Groundwater Management Plan
Bulk Sampling Activities, Balranald Mineral Sands Project

Prepared for Iluka Resources Limited
March 2020

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Groundwater Management Plan

Bulk Sampling Activities, Balranald Mineral Sands Project

Report Number

S180539 RP1

Client

Iluka Resources Limited

Date

27 March 2020

Version

v5 Final

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27 March 2020

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27 March 2020

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1 Introduction

1.1 Overview

On 5th April 2016 Iluka Resources Limited (Iluka) was granted Development Consent under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for a mineral sands mine in south-western New South Wales, known as the Balranald Mineral Sands Project (the Balranald Project). The project was assessed and approved as State Significant Development 5285 (SSD-5285).

The Balranald Project includes construction, mining, primary processing and rehabilitation of two linear mineral sand deposits, known as the West Balranald and Nepean deposits located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald (Balranald town), respectively (Figure 1.1).

The Balranald Project included undertaking a bulk sampling activity (the activity) at the West Balranald deposit to test the selective in-situ removal of up to 100,000 tonnes (t) of ore.

1.2 The activity

The activity is an unconventional mining method to test the selective in-situ removal of mineral ore and reflects a continuation of a smaller bulk sampling activity (known as T1) undertaken by Iluka during Q1-2015 and Q1-2016 in accordance with approval under Part 5 of the EP&A Act from NSW Trade & Investment, Resources & Energy (Reference OUT13/28341 and OUT15/27702).

The activity commenced under SSD-5285 in Q2-2016 and Q3-2016 and successfully extracted approximately 6,400 t of ore from three stopes (referred to as Stopes 1B, 3 and 4) and backfilled approximately 700 t of mining by product (known as T2). Iluka placed the activity site into care and maintenance during 2017 and 2018 to review the mining and environmental monitoring outcomes.

Iluka now propose to recommence unconventional mining (known as T3) to trial the selective in-situ removal of the remaining 93,600 t of ore approved under SSD-5285. The objectives of T3 are to determine whether the unconventional mining method can:

- sustain production over a larger sample set (ie longer and multiple stope length);
- backfill process to deliver a mining by product management strategy; and
- further validate groundwater and subsidence impact prediction models.

T3 will create up to three additional underground cavities (referred to as Stopes 5, 6 and one of either the remainder of Stope 4, or 3B), each with an approximate volume of 21,000 cubic metres (m^3) in volume, located approximately 65–69 m below the natural surface level. The overburden typically comprises sands, clayey sands and clay layers with minimal or not continuous induration or rock.

The activity site is located entirely within the disturbance footprint of the West Balranald mine, including the area of the open cut pit. As such, all land disturbed by the activity will eventually be subsumed by mining of the West Balranald mine (Figure 1.2). T3 activities are scheduled to commence in Q4, 2019.

1.3 GMP purpose

This Groundwater Management Plan (GMP) has been prepared to manage potential groundwater risks associated with the T3 activity and considers all the requirements under SSD-5285 and matters raised by the former Department of Industry in their letter to Iluka dated 3 May 2018 (Ref: OUT18/6975).

1.3.1 Supporting documentation

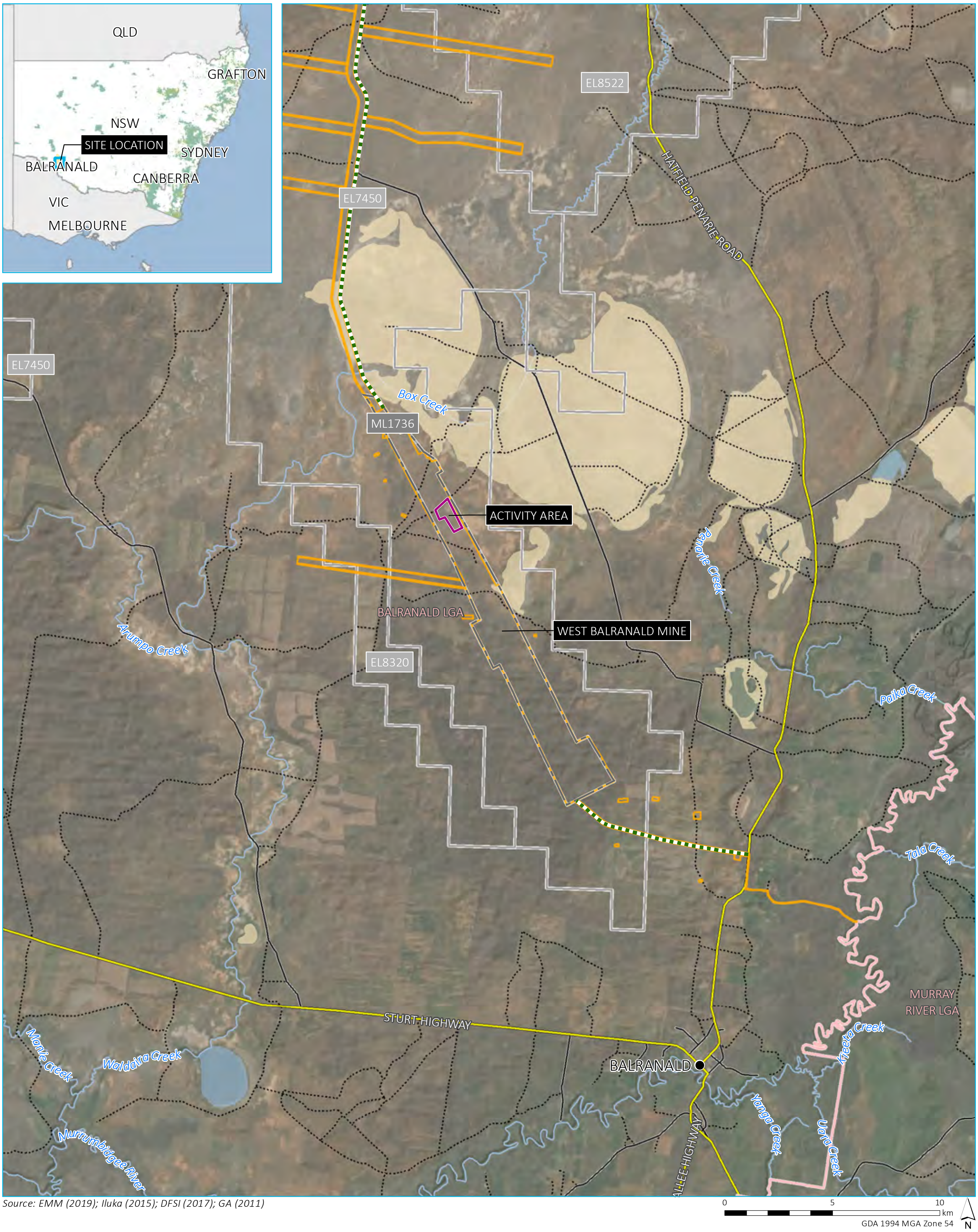
A copy of EMM's historical groundwater assessment and summary report prepared to compliment the GMP is provided in Appendix A. The intent of this report is to summarise the main hydrogeological and hydrogeochemical assessments undertaken to date and address the comments made by the Department of Planning, Industry and Environment – Water (DPIE Water) on the previous GMP (Reference number OUT18/6975).

1.4 Regulator contact details

The Government regulator contacts related to bulk sampling activities, including any reporting requirements and environmental risks are detailed in Table 1.1.

Table 1.1 Regulator contact details

Contact (position)	Department	Phone contact	Email address
Darren Wallet (Head Regional Operations Unit)	NSW EPA	T: 02 6969 0700 M: 0427 255 214	Darren.wallett@epa.nsw.gov.au
Tim Baker (Senior Water Regulator Officer)	DPIE- Water	T: 02 6841 7403 M: 0428 162 097	Tim.Baker@dpi.nsw.gov.au



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

KEY

- Activity area
- Project boundary
- Place
- Access road
- Mining Lease 1736
- Iluka mineral tenement
- Main road
- Local road
- Vehicular track
- Named watercourse
- Perennial lake
- Ephemeral lake
- Local government area

Regional location

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Groundwater Management Plan
Figure 1.1

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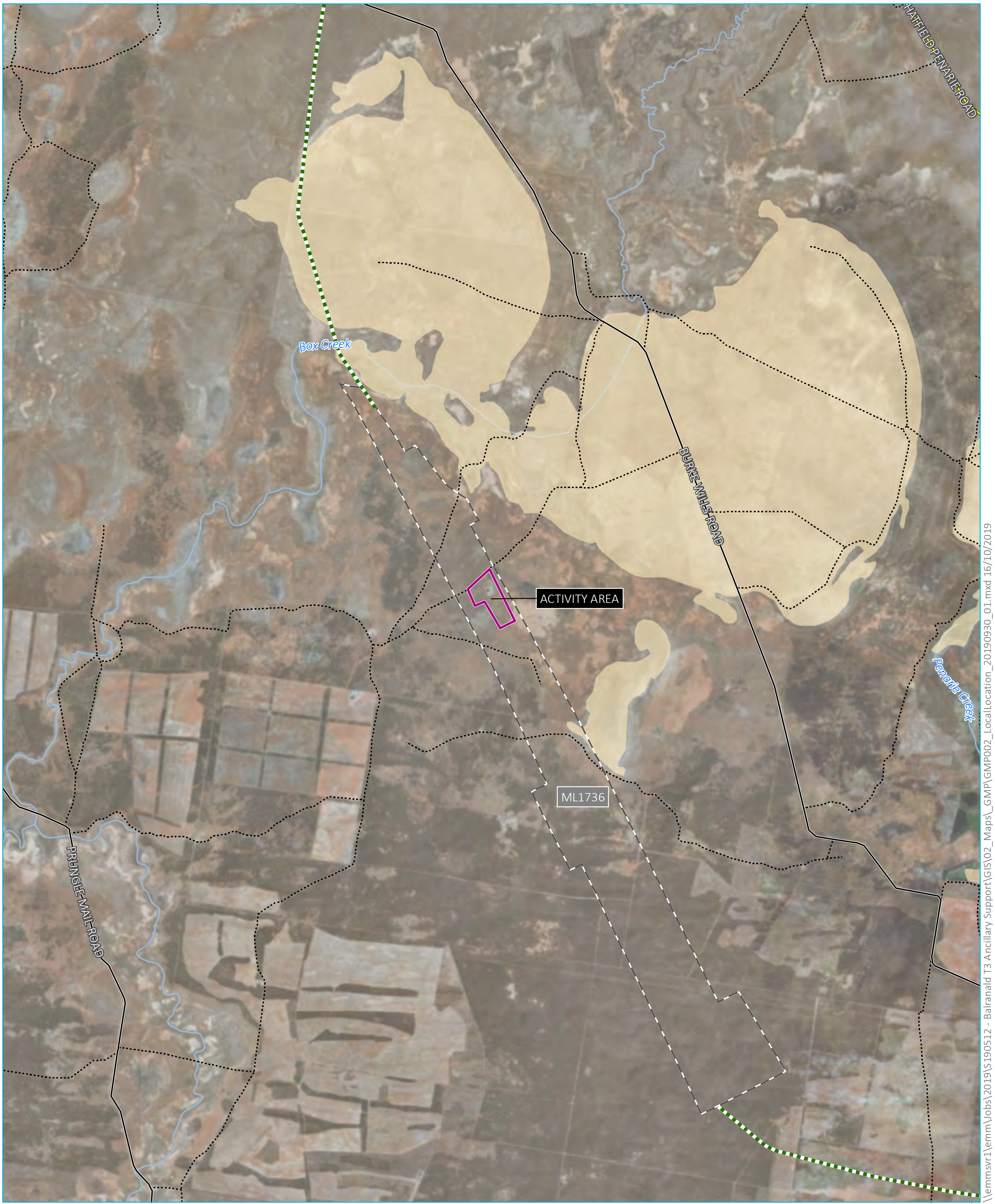

Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

KEY

- Activity area
- Access road
- Mining Lease 1736
- Main road
- Local road
- Vehicular track
- Named watercourse
- Ephemeral lake

Location of the T3 activity within the Balranald project mine footprint

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Groundwater Management Plan
Figure 1.2

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2 Water Sources

Iluka's groundwater studies relating to the West Balranald and Nepean Deposits commenced with a hydrogeological review and assessment by GHD (2006). From 2009, groundwater investigation efforts increased and culminated in a series of field trials and numerical modelling activities undertaken both independently by URS (2009; 2011; 2012), SKM (2013) and Jacobs (2014; 2015a; 2015b), and internally by Iluka (2015b).

Surface water assessments have formed aspects of all the reports outlined above, however due to the limited surface water resources within the bulk sampling activity area and wider Balranald Project, WRM (2015) is the only hydrological-specific study completed to date.

This section presents a summary of the previous hydrological and hydrogeological findings of the broader Balranald Project relevant to this GMP.

2.1 Surface water

The Murrumbidgee and Murray rivers are the major permanent surface water features in the vicinity of the Balranald Project area, shown in Figure 1.1. The Lachlan River terminates at the Great Cumbung Swamp, approximately 48 km east of the Balranald Project, a major permanent surface water feature in areas upstream of Balranald. The Murrumbidgee and Murray rivers provide key water resources for large populations within the Murray Darling Basin including town water supplies, agriculture and the environment. The Murrumbidgee River is about 10 km south of the Balranald Project, and flows in a south-westerly direction, to its confluence with the Murray River about 40 km to the south-west of the Balranald township.

The main surface water feature within the Balranald Project area is Box Creek, which is an ephemeral watercourse and a tributary of the Murray River. Almost all of the Balranald Project is located within the Box Creek catchment, however the creek only flows during and immediately following heavy local rainfall or large flooding events. Flow has only occurred in Box Creek on 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 Balranald Project area.

2.2 Hydrogeology

There are three main aquifer units in the immediate vicinity of the Balranald Project area: the Shepparton Formation, the ore-hosting Loxton-Parilla Sands (LPS) and the Lower Renmark Group Formation (also known as the Olney Formation; Brown and Stephenson, 1991). Other units, whose sediments are heterogeneous in nature, can act as aquifers in localised instances. The Olney Formation is the regionally extensive early-Tertiary lacustrine system, specifically underlying the wider Balranald Project, and consists of the Upper, Middle and Lower Renmark Group.

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.

2.2.1 Local Balranald Stratigraphy

The regional geology and hydrostratigraphy of the Murray Basin within the Balranald region is shown on Figure 2.1.

