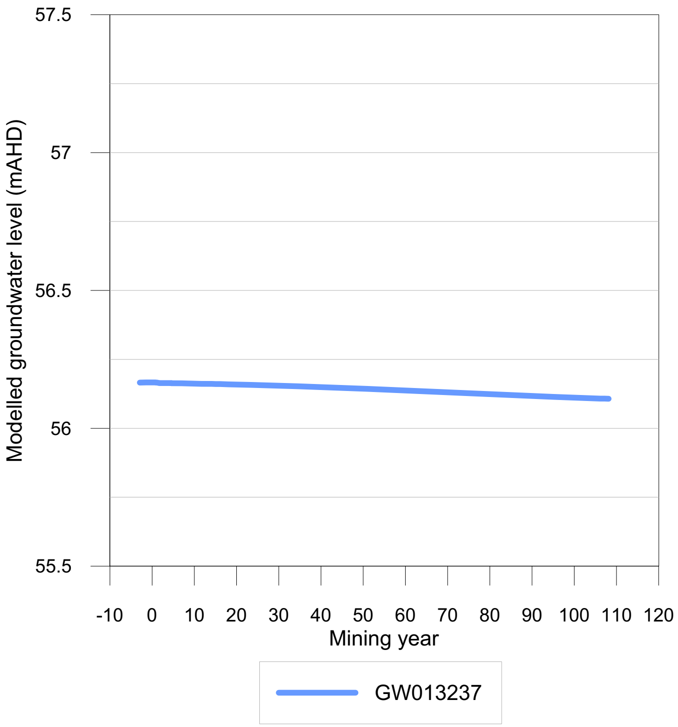
Mining year
GW007200



57.5
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56.5
56
55.5
Modelled groundwater level (mAHD)
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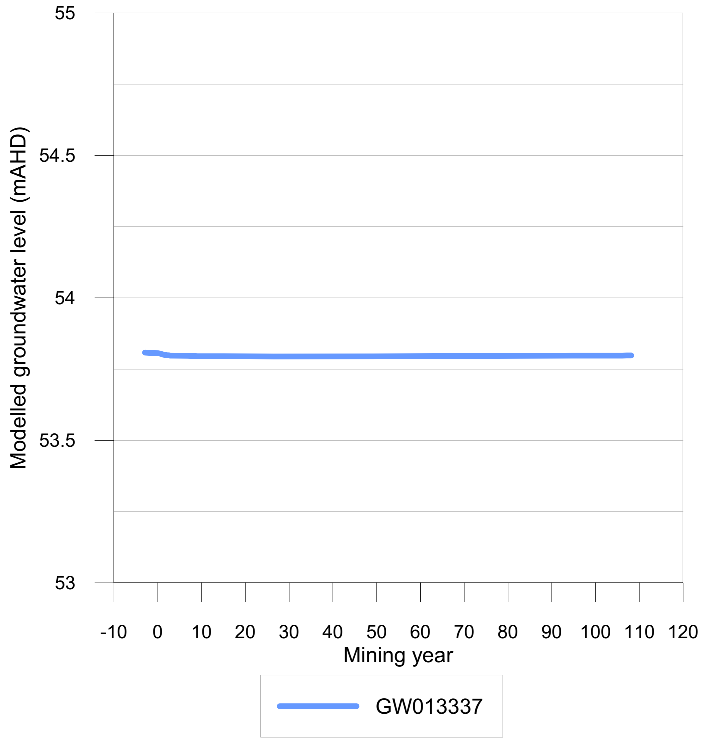
Mining year
GW013237



55
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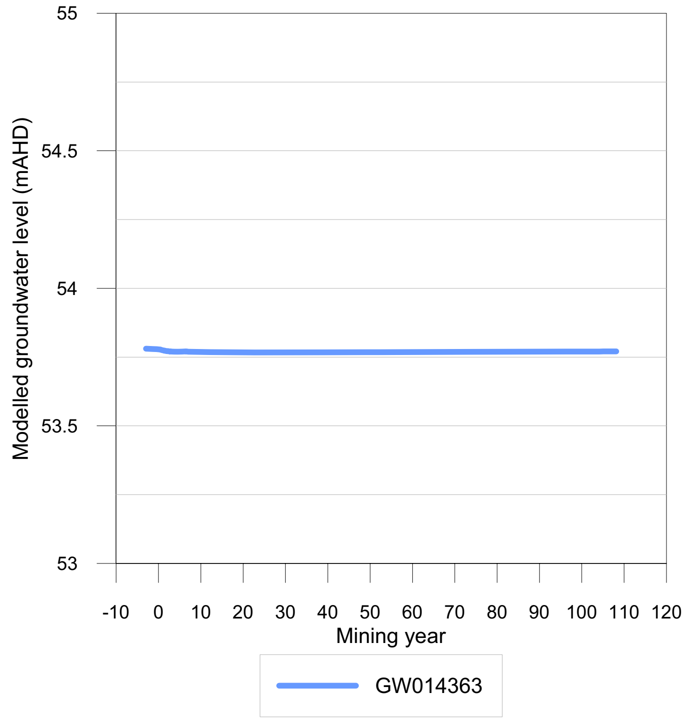
Mining year
GW013337



55
54.5
54
53.5
53
-10
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60
70
80
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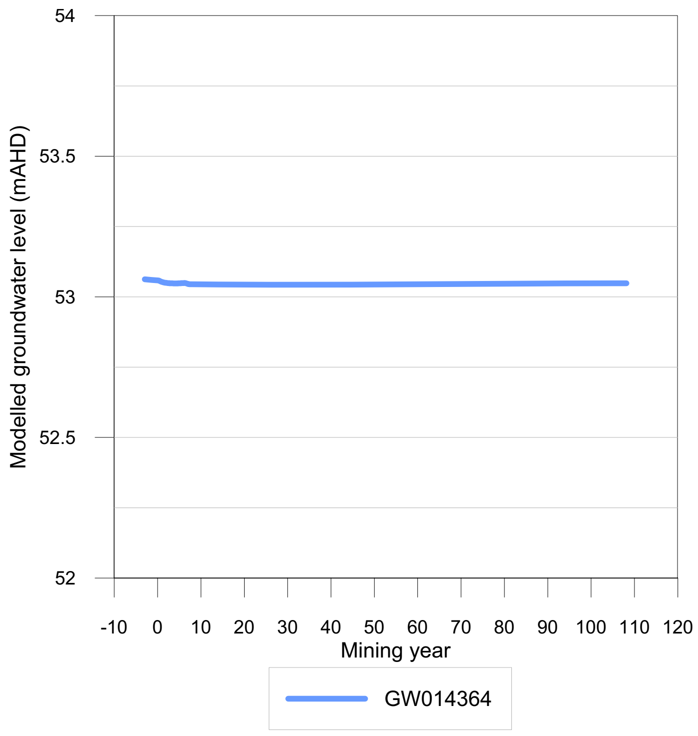
100
110
120
Modelled groundwater level (mAHD)
Mining year
GW014363



54
53.5
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52.5
52
-10
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20
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60
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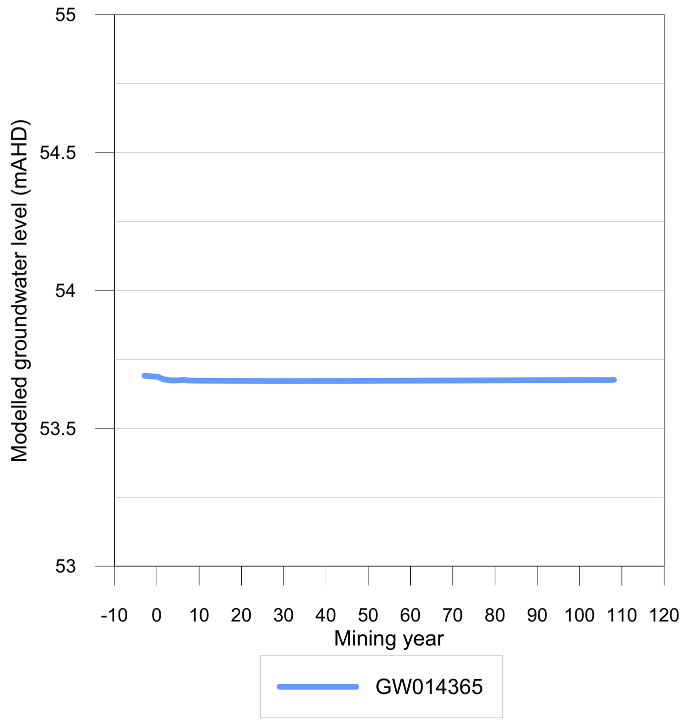
80
90
100
110
120
Modelled groundwater level (mAHD)
Mining year
GW014364



55
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-10
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80
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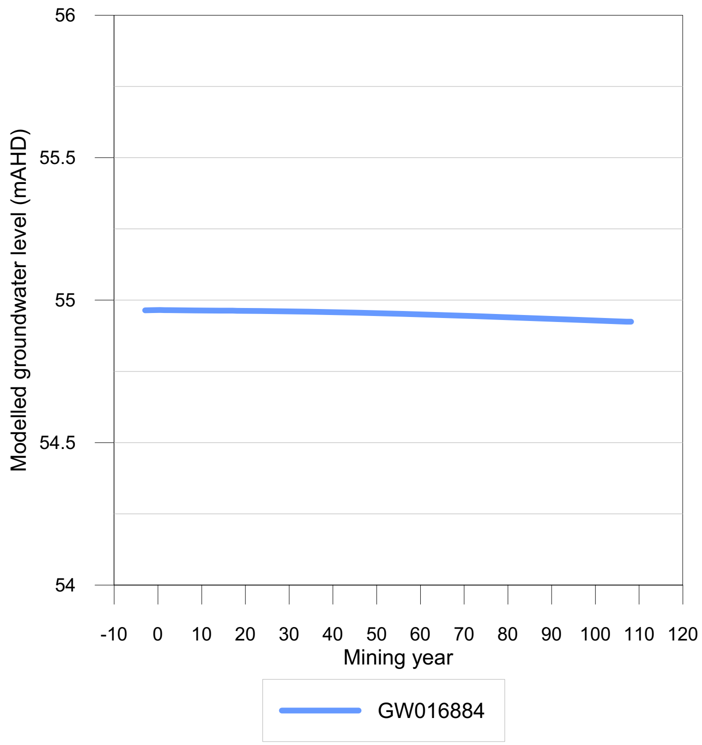
100
110
120
Modelled groundwater level (mAHD)
Mining year
GW014365



56
55.5
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54.5
54
-10
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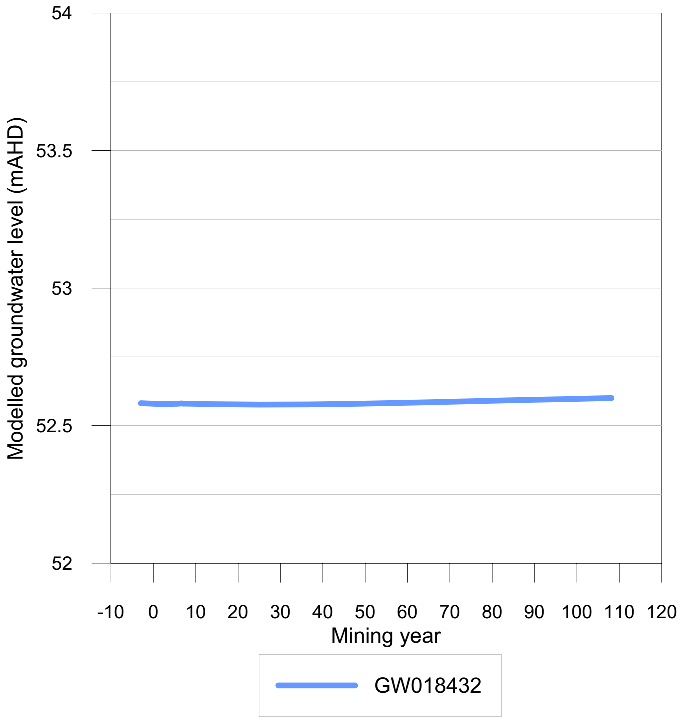
50
60
70
80
90
100
110
120
Modelled groundwater level (mAHD)
Mining year
GW016884



54
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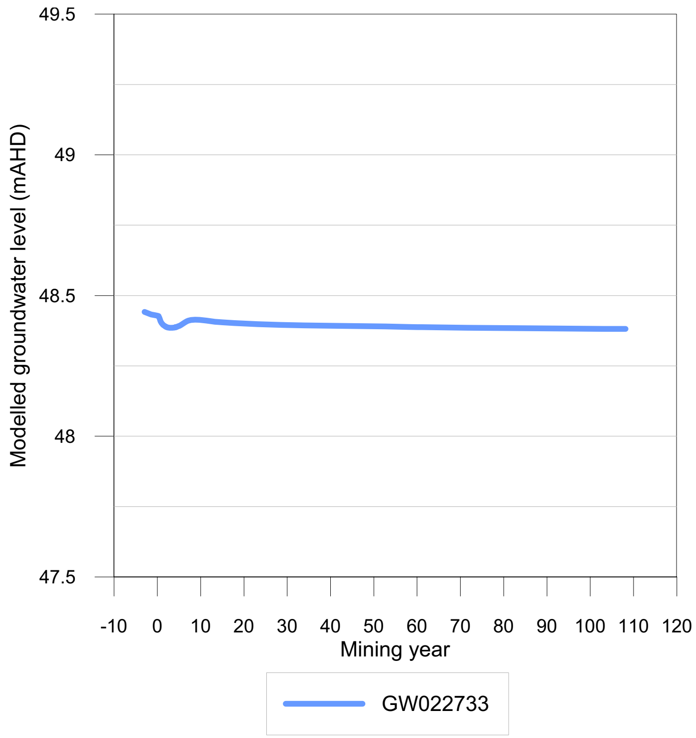
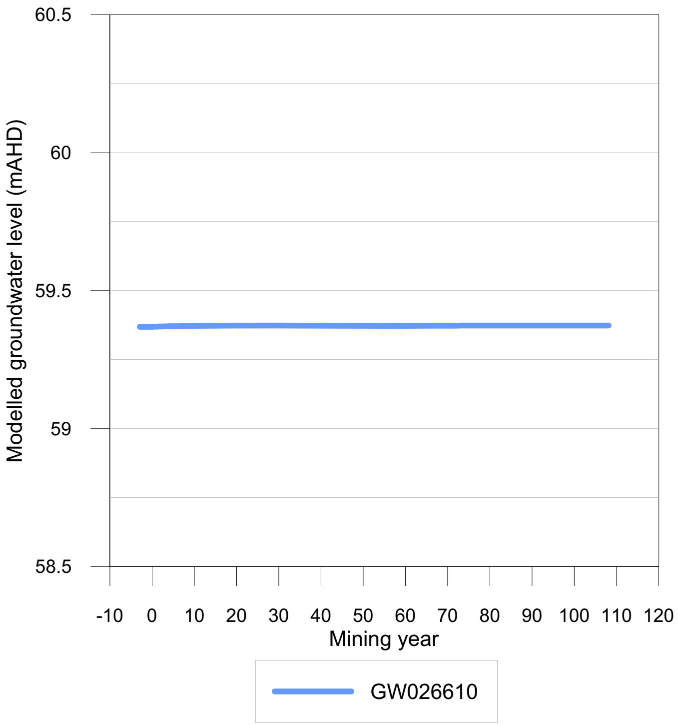
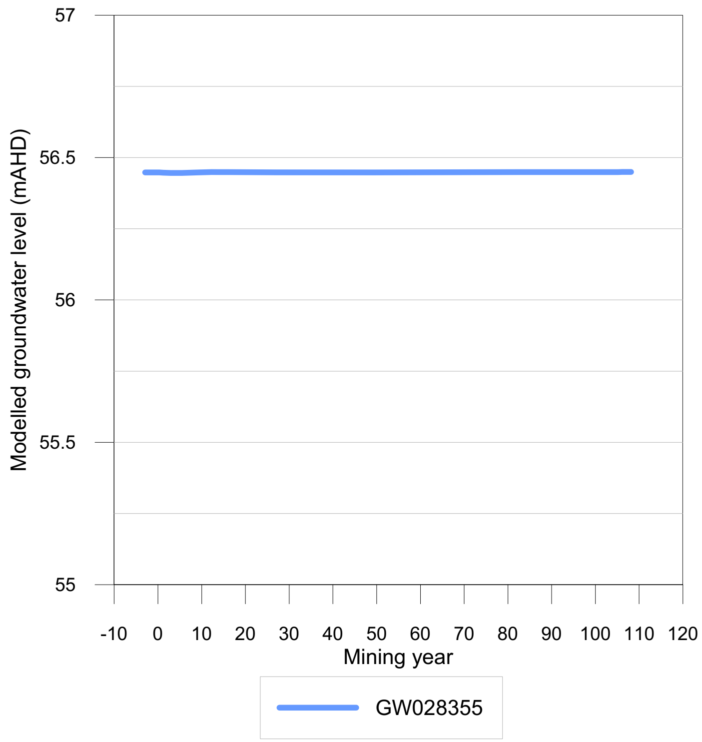
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW018432



49.5
49
48.5
48
47.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW022733



60.5
60
59.5
59
58.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW026610



57
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55.5
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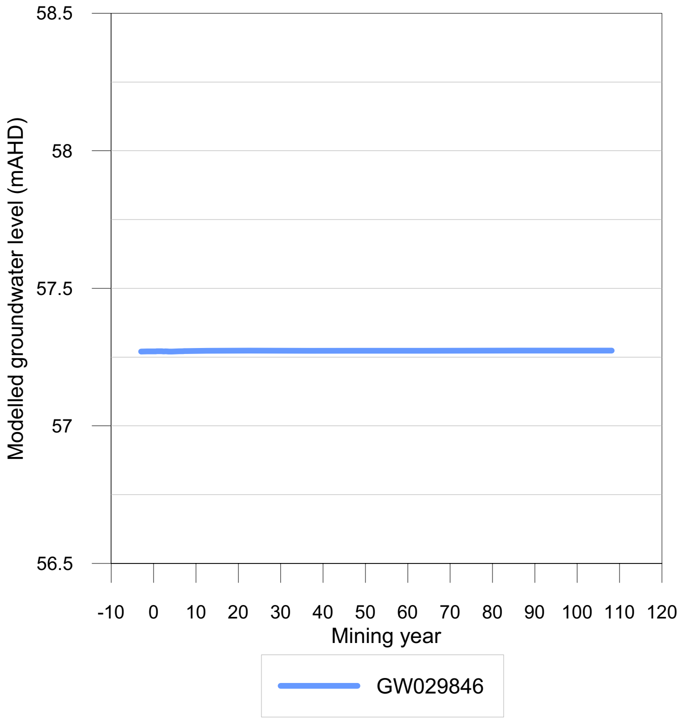
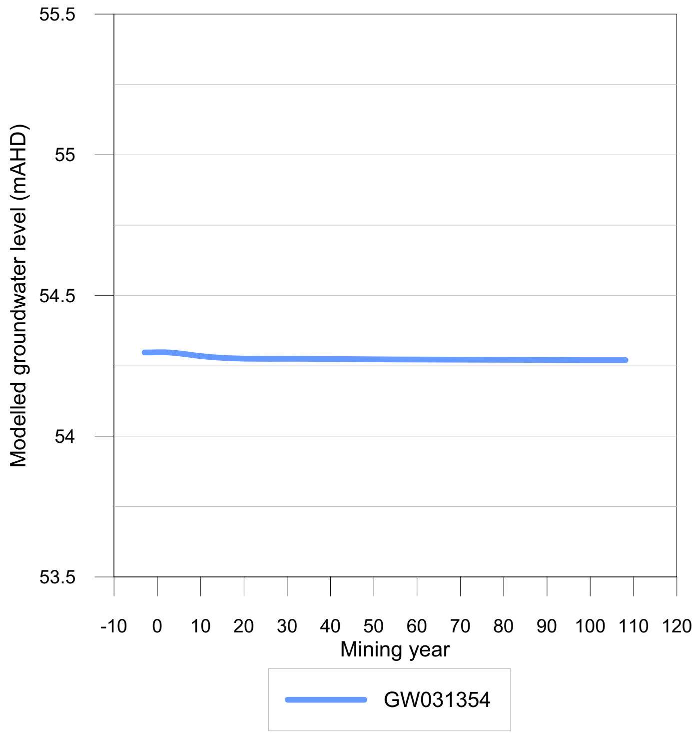
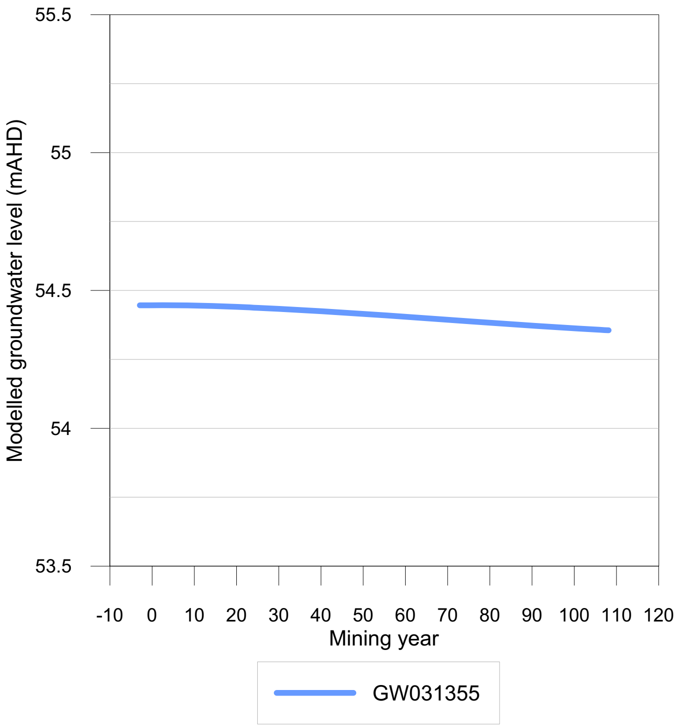
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW028355