The local stratigraphy is shown conceptually in Figure 2.1, which represents an idealistic interpretation based on logging data acquired during the pre- and detailed- feasibility hydrogeological studies (Iluka, 2015 and 2016b) and data collected during the installation of monitoring infrastructure to support the previous T2 activity. The local stratigraphy consists of the following sequence (from shallowest to deepest):

1. The Shepparton Formation (SFM): Deposited within a fluvial-lacustrine environment, the water-table hosting unit consists of sand-clay to clay sediments with bands of fine grained sand. The base of this unit was often defined by a ferricrete/lateritic horizon. The unit was consistently 30 to 35 m thick throughout the trial sites;

2. LPS 1 dunal sequence: Occasionally, a fine to very fine narrow band of sand is encountered representing the aeolian-dunal sequence of the ancient beach. This light grey to pale yellow sand is very well sorted and sub rounded to sub-angular in nature with an abraded appearance;

3. LPS1 foreshore: Deposited within a low energy marine environment, this light to dark grey coloured sand consisted of predominantly fine, sub-angular to sub-rounded grains with moderate sorting. Above this unit, occasionally a moderate to highly plastic clay existed which resembled a “natural bentonite”;

4. LPS1 surf zone: Deposited within a high energy marine environment, this light to dark grey/brown coloured sand consisted of medium to gravel-sized sand, with moderate to well sorting. Occasionally, lignitic and/or carbonaceous material was present within this unit;

5. LPS1 lower-shore: The lower- or off-shore sediments are deposited within low energy deep water environments. These sediments generally consist of light to dark grey/black sand to silty-sand with sub angular to sub rounded grains of moderate sorting. The presence of lignitic and carbonaceous material was common and tended to be more prolific from these depths onwards;

6. LPS2 foreshore: Although the lithology of this unit is similar to the LPS1 lower-shore package above, there are subtle changes in grain morphology. The grains tend to be fine to very fine sand with less silts being present. Grain size is more highly sorted than the overlying LPS1 lower-shore package. Mica and pyrite are also present, with traces of heavy mineral (HM);

7. LPS2 surf zone: Deposited within a high energy marine environment, this light to dark grey/brown/black coloured sand consists of medium to gravel-sized grains and is well sorted. Occasionally, lignitic and/or carbonaceous lagoonal material is present. However, unlike the LPS1 surf zone package, this unit consists of mica and pyrite and generally hosts large percentages of HM on strike;

8. LPS2 lower-shore: These sediments generally consist of light to dark grey/black very fine to fine sand, which is well sorted in nature. Often lignitic with traces of HM, mica and pyrite;

9. Geera Clay: A thick regionally extensive sequence of marginal marine and estuarine clays and muds, with a confirmed thickness of greater than 70 m[1] to the west of the deposit. This unit is generally black with a blue/green tinge, highly plastic with some fossiliferous/calcareous matter. The transition zone into the Geera Clay from the LPS generally consists of a mudstone with hard red and white fine clay shards with low plasticity and the presence of low competent lignite was common; and

10. Olney Formation: This formation was deposited within a fluvial/lagoonal environment and generally consists of dark grey to brown black silty sand to sand, with poorly sorted silt to medium sized sand grains. Groundwater within the Olney Formations’ Lower Renmark Group (LRG), is sub artesian to artesian, with water quality generally acceptable for most stock watering purposes.

[1] The Geera Clay thickness was confirmed at the Long Term Trial (LTT site) during the HP3 program conducted between November 2013 and May 2014.

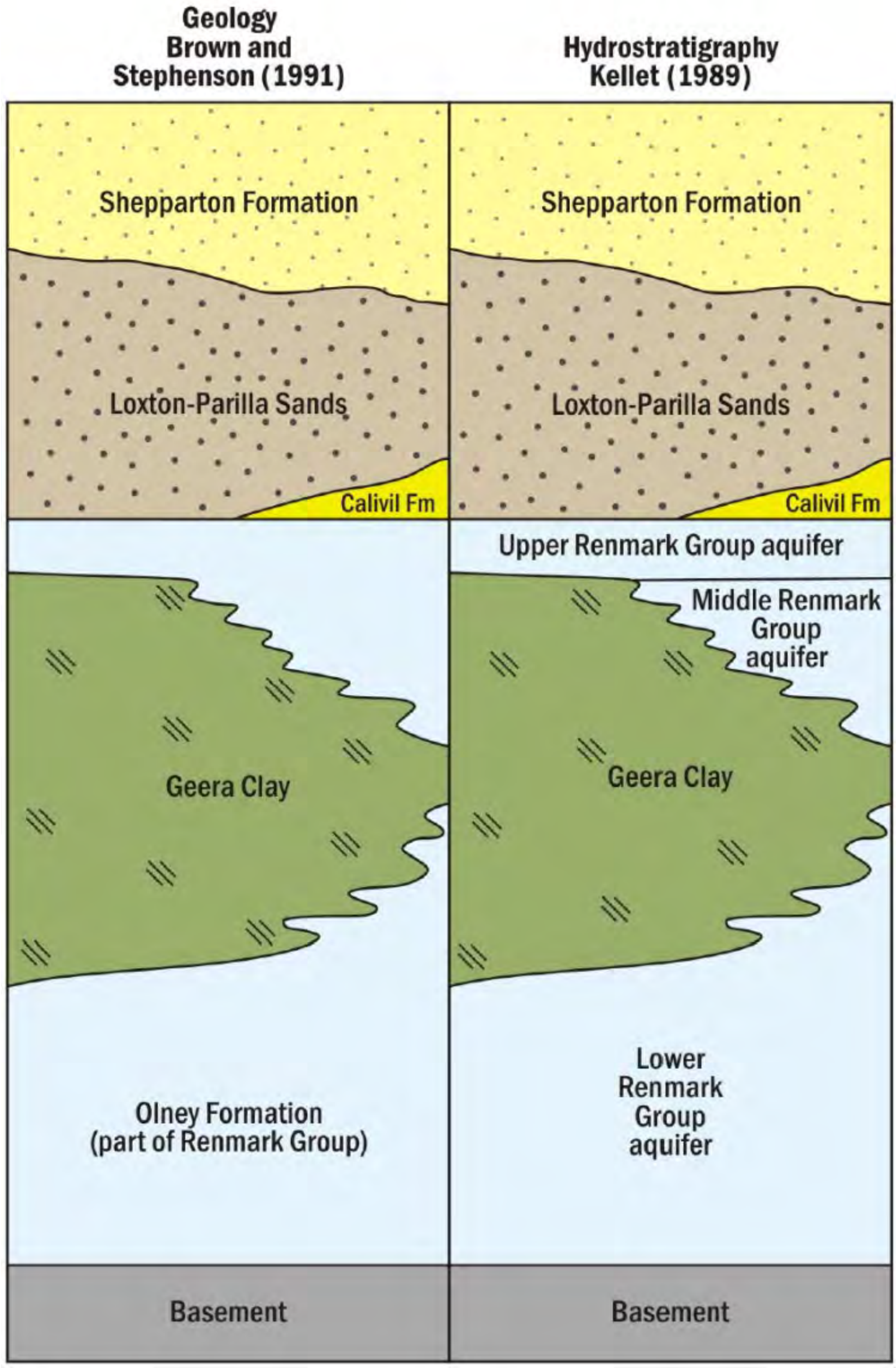


Figure 2.1 **Geological (Brown and Stephenson, 1991) and hydrostratigraphic (Kellet, 1989) models of the study area (after Jacobs, 2015).**

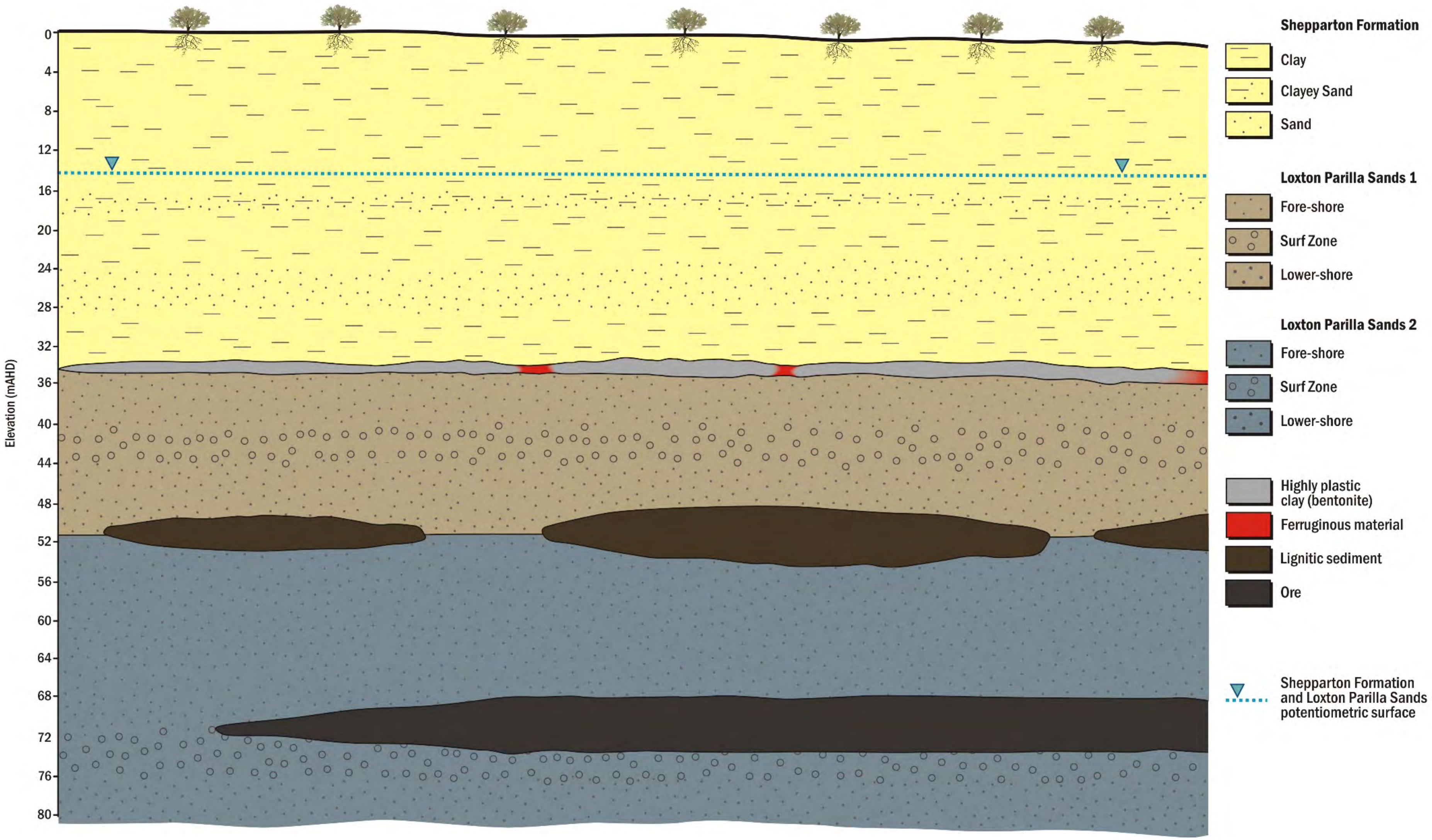


Figure 2.2 Idealised site stratigraphy

2.3 Groundwater Levels and Flow

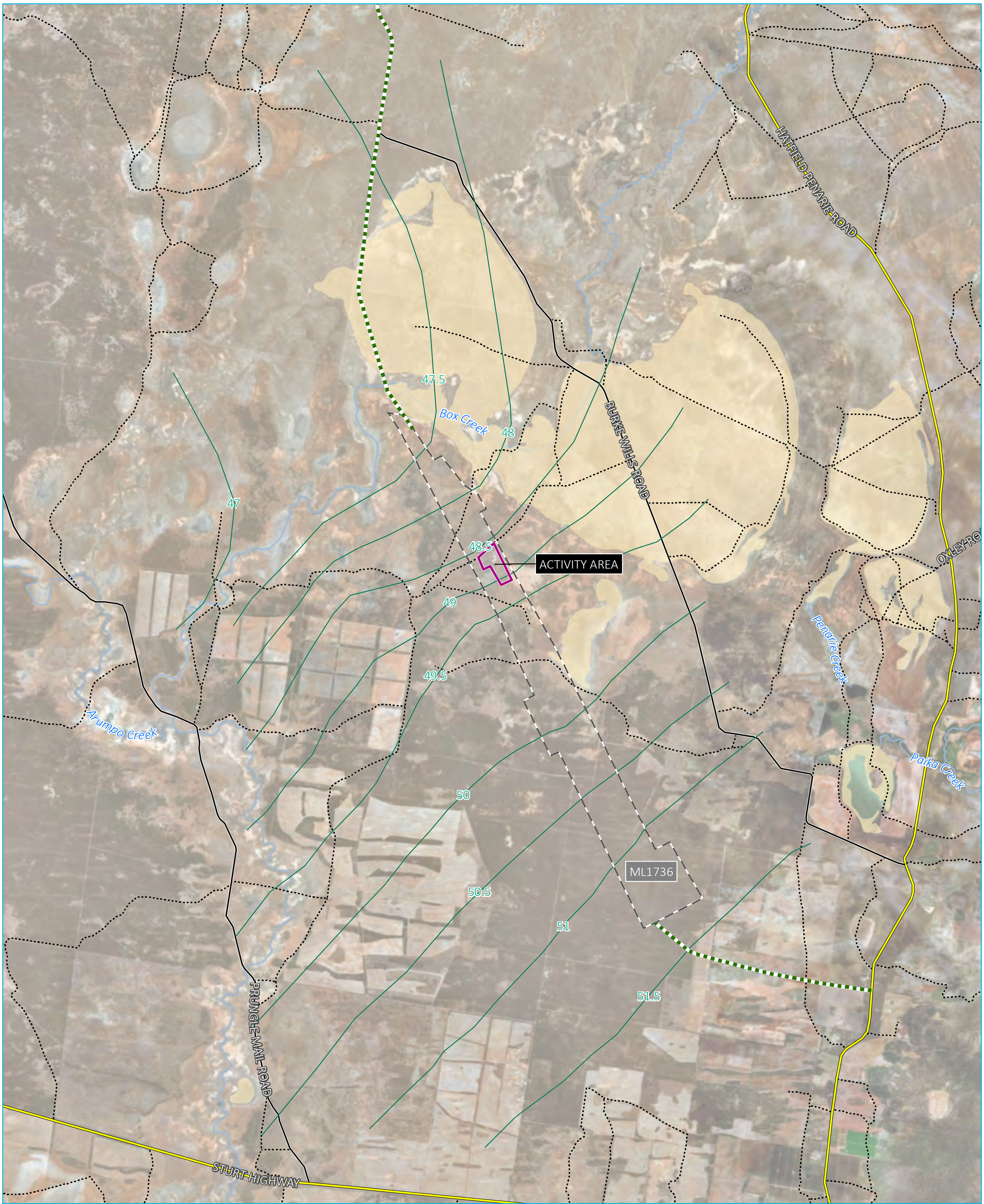
Regional groundwater level measurements during 2014 have been used to develop plan-view unstressed potentiometric surfaces for the following main aquifers of interest:

- Figure 2.3- SFM unstressed potentiometric surface shown on a 0.5 m interval;
- Figure 2.4- LPS unstressed potentiometric surface shown on a 0.5 m interval; and
- Figure 2.5- Olney Formation unstressed potentiometric surface shown on a 1 m interval.

The contours have been developed using surveyed bore collars associated with previous Balranald field programs and the quarterly baseline data collection program. In summary, the potentiometric surfaces suggest:

- the potentiometric surfaces for the SFM and LPS are near identical under natural/unstressed conditions;
- local groundwater elevations greater than 52 mAHD prevail at the southern end of the West Balranald deposit. Groundwater levels between 48 and 49 mAHD dominate further north;
- the local groundwater flow direction is from the southeast to the north-west; and
- groundwater heads recorded within the Olney Formation range from 63 mAHD at the southern end of the West Balranald deposit, to 57 mAHD to the west. The prevailing groundwater flow direction in this unit is from east to west, and consistent with the historical groundwater maps produced by Kellet (1989, 1994).

Iluka undertake groundwater monitoring events (GMEs) across the Balranald site on a 6-monthly frequency. The Balranald bore network targeted for the GMEs is shown in Figure 2.6, and includes a selection of Iluka installed bores, third party bores and government bores. A selection of hydrographs across the site are shown in Figure 2.7, and the time series for all hydrographs measured between 2016 and early 2019 are shown in Appendix B.