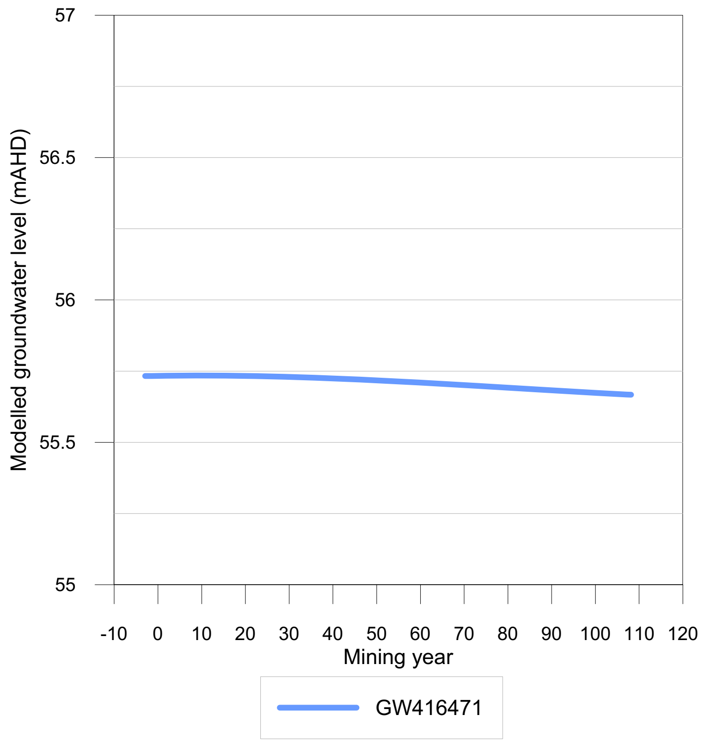
Modelled groundwater level (mAHD)
58.5
58
57.5
57
56.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW029846



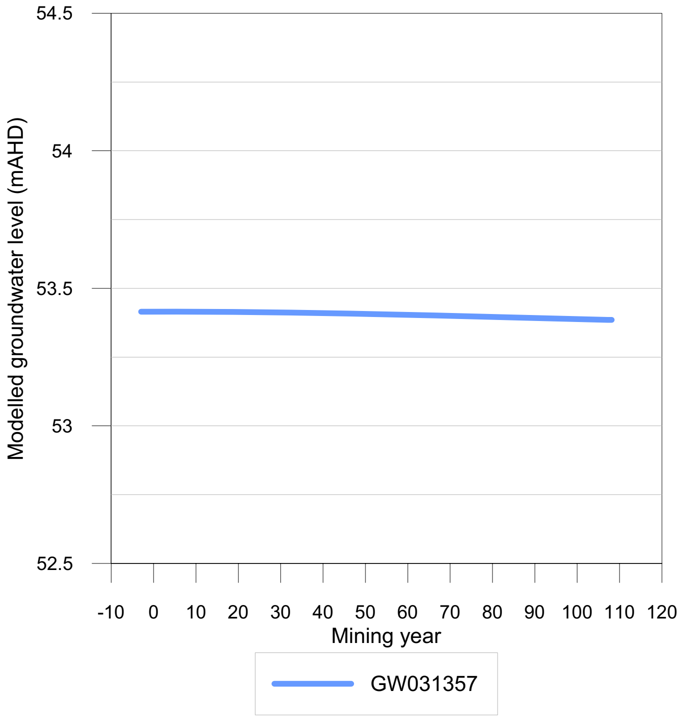
Modelled groundwater level (mAHD)
55.5
55
54.5
54
53.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW031354

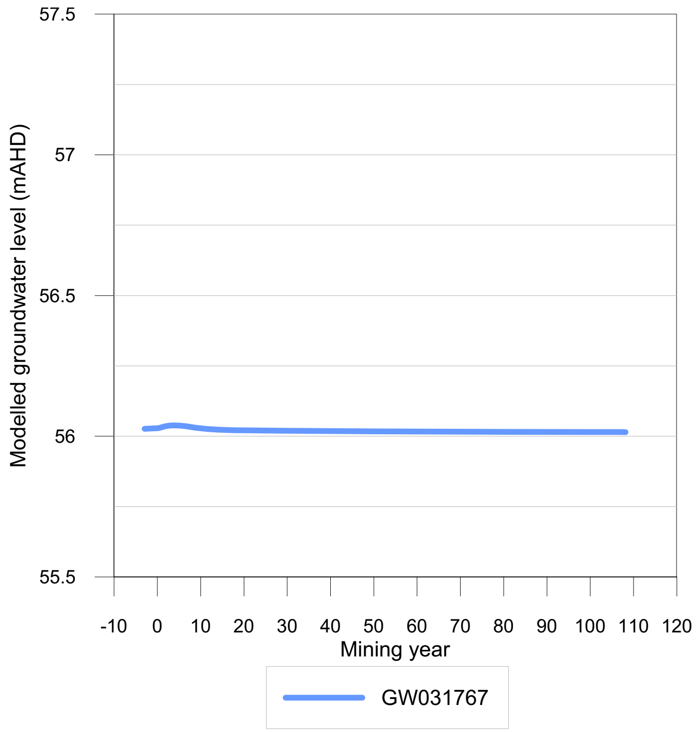


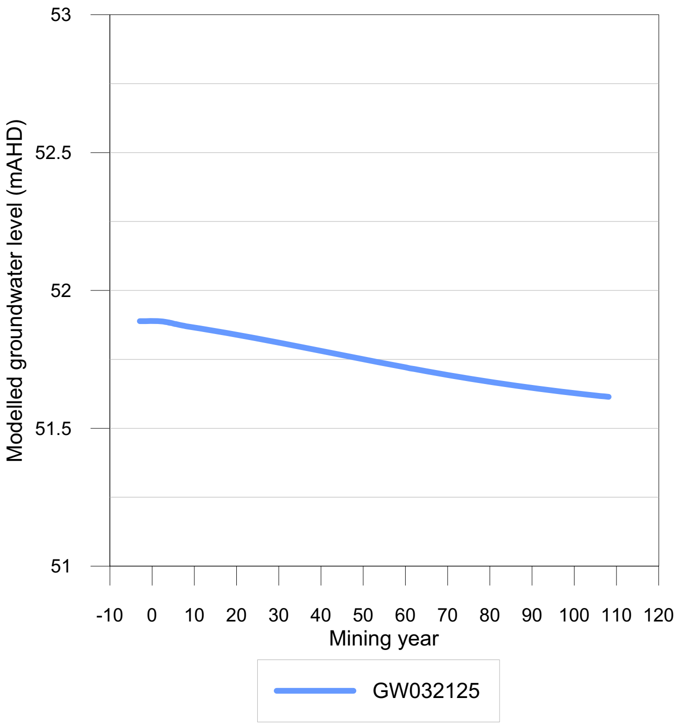
Modelled groundwater level (mAHD)
55.5
55
54.5
54
53.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW031355

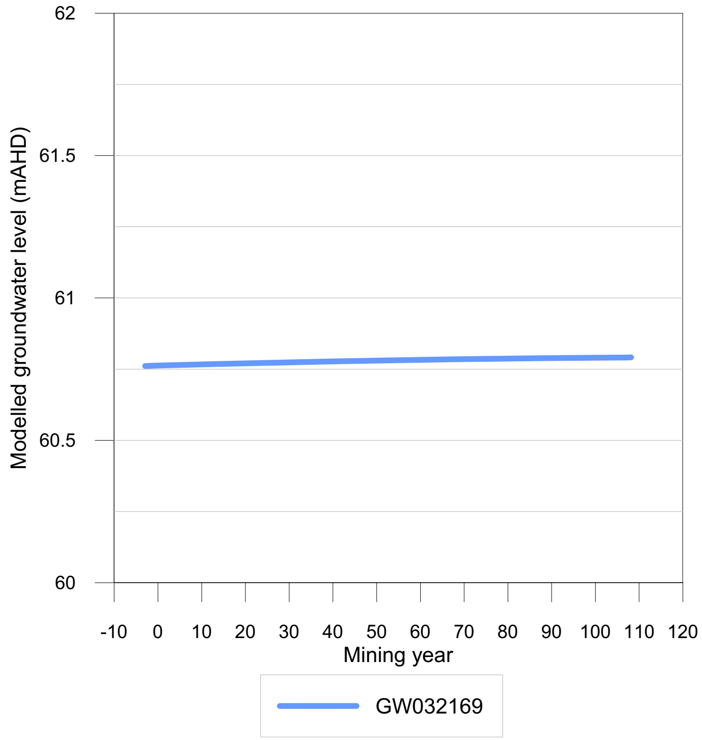


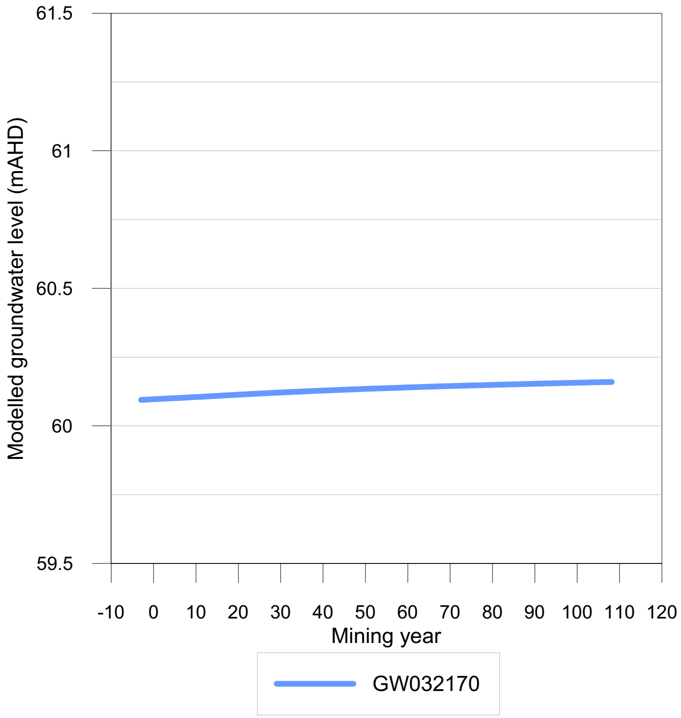
Modelled groundwater level (mAHD)
57
56.5
56
55.5
55
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW416471


Modelled groundwater level (mAHD)
54.5
54
53.5
53
52.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW031357

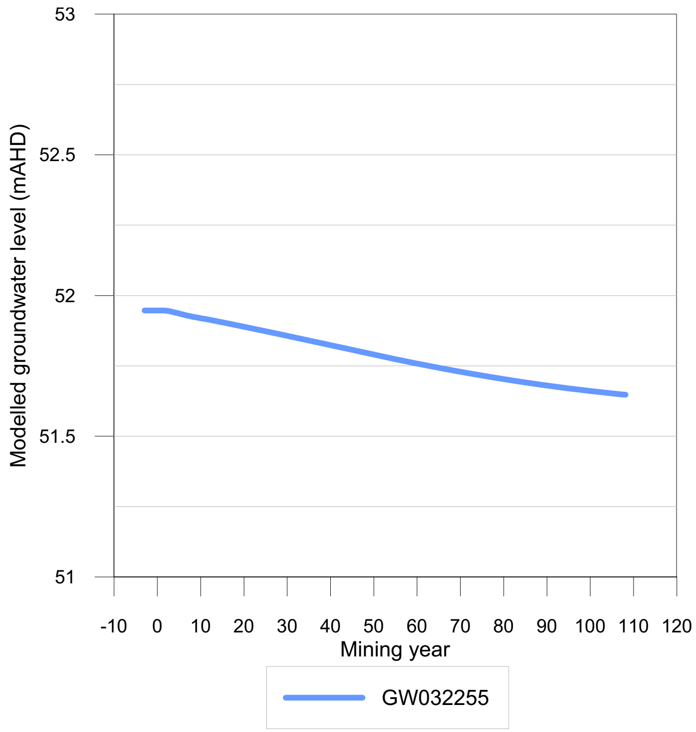

Modelled groundwater level (mAHD)
57.5
57
56.5
56
55.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW031767


Modelled groundwater level (mAHD)
53
52.5
52
51.5
51
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032125

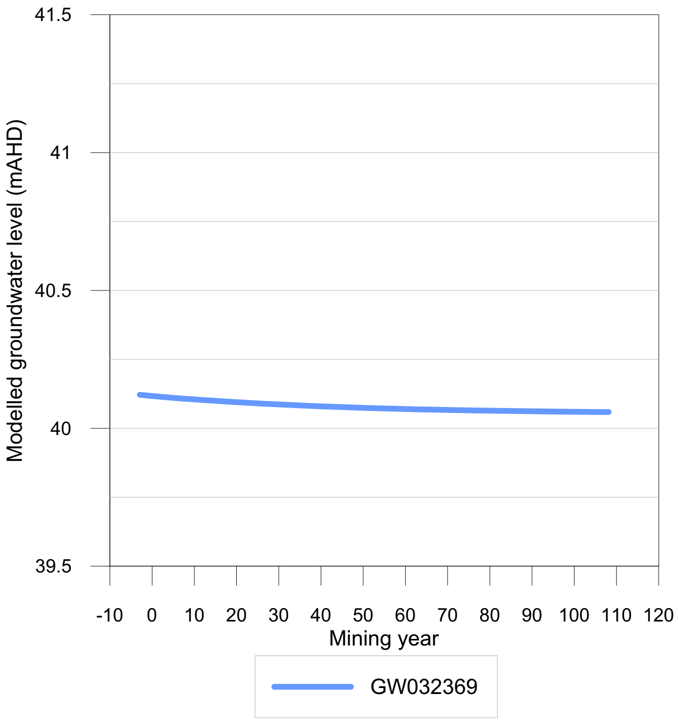

Modelled groundwater level (mAHD)
62
61.5
61
60.5
60
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032169



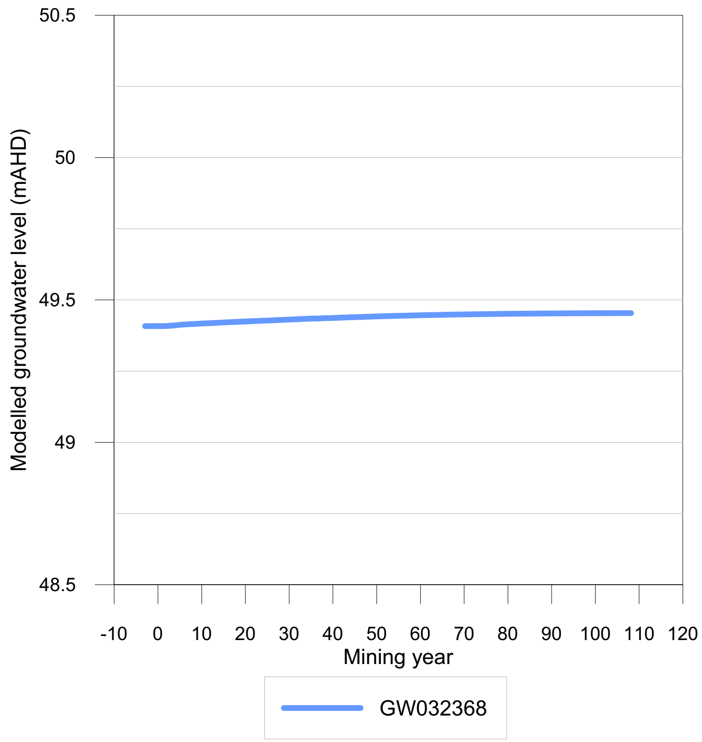
61.5
61
60.5
60
59.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032170



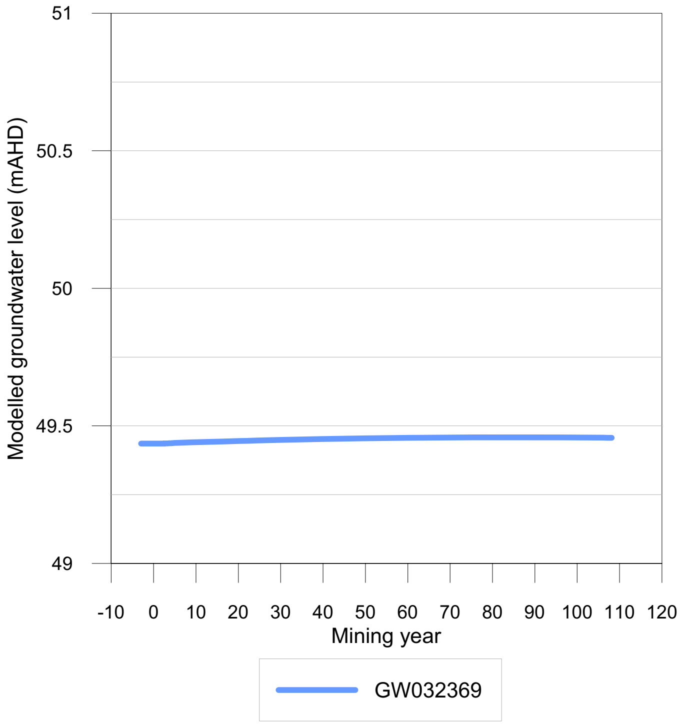
53
52.5
52
51.5
51
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032255



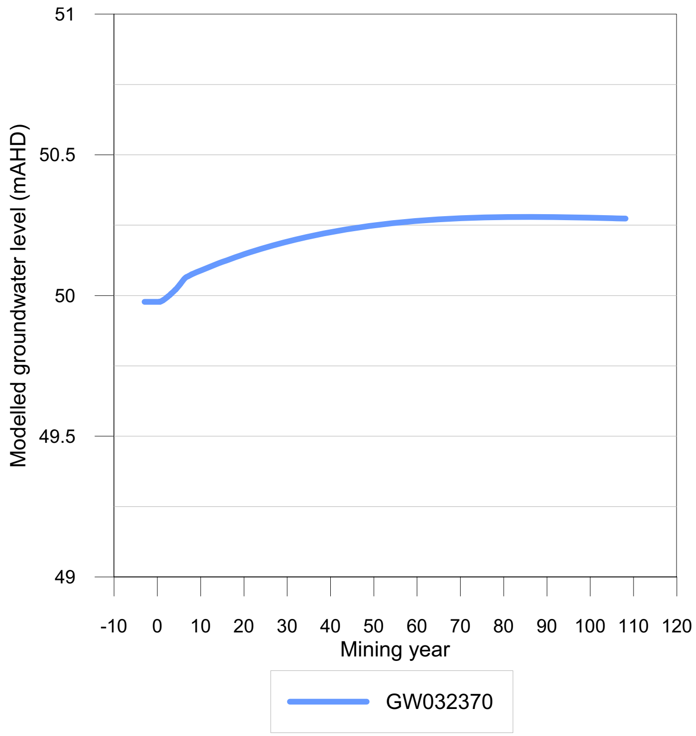
41.5
41
40.5
40
39.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032369



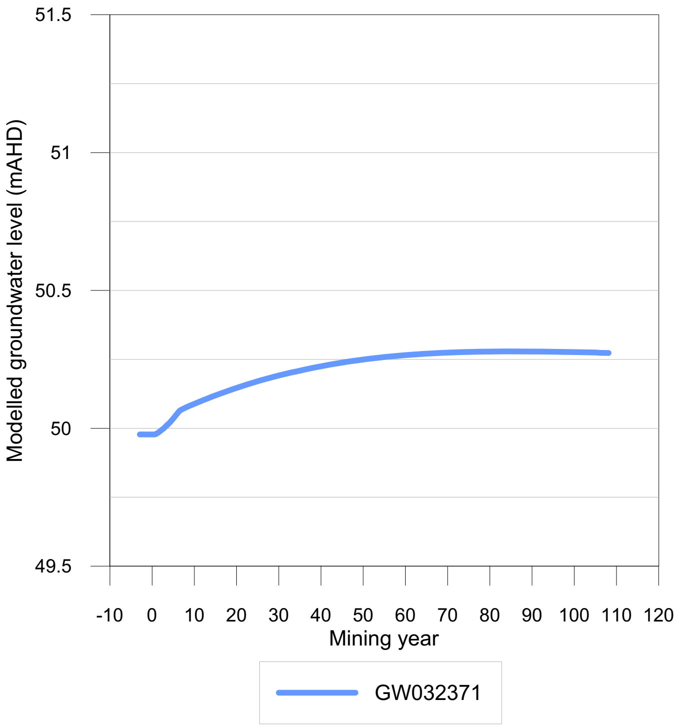
50.5
50
49.5
49
48.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032368



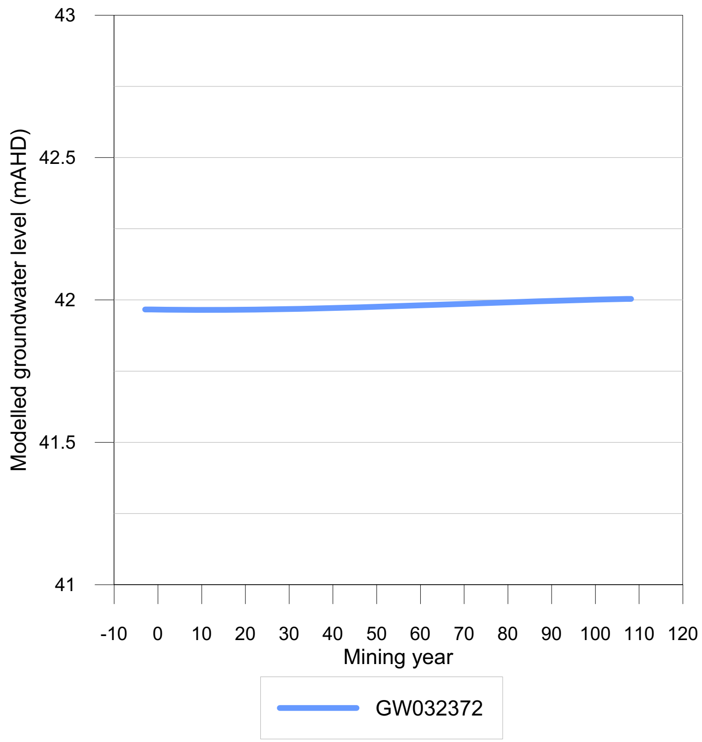
Modelled groundwater level (mAHD)
51
50.5
50
49.5
49
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032369



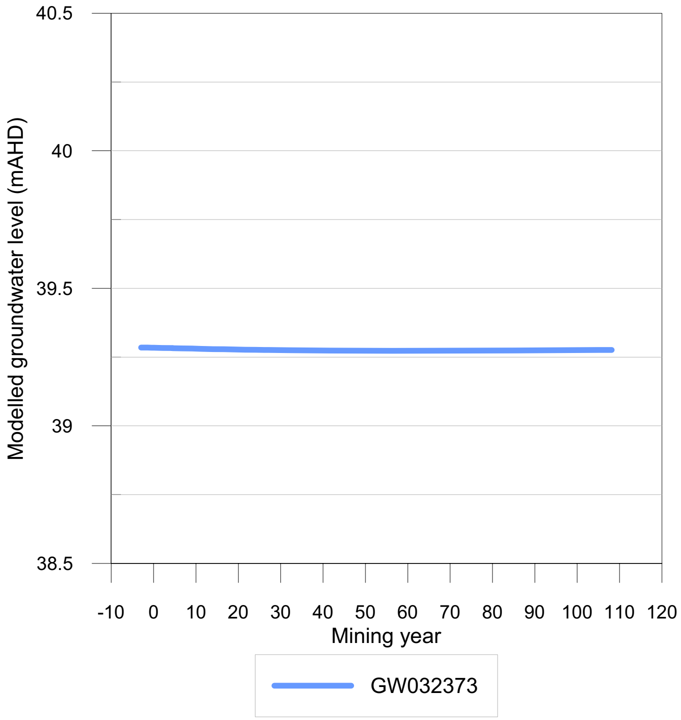
Modelled groundwater level (mAHD)
51
50.5
50
49.5
49
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032370



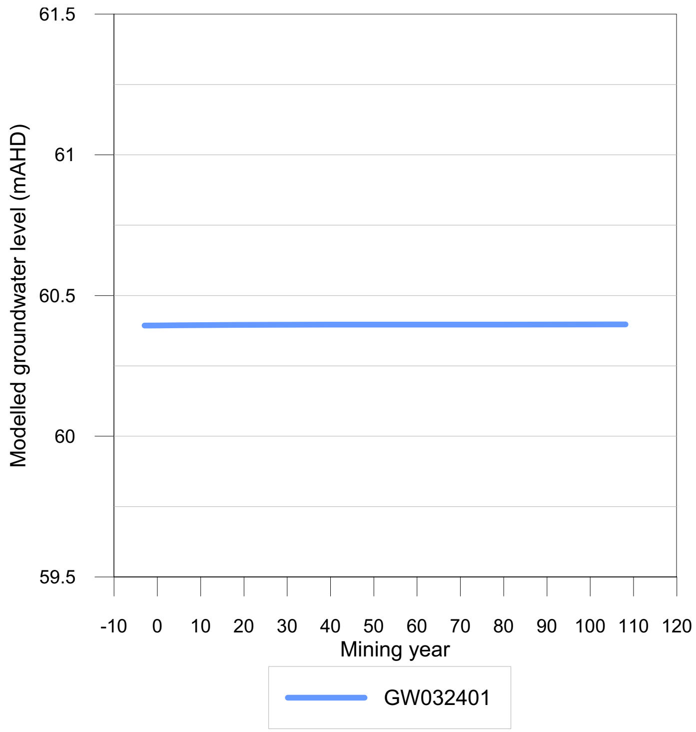
Modelled groundwater level (mAHD)
51.5
51
50.5
50
49.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032371



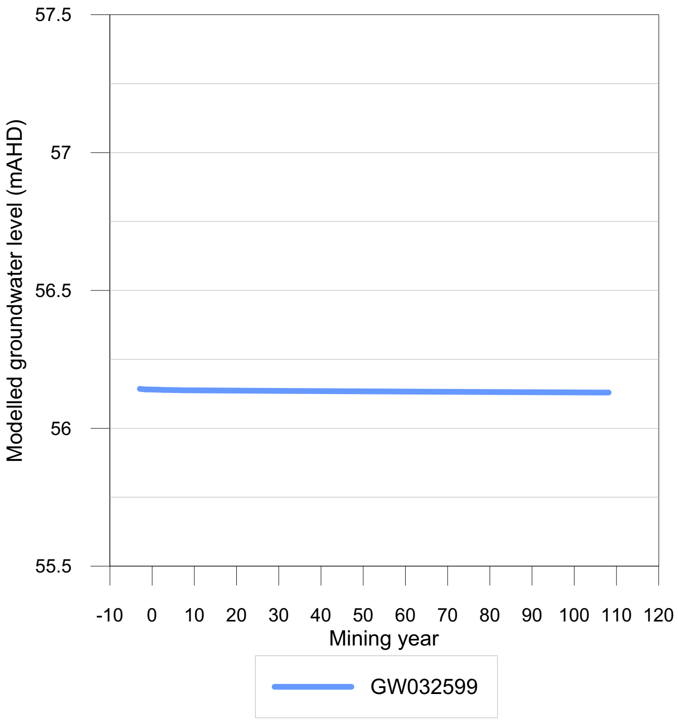
Modelled groundwater level (mAHD)
43
42.5
42
41.5
41
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032372



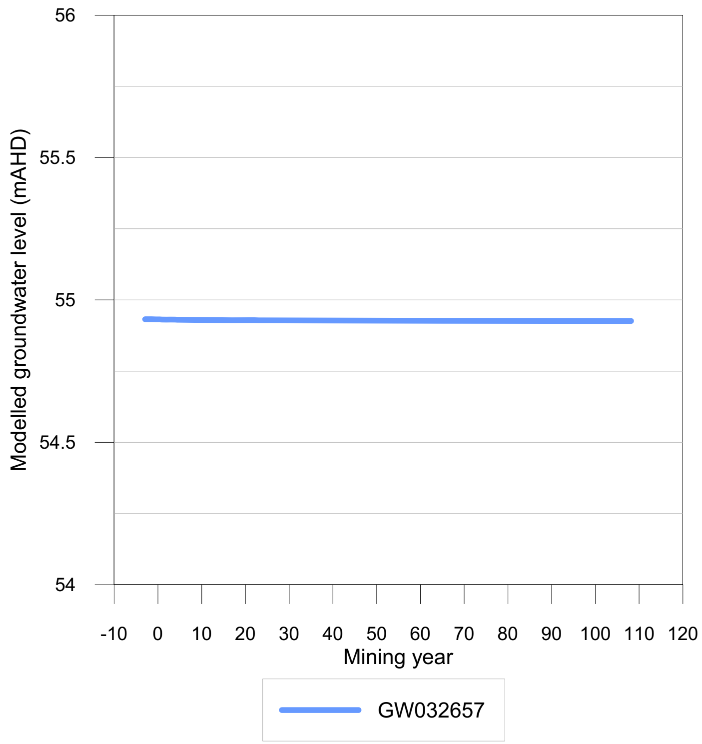
Modelled groundwater level (mAHD)
40.5
40
39.5
39
38.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032373



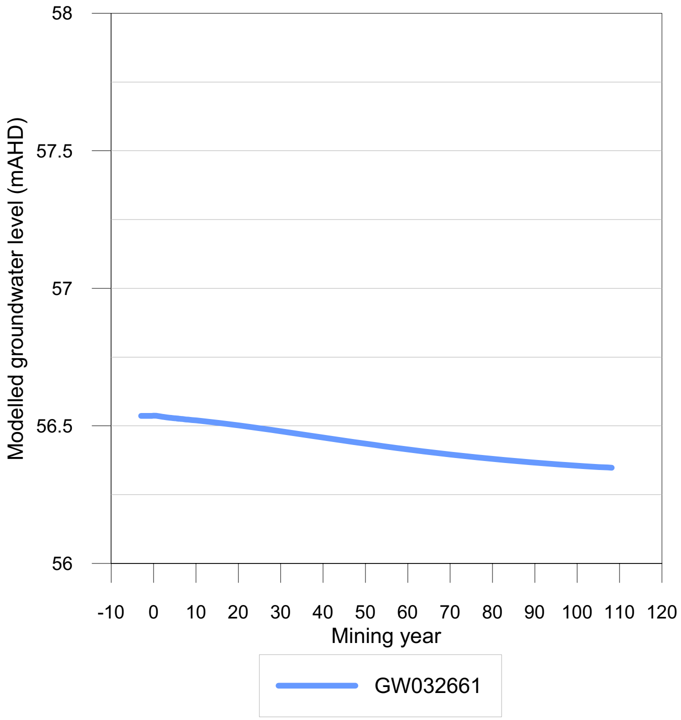
Modelled groundwater level (mAHD)
61.5
61
60.5
60
59.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032401



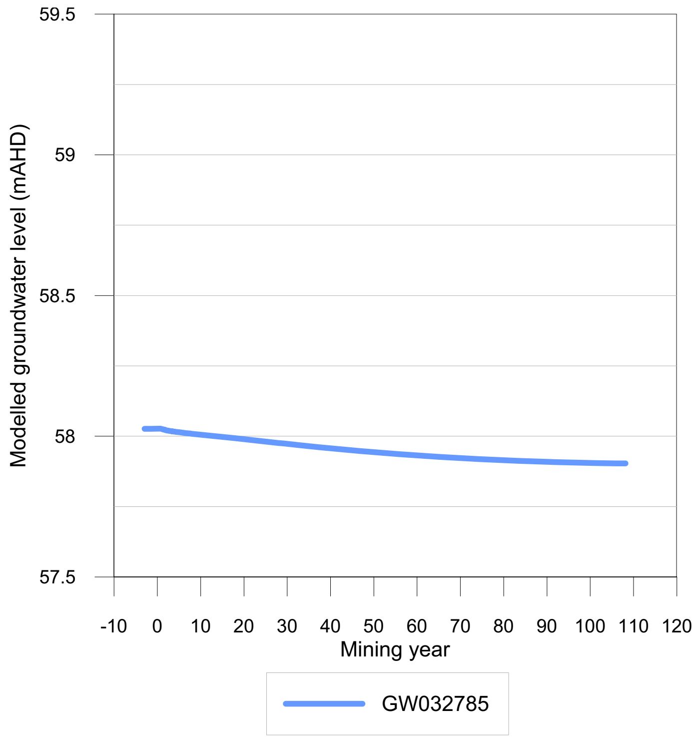
Modelled groundwater level (mAHD)
57.5
57
56.5
56
55.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032599



Modelled groundwater level (mAHD)
56
55.5
55
54.5
54
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032657



Modelled groundwater level (mAHD)
58
57.5
57
56.5
56
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032661



Modelled groundwater level (mAHD)
59.5
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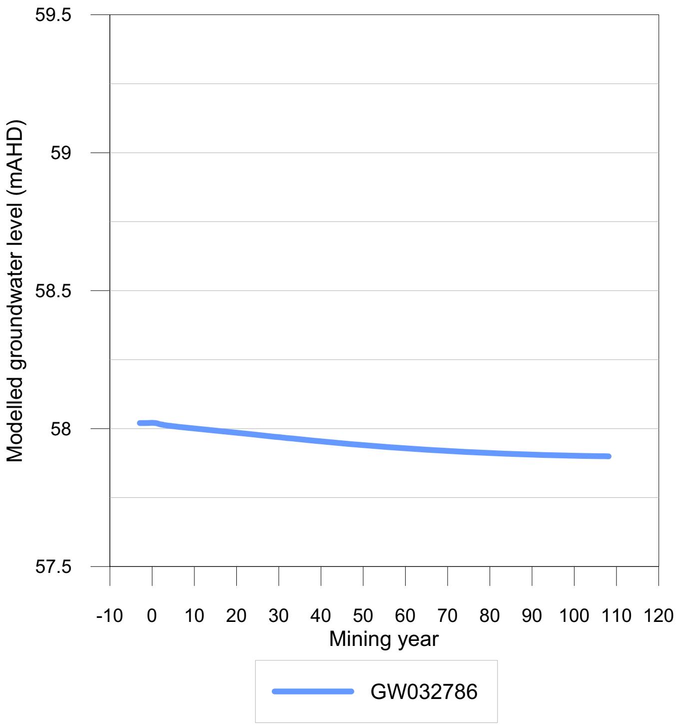
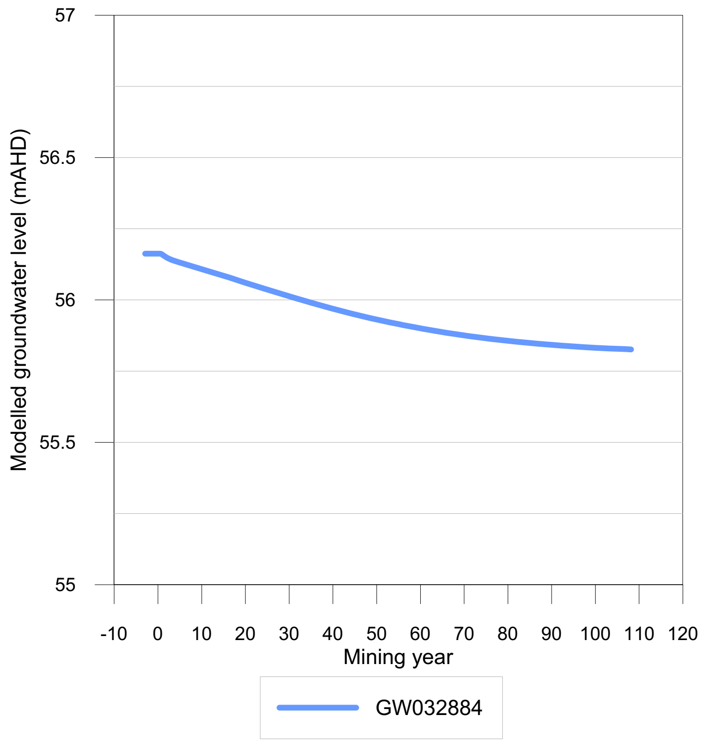
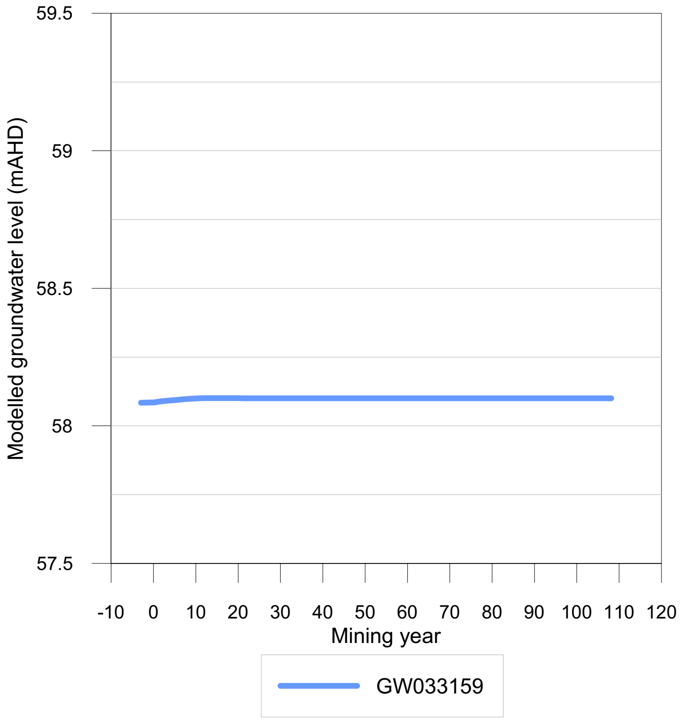
58.5
58
57.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032785



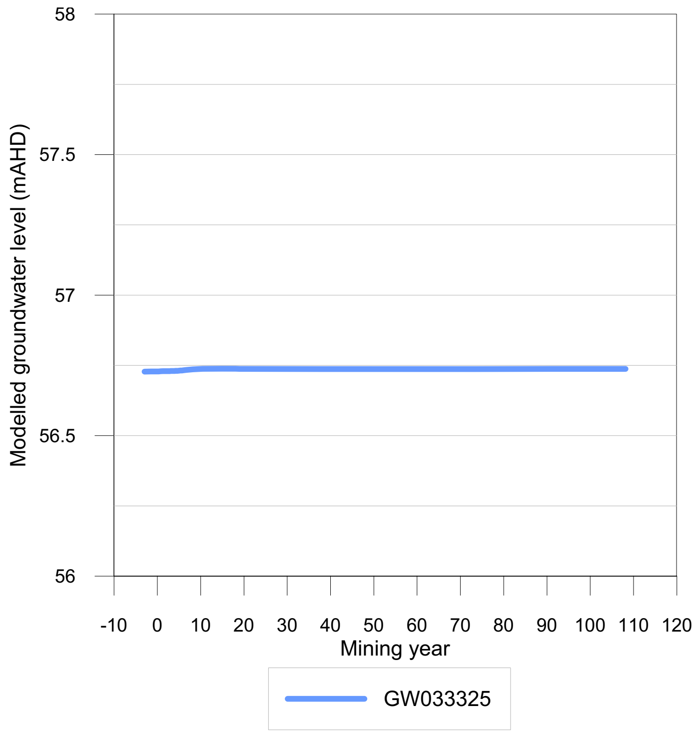
Modelled groundwater level (mAHD)
59.5
59
58.5
58
57.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032786



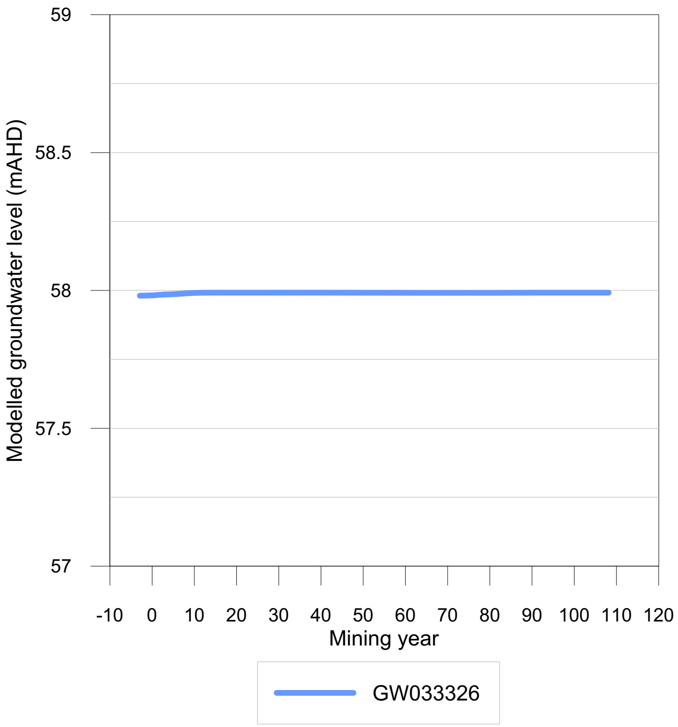
Modelled groundwater level (mAHD)
57
56.5
56
55.5
55
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032884



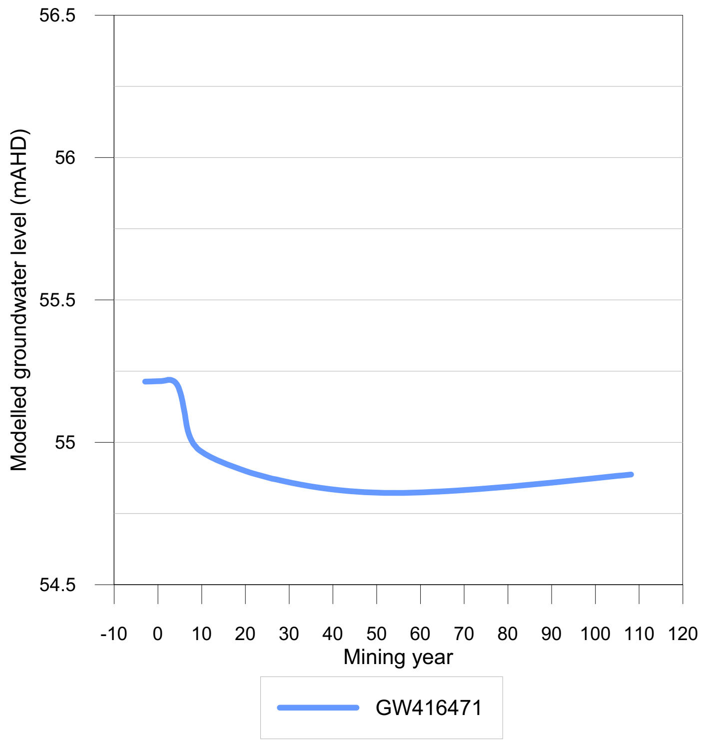
Modelled groundwater level (mAHD)
59.5
59
58.5
58
57.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033159



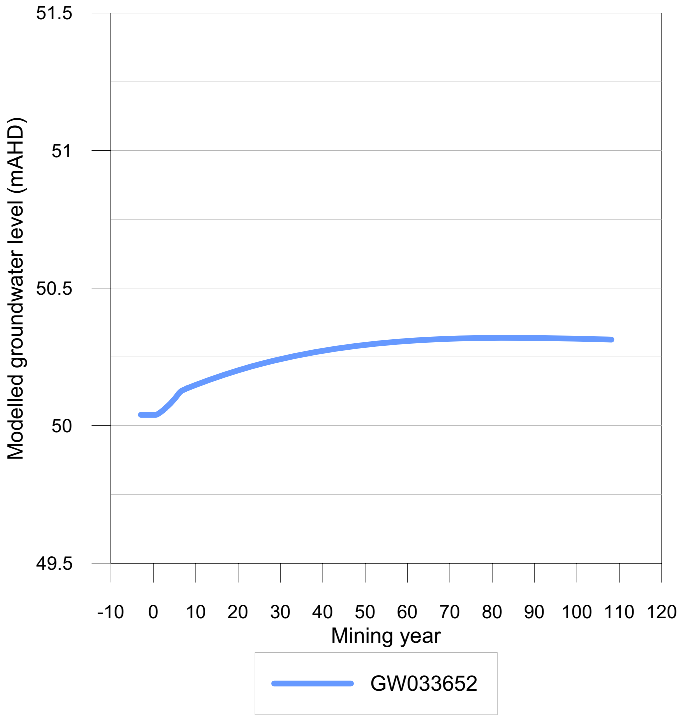
Modelled groundwater level (mAHD)
58
57.5
57
56.5
56
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033325