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 2.5 5 km
GDA 1994 MGA Zone 54
N

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KEY

- Activity area
- Potentiometric surface (m AHD)
- Access road
- Mining Lease 1736
- Main road
- Local road
- Vehicular track
- Named watercourse
- Ephemeral lake

Shepparton Formation (unstressed) potentiometric surface (m AHD)

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Figure 2.3

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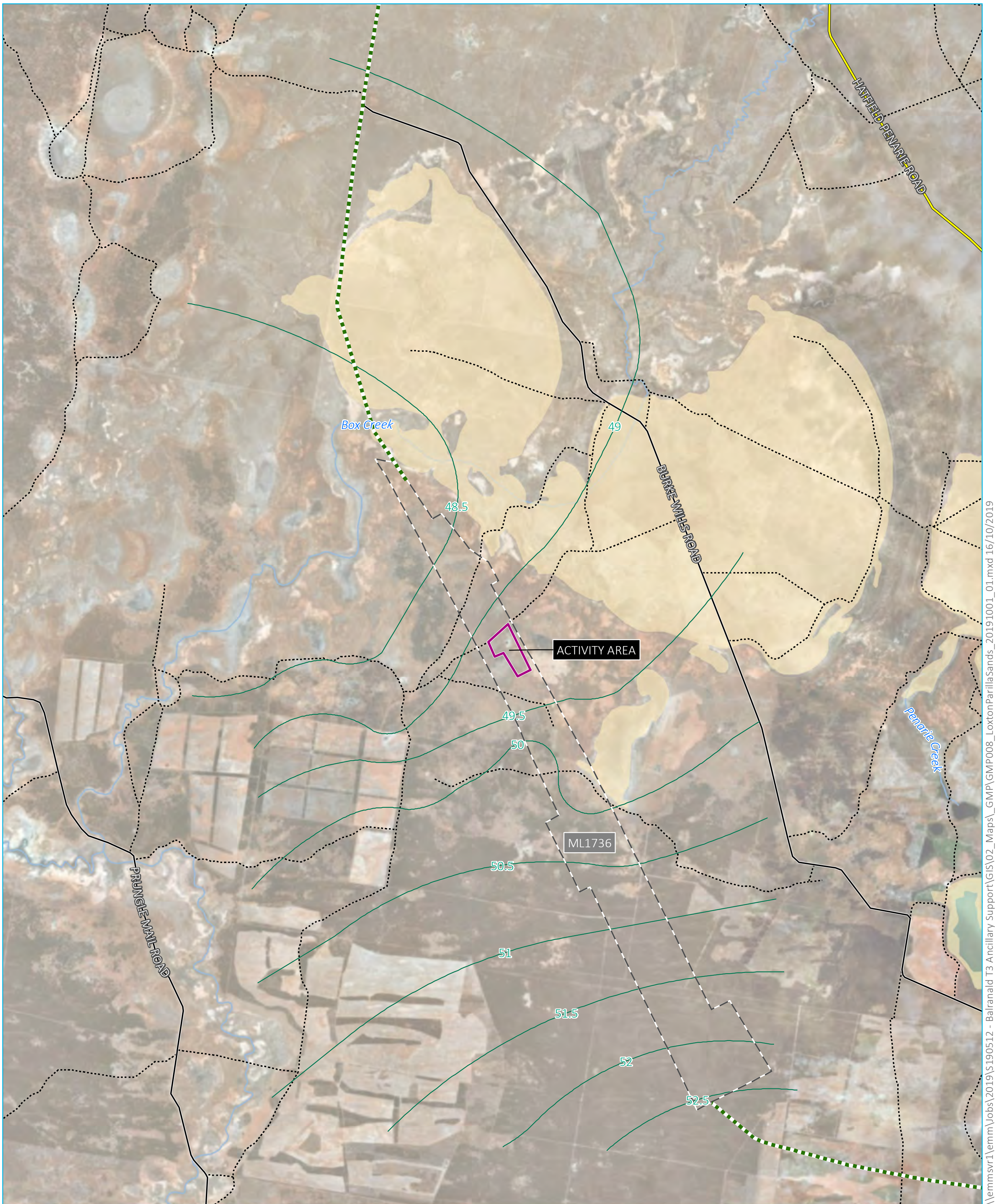

Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

KEY

- Activity area
- Potentiometric surface (m AHD)
- Access road
- Mining Lease 1736
- Main road
- Local road
- Vehicular track
- Named watercourse
- Ephemeral lake

Loxton Parilla Sands (unstressed) potentiometric surface (m AHD)

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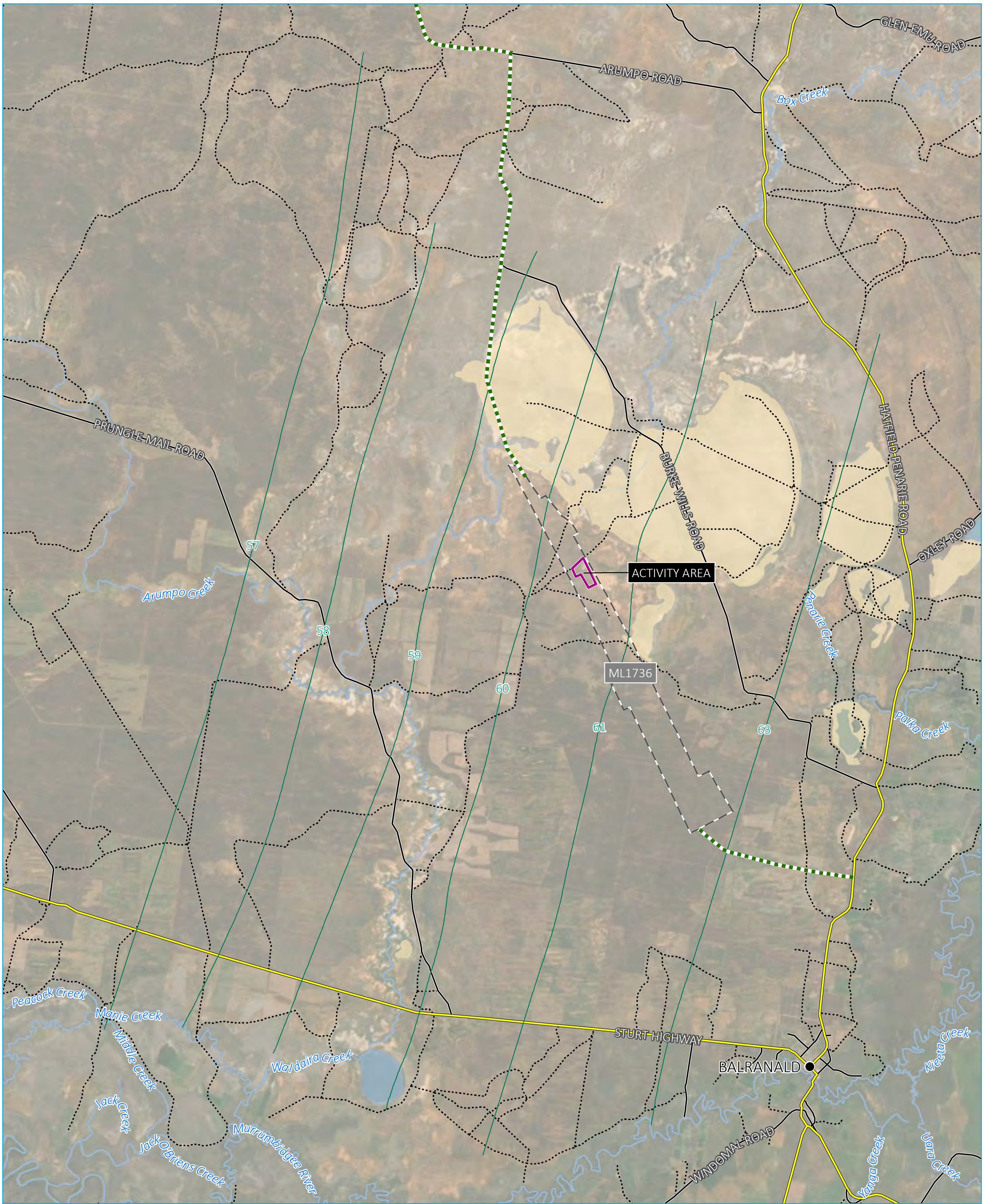
Groundwater Management Plan
Figure 2.4

creating opportunities



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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 2.5 5 km
GDA 1994 MGA Zone 54
N

KEY

- Activity area
- Place
- potentiometric surface (m AHD)
- Access road
- Mining Lease 1736
- Main road
- Local road
- Vehicular track
- Named watercourse
- Perennial lake
- Ephemeral lake

Olney Formation (unstressed) potentiometric surface (m AHD)

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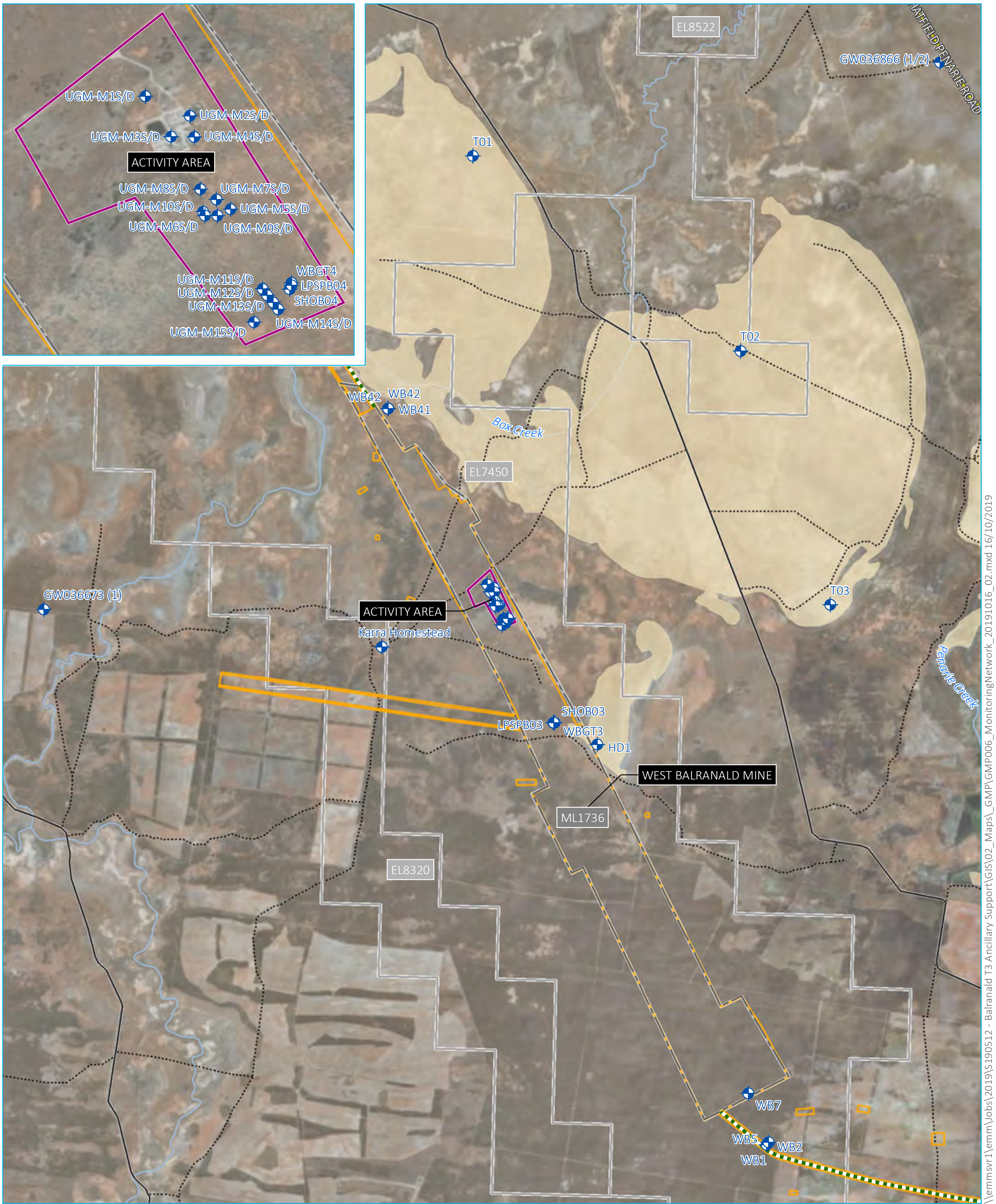
Groundwater Management Plan
Figure 2.5

creating opportunities



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

KEY

- Activity area
- Project boundary
- Groundwater bore location
- Access road
- Mining Lease 1736
- Iluka mineral tenement
- Main road
- Local road
- Vehicular track
- Named watercourse
- Ephemeral lake

Balranald monitoring network
(GME and T3 network)

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Groundwater Management Plan
Figure 2.6

EMM
creating opportunities

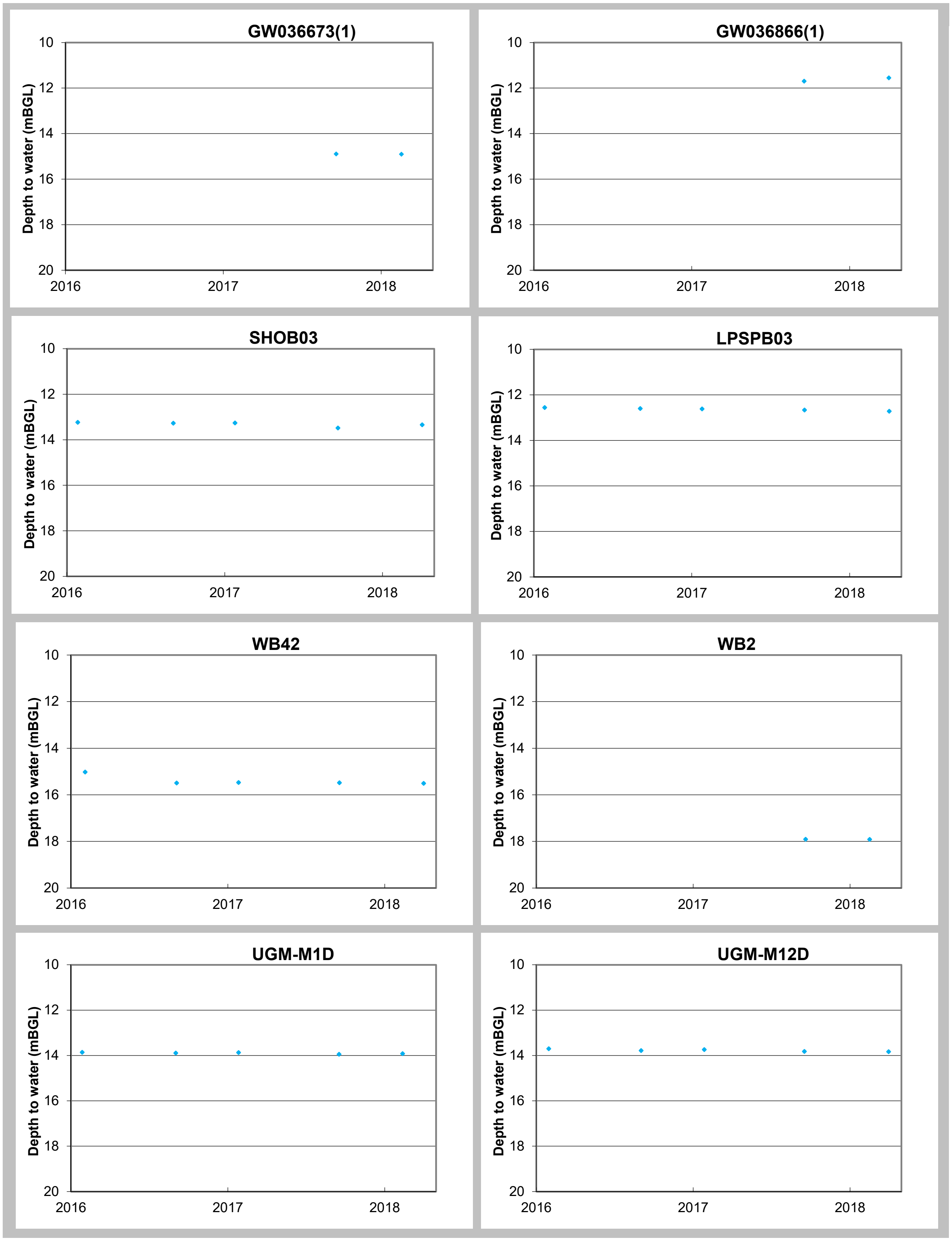


Figure 2.7 Selected hydrographs

T:\Jobs\2018\S180539 - Iluka provisional support Balranald 2019\Technical studies\Groundwater\Data\EMM Processed Data\[Balranald_GME hydrographs.xlsm]GME Fig 2.6

2.4 Groundwater Chemistry

In order to provide a regional context to the groundwater operating rules and monitoring strategies applied later in this report (Sections 4, 5 and 6), this section summarises published groundwater chemistry reports and data from Earth Systems (2015), LWC (2015) and Iluka (2015a).