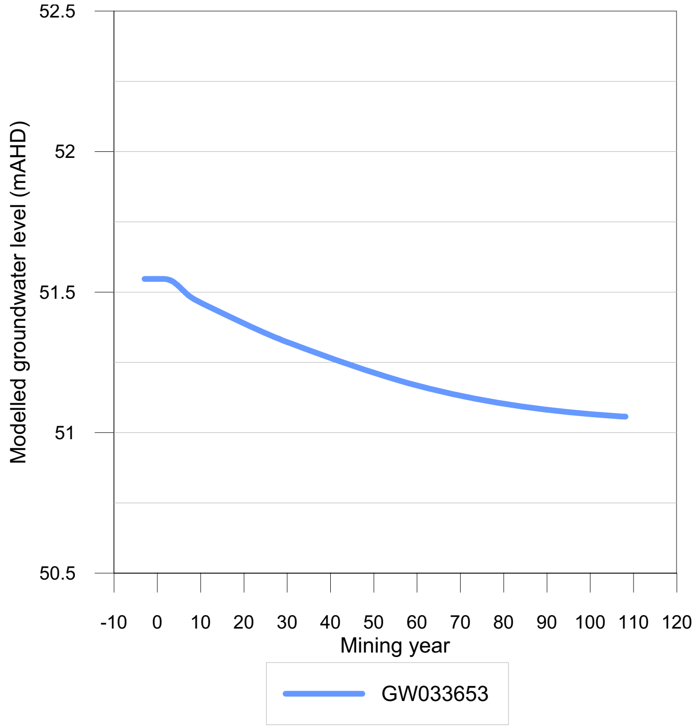
Modelled groundwater level (mAHD)
59
58.5
58
57.5
57
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033326



Modelled groundwater level (mAHD)
56.5
56
55.5
55
54.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW416471



51.5
51
50.5
50
49.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033652



52.5
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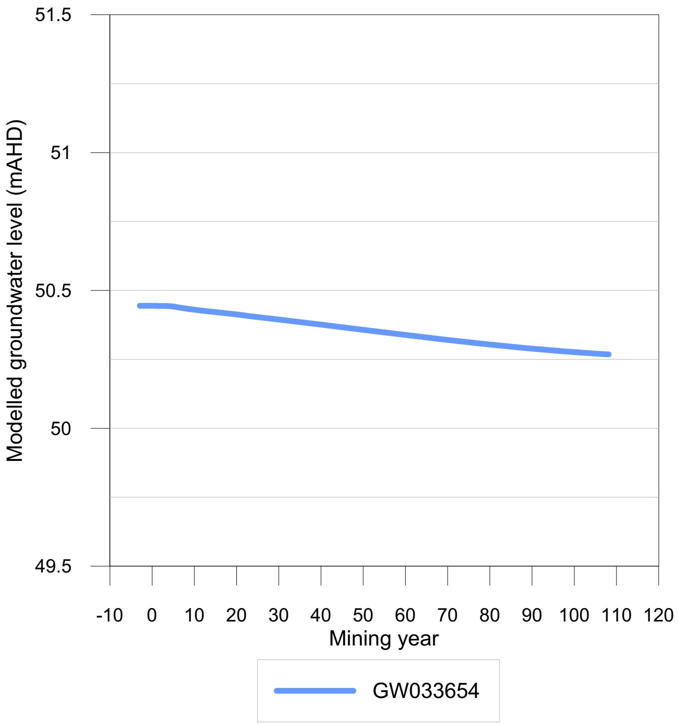
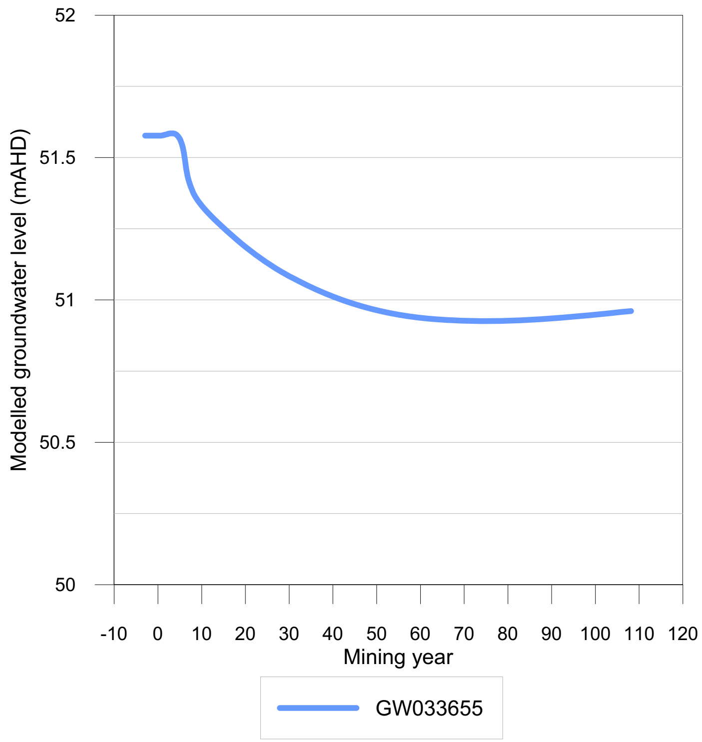
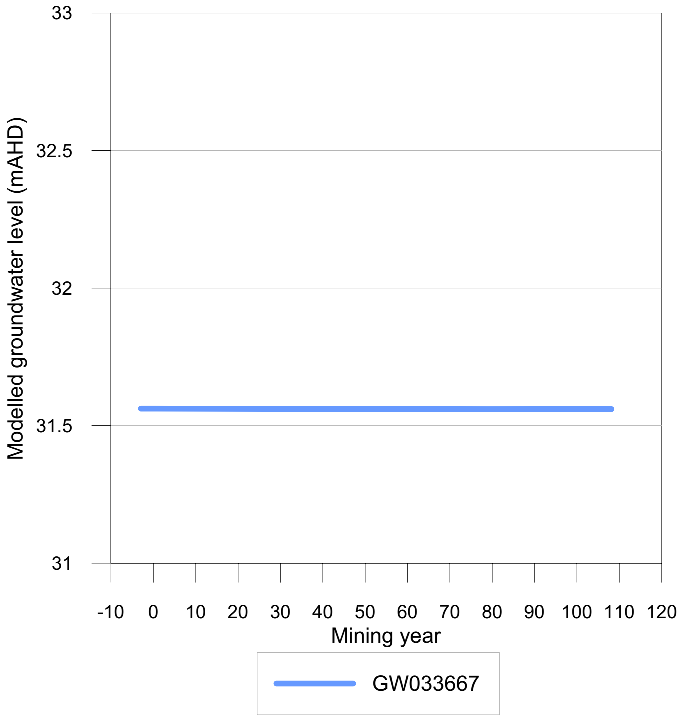
51.5
51
50.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033653



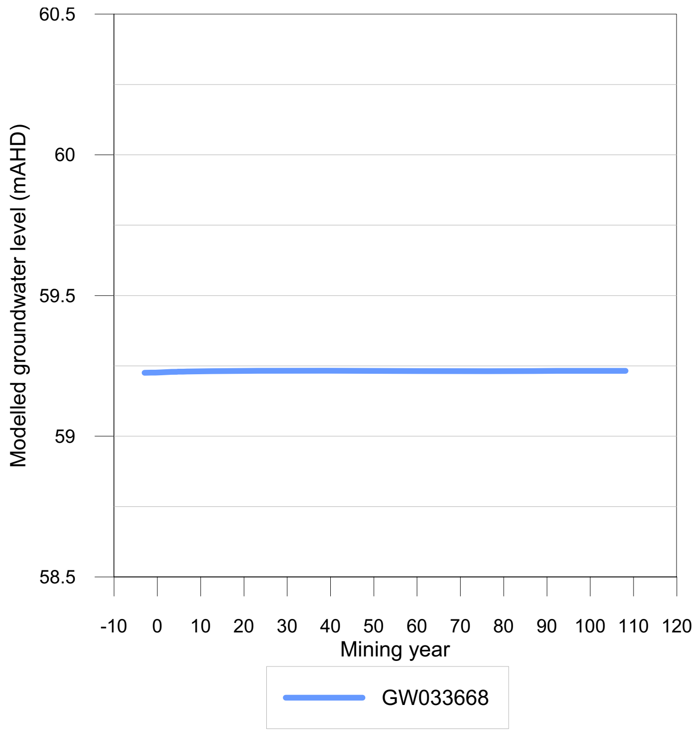
51.5
51
50.5
50
49.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033654



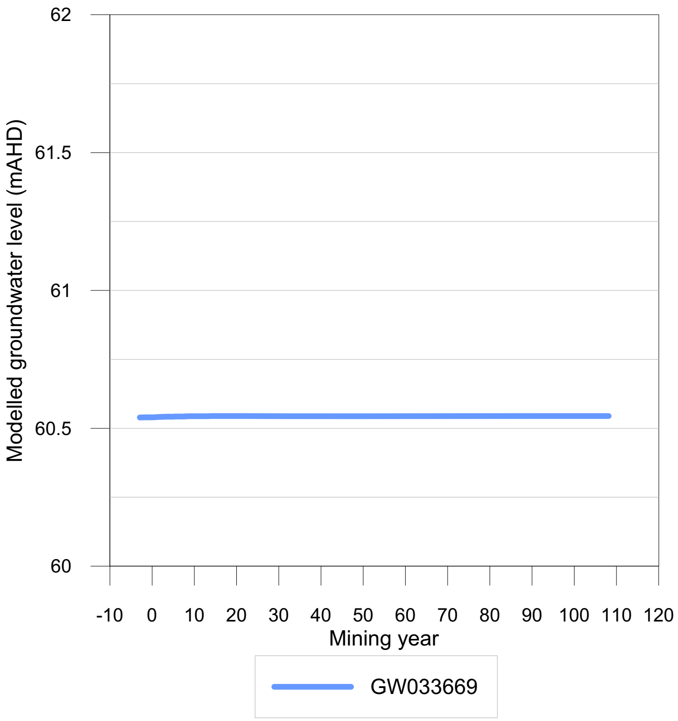
52
51.5
51
50.5
50
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033655



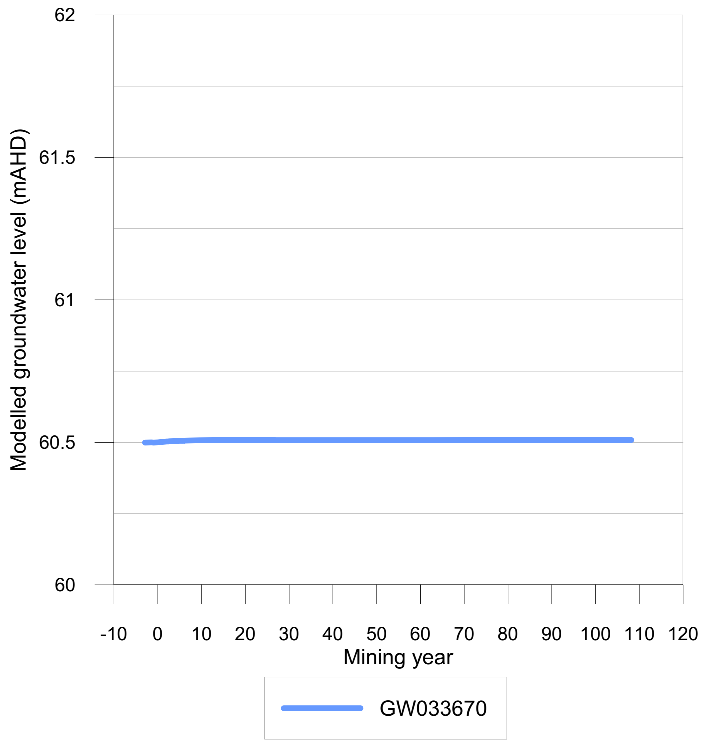
Modelled groundwater level (mAHD)
33
32.5
32
31.5
31
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW033667



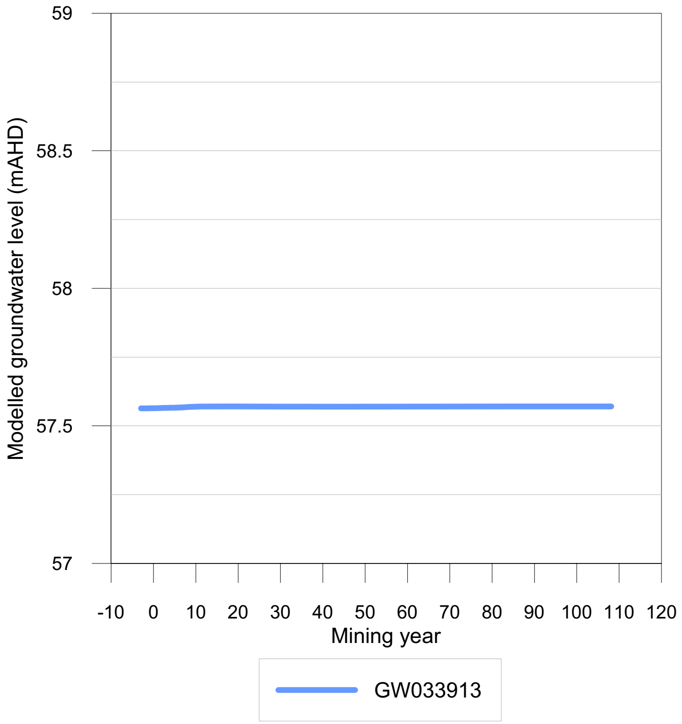
Modelled groundwater level (mAHD)
60.5
60
59.5
59
58.5
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW033668

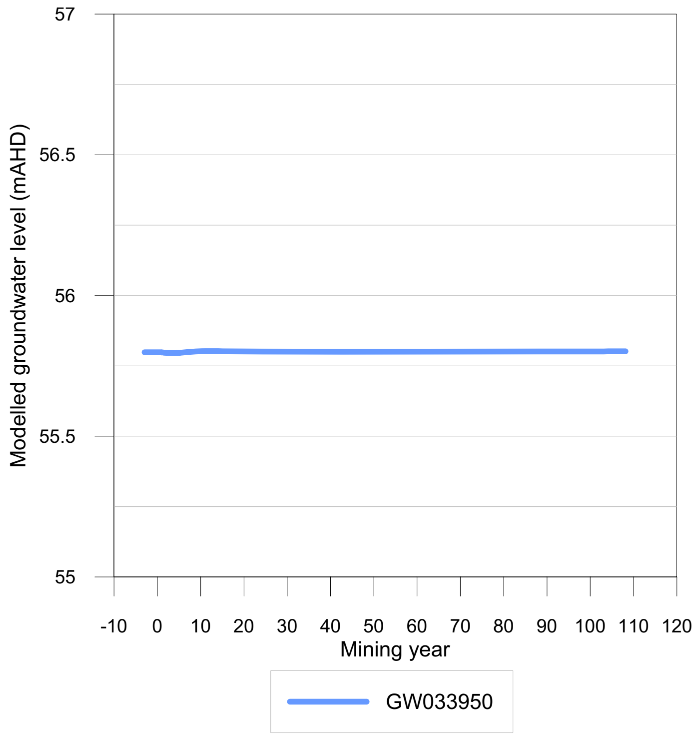


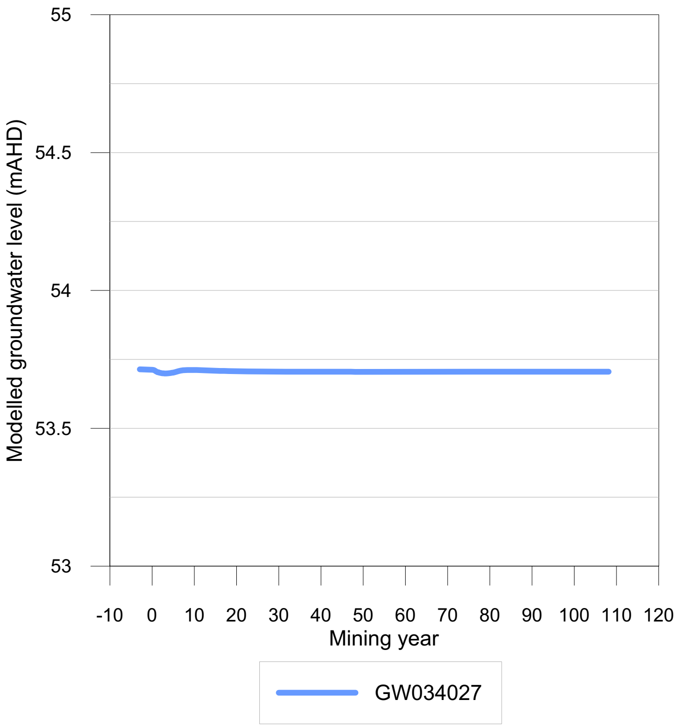
Modelled groundwater level (mAHD)
62
61.5
61
60.5
60
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW033669

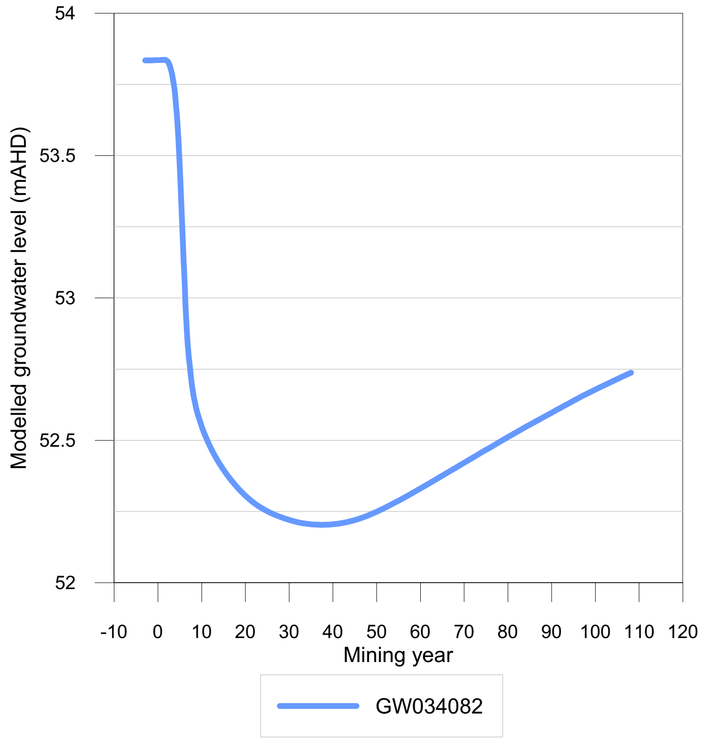


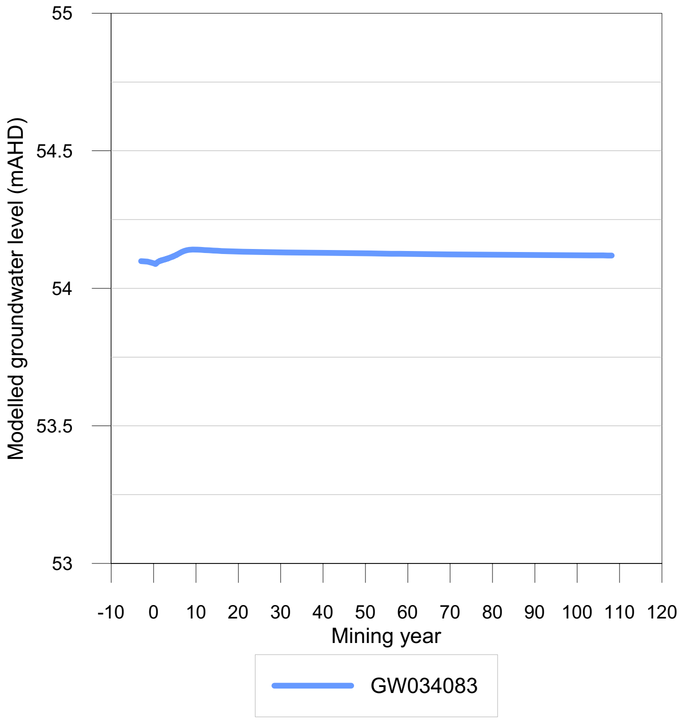
Modelled groundwater level (mAHD)
62
61.5
61
60.5
60
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW033670


Modelled groundwater level (mAHD)
59
58.5
58
57.5
57
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033913

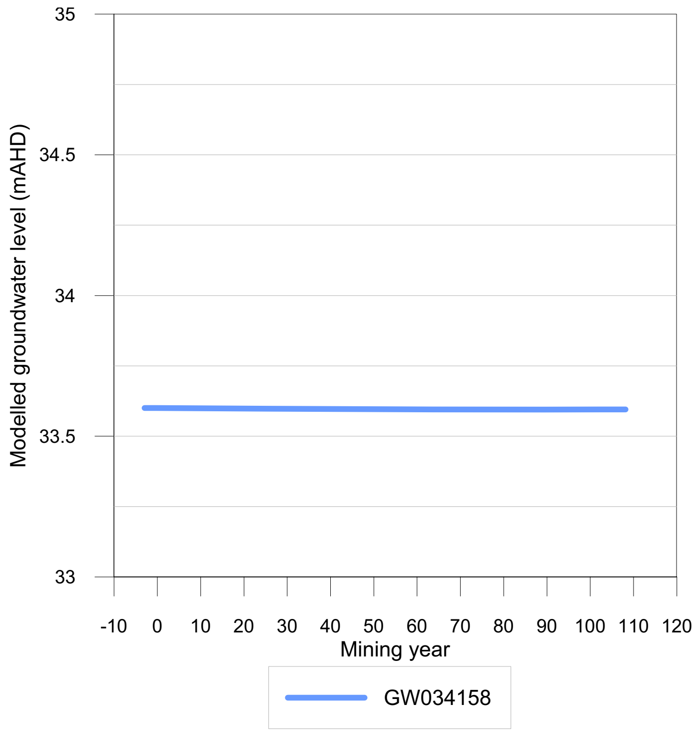

Modelled groundwater level (mAHD)
57
56.5
56
55.5
55
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW033950