The steady-state variation in groundwater chemistry from the Shepparton, Loxton Parilla Sands and Lower Renmark Group aquifers has been compiled to assist in the delineation of a tiered groundwater trigger action response plan (TARP) (Section 8). Statistical analysis of major ions and other select analytes, constituting the baseline summaries for the Shepparton, Loxton Parilla Sands and Lower Renmark Group aquifers, are presented in Table 2.2.1, Table 2.2 and Table 2.3 respectively. As other groundwater users predominately utilise the Lower Renmark Group Aquifer for stock purposes, the ANZG trigger values for irrigation and general use are displayed for comparative purposes only (ANZG, 2018).

In summary:

- The Shepparton Aquifer is regarded as saline to hypersaline (Median TDS = 39,650 mg/L), with TDS ranging between 19,700 and 57,200 mg/L, and is deemed unsuitable for irrigation, stock and domestic purposes (ANZG, 2018). The median pH is neutral (7.13), but ranges between 3.85 and 8.1, whilst the redox (oxidation-reduction potential) is considered denitrifying to oxidising (-2 to 253 mV; Strumm and Morgan, 1981).

- The LPS Aquifer is regarded as saline to hypersaline (Median TDS = 33,000 mg/L), with TDS ranging between 8,870 and 48,200 mg/L and is deemed unsuitable for irrigation. Certain bores are identified as a tolerable drinking source for sheep (ANZG, 2018), however these bores are located adjacent the Murrumbidgee River and, similar to the Shepparton Formation, may represent diffusion of river water into the LPS. The Murrumbidgee River is regarded as a losing-system. The median pH is neutral (7.16), but ranges between 6.19 and 8.40, whilst the redox condition is considered denitrifying to moderately reducing (-6 to 193 mV).

- Within the Balranald Project area, the Geera Clay has no representative chemical analyses and no monitoring locations are discretely screened within the formation. Pore-water samples extracted from the Geera Clay in bores drilled near Piangle in northern Victoria yielded TDS concentrations of approximately 200,000 mg/L (Evans, 2014) and EC determinations in two bores in the area yielded salinities of ~37,000 µS/cm, which are potentially associate with the Middle Renmark Group, which inter-fingers with the Geera Clay.

Brackish to saline groundwater is observed in the Lower Renmark Group Aquifer (Median TDS = 4,349 mg/L), with TDS ranging between 2,490 and 10,265 mg/L and is deemed suitable for irrigation of salt tolerant crops and as a tolerable drinking source for most stock purposes (ANZG, 2018). The median pH is circum-neutral (7.50), but ranges between 5.70 and 9.63, whilst the redox condition is considered denitrifying to slightly reducing (-1 to 254 mV).

Table 2.2.1 Shepparton Aquifer: Statistical summary

Statistic	pH	Total Alkalinity (mg/L $CaCO_3$)	Total Dissolved Solids (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	Al (mg/L)	As (mg/L)	Cu (mg/L)	Fe (mg/L)	Li (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Sr (mg/L)	U (mg/L)	Zn (mg/L)
Number	96	95	96	96	96	96	96	96	96	96	27	96	93	96	96	27	27	96	96	96
Minimum	3.85	177	19700	340	710	6800	19	1800	12300	0.003	0.001	<LOR	0.003	0.010	<LOR	<LOR	<LOR	7.320	<LOR	0.003
Lower Fence[2]	6.16	223	19700	340	710	6800	19	1800	12300	0.003	0.001	<LOR	0.003	0.010	0.001	0.001	0.001	9.213	<LOR	0.003
Quartile 1 (25th percentile)	6.85	328	33675	502	1200	9088	35	3600	15575	0.005	0.001	0.005	0.240	0.061	0.093	0.002	0.005	14.950	0.003	0.020
Median	7.13	359	39650	598	1530	11200	42	4245	20200	0.025	0.004	0.012	0.630	0.088	0.270	0.004	0.010	16.950	0.012	0.033
Quartile 3 (75th percentile)	7.30	398	43650	657	1750	13000	66	4801	23000	0.050	0.010	0.018	3.570	0.1218	0.591	0.010	0.017	18.775	0.025	0.072
Upper Fence[3]	7.98	503	57200	890	2550	16200	113	6603	30500	0.118	0.024	0.038	8.565	0.211	1.338	0.022	0.035	24.513	0.059	0.151
Maximum	8.10	570	57200	1100	2550	16200	115	9309	30500	28.90	0.028	0.071	10.400	0.368	6.200	0.053	0.057	32.900	0.229	0.244
IQR[4]	0.46	70	9975	155	550	3913	31	1201	7425	0.045	0.009	0.013	3.330	0.060	0.498	0.008	0.012	3.825	0.023	0.053
Number of Upper Outliers[5]	2	4	0	2	0	0	1	8	0	19	2	2	2	6	15	1	3	2	9	3

[2] Lower fence is defined as the 25th percentile minus 1.5 multiplied by the IQR.

[3] Upper fence is defined as the 75th percentile plus 1.5 multiplied by the inter IQR.

[4] IQR = Inter Quartile Range, which represents 50% of the data between the 25th and 75th percentile (ie. IQR = Q3-Q1).

[5] Upper outliers are defined as data that fall between the upper fence and the maximum.

Table 2.2.1 Shepparton Aquifer: Statistical summary

Statistic	pH	Total Alkalinity (mg/L $CaCO_3$)	Total Dissolved Solids (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	Al (mg/L)	As (mg/L)	Cu (mg/L)	Fe (mg/L)	Li (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Sr (mg/L)	U (mg/L)	Zn (mg/L)
Number of Lower Outliers[6]	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
ANZG 2018[7]	4 - 9	N/A	5 000	N/A	N/A	N/A	N/A	N/A	N/A	5	0.1	0.2	N/A	2.5	0.2	0.01	0.2	N/A	0.01	2

[6] Lower outliers are defined as data that fall between the lower fence and the minimum.

[7] ANZG 2018 guideline value for irrigation and general water use.

Table 2.2 Loxton Parilla Sands Aquifer: Statistical summary

Statistic	pH	Total Alkalinity (mg/L $CaCO_3$)	Total Dissolved Solids (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	Cl (mg/L)	Al (mg/L)	As (mg/L)	Cu (mg/L)	Fe (mg/L)	Li (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Sr (mg/L)	U (mg/L)	Zn (mg/L)
Number	173	173	173	173	173	173	173	173	173	173	36	173	164	173	173	36	36	173	173	173
Minimum	6.19	207	8870	105	225	3200	10	500	5240	0.005	<LOR	<LOR	0.025	0.017	0.064	<LOR	<LOR	2.990	<LOR	0.003
Lower Fence	6.30	252	8870	105	225	3200	10	500	5240	0.005	0.001	<LOR	0.025	0.017	0.064	0.001	0.001	2.990	<LOR	0.003
Quartile 1 (25th percentile)	6.93	376	18500	276	594	5330	31	991	10000	0.005	0.001	0.003	0.450	0.087	0.220	0.001	0.001	6.260	<0.001	0.013
Median	7.16	427	33000	368	1100	9000	40	2460	16600	0.025	0.001	0.005	1.370	0.112	0.427	0.001	0.002	9.480	0.003	0.029
Quartile 3 (75th percentile)	7.35	458	38000	556	1420	11000	52	3680	19400	0.050	0.008	0.008	4.120	0.155	0.620	0.003	0.004	14.600	0.005	0.080
Upper Fence	7.98	582	48200	848	2659	14200	84	6170	26000	0.118	0.018	0.016	9.625	0.257	1.220	0.006	0.009	27.110	0.012	0.181
Maximum	8.40	914	48200	848	1930	14200	110	6170	26000	0.340	0.045	0.058	12.300	0.279	1.650	0.010	0.010	33.300	0.027	1.100
IQR	0.42	83	19500	280	826	5670	21	2689	9400	0.045	0.007	0.006	3.670	0.068	0.400	0.002	0.003	8.340	0.005	0.068
Number of Upper Outliers	10	16	0	0	0	0	5	0	0	22	2	9	4	1	11	4	4	1	30	19
Number of Lower Outliers	1	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANZG 2018	4 - 9	N/A	5 000	N/A	N/A	N/A	N/A	N/A	N/A	5	0.1	0.2	N/A	2.5	0.2	0.01	0.2	N/A	0.01	2

Table 2.3 Lower Renmark Group Aquifer: Statistical summary

Statistic	pH	Total Alkalinity (mg/L $CaCO_3$)	Total Dissolved Solids (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	Cl (mg/L)	Al (mg/L)	As (mg/L)	Cu (mg/L)	Fe (mg/L)	Li (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Sr (mg/L)	U (mg/L)	Zn (mg/L)
Number	209	32	117	58	58	58	58	55	51	47	21	21	42	21	51	21	21	15	14	1
Minimum	5.70	379	2490	21	28	793	16	1	1180	<LOR	<LOR	<LOR	0.009	0.041	0.006	<LOR	<LOR	0.818	<LOR	<LOR
Lower Fence	6.72	379	2490	21	28	793	16	1	1180	<LOR	0.001	0.001	0.009	0.041	0.006	0.001	0.001	0.818	<LOR	<LOR
Quartile 1 (25th percentile)	7.29	400	3570	35	47	1073	23	1	1570	0.020	0.001	0.001	0.330	0.051	0.014	0.001	0.001	0.958	0.001	<LOR
Median	7.50	432	4349	40	59	1235	27	1	1840	0.050	0.001	0.001	0.660	0.060	0.020	0.001	0.001	1.160	0.001	<LOR
Quartile 3 (75th percentile)	7.67	445	5675	53	70	1565	29	2	2400	0.115	0.001	0.002	1.533	0.075	0.038	0.001	0.001	1.940	0.001	<LOR
Upper Fence	8.24	511	8833	81	104	2304	37	4	3645	0.256	0.001	0.003	3.336	0.111	0.075	0.001	0.001	2.830	0.001	<LOR
Maximum	9.63	603	10265	120	160	2530	49	35	4280	1.980	0.006	0.003	7.390	0.158	0.091	0.001	0.004	2.830	0.001	<LOR
IQR(1)	0.38	45	2105	18	23	493	6	1	830	0.095	0.000	0.001	1.203	0.024	0.025	0.000	0.000	0.983	0.000	<LOR
Number of Upper Outliers	5	2	2	3	8	4	7	9	7	5	5	0	2	2	4	0	3	0	0	0
Number of Lower Outliers	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
ANZG 2018	4 - 9	N/A	5 000	N/A	N/A	N/A	N/A	N/A	N/A	5	0.1	0.2	N/A	2.5	0.2	0.01	0.2	N/A	0.01	2

2.5 Sensitive Receptors

A number of natural and anthropogenic receptors have been identified as being potentially sensitive to water impacts across the Balranald Project, including:

- ecosystems that rely on groundwater, including Groundwater Dependant Ecosystems (GDEs);
- the Murrumbidgee River and ephemeral surface water courses; and
- private groundwater abstraction licensees and infrastructure.

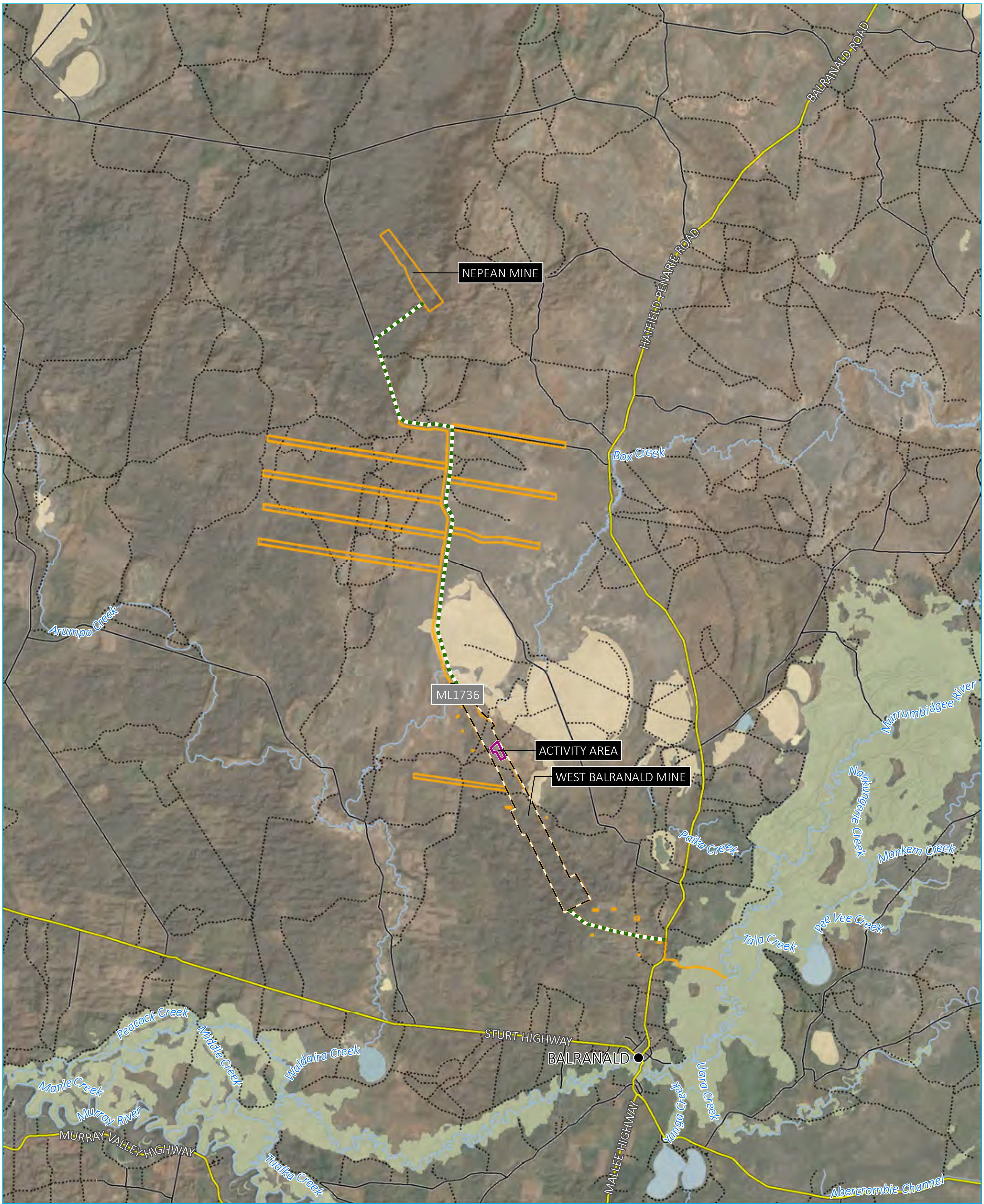
As indicated by Jacobs (2014) and CDM Smith (2015), ecosystems that rely on groundwater are important environmental assets and typically occur where groundwater is at or near the land surface, with the major potential GDE types across the Balranald Project being:

- wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments; and
- vegetation (primarily Black Box trees) located outside the floodplain area but within topographic depressions where the water table may be shallow enough and not too saline.