Modelled groundwater level (mAHD)
55
54.5
54
53.5
53
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW034027


Modelled groundwater level (mAHD)
54
53.5
53
52.5
52
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW034082



55
54.5
54
53.5
53
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW034083



35
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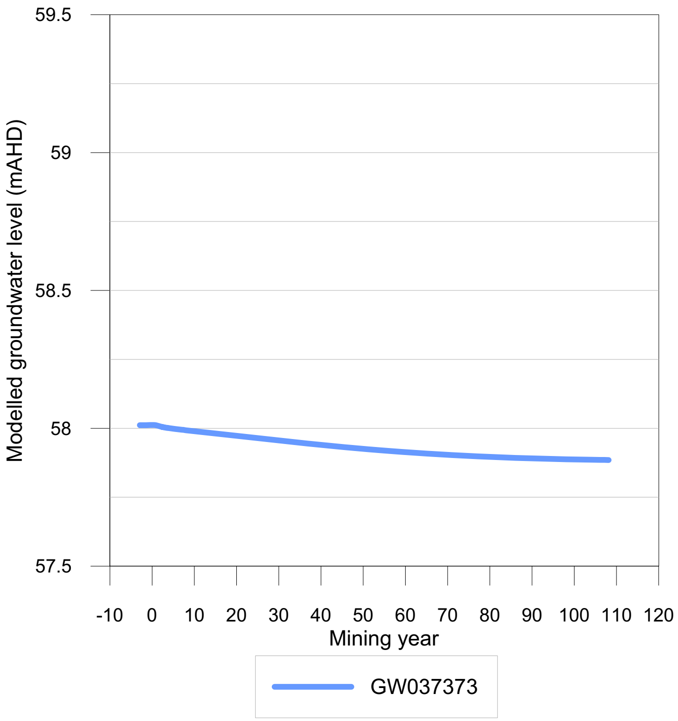
33
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW034158



59.5
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Modelled groundwater level (mAHD)
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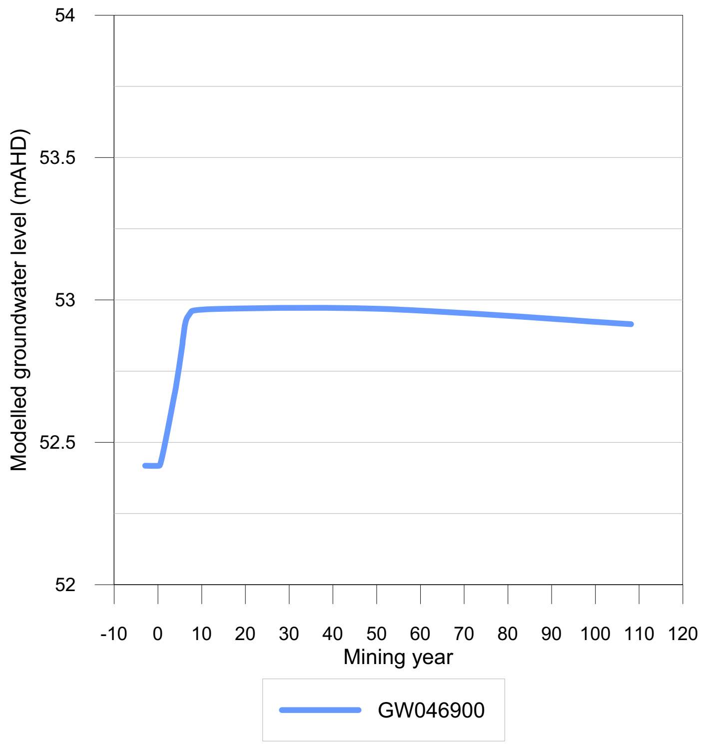
Mining year
GW037373



54
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Modelled groundwater level (mAHD)
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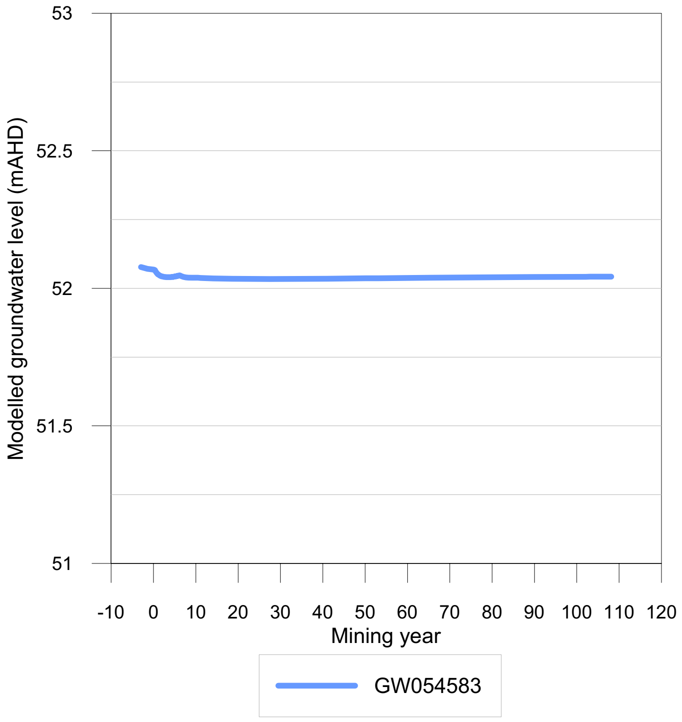
Mining year
GW046900



53
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51.5
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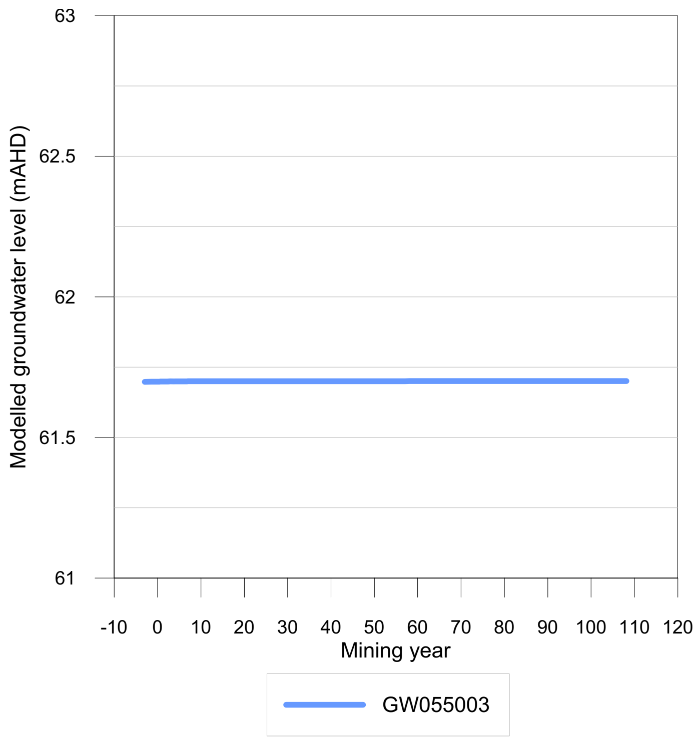
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW054583



63
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61.5
61
Modelled groundwater level (mAHD)
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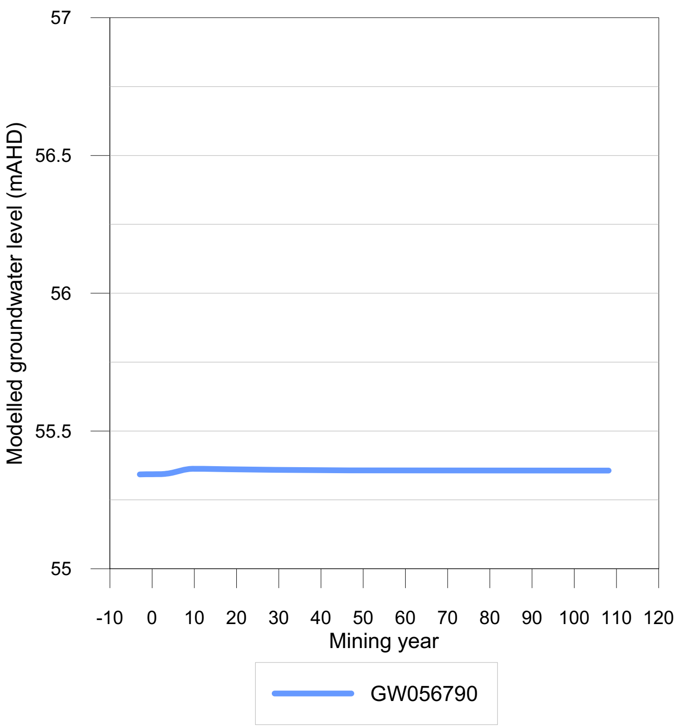
Mining year
GW055003



57
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Modelled groundwater level (mAHD)
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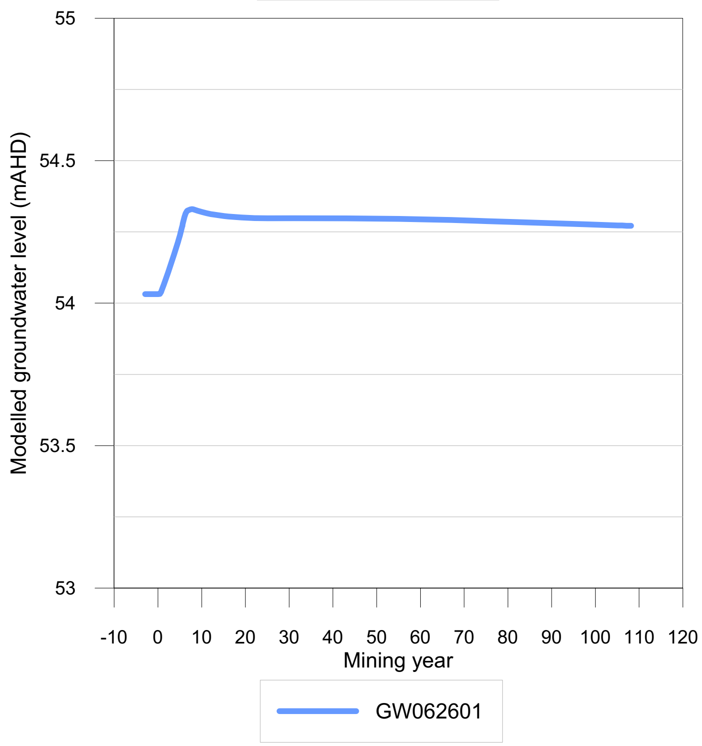
Mining year
GW056790



55
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Modelled groundwater level (mAHD)
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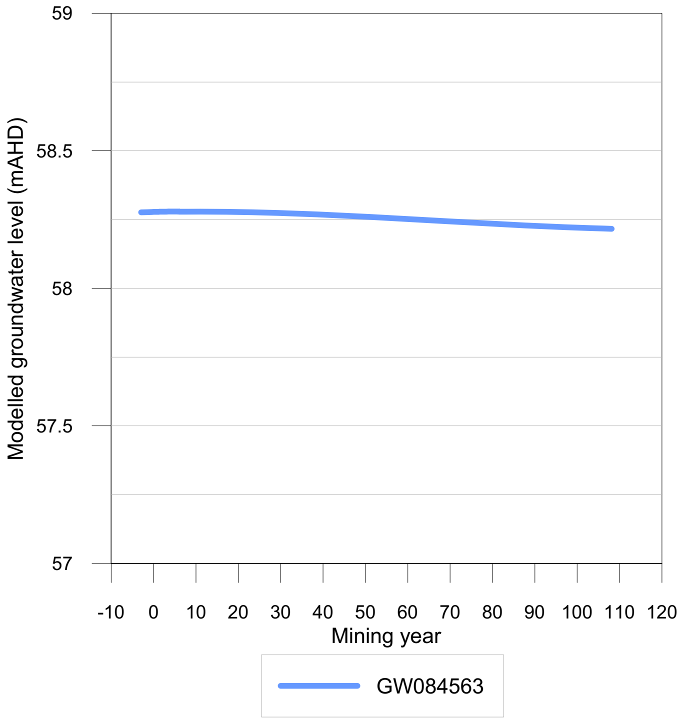
Mining year
GW062601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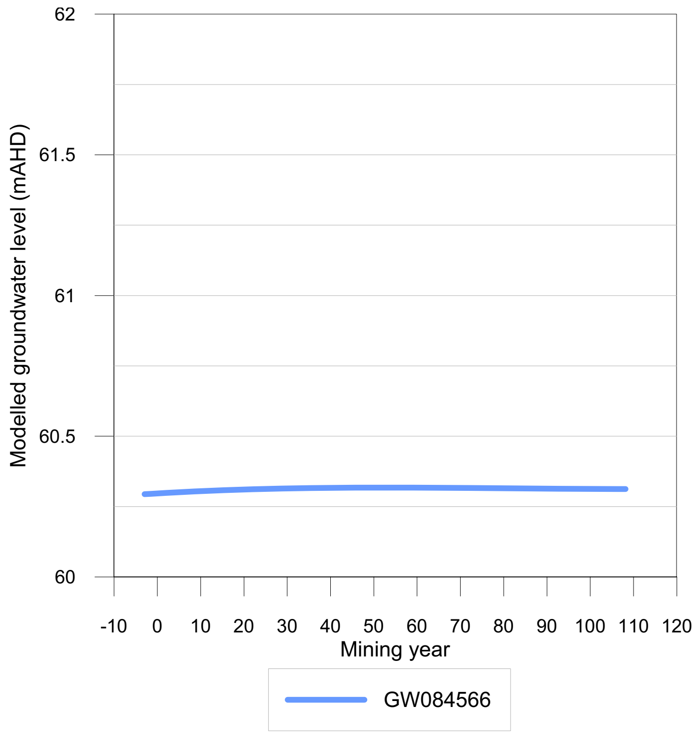
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW084563


62
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Modelled groundwater level (mAHD)
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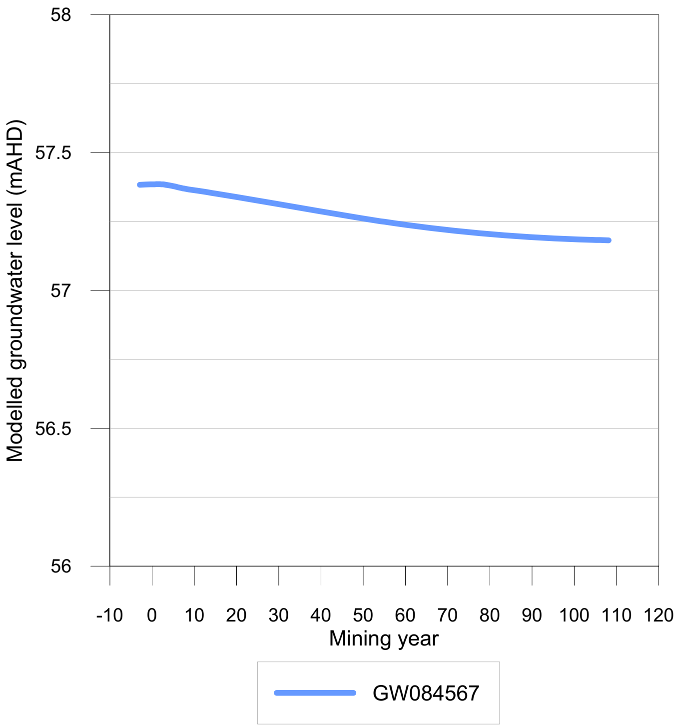
Mining year
GW084566


58
57.5
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56.5
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Modelled groundwater level (mAHD)
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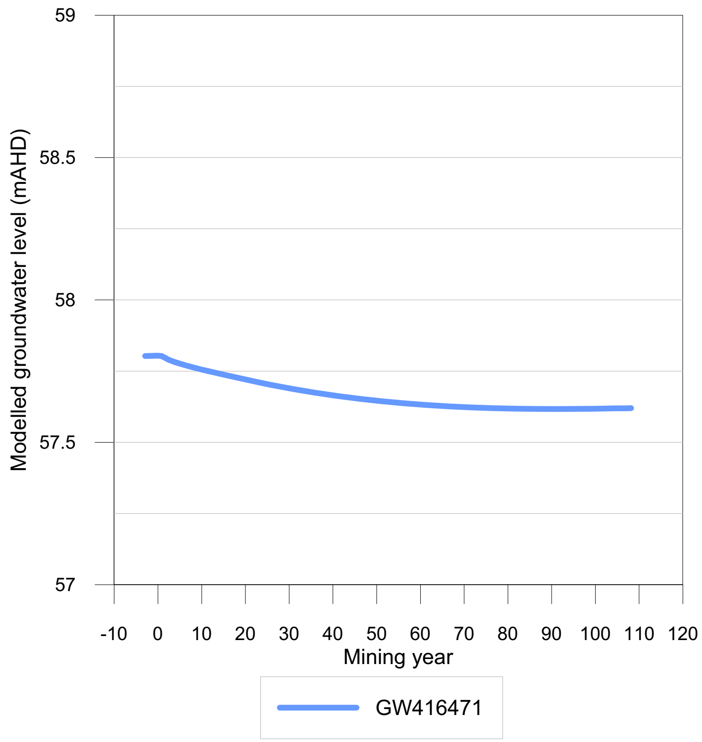
Mining year
GW084567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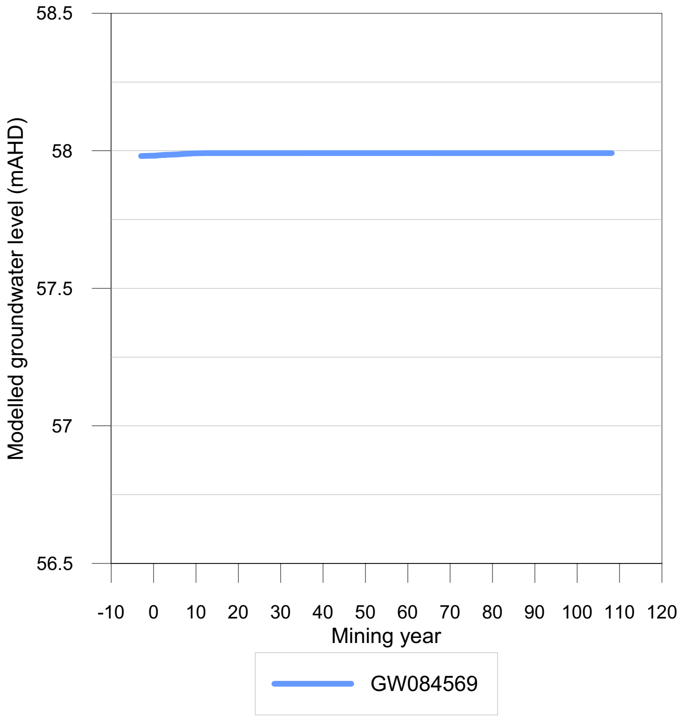
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW416471



58.5
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56.5
Modelled groundwater level (mAHD)
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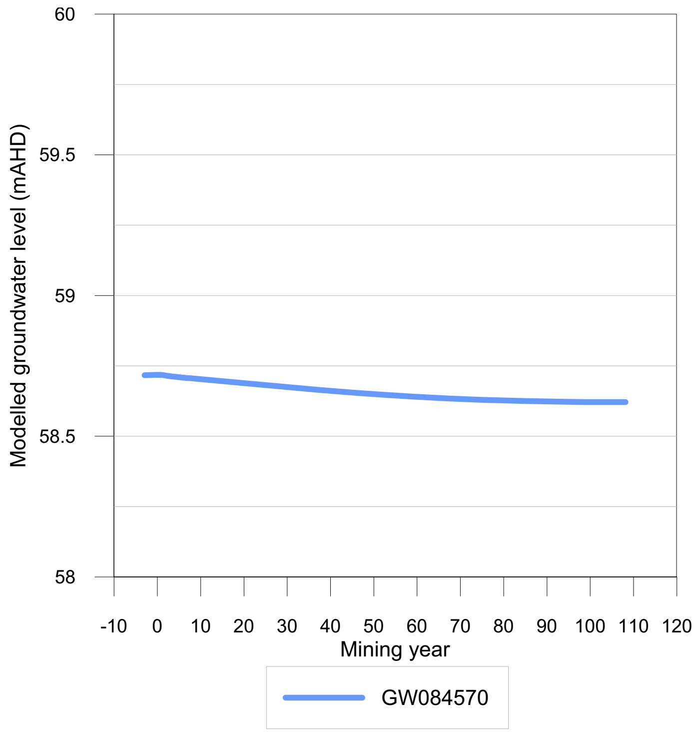
Mining year
GW084569



60
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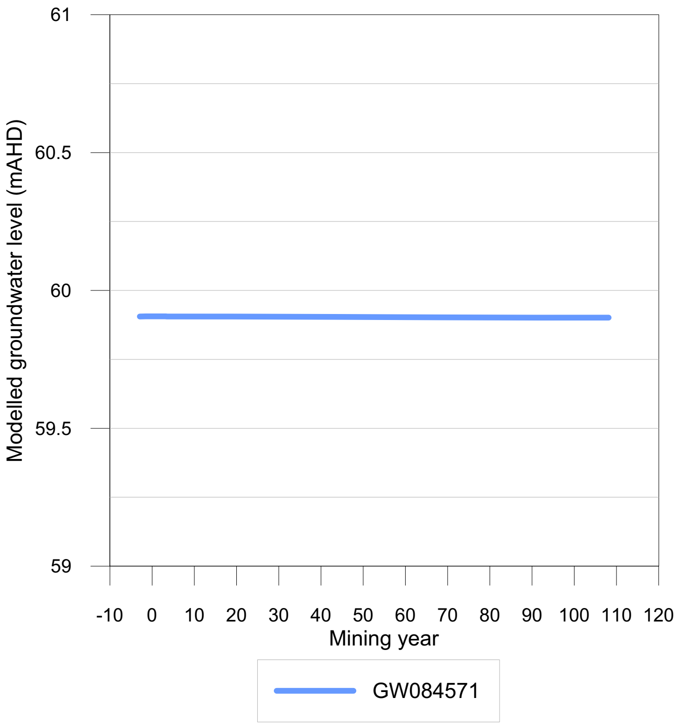
58
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW084570



61
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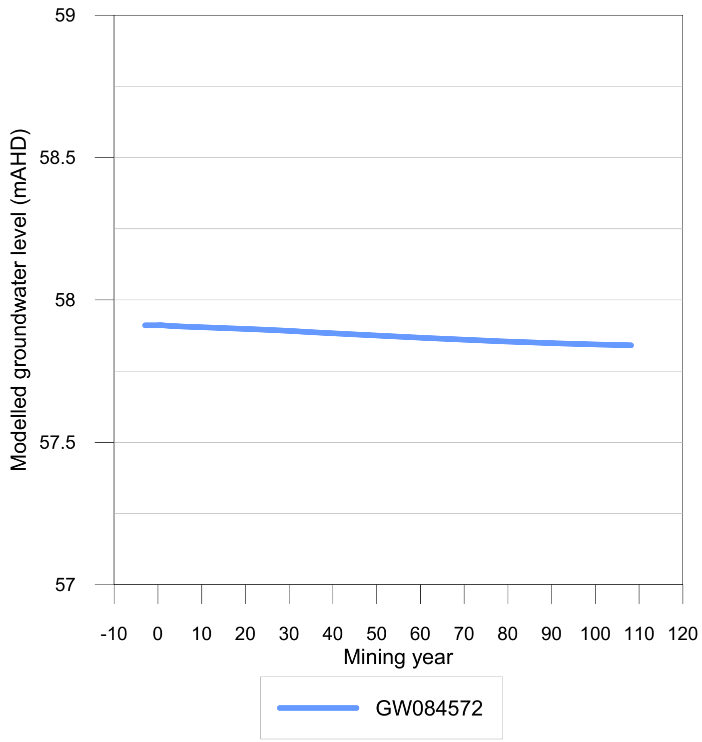
59.5
59
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW084571



59
58.5
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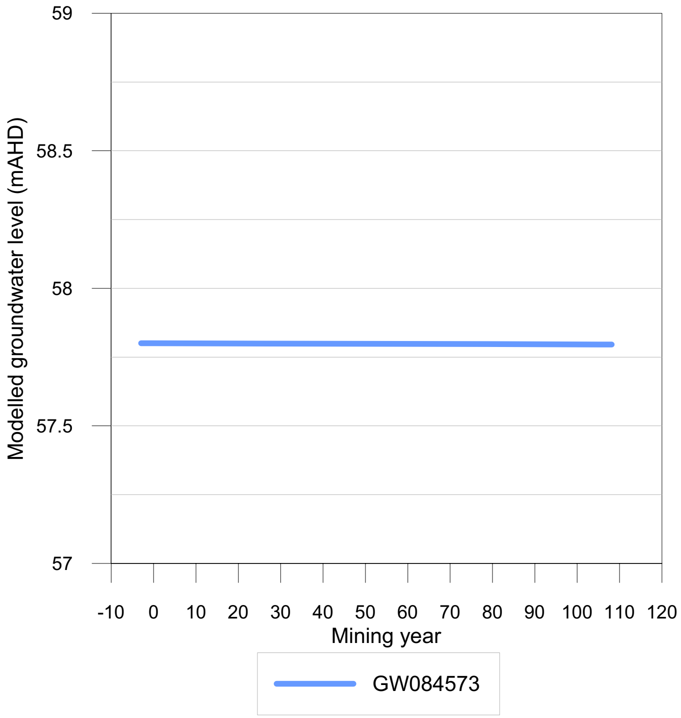
57.5
57
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW084572



59
58.5
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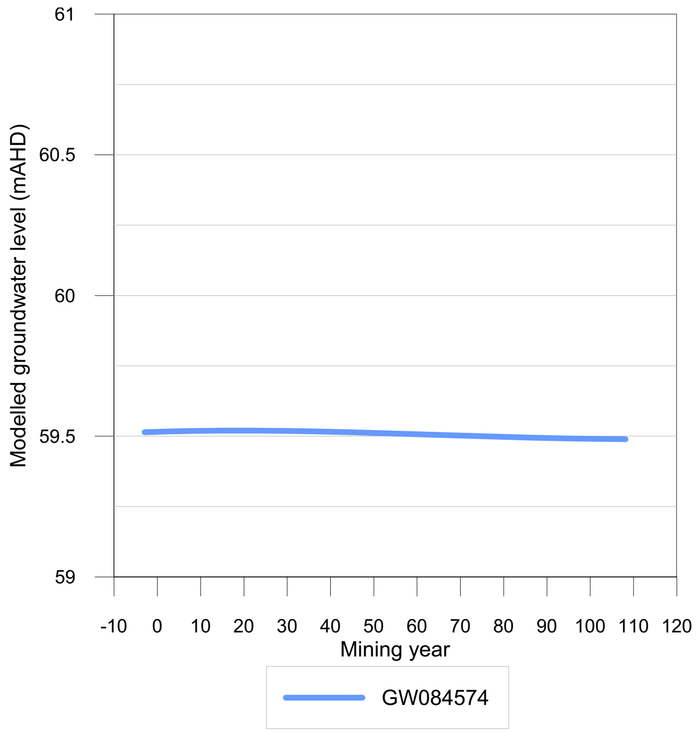
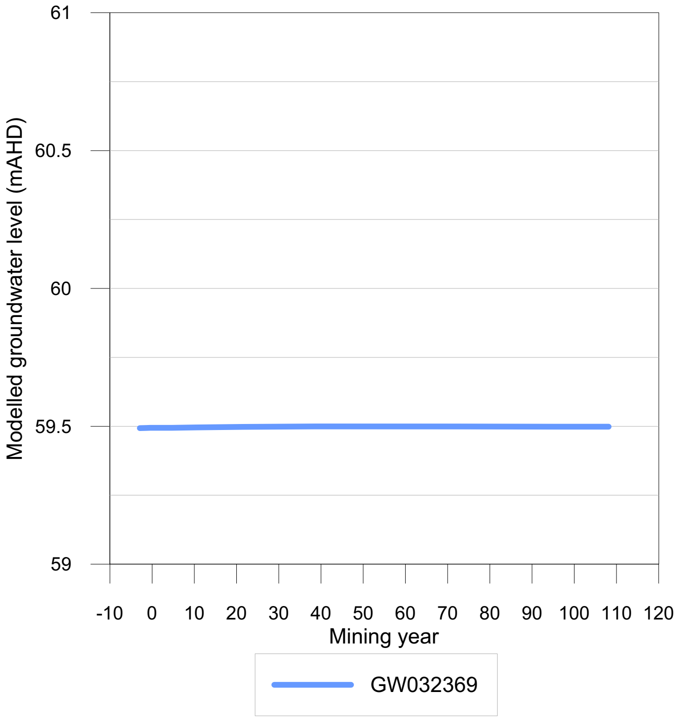
57.5
57
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW084573



61
60.5
60
59.5
59
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW084574



61
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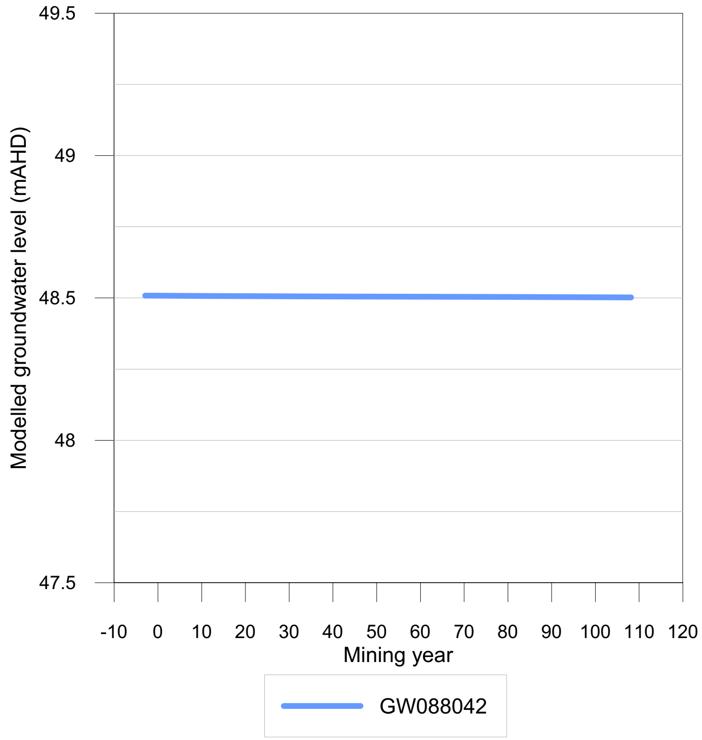
59.5
59
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW032369



49.5
49
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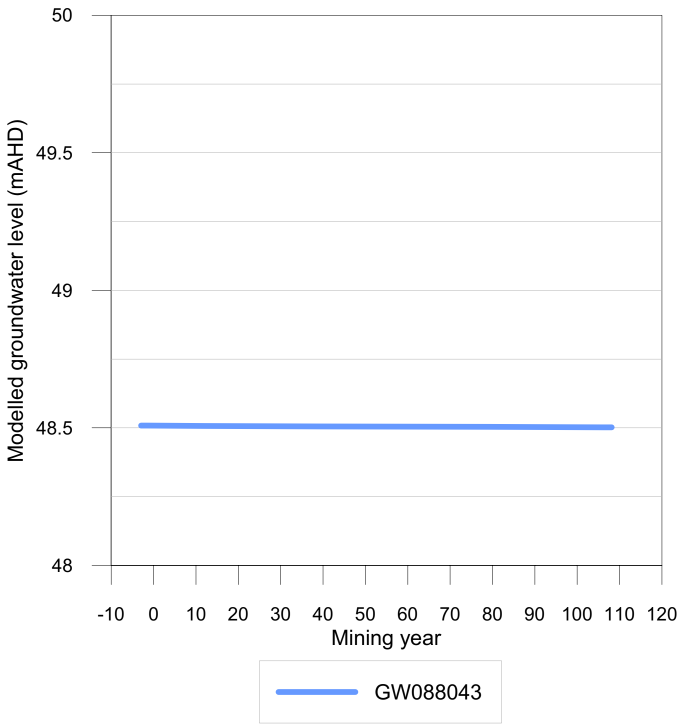
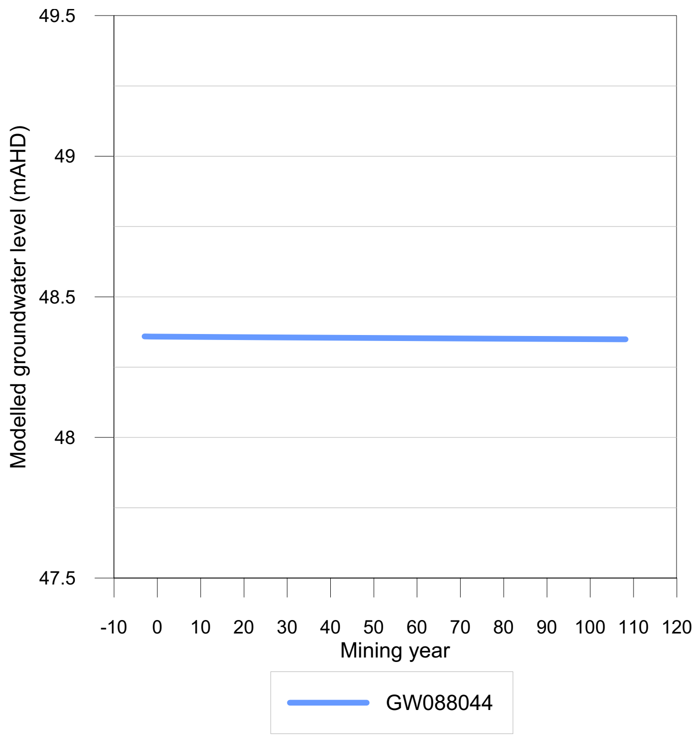
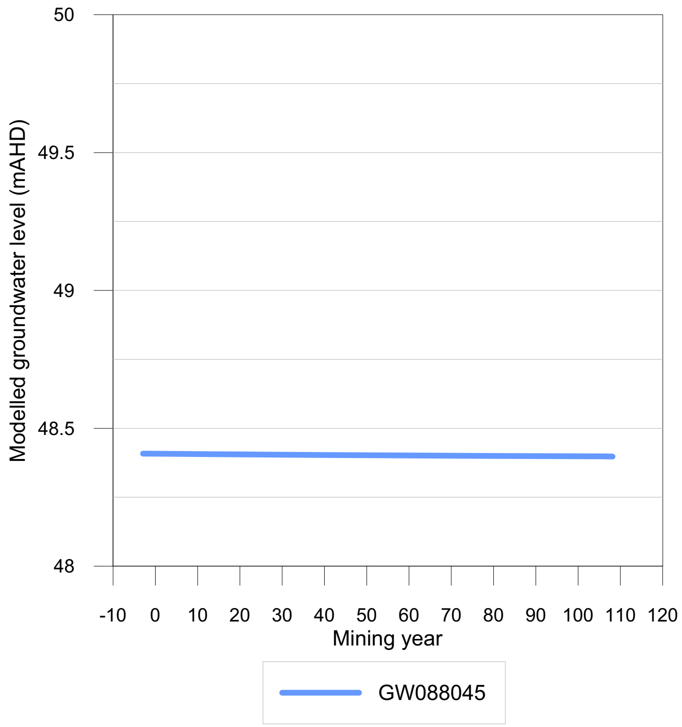
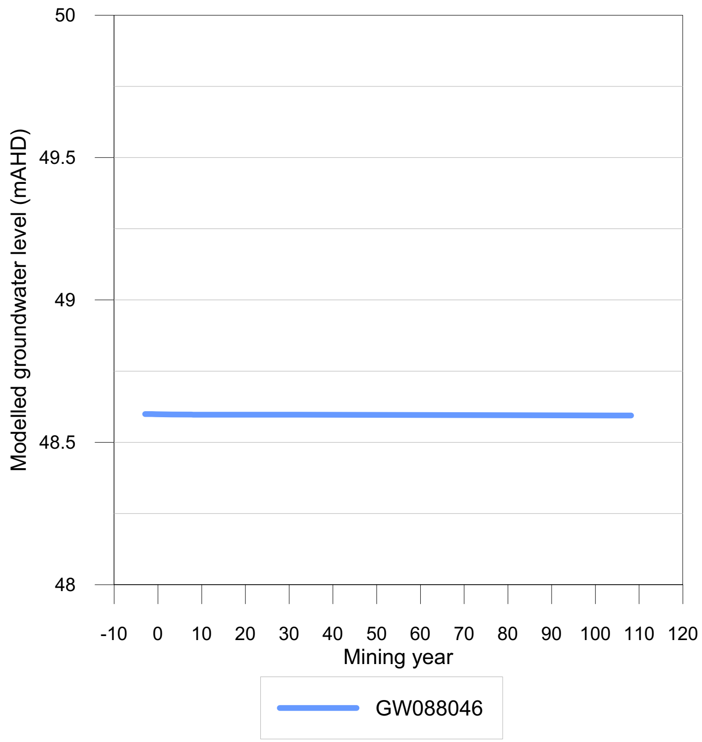
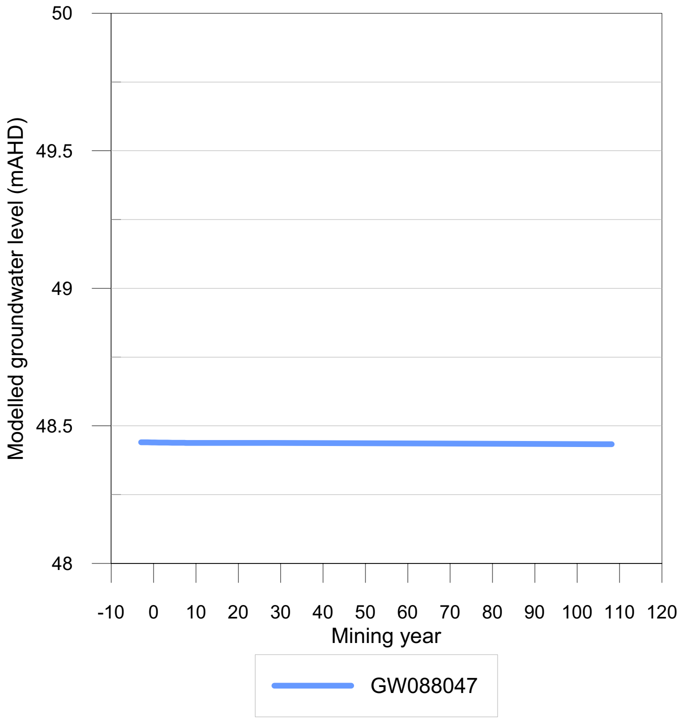
48
47.5
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW088042

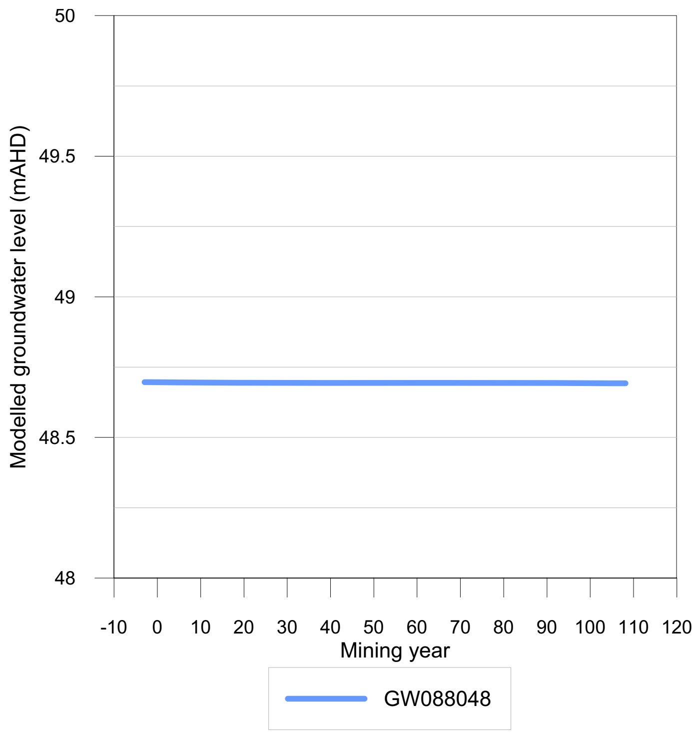

Modelled groundwater level (mAHD)
50
49.5
49
48.5
48
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW088043


Modelled groundwater level (mAHD)
49.5
49
48.5
48
47.5
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW088044


Modelled groundwater level (mAHD)
50
49.5
49
48.5
48
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW088045


Modelled groundwater level (mAHD)
50
49.5
49
48.5
48
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW088046


Modelled groundwater level (mAHD)
50
49.5
49
48.5
48
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW088047


Modelled groundwater level (mAHD)
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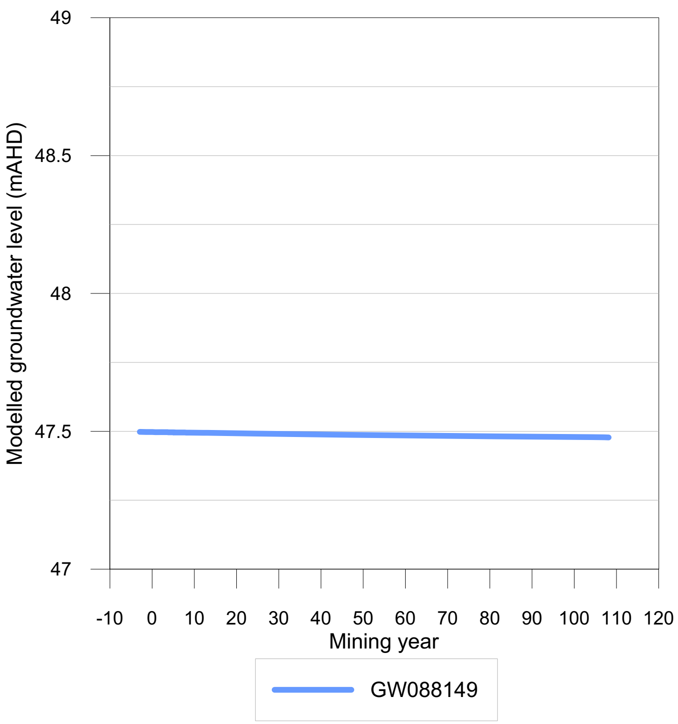
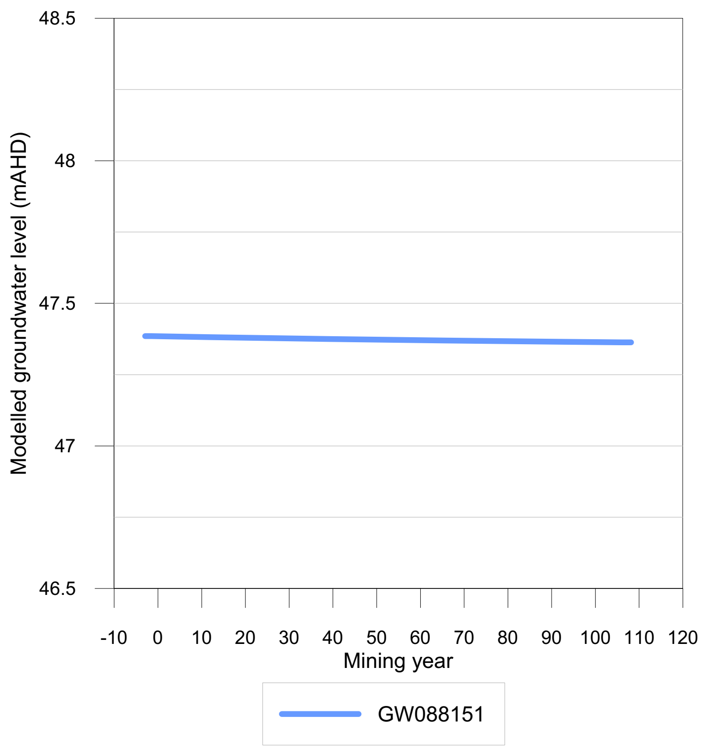
49.5
49
48.5
48
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW088048