The Murrumbidgee River is a permanent surface water feature located to the south and east of the Balranald Project region. 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 rely on water from the River for predominantly irrigation and potable supply.

A number of landholders in the area rely on groundwater, sourced from the Lower Renmark Group Aquifer, for stock, irrigation and domestic use. These landholder bores are located throughout the Balranald Project area and the groundwater that they extract can provide a vital source of water. Figure 2.6 shows the locations of known third party bores in relation to the T3 activity, which also includes the location of the T3 water supply bores; Karra Homestead and P2. Other known third party bores screened within the Lower Renmark Group Aquifer include T01, T02, T03 and HD1. Appendix B includes hydrographs at these locations.

The T3 activity area is located outside the area of any defined groundwater-reliant ecosystems and surface water resources (Figure 2.8).



Source: EMM (2019); Iluka (2015);BOM (2017); DFSI (2017); GA (2011)

0 5 10 km
GDA 1994 MGA Zone 54
N

KEY

- Activity area
- Project boundary
- Place
- Access road
- Mining Lease 1736
- Main road
- Local road
- Vehicular track
- Named watercourse
- Perennial lake
- Ephemeral lake
- Groundwater dependant ecosystem

Potential GDE Locations

Iluka Resources Limited
Groundwater Management Plan
Figure 2.8

EMM
creating opportunities

3 Site overview

A site layout plan of Balranald's T3 activity site is shown in Figure 3.1, and includes the following main features:

- site entrance track;
- the main processing area which includes the Process Water Dam (PWD); various processing plant equipment, fines storage, sand/ore stacking pad, site offices and the hard stand area which accommodates the Horizontal Directional Drilling (HDD) rig and supporting equipment;
- the T3 HDD decline holes; and
- up to three (3) mine stopes representing the T3 activity, each measuring approximately 500 m long and between 10 and 20 m wide.

3.1 Mine Water Distribution Network and Infrastructure

The process to extract the mineral ore will comprise of, in summary:

- extracting groundwater from the P2 production bore and storing in the adjacent lined PWD;
- water from the PWD will be utilised in the drilling, extraction and backfilling process;
- during extraction, the ore is fluidised and becomes a slurry, which is conveyed to the surface;
- the ore will be separated into heavy mineral and mining by-products of varying grade sizes, using a trommel, thickener, conventional cyclones and sand stacking units;
- the cyclone overflow reports to a thickener, where flocculent is added to create a thickened fines by-product stream, known as thickener underflow (fines stream);
- the thickener underflow will be stored for backfilling in the lined Fines Storage Pond. The water from the thickener will overflow to the PWD for reuse in the mining operation;
- the cyclone underflow (sand stream) is pumped through spirals circuit for separation of heavy minerals and sands tails;
- both the sand tails and ore will be stacked on an existing and new ore pad, appropriately bunded with drainage captured for re-cycling in the mining process; and
- to test the backfilling process, fines material will be combined with process water and sand fraction and re-injected via hydraulic backfill bores (HBFs) targeting the cavities.

The groundwater monitoring and management plan associated with this infrastructure is detailed in Section 5.

3.2 Water supply

Integral to the operation of the T3 activity, saline groundwater will be abstracted from the LPS Aquifer as a process water supply and during in-situ mineral extraction and backfilling. This will occur via the P2 production bore, located at the south-western corner of the PWD as shown in Figure 3.1.

Subsequently, water sourced from the PWD will be re-injected into the LPS Aquifer as a component of the in-situ mining process and during stope-backfilling with mining by-products.

A Water Trade for the LPS Aquifer of 2,350 ML for the 2019/2021 period has been secured under Water Access License (WAL) No. 3110.

Groundwater abstraction will also be undertaken from Karra Homestead Bore, which is screened within the Lower Renmark Group Aquifer. This brackish water source will be used primarily for dust suppression and soil/heavy-mineral stockpile management. A separate abstraction allowance of 150 ML has been granted by DPIE-Water under Water Access License (WAL) No. 31101 for the 2019/2021 period.

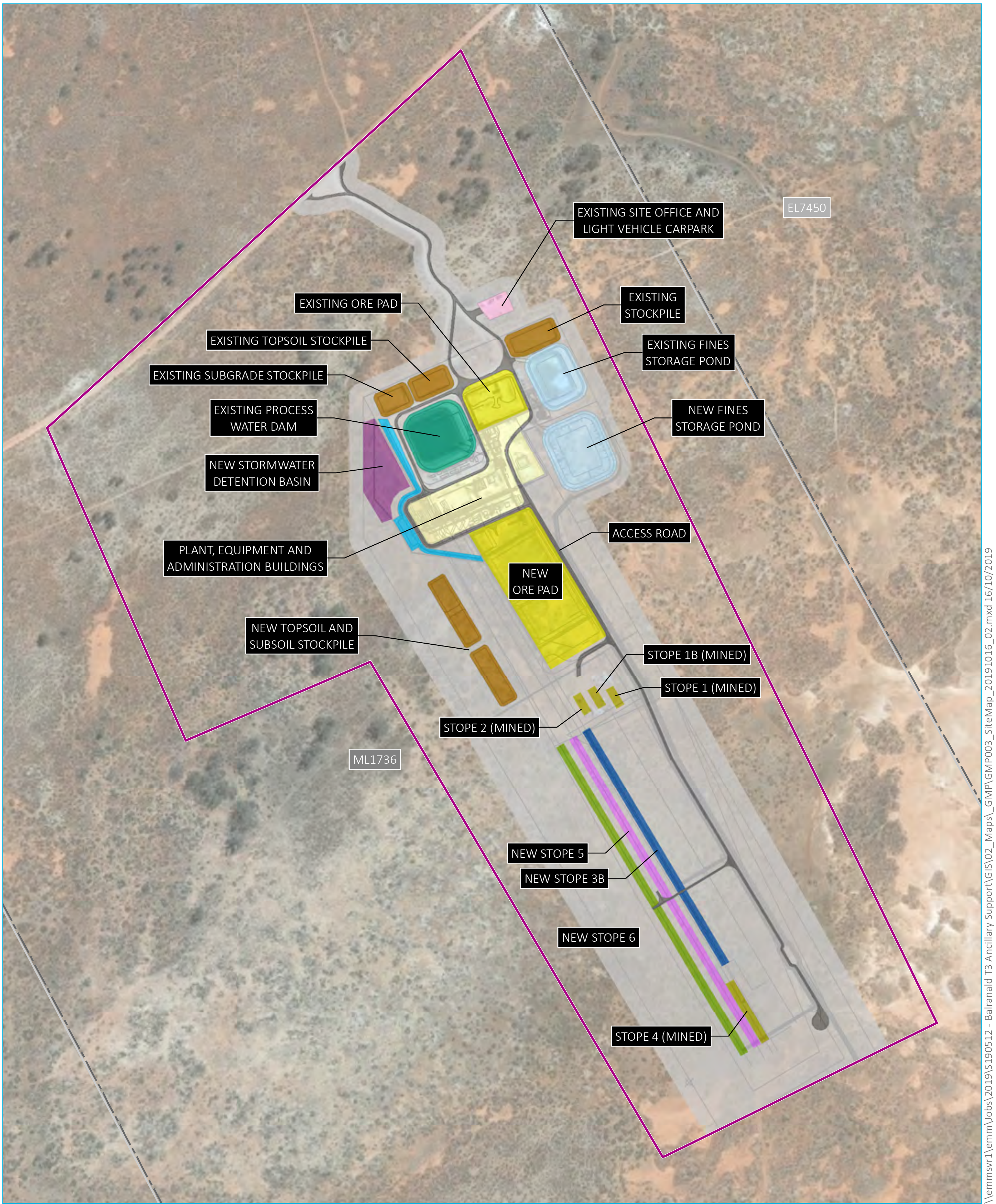
The location of the Karra Homestead bore in shown in Figure 2.6, in relation to T3 activity and other bores sampled as part of Iluka's GMEs.

The construction details for the P2 and the Karra Homestead bore are summarised in Table 3.1.

Table 3.1 Production bore construction details

Bore	Depth (mBGL)	Details
Karra Homestead	0-216.5	177 mm ND[1] blank µPVC
	216.5-218.3	100 mm ND blank µPVC
	218.3-230.3	100 mm ND stainless steel screen
	230.3-239.0	100 mm ND blank µPVC
P2 (PWD Bore)	0-57	300 mm ND CL18 blank µPVC
	57-81	300 mm ND CL18 blank µPVC

Note: 1. ND = Nominal diameter



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

KEY

Activity area
Mining Lease 1736
Iluka mineral tenement

Indicative site layout
Access road
Activity footprint
Existing site office and light vehicle carpark
Fines storage pond
Ore pad
Plant, equipment and administration buildings

Process water dam
Spoon drain
New stormwater detention basin
Stockpile
Stope (mined)
Stope 3B
Stope 5
Stope 6

Site map

Iluka Resources Limited
Groundwater Management Plan
Figure 3.1

creating opportunities

4 Groundwater criteria

The operational conditions for hydraulic pressures are summarized in Table 4.1 and the water quality suite specific trigger levels (SSTLs) for each aquifer unit, applicable to both field and laboratory data are summarised in Appendix C. Derivation of both the hydraulic pressure operational conditions and the SSTL's are based on baseline groundwater chemistry, the beneficial use of each aquifer, and a factor that acknowledges temporary variations that are expected during the unconventional mining activities.

4.1 Operational hydraulic pressure

The initial hydraulic operational conditions or HOCs (Table 4.1), especially related to the LPS, are identified operational site conditions and are not considered to be site/operational constraints nor reportable incidents for the purposes of the Trigger Action Response Plan (see Section 7.1) or compliance with the GMP. However, the HOCs associated with the SFM are considered to be site/operational constraints since the non-saline overburden is required to be protected from any potential upwelling of saline groundwater.

The HOCs represent the historical maximum pressures that have been experienced within the LPS aquifer without any adverse impacts being observed, including saline water movement to surface. As the T3 site activities progress, it is envisaged that the HOCs will be progressively updated as part of Iluka's adaptive management philosophy.

It is critical that the HOCs remain relatively flexible from one location to the next (to allow for localised heterogeneity in the geological conditions).

The ability for site aquifers to handle induced change without any adverse impacts to stratigraphic (aquitard) integrity will be a function of site-specific conditions, which will vary along the orebody (strike) due to the inbuilt heterogeneity within the system. During times of active mining/backfilling within the LPS, groundwater pressures within the overlying (SFM) and underlying (LRG) aquifers will be observed closely, with the results in forming a new reiteration of the HOCs. This will be facilitated by Iluka's operational adaptive management philosophy. For example, increased pressures within the SFM and LRG beyond the Yellow and Red zones indicates that the mining and backfill pressures are too large within the LPS. The HOCs for the LPS at this particular location will then need to be reduced. Likewise, if mining and backfilling activities result in pressures beyond the HOCs stated within Table 4.1 (or any new reiteration that has been iteratively established from the previous stope) with no levels occurring within the Yellow and Red zones for the SFM and LRG, then the HOCs for the LPS may be incrementally increased.

Table 4.1 Initial hydraulic operational conditions

Parameter	Shepparton			Loxton Parilla Sands			Lower Renmark Group		
	Green	Yellow	Red	Green	Yellow	Red	Green	Yellow	Red
Depth to groundwater (mounding)	>8 mBGL[1]	≤8to >6 mBGL	≤6 mBGL	<15 mAGL[2]	≥15 to <20 mAGL	≥20 mAGL	N/A	N/A	N/A
Depth to groundwater (dewatering)	N/A	N/A	N/A	N/A	N/A	N/A	≤8 mBGL	>8 to ≤10 BGL	>10 mBGL

Notes: 1. mBGL: metres below ground level

2. mAGL: metres above ground level

4.2 Water quality

Groundwater quality SSTLs have been defined for both field and laboratory analytical parameters across each formation, based on data collected before the T2 trial and up to August 2015. Post the T2 activity, Land and Water Consulting (LWC) were engaged by Iluka Resources to review groundwater data collected to date to: a) assess potential impacts as a result of the mining and backfilling trials, and b) assess the appropriateness of the SSTLs and measured suites. Appendix C incorporates these revisions and is consistent with Iluka's adaptive management philosophy. Any future proposed changes to SSTLs need to be justified, and Regulators (summarised in Table 1.1) need to be notified for approval.

As discussed in the original 2016 management plan developed for the T2 trial (Iluka, 2016),the SSTLs have been calculated in a way that acknowledges temporary variations are expected during the unconventional mining activities and groundwater quality may change spatially compared to the monitoring points used to define the historical water quality statistics (refer to Section 2.4). SSTLs are categorised as posing either a direct or indirect risk to beneficial users. Species which are classified as a direct risk could present adverse risk to beneficial users if the SSTLs are exceeded, while indirect risk species only indicate a change in groundwater chemistry, but do not present an adverse risk on their own.

'Direct' and 'Indirect' SSTLs for the Green, Yellow and Red management responses are defined below:

- Direct risk
  - The Green SSTL indicates normal operations and incorporates all values less than the Yellow management response.
  - The SSTL for a Yellow management response is defined as the Upper fence multiplied by 1.1.
  - The SSTL for a Red management response is defined as the Upper fence multiplied by 1.25.
- Indirect risk
  - The Green SSTL indicates normal operations and incorporates all values less than the Yellow management response.
  - The SSTL for a Yellow management response is defined as the Upper fence multiplied by 1.25.
  - The SSTL for a Red management response is defined as the Upper fence multiplied by 1.5.

The Balranald groundwater quality SSTLs are summarised in Appendix C.

5 Groundwater Monitoring and Management Program

5.1 Monitoring objectives

The monitoring objectives of the T3 network are to:

- measure the groundwater pressure and chemical changes at various locations within the SFM and LPS during both mining and backfilling periods;
- ensure adequate monitoring bores located within each SSTL zone as described in Section 5.2;
- monitor the groundwater within the SFM along the HDD access holes to ensure the water table elevation does not breach the trigger levels during mining/backfilling periods;
- measure of the variable reinjection rates and operational conditions on resulting ground water pressures and geochemical changes;
- allow for flow net/pressure analysis to be performed radially within the LPS;
- develop an understanding of operational constraints; and
- provide a robust dataset which future groundwater modelling can use to assist with assessing the feasibility of an underground mining method for the Project.

5.2 Chemical SSTL zones

It is accepted that the groundwater system will change directly adjacent to the mine stopes. However, the management objectives for groundwater chemical changes is focused on protecting the beneficial use[8] of the groundwater system down hydraulic gradient from the mining site, more-so within the mine footprint itself.

Hydrogeochemical modelling (LWC, 2017) suggest a leading edge of backfill related geochemical impact within the LPS is likely to occur if dosing the tailings prior to backfill does not take place. In order to reflect this spatial variation, a zoned approach to hydrogeochemical SSTLs has been adopted with the definitions summarised in Table 5.1 and shown spatially in Figure 5.1. The spatial SSTLs zones are based on hydrogeochemical modelling completed by LWC (2017b) that suggests large groundwater quality changes could be observed within 20 m of the stope edges, which will then dissipate to background conditions within a 300 m buffer zone from the stope edges. The zones are based on preliminary modelling and should be updated using an adaptive approach as the understanding of the system increases (see Section 7.1). The current SSTL zones also treat the T3 stopes as a small mine site and assumes the three stopes represent the entire mining footprint.

[8] Although there no direct beneficial users currently identified for the SFM and LPS aquifers, the chemical SSTLs are designed to not decrease the water quality of the aquifer down gradient of the T3 activity and maintain water quality within historical statistical ranges.

Table 5.1 Zoned hydrogeochemical SSTL framework

Groundwater Monitoring Zone	Purpose	Details
Zone 1 **Mining Zone**	Operational	Adjacent and surrounding the actual mining area. Includes the stope areas plus a 20 m buffer. Required to understand immediate changes to groundwater quality and pressure. Large changes relative to baseline conditions, are expected in this zone and represent the source location of both pressure and geochemical changes. Provide a leading indicator to potential impacts within Zone 2.
Zone 2 **Transition Zone**	Operational	Non mining area and represents the zone between 20 m and 300 m from the stope edges. Data and trends within this zone are used to understand aquifer responses at various locations away from the stopes, during mining and backfill. Provide a leading indicator to potential impacts within Zone 3.
Zone 3 **Background Zone**	Compliance	Non mining area and represents the zone beyond 300 m from the stope edges. Bores located in this zone are part of the EPA Licence and will therefore be required to adhere to the nominated SSTL's and associated compliance reporting.

5.3 T3 monitoring network

Table 5.2 summarises the groundwater monitoring network for the T3 activity, and the bore locations are shown spatially on Figure 5.1. The monitoring network consists of the following:

- ten new monitoring bores (BH-M16 to BH-M25);
- eight existing monitoring bores (noting that UGM-M08 may be decommissioned); and
- nine new vibrating wire piezometers.

Note that up to five new hydraulic backfill (HBF) bores are also planned to facilitate backfill injection.

The monitoring bore network is designed to meet the objectives stated in Section 5.1.

Table 5.2 T3 activity monitoring network

Bore ID	Easting (m)	Northing (m)	Status	Screen	SSTL zone
UGM-M01	723217	6189938	existing	SFM/LPS	3 (background)
UGM -M02	723332	6189842	existing	SFM/LPS	3 (background)
UGM -M04	723348	6189745	existing	SFM/LPS	3 (background)
UGM -M06	723373	6189400	existing	SFM/LPS	2 (transition)
UGM -M12	723639	6189000	existing	SFM/LPS	1 (mining)
UGM -M15	723555	6188886	existing	SFM/LPS	2 (transition)
LPSPB04	723702	6189053	existing	LPS	2 (transition)
BH-M16	723484	6189656	new	SFM/LPS	3 (background)
BH-M17	723318	6189364	new	SFM/LPS	2 (transition)
BH-M18	723363	6189255	new	SFM/LPS	2 (transition)
BH-M19	723377	6189038	new	SFM/LPS	2 (transition)
BH-M20	723676	6189207	new	SFM/LPS	2 (transition)
BH-M21	723672	6189008	new	SFM/LPS	2 (transition)
BH-M22	723682	6188854	new	SFM/LPS	2 (transition)
BH-M23	723631	6188619	new	SFM/LPS	3 (background)
BH-M24	723779	6189359	new	SFM/LPS	3 (background)
BH-M25	723238	6189003	new	SFM/LPS	3 (background)
VWP16	723414	6189262	new	SFM	1 (mining)
VWP17	723453	6189284	new	SFM	1 (mining)
VWP18	723466	6189175	new	SFM	1 (mining)
VWP19	723504	6189198	new	SFM	1 (mining)
VWP20	723713	6189335	new	SFM	1 (mining)
VWP21	723517	6189090	new	SFM	1 (mining)
VWP22	723555	6189112	new	SFM	1 (mining)
VWP23	723631	6188902	new	SFM	1 (mining)
VWP24	723668	6188926	new	SFM	2 (transition)
HBF4-FE1	723630	6188994	new	Stope	1 (mining)
HBF5-MP1	723551	6189121	new	Stope	1 (mining)
HBF6-MP1	723450	6189216	new	Stope	1 (mining)
HBF5- North	723399	6189356	New	Stope	1 (mining)
HBF6- North	723381	6189345	new	Stope	1 (mining)

Notes: 1. SFM: Shepparton Formation Aquifer
2. LPS: Loxton-Parrilla Sands Aquifer

5.4 GME overview

The existing Balranald bore network, including previous near-mining bores, regional monitoring bores, third party bores and process water abstraction bores is listed in Table 5.3 and shown spatially in Figure 2.6. These bores are sampled on an approximate 6-monthly basis as part of Iluka's ongoing groundwater monitoring events (GMEs) and include a comprehensive sampling regime of both field and laboratory parameters, similar to the planned T3 suites outlined in Table 5.4.

The objectives for the various bore categories are summarised below:

1. Near-mining monitoring bores – used to collect post-mining data from the LPS and SFM aquifers in the area surrounding the mining trial to assess what, if any, changes have occurred following mining.

2. Third-party bores – used to obtain pre-mining groundwater level and chemistry data, as well as investigate changes that could potentially impact third-party water users.

3. Regional bores – used to provide regional pre-mining background data in addition to ongoing data that is unaffected by mining activities.

4. Process Water – used to assess the water quality of the process water dam to determine if it is within approved ranges, which minimises impacts of the aquifer during mining/backfill trials.

Table 5.3 Existing GME bore network

Bore ID	Licence number	Easting	Northing	SFM screen interval (mBGL[1])	LPS screen interval (mBGL)	Category
UGM-M1	60BL216700	723166	6189938	15 - 18	71 - 77	near mining
UGM-M2	60BL216700	723332	6189842	25 - 28	68 - 71	near mining
UGM-M4	60BL216700	723348	6189745	24 - 27	71 - 77	near mining
UGM-M5	60BL216700	723478	6189409	26 - 29	66 - 72	near mining
UGM-M6	60BL216700	723373	6189400	20 - 23	68 - 71	near mining
UGM-M7	60BL216700	723425	6189454	29 - 32	74 - 77	near mining
UGM-M8	60BL216700	723364	6189505	26 - 29	66 - 72	near mining
UGM-M10	60BL216700	723380	6189381	30-33	71 - 77	near mining
UGM-M11	60BL216720	723591	6189038	15 - 18	74 - 77	near mining
UGM-M12	60BL216720	723609	6189009	15 - 18	74 - 77	near mining
UGM-M13	60BL216720	723630	6188974	15 - 18	74 - 77	near mining
UGM-M14	60BL216720	723649	6188941	15 - 18	71 - 77	near mining
UGM-M15	60BL216720	723555	6188886	15 - 18	74 - 77	near mining
GW036673 (1)	n/a	711680	6189281	32 - 37	n/a	regional
GW036866 (1/2)	n/a	734900	6203463	21 - 27	52 - 58	regional
SHOB03	60BL216540	724911	6186351	17 - 23	n/a	regional
SHOB04	60BL216539	723695	6189033	16 - 22	n/a	regional

Table 5.3 Existing GME bore network

Bore ID	Licence number	Easting	Northing	SFM screen interval (mBGL[1])	LPS screen interval (mBGL)	Category
WB41	60BL216632	720596	6194488	n/a	35 - 77	regional
WB42	60BL216625	720599	6194491	23 - 27	n/a	regional
WBGT3	n/a	724880	6186352	n/a	76 - 82	regional
WBGT4	n/a	723703	6189063	n/a	76 - 82	regional
LPSPB03	60BL216540	724893	6186351	n/a	62 - 72	regional
LPSPB04	60BL216539	723702	6189053	n/a	58 - 70	regional
WB1	60BL216637	730399	6175412	22 - 28	n/a	regional
WB2	60BL216621	730402	6175415	n/a	52 - 100	regional
WB5	60BL216646	730450	6175489	n/a	96 - 102	regional
WB7	60BL216621	729924	6176754	15 - 31	n/a	regional
HD1	n/a	726021	6185781	n/a	225 - 235 (LRG)	third-party
T01	n/a	722791	6201032	n/a	208 - 216 (LRG)	third-party
T02	n/a	729728	6195981	n/a	176.5 - 185 (LRG)	third-party
T03	n/a	732044	6189404	n/a	204 - 210 (LRG)	third-party
Karra Homestead bore	60WA583109	720430	6188310	n/a	218.3 - 230.3 (LRG)	third-party/process water
P2	60WA583169	723191	6189730	n/a	57 - 81	process water

Notes: 1. mBGL: metres below ground level
2. SFM: Shepparton Formation Aquifer
3. LPS: Loxton-Parrilla Sands Aquifer
4. LRG: Lower Renmark Group Aquifer

5.5 Bore development

Bores must be developed following installation and prior to groundwater monitoring, aquifer testing or operation. Most development methods reverse flow through the screen to loosen fine-grained materials, draw them out of the area surrounding the screen and rearrange the filter pack and the formation material for greater pumping efficiency. The flow reversals can be induced by surge blocks, bailers, pumps, airlifting with compressed air or by water jetting. To be effective, bore development must reach past the screen and the filter/gravel pack to the borehole wall to rectify drilling damage to the formation and to remove any drilling fluids.

Bore development is performed after the annular seal materials have set/cured. Development before the annular seal has set may result in the formation of gaps between the filter pack/gravel pack and the annular seal as the filter/gravel pack materials settle and compact.

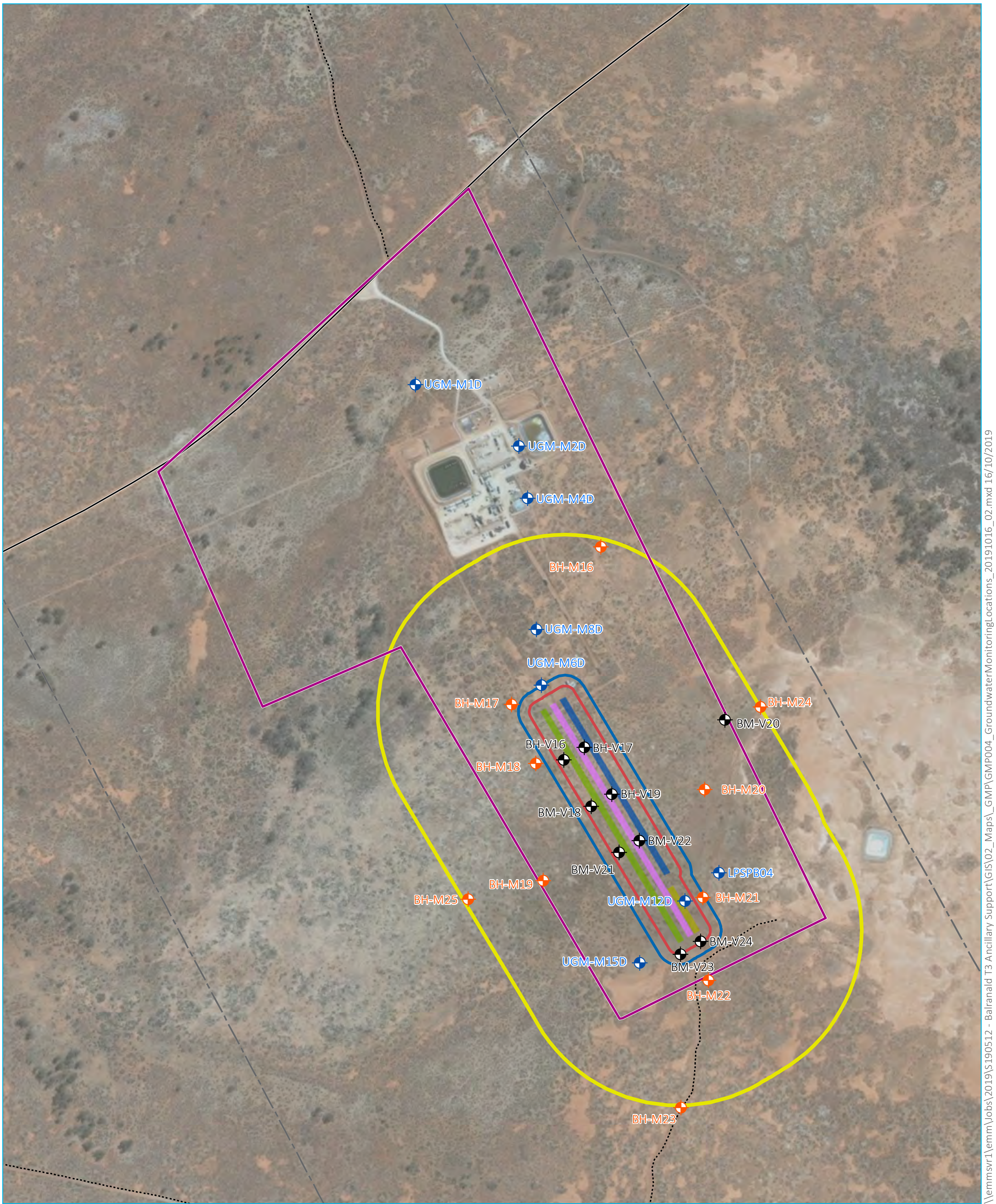
During bore development the following should be recorded:

- initial and final groundwater level measurements;
- airlift yield;

- volume purged; and
- field water quality parameters, such as temperature, pH and electrical conductivity at regular intervals during the bore development process.

The bore is commonly developed until the discharge water is clear or until no further improvement is observed.

Bore development is to be undertaken in accordance with EMM's bore development Standard Operating Procedure (SOP) provided in Appendix D. This has been developed using extensive inhouse experience and following the guidance in the Minimum Construction Requirements for Water Bores in Australia, 3rd Edition (NUDLC 2012). The EMM SOP includes a template for the collection of bore development details.



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 100 200 m
GDA 1994 MGA Zone 54
N

KEY

- Activity area
- Proposed new T3 bores
- Proposed new T3 VWPs
- Existing bores
- Local road
- Vehicular track
- Restricted area
- Mining zone boundary
- Transition zone boundary
- Mining Lease 1736
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

T3 activity monitoring site plan

Iluka Resources Limited
Environmental Management Plan
Figure 5.1

creating opportunities

5.6 Monitoring suites

Monitoring suites are classified as follows:

- Suite 1- These represent the field-based properties which will be collected via a water level dipper (water levels), the YSI Pro water quality meter or something similar (EC, pH, DO, temperature and redox) and HACH portable colorimeter (Ferrous and Total Fe). Given that the field-based pH is probably the most important field analyte, it is recommended that the water quality meter be frequently calibrated;

- Suite 2- This suite represents the major cations and anions (including alkalinity), and are required to consider whether the major constituents of groundwater change significantly between pre-mining, mining and post mining conditions;

- Suite 3- The species listed in this suite are considered the key leading indicators and have the most notable effect on groundwater metal composition with respect to pH-sensitive species and general dissolution of ferric hydroxide phases (which may release sorbed species). Further indicators of acidification caused by pyritic oxidation are to observe the chloride to sulphate ratio, and the ferrous and total iron relationship; and

- Suite 4- Iluka is obliged to analyse and monitor for Naturally Occurring Radioactive Materials (NORM). These elements can be concentrated within heavy mineral deposits associated with monazite sands and include isotopes of uranium, thorium, radium and potassium. Two of the short-lived daughter isotopes including Ra-226 and Ra-228 are commonly monitored by Iluka, due to their high mobility under certain environmental condition and detrimental impact to ecosystems and humans following uptake (IAEA, 2014). Th, U, Ra-226 and Ra-228 should be monitored pre- and post-trial.