Modelled groundwater level (mAHD)
49
48.5
48
47.5
47
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW088149


Modelled groundwater level (mAHD)
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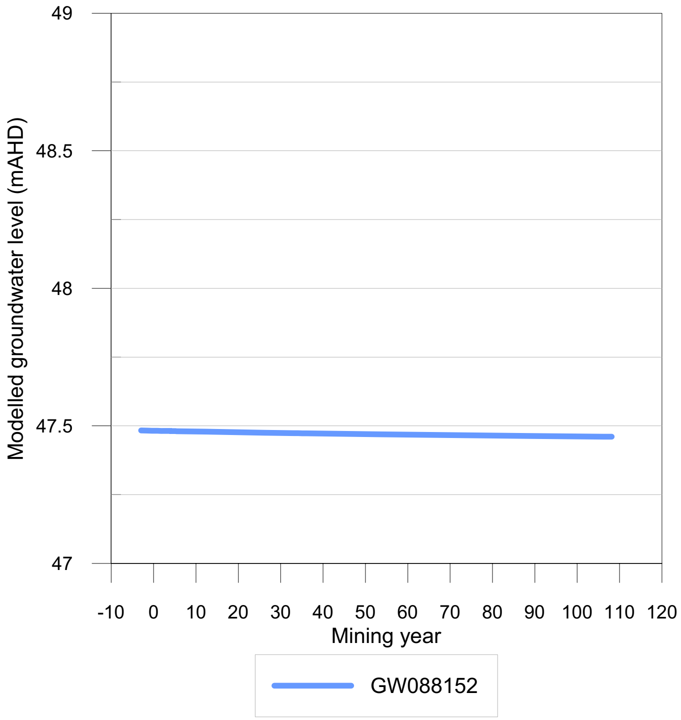
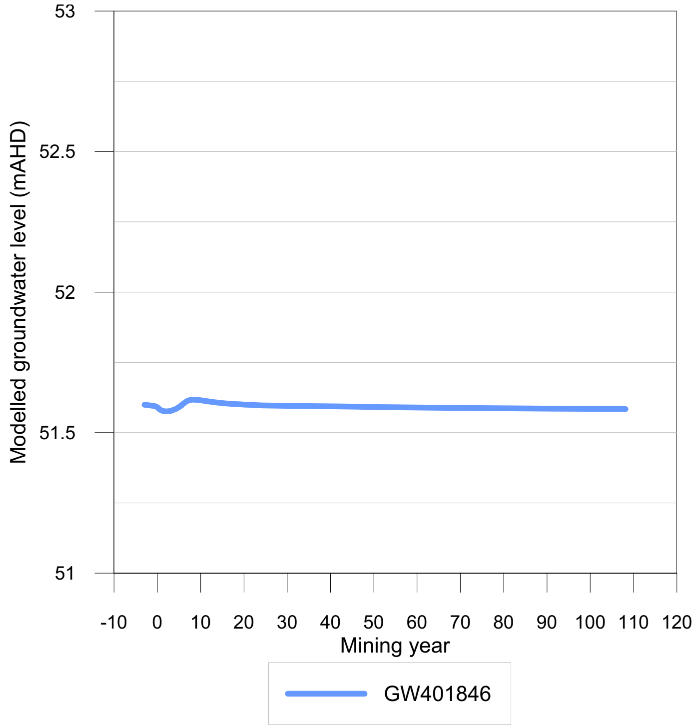
48
47.5
47
46.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW088151



Modelled groundwater level (mAHD)
49
48.5
48
47.5
47
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW088152



Modelled groundwater level (mAHD)
53
52.5
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51.5
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-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
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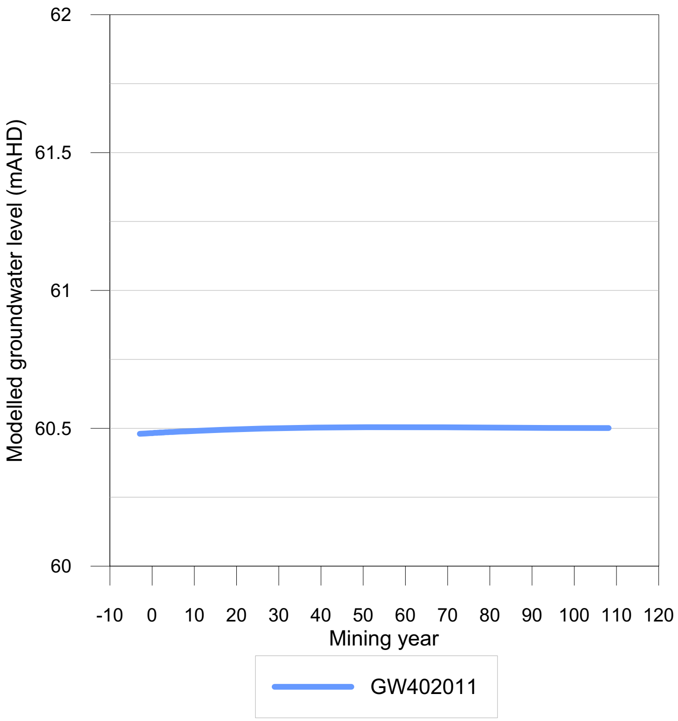

Modelled groundwater level (mAHD)
62
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-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
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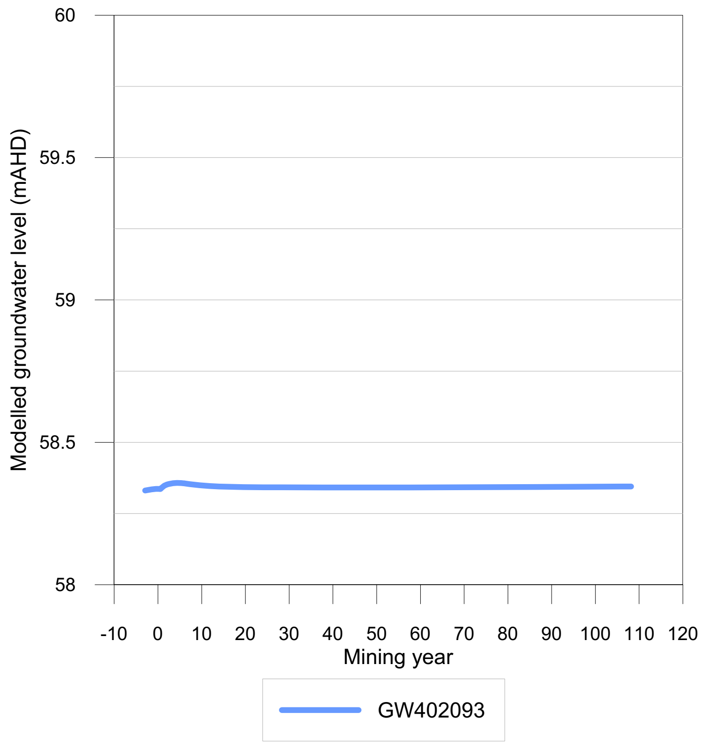

Modelled groundwater level (mAHD)
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58.5
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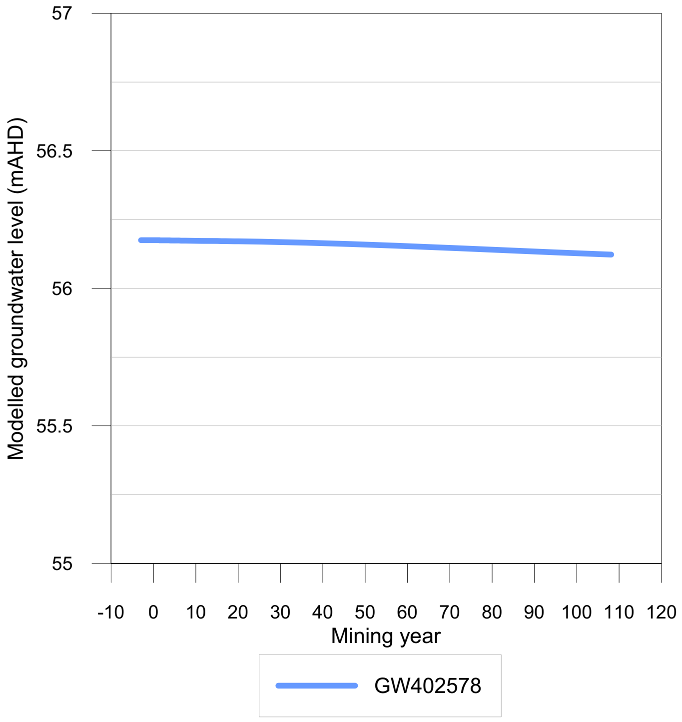
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW402093


57
56.5
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55.5
55
Modelled groundwater level (mAHD)
-10
0
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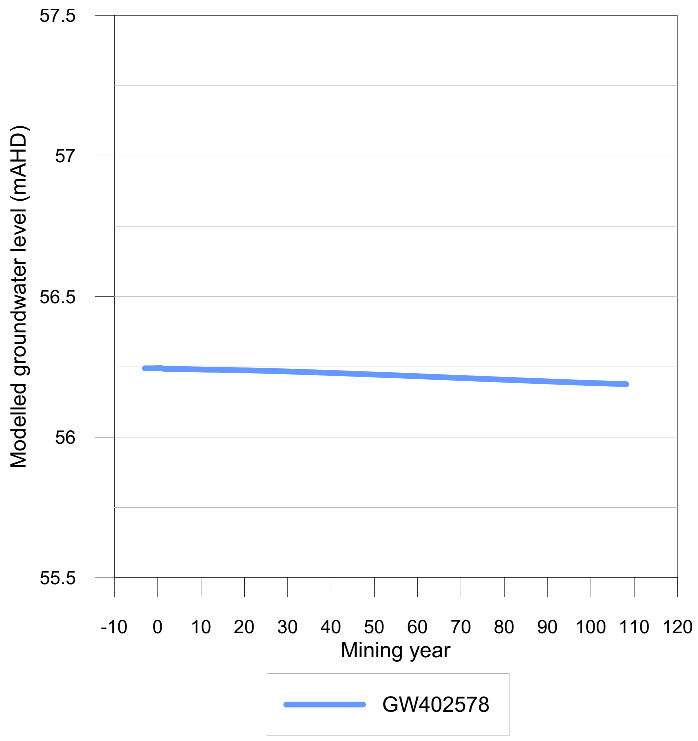
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW402578


57.5
57
56.5
56
55.5
Modelled groundwater level (mAHD)
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40
50
60
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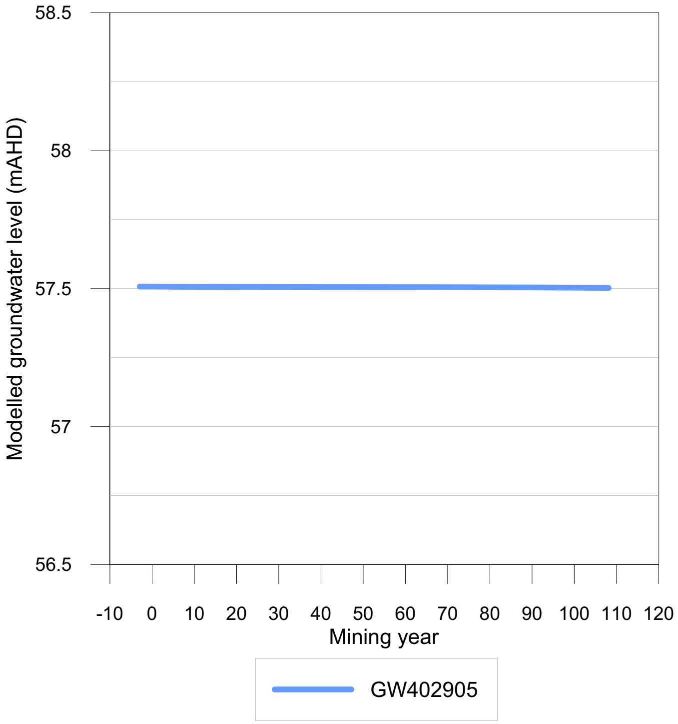
80
90
100
110
120
Mining year
GW402578


58.5
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57.5
57
56.5
Modelled groundwater level (mAHD)
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50
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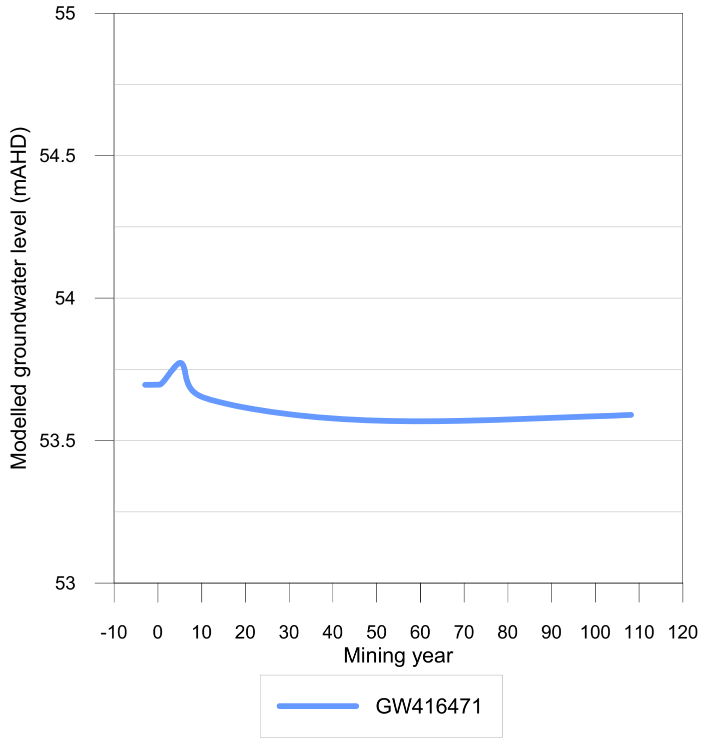
80
90
100
110
120
Mining year
GW402905


55
54.5
54
53.5
53
Modelled groundwater level (mAHD)
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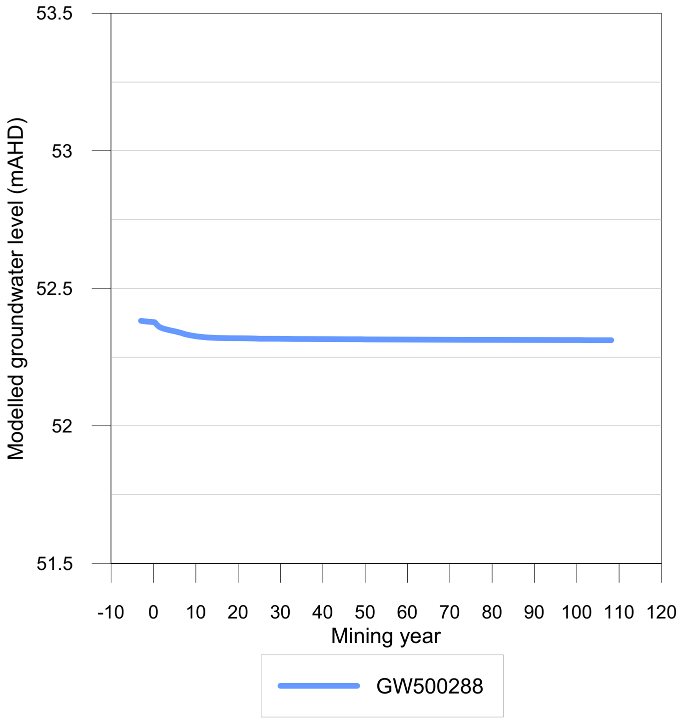
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW416471


Modelled groundwater level (mAHD)
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52.5
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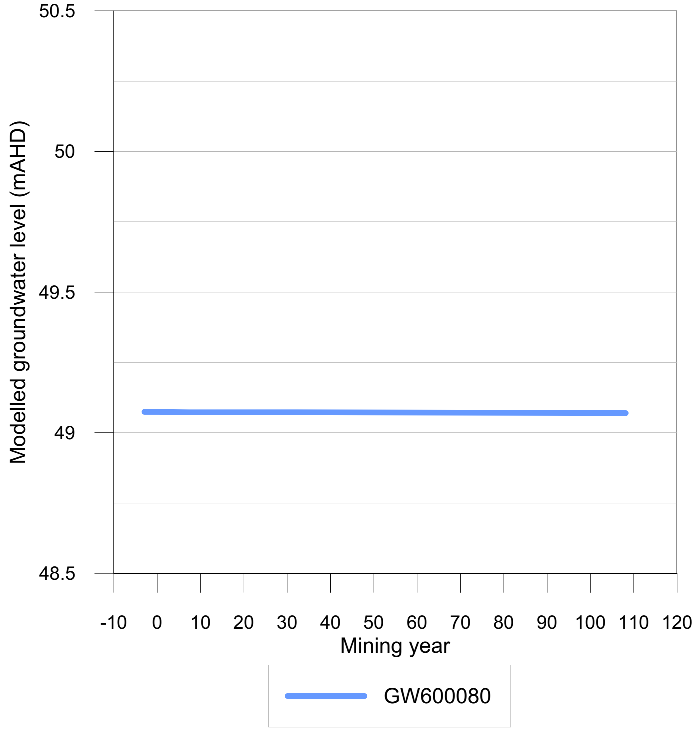
51.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW500288


Modelled groundwater level (mAHD)
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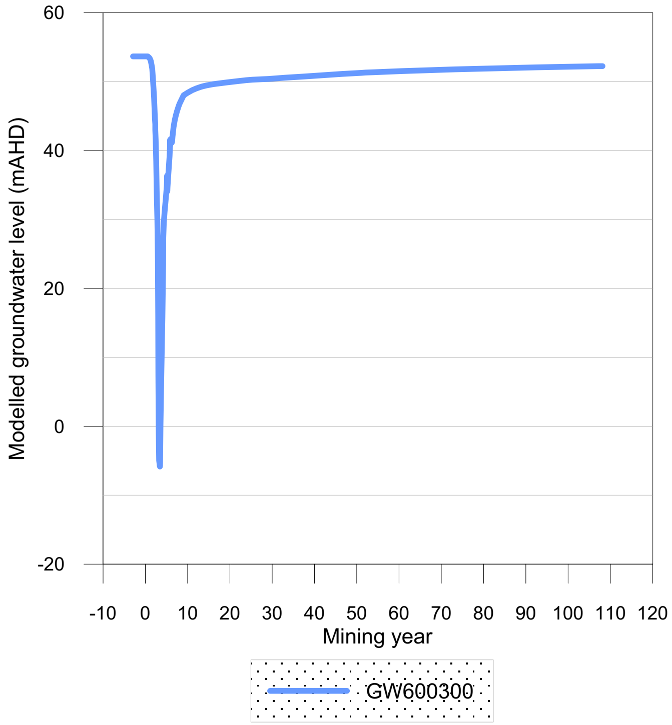
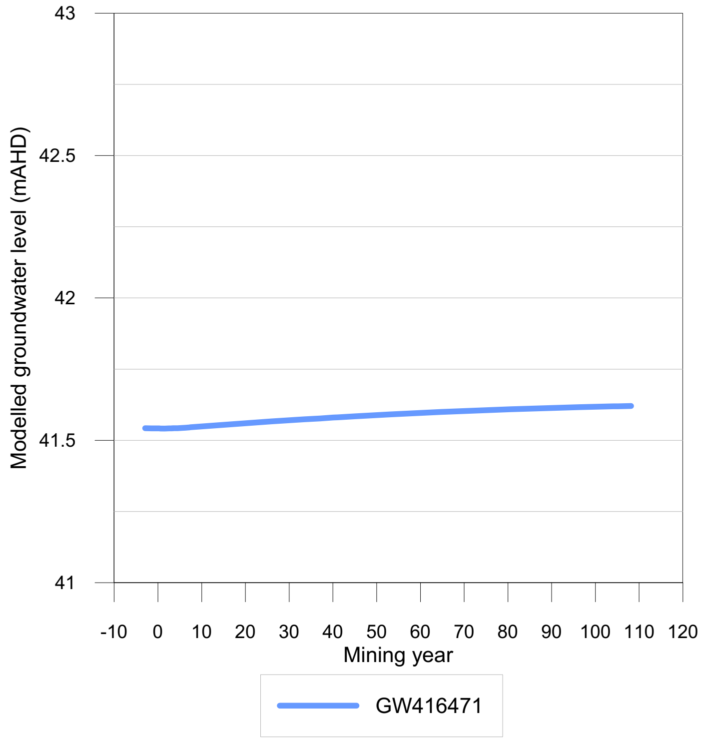
49.5
49
48.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW600080


Modelled groundwater level (mAHD)
60
40
20
0
-20
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW600300