Table 5.4 T3 activity monitoring program overview

Suite	Description	Parameters	Frequency
1	Field parameters	Water levels, Electrical conductivity (EC), pH, dissolved oxygen, temperature, oxidation reduction potential (redox), Ferrous and Total Fe	Pre- and post-trial, daily for bore transects adjacent to active mining and backfill periods, fortnightly for other bore locations
2	Major ions	Ca, Mg, Na, K, SO_2^-, SO_4^{2-}, Cl, alkalinity (bicarbonate, carbonate, hydroxide and total as $CaCO_3$)	Pre- and post-trial, and monthly[1] during trial. Aim to collect water samples at bore transects at times adjacent to active backfill periods.
3	Leading indicators	Al, Mg, S, Cl:SO_4^{2-} , Ferrous and Total Fe.	As Suite 2
4	Radionuclides	Th, U, Ra-226 and Ra-228	Pre- and post-trial

1 Suite 2 should be sampled at times during active mining and backfilling

5.7 Monitoring schedule

Table 5.5 provides a summary of the groundwater monitoring requirements and intended monitoring frequency for the pre-, during- and post-T3 activity periods. The frequency of measurement documented in Table 5.5 refers to manual measurements only, not autonomous based datasets (which includes water pressure only) collected via loggers.

The measurement frequencies within the Mining Zone and Transition Zone will be reviewed throughout the trial and may be adjusted to suit the groundwater response being observed, and would not be less frequent than in the Background Zone.

Referring to post-trial sampling schedule, a selection of the newly installed bores may be chosen to include within Balranald's standard GMEs. Post-trial cessation, a T3 assessment report will be developed and recommendations for ongoing monitoring.

In addition to the groundwater level and quality monitoring requirements, production volumes from both the Karra Homestead bore and P2 bore will be recorded. Totaliser gauges are installed on both production bores and accumulative volumes will be recorded on a weekly basis. A pre-mining gauge recording is required prior to any abstraction occurring.

Table 5.5 T3 activity monitoring schedule

<table>
<tr><th>Aspect</th><th>Location</th><th>Frequency</th><th>Suites</th><th>Bore ID</th></tr>
<tr><td colspan="5">Pre-activity</td></tr>
<tr><td>Groundwater quality</td><td rowspan="2">Mining Zone</td><td rowspan="6">Once off</td><td>1, 2, 3 and 4</td><td rowspan="6">All bores</td></tr>
<tr><td>Groundwater levels</td><td>n.a</td></tr>
<tr><td>Groundwater quality</td><td rowspan="2">Transition Zone</td><td>1, 2, 3 and 4</td></tr>
<tr><td>Groundwater levels</td><td>n.a</td></tr>
<tr><td>Groundwater quality</td><td rowspan="2">Background Zone</td><td>1, 2, 3 and 4</td></tr>
<tr><td>Groundwater levels</td><td>n.a</td></tr>
<tr><td colspan="5">During activity</td></tr>
<tr><td rowspan="2">Groundwater quality</td><td rowspan="3">Mining Zone</td><td>Daily (when mining is close to bore location) otherwise fortnightly.[1]</td><td>1</td><td rowspan="9">Refer to Table 5.2 for impact zones</td></tr>
<tr><td>Monthly</td><td>2 and 3</td></tr>
<tr><td>Groundwater levels</td><td>Daily</td><td>n.a</td></tr>
<tr><td rowspan="2">Groundwater quality</td><td rowspan="3">Transition Zone</td><td>Fortnightly</td><td>1</td></tr>
<tr><td>Monthly</td><td>2 and 3</td></tr>
<tr><td>Groundwater levels</td><td>Daily</td><td>n.a</td></tr>
<tr><td rowspan="2">Groundwater quality</td><td rowspan="3">Background Zone</td><td>Fortnightly</td><td>1</td></tr>
<tr><td>Monthly</td><td>2 and 3</td></tr>
<tr><td>Groundwater levels</td><td>Weekly</td><td>n.a</td></tr>
<tr><td colspan="5">Post-activity</td></tr>
<tr><td>Groundwater quality</td><td rowspan="2">Mining Zone</td><td rowspan="2">Once off as a minimum with some bores being biannual (pending T3</td><td>1, 2, 3 and 4</td><td rowspan="2">All bores</td></tr>
<tr><td>Groundwater levels</td><td>n.a</td></tr>
</table>

Table 5.5 T3 activity monitoring schedule

Aspect	Location	Frequency	Suites	Bore ID
Groundwater quality	Transition Zone	assessment report and on-going GME requirements)	1, 2, 3 and 4	
Groundwater levels			n.a	
Groundwater quality	Background Zone		1, 2, 3 and 4	
Groundwater levels			n.a	

Note: Bores UGM-M6, UGM-M12 and BH-M21 are located within the restricted access zone, and thus will be sampled via the remote sampling system. During active mining and backfilling, monitoring frequencies for Suite 2 and 3 will be collected from the nominated bores and aligned with the monthly schedule.

1. The suggested daily monitoring frequency will be reviewed throughout the trial and may be adjusted to suit the groundwater response being observed across the site at various locations.

5.8 Monitoring equipment

Similar equipment to the following will be used to sample and monitor groundwater during the T3 activity:

- water level dipper (such as OTT KL010, solinst or similar);
- water quality meter (such YSI Pro 1030, Aqua Troll or similar);
- HACH DR/890 colorimeter;
- down-hole data level loggers (Schlumberger, Solinst or similar); and
- Vibrating Wire Piezometers (VWPs) and loggers.

One of the most important requirements of the water licence conditions (reference 60WA583169 and 60BL216701) is to ensure:

- the pH of the water to be reinjected is between 6.5 and 8.5, or is treated to bring the pH within this range; and
- water injected to the aquifer to during mining and backfill periods must be of the same or better quality as the aquifer receiving water (as per the beneficial use classification) and should be free of any pollutants.

The water quality within the backfill material will be monitored (see Section 5.11), and the potential effects on the groundwater system will also be monitored. This will be accomplished by collecting real-time data from bores located close to the stopes by manually collected data via the groundwater sampling system, specifically designed to remote sample from bores located within the exclusion zone during time of active mining/backfilling.

5.9 Monitoring procedures

Best practise sampling using a combination of low-flow sampling methods and collection via passive samplers (Hydrasleeves). EMM's standard operating procedures (SOPs) for these methods are provided in Appendix D, which are consistent with the following Australian/New Zealand Standards:

- AS NZS 5667.1, 1998 – Water Quality Sampling – Part 1 Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples; and

- AS NZS 5667.11, 1998 – Water quality - Sampling guidance on sampling of groundwaters.

5.10 Process Water Monitoring

Process water monitoring will be carried out at the Process Water Dam.

Manual water quality monitoring of water samples from the PWD will involve measuring of analytical suites outlined in Table 5.6.

Automatic logging will also be undertaken at three locations to ensure the pH of the PWD is maintained between 6.5 and 8.5. If necessary, the process water pH will be adjusted by dosing with lime during mining and backfill activities. Three locations will be monitored by probes throughout the circuit including:

1. the PWD offtake;
2. the HBF tank; and
3. Constant Density (CD) tank-outlet.

Table 5.6 PWD monitoring schedule

Period	Frequency	Suites
Pre-activity	Once off	All
During-activity	Weekly Monthly	1 2 and 3
Post-activity	Once off or as required	All

5.11 Backfill Quality Monitoring

Automated backfill water quality monitoring will be conducted via a telemetry system which will feed into the onsite Citect system. However, field-based manual water quality monitoring of pH, redox potential and salinity will be required on a daily basis during backfill periods from the designated sampling valve installed within the Plant and located after the dosing unit within the processing circuit.

5.12 Quality Control and Quality Assurance Plan

Quality assurance/quality control (QA/QC) measures are activities undertaken to demonstrate the accuracy and precision of the monitoring program. QC consists of the steps Iluka will take to determine the validity of specific sampling and analytical procedures. QA generally refers to Iluka’s broad plan for maintaining quality in all aspects of a work program. The reliability of and confidence in the data collected as part of this GMP will be determined by implementing the following quality controls:

- routine and regular equipment maintenance, checks and calibrations;
- internal data validation; and
- external data validation.

All QA/QC results will be assessed firstly by an appointed hydrogeologist to inform the overall adequacy and reliability of each parameter to meet the monitoring program objectives.

Based on the quality assessment, one or more aspects of the QA/QC program may be modified as required at any stage of this monitoring program.

The following sub-sections outline Iluka's QA/QC plan associated with the T3 activity.

5.12.1 Equipment maintenance, checks and calibrations

Down-hole pH, EC and redox sensors will be installed down selected bores within the restricted access areas close to the stopes, and will be calibrated prior to use, according to the manufacturer's recommendations. At a minimum, the down-hole sensors will be calibrated again post trial datasets to assess any potential deviation or drift. Field meters used to measure water levels, pH, EC, redox, ferrous ion and ferric iron from the standard monitoring bores will be calibrated daily.

The requirement for recalibration during the trial will be assessed as needed based on any observed measurement drift, measurement error, equipment malfunction, or discrepancy with manually collected field data. At a minimum, each sensor will be calibrated according to the guidance provided by the instrument manufacturer. When not in use, equipment will be stored and maintained according to the manufacturer's guidance.

All calibrations will be recorded in an electronic calibration log that will include the sensor number (or serial number), the measured parameter both before and after calibration. This log will allow detection of possible instrument issues over time and serve as a reference to increase data confidence should future validation be required.

All equipment will be cleaned routinely as part of the calibration and maintained according to the manufacturer's specifications or more frequently as required.

5.12.2 Internal data validation

Internal data validation measures and database management will be undertaken by the appointed field hydrogeologist, and will include reviewing the following as a minimum:

- manual groundwater level measurements and downloaded logger data from both down-hole logger sensors and VWPs;
- the Suite 1 manual discrete water quality measurements;
- comparison of the Suite 1 measurements with the downhole logger data to assess logger performance and consistency;
- measured water abstraction volumes and calculated rates; and
- comparison of the collected data against the HOCs and SSTLs (see Section 5.12.4).

Field based measurements and the T3 activity groundwater database will be uploaded to numerous servers on a frequent basis, which will facilitate additional reviews by senior Iluka and EMM staff.

5.12.3 External data validation

External checks are performed by non-Iluka personnel such as an external monitoring contractor and the analytical laboratory. Iluka will select one or more laboratories that are accredited by the Australian National Association of Testing Authorities (NATA). As such, each laboratory selected operates according to the guidelines set out in ISO/IEC 17025 - "General requirements for the competence of calibration and testing laboratories". Iluka will review the external laboratory QA/QC program as part of the laboratory selection process.

External laboratories should provide a QA/QC report with each batch of samples given. To avoid data entry errors, the laboratory should transcribe all data and reports electronically.

Iluka may undertake inter- and intra-laboratory testing as part of this GMP.

5.12.4 Data Management and Reporting

A summary of the data reporting requirements and timeframes are outlined in Table 11 and are discussed below.

All water monitoring and environmental data collected during the T3 activity, from automated and manual sources, will be stored and managed using Monitor Pro 5 (MP5; EHS Data, 2015). All MP5 data will sit within the Balranald Project server located at: Iluka Resources head office, located at St Georges Terrace, Perth, WA.

It will be the responsibility for the site environmental specialist to keep a field-based Excel database, which can be configured to the required MP5 format for easy upload. The internal validation process will most likely be undertaken on the Excel-based database and prior to MP5 upload and storage. The Excel database review will be conducted by the Supervising Hydrogeologist on a daily basis. Subsequent upload to the MP5 platform will occur weekly.

Automated dataloggers, which are not telemetric, will be downloaded on a weekly basis as a minimum and entered into MP5 within 24 hours of download.

All field-based worksheets, templates or similar will be captured in TRIM and uploaded to various servers at the end of each shift.

Groundwater level and water quality data will be compared to Balranald HOCs and SSTLs either on a daily basis or within 24 hours of receipt of laboratory data and/or download from automated dataloggers.

If a breach of the HOCs or SSTL occur, the procedure outlined by the Hydrogeological Trigger Action Response Plan or TARP (see Section 7), will be implemented.

In addition to the comparing the T3 activity data to the HOCs and SSTLs, additional comparisons will be made with the background data collected as part of the Balranald's GMEs. This more detailed assessment is likely to take place once the trial is completed and all data is collated. The T3 assessment report will be made available to both DPIE-Water and EPA, within six months of trial completion.

Table 5.7 Summary of Data Reporting Timeframes

Data Analysis and Reporting	Timeframe
Communication of field data results to either an Iluka Manager (email or verbal) or an Iluka appointed Hydrogeologist.	At the conclusion of each day in the field.
Entry of Field Data into the site-based MP5 Database or similar and comparison to SSTL.	Within 1 day of data being collected and entered into site Excel database.

Table 5.7 Summary of Data Reporting Timeframes

Data Analysis and Reporting	Timeframe
Review and Sign-off of Field Data by Iluka Manager / Hydrogeologist.	
Review and Sign-off of Laboratory Data by Iluka Manager/ Hydrogeologist.	Within 1 week of data being entered and outputs provided.
Entry of Laboratory Data into the site-based MP5 Database or similar and comparison to SSTL.	Within 2 days of receipt of the final laboratory reports.
Downloading of logger-based data and subsequently upload to MP5.	Downloaded weekly and uploaded to MP5 at the end of each shift.
All field based data sheets and templates.	Uploaded to Iluka server, EMM server and TRIM at the end of each shift.
SSTL breach report sent to DPIE-Water and EPA.	Within 3 days of all data being received and reviewed (see Section 7).
T3 Assessment Report sent to DPIE-Water and EPA.	Within 6 months of trial completion.

6 Groundwater modelling and ongoing validation

The T2 trial demonstrated that the mining process had minor hydraulic responses in comparison to re-injection, which forms part of the backfill process. Accordingly, the T3 numerical simulations focused primarily on the responses during backfilling.

The T3 prediction scenarios simulated backfilling of Stopes 4 to 6 assuming a backfill rate of 150 m^3/hr and using the modelled calibrated parameter set based on the previous T2 activity. This parameter set enhances the vertical conductance between the LPS and the overlying SFM in order to capture the mounding impacts observed in the SFM.

There is presently significant uncertainty associated with the predicted mounding within the SFM and LPS caused by the T3 activity. Characteristics contributing to uncertainty include:

1. Stope conditions prior to commencement of backfill.
    a) a large relatively open stope will facilitate backfill with minimal observable mounding impacts initially because there is a large highly conductive void space available, which facilitates rapid propagation of pressure along the stope; and
    b) a stope that has collapsed will have reduced void space and less ability to propagate pressure, which may result in large mounding impacts very early in the backfill process.
2. Integrity of the aquifer material above the stopes post-mining.
    a) if the aquifer material above the stopes remains cohesive then mounding impacts in the Shepperton are likely to remain minimal during backfill. There is a naturally occurring bentonite layer at the base of the Shepperton which confines the LPS facilitating artesian conditions with pressures well above surface level; and
    b) enhanced permeability of the bentonite layer above the mined stope may promote a rapid mounding response in the SFM, although the magnitude of this response will vary and depend on the ability of the SFM to dissipate the mounding pressure. Enhance permeability may occur for multiple reasons including slumping, weakening of material above the stope due to pressurisation during backfilling, historical exploration drilling and leakage around the annulus of monitoring and/or injection/mining bores.
3. Extraction at P2 could potentially mitigate the mounding impacts from backfilling, depending on timing and extraction rate from this bore. Likewise, Iluka may decide to extract groundwater from adjacent HBF bores as a means of managing mounding pressures during backfill stages.

Regardless of the inherent uncertainty in the current model, the prediction results still give some valuable insights to how the system may behave during the T3 activity. Referring to Figure 6.1 to Figure 6.4, notable responses are summarised below and site staff should be aware of such possible processes during the trial. To assist with interpretation, Table 6.1 summarises the bore locations which are assessed below and their distance from the nearest stope:

- the hydrographs show mounding in the SFM and LPS at specific bore locations. The three horizontal lines represent the surface level (brown), yellow (yellow) and red (red) SSTLs. The "open", "closing" and "closed" scenarios reflect different stope behaviour during backfill, with increasing difficulty of returning tailings to the voids. Backfill starts 10 weeks after siteworks commence. Note some scenarios overlie each other and the mounding contours show the modelled responses to a "closing" stope condition only, which represents the situation when the stope progressively becomes backfilled with tailings which decreases permeability over time;

- the hydrographs identify maximum mounding in the LPS at the points of injection (ie at the HBF bores). The hydrographs of monitoring points are in order of increasing distance from any stope (refer to Figure 5.1 and Table 6.1). Groundwater pressure increases within the SFM appear minimal despite significant hydraulic heads being simulated within the LPS, notably at HBF6-NTH;

- the modelled hydrographs also suggest that backfilling may cause less mounding response at the beginning of the backfill schedule, as indicated by responses simulated at HBF4-FE1, compared to the responses simulated at the end of the backfill schedule as indicated at HBF6-NTH. The modelled responses assume a constant backfill rate and may be required to reduce over time, as void spaces reduce and become increasingly filled with tailings;

- there appears to be very little East-West lateral propagation of mounding in the upper portion of SFM which can be regarded as the water table (Figure 6.3 and Figure 6.4, Layer 1) away from the stopes. The mounding propagation migrates along the stope in line with the regional gradient, which is from South-East to North-West. Mounding may show greater lateral extent in the upper SFM within the angle of draw of the void due to loss of cohesion in the overlying aquifer material;

- mounding associated with backfilling may appears to have limited observable effect at the water table with increasing distance from the stope;

- the lower (or deeper) portion of the SFM (Figure 6.3 and Figure 6.4, Layer 2) shows greater response to the injection into the LPS;

- there is potential for excessive mounding in the LPS if the stope voids collapse or have reduced conductivity from backfilling. Continued injection into a low conductivity stope could result in head pressures tens of meters above ground level. Regardless of stope initial behaviour, these conditions are very likely in the final stages of the backfill. Careful monitoring of VWP data and trends should provide adequate warning of rapidly increasing mound trends above the stopes;

- there is no observable impact to third party bore users extracting from the LRG. Full annual entitlement extraction Karra Homestead bore during 5 months of siteworks may cause a <0.1 m drawdown impact at HD1; and

- there are no identified GDEs that could be impacted by drawdown or mounding from the T3 activity.

Post-trial completion, a summary assessment report will be developed within 6-months as defined in Section 5.12.4. As part of this reporting phase, all data will be collated and assessed, which will provide valuable data to validate and possible recalibrate the numerical model. This process will further reduce uncertainty related to future model predictions.

Table 6.1 Bore locations relative to stopes

Bore	Screen	Distance to nearest stope (m)	Nearest Stope
HBF6-NTH	LPS (stope)	0	6
HBF5-MP1	LPS (stope)	0	5
HBF4-FE1	LPS (stope)	0	4
UGM-M12S	SFM	25	6
UGM-M12D	LPS	25	6
BH-M17S	SFM	75	6
BH-M17D	LPS	75	6
BH-M19S	SFM	125	6
BH-M19D	LPS	125	6
BH-M25S	SFM	250	6
BH-M25D	LPS	250	6

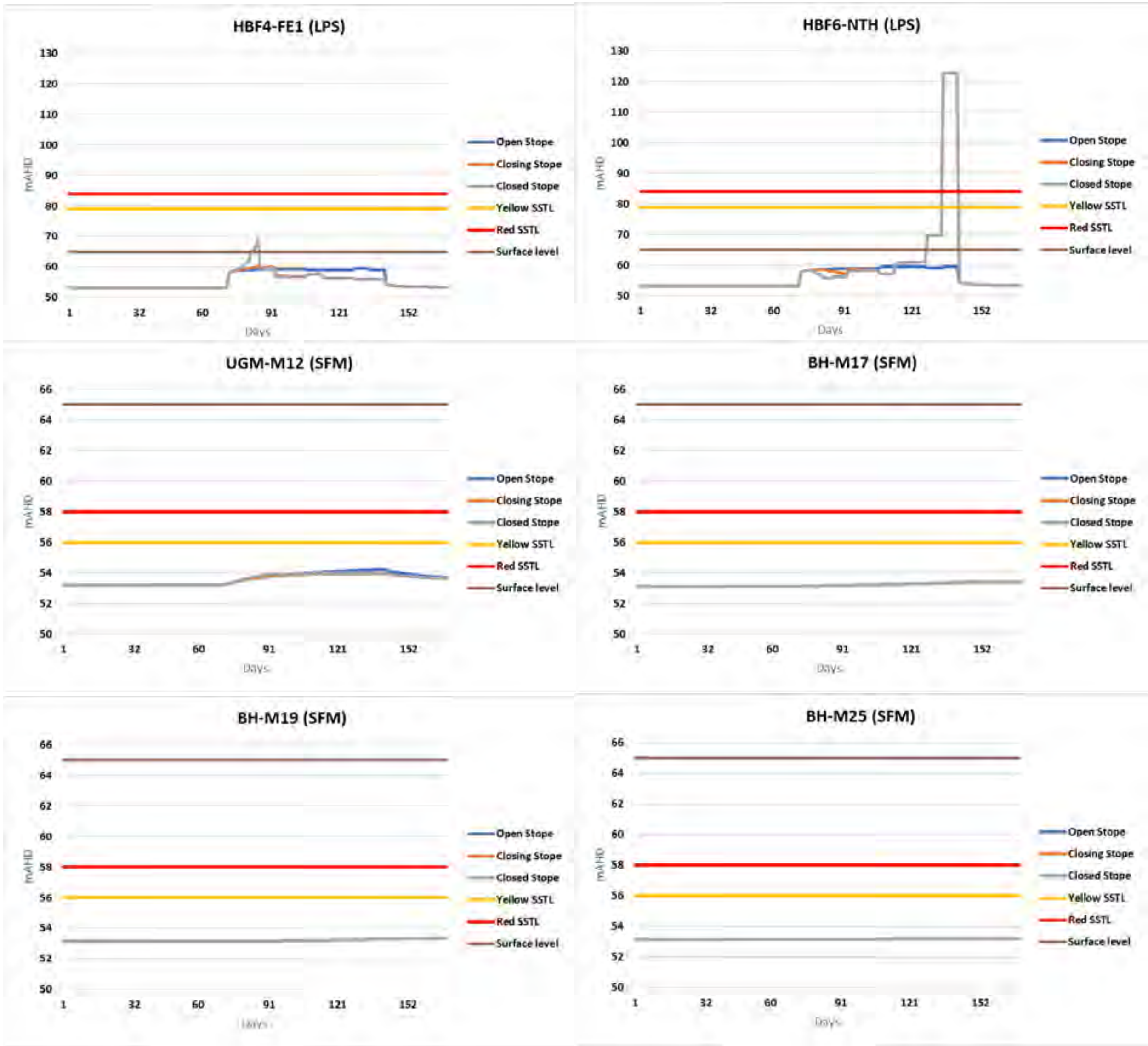


Figure 6.1 Modelled T3 activity hydrographs- HBF and SFM bores

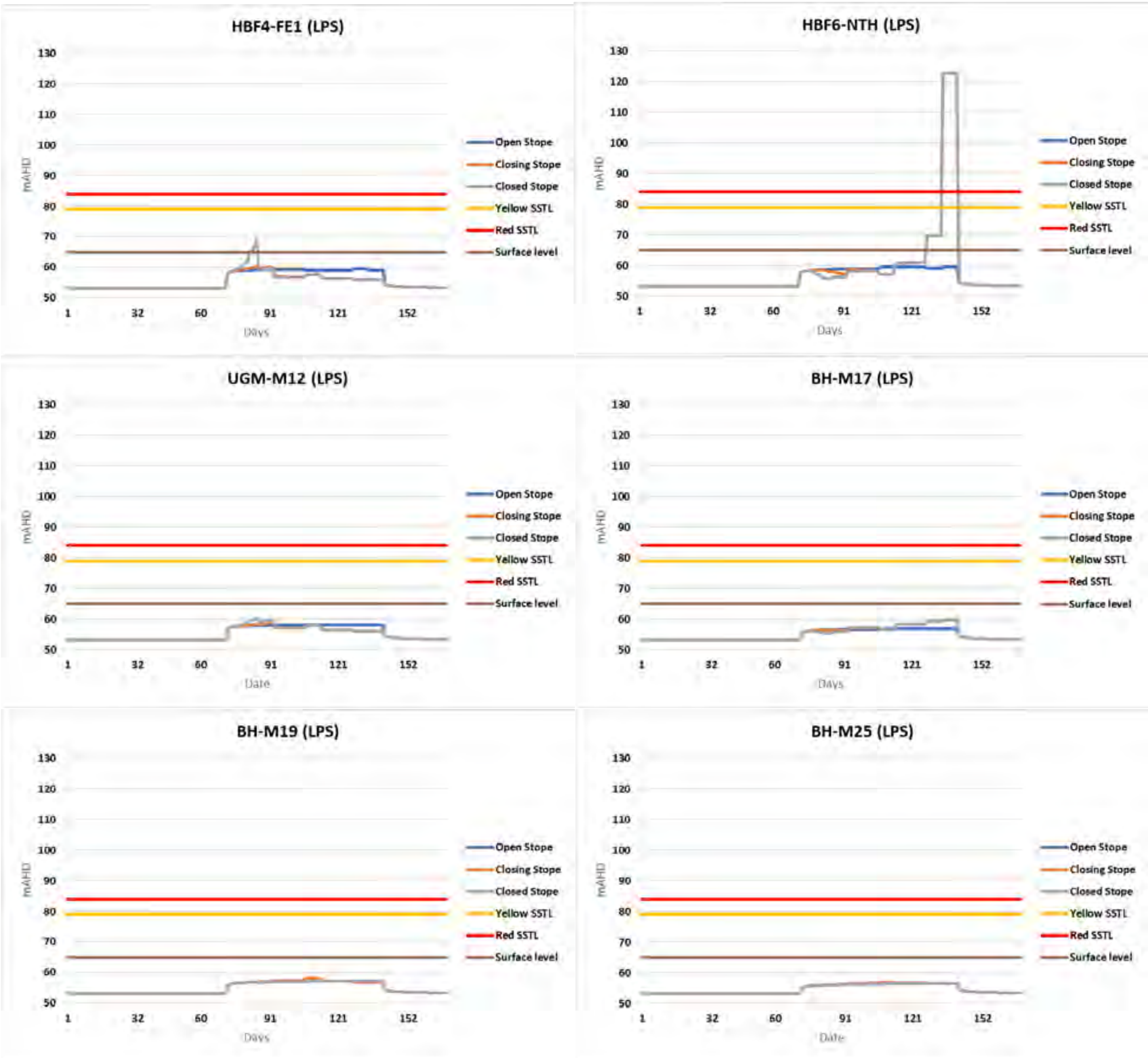
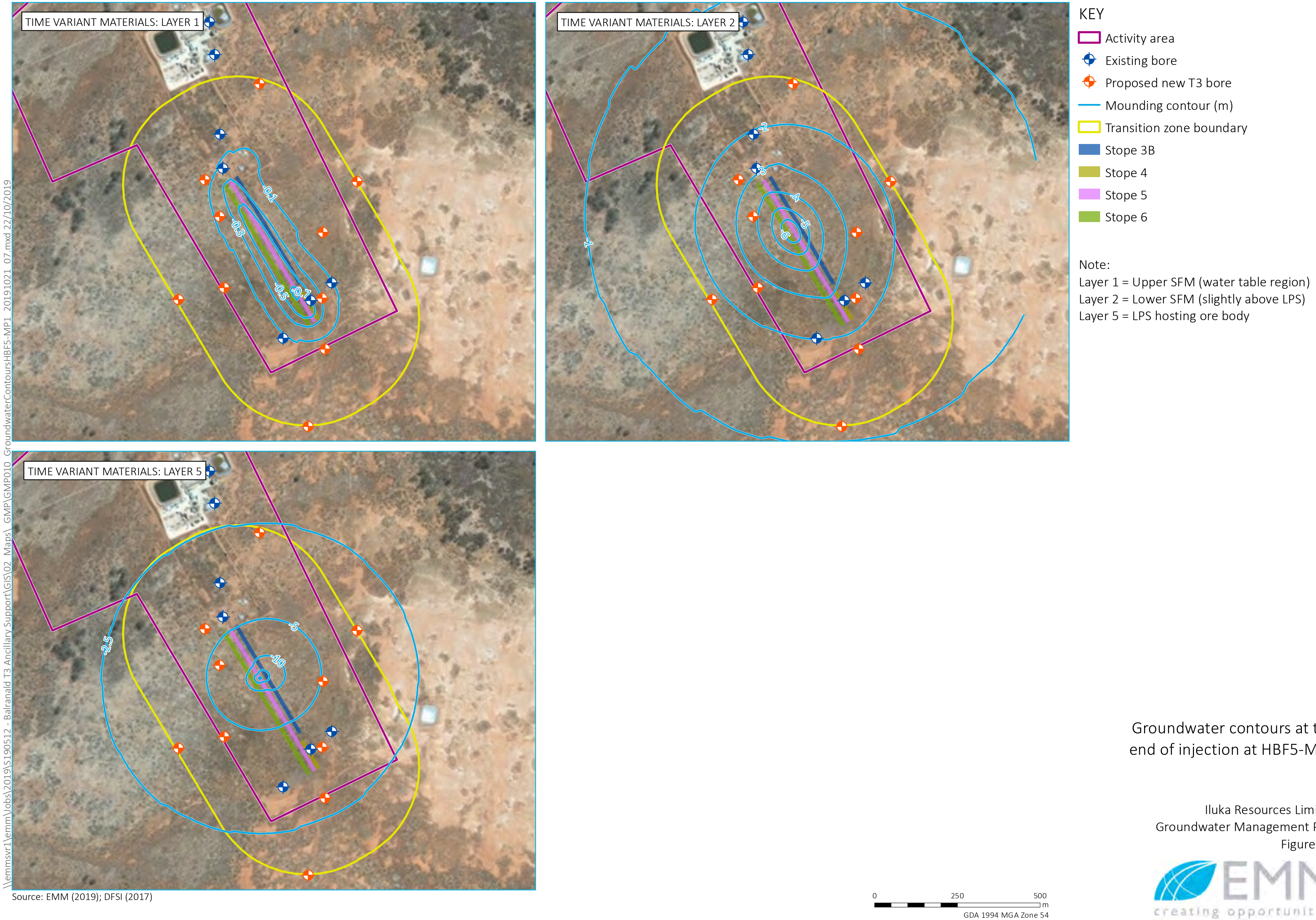