Modelled groundwater level (mAHD)
43
42.5
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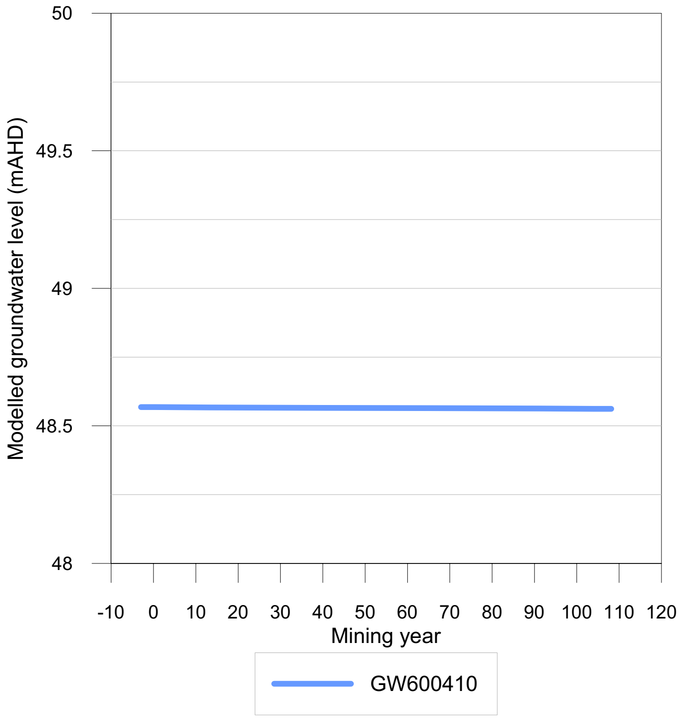
41.5
41
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW416471



Modelled groundwater level (mAHD)
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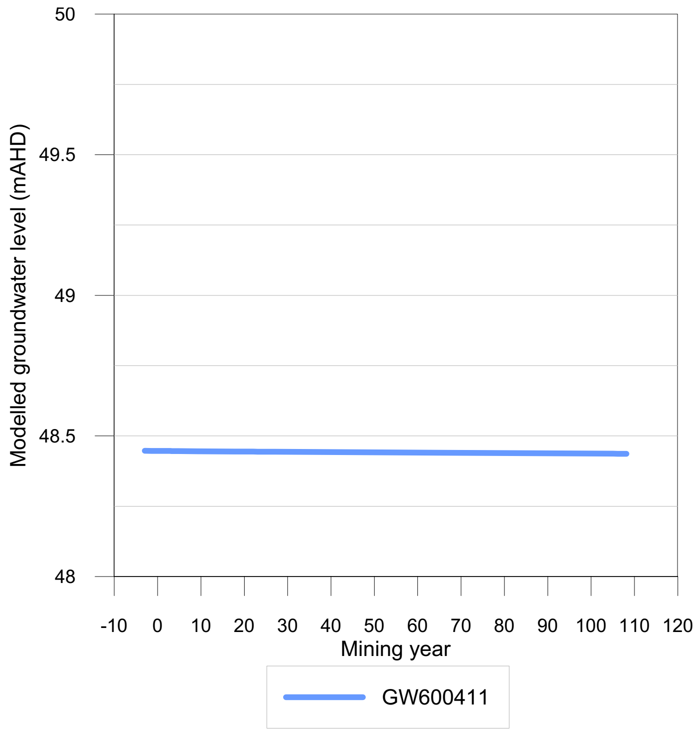
49.5
49
48.5
48
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW600410



Modelled groundwater level (mAHD)
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48.5
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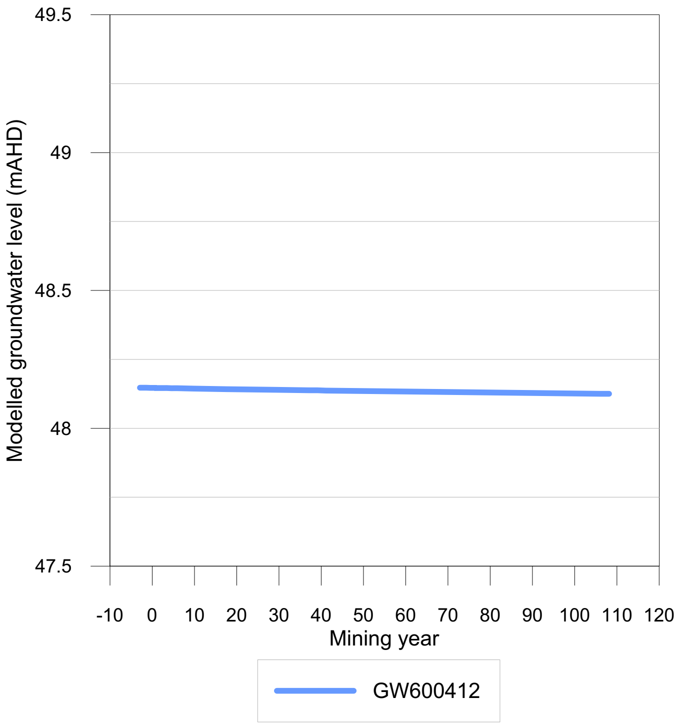
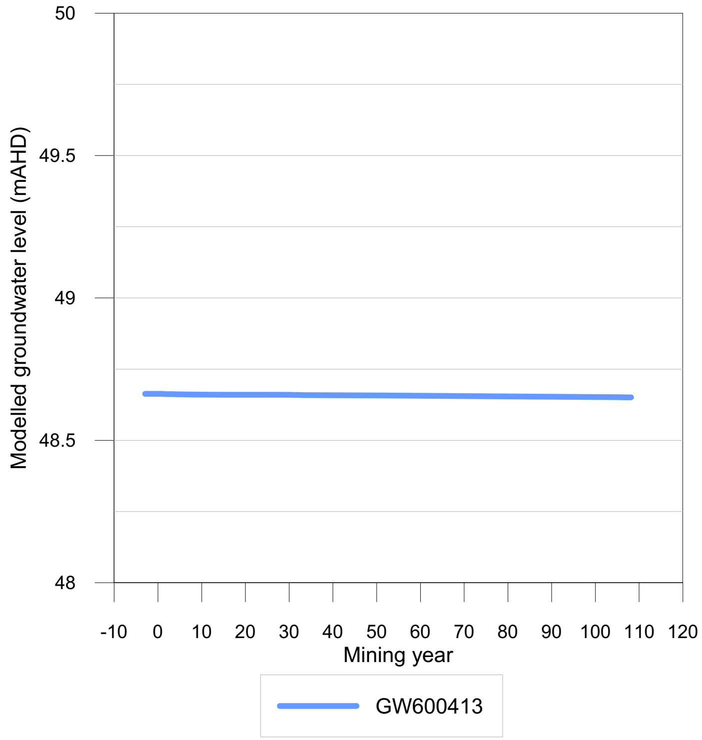
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW600411



Modelled groundwater level (mAHD)
49.5
49
48.5
48
47.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW600412



Modelled groundwater level (mAHD)
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49.5
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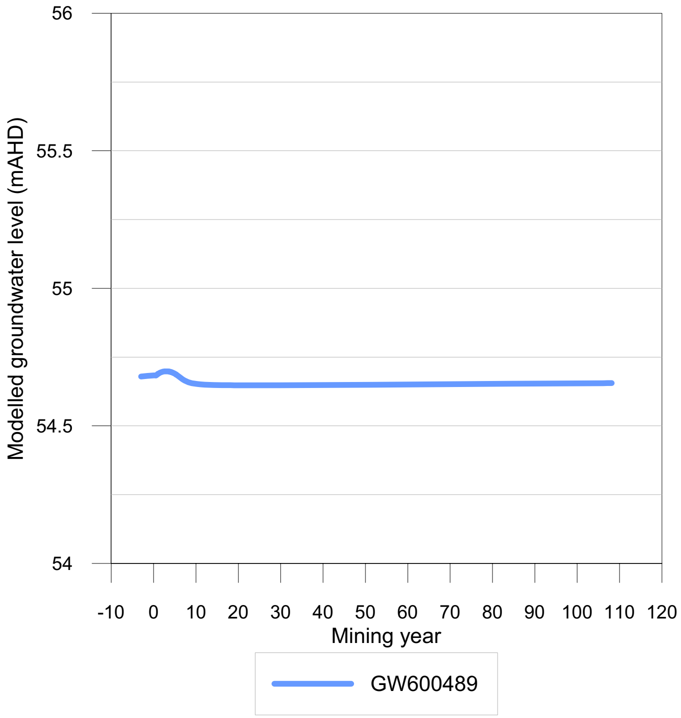
48.5
48
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW600413



56
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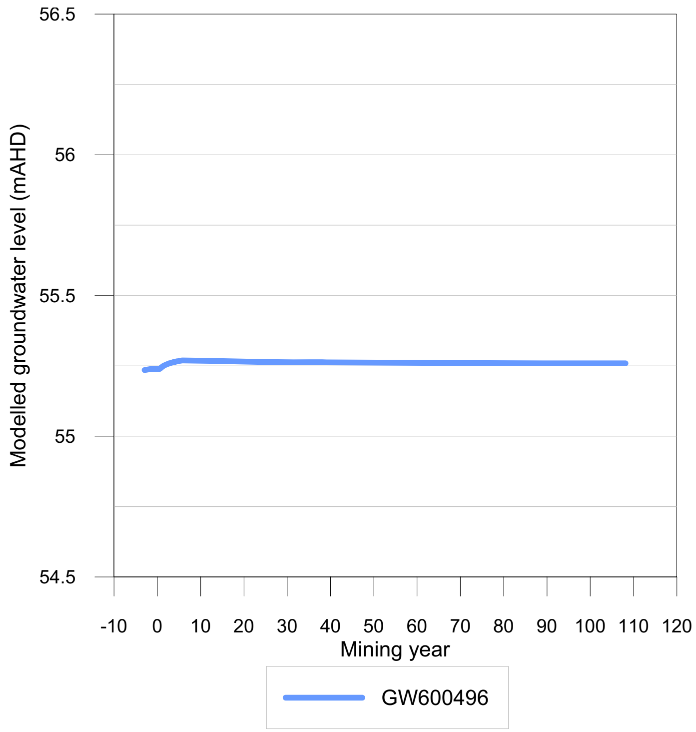
54.5
54
Modelled groundwater level (mAHD)
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW600489



56.5
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55.5
55
54.5
Modelled groundwater level (mAHD)
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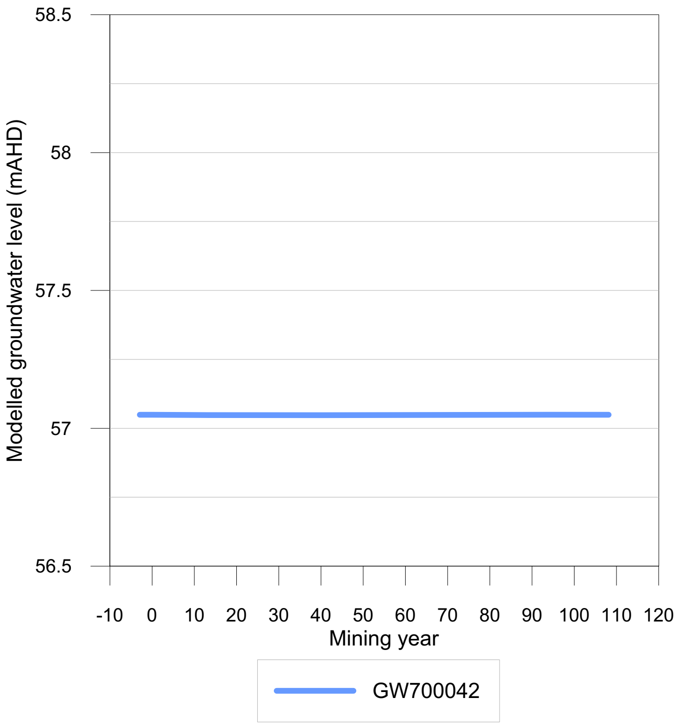
Mining year
GW600496



58.5
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57.5
57
56.5
Modelled groundwater level (mAHD)
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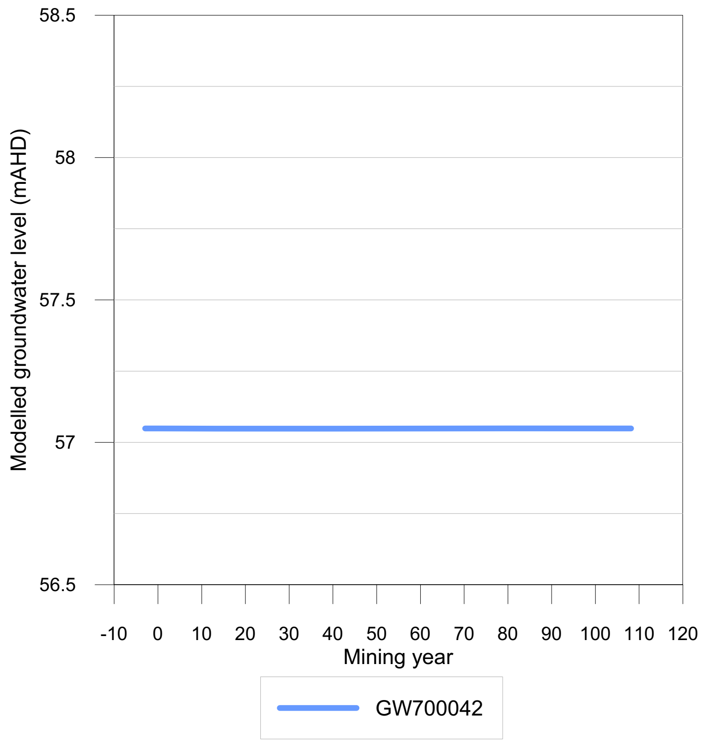
Mining year
GW700042



58.5
58
57.5
57
56.5
Modelled groundwater level (mAHD)
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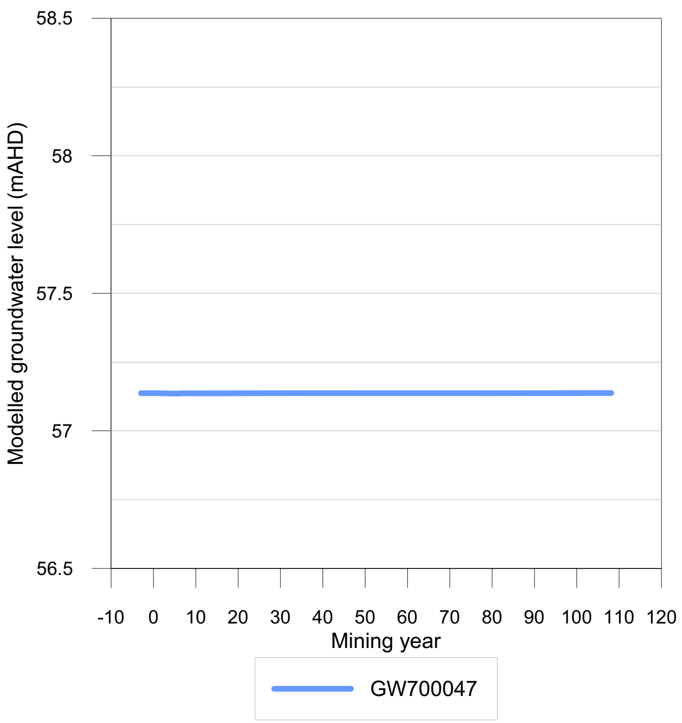
Mining year
GW700042



Modelled groundwater level (mAHD)
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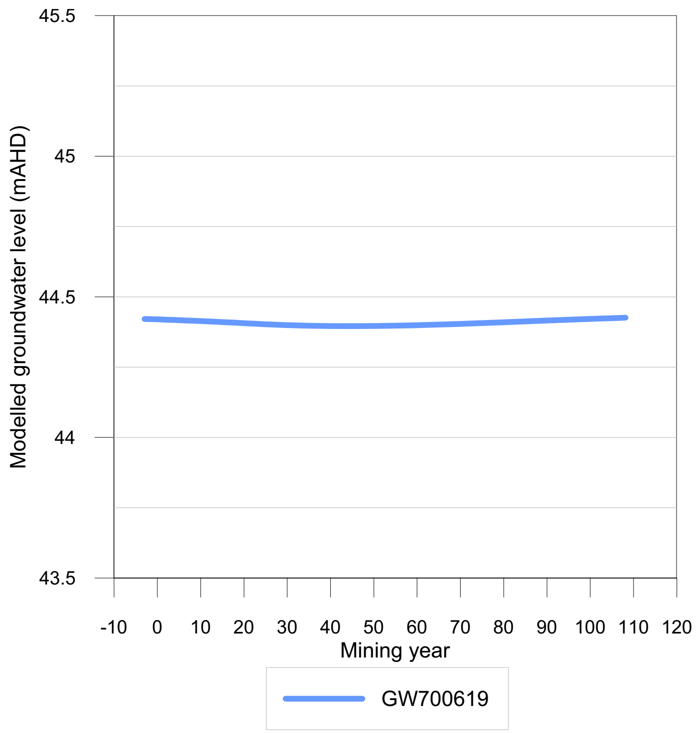
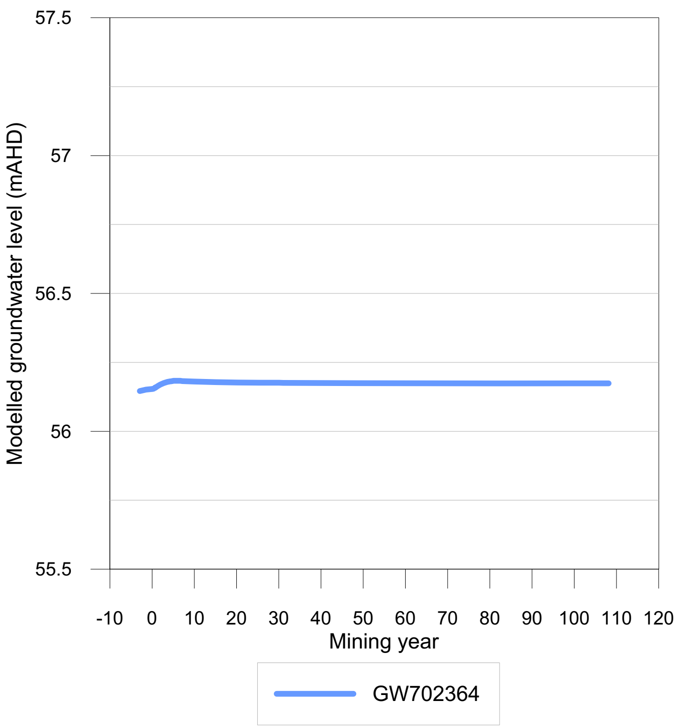
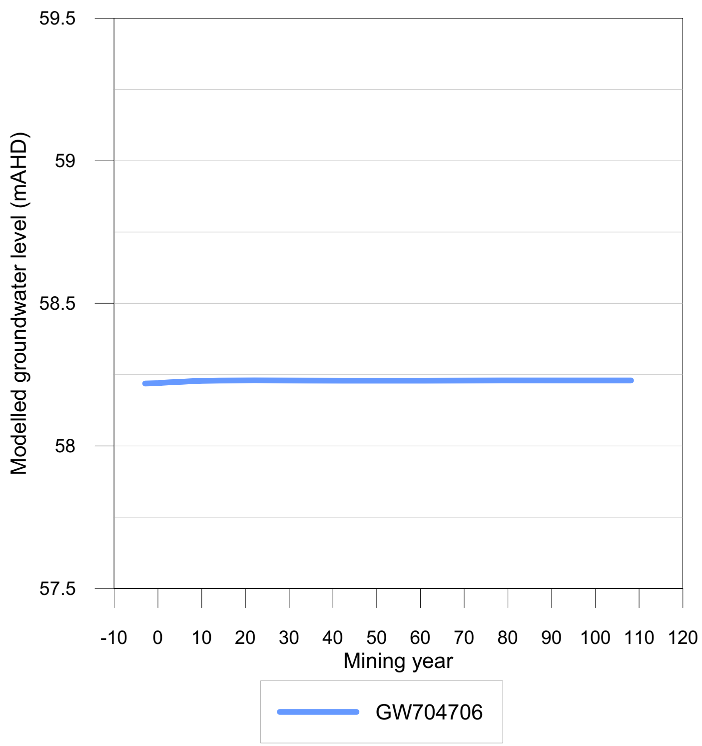
57.5
57
56.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW700047



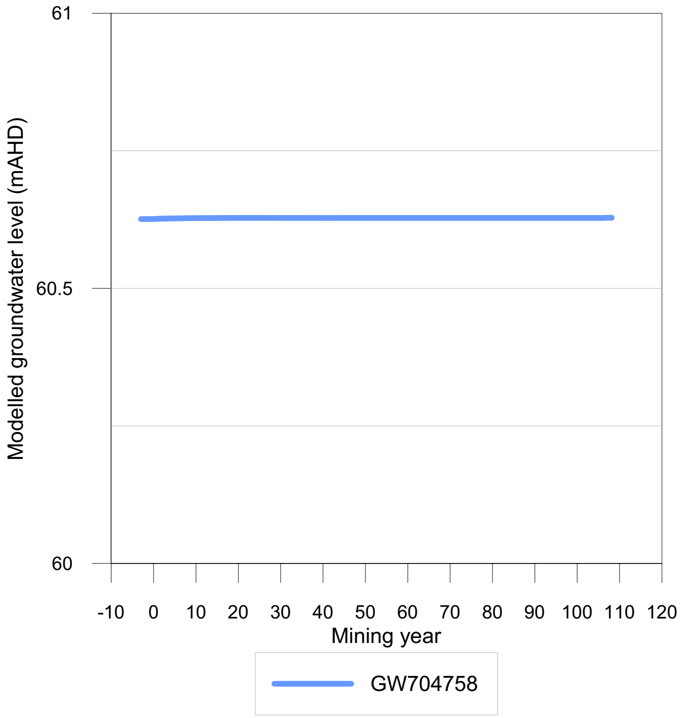
Modelled groundwater level (mAHD)
45.5
45
44.5
44
43.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW700619



Modelled groundwater level (mAHD)
57.5
57
56.5
56
55.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW702364



Modelled groundwater level (mAHD)
59.5
59
58.5
58
57.5
-10 0 10 20 30 40 50 60 70 80 90 100 110 120
Mining year
GW704706



61
60.5
60
Modelled groundwater level (mAHD)
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
Mining year
GW704758

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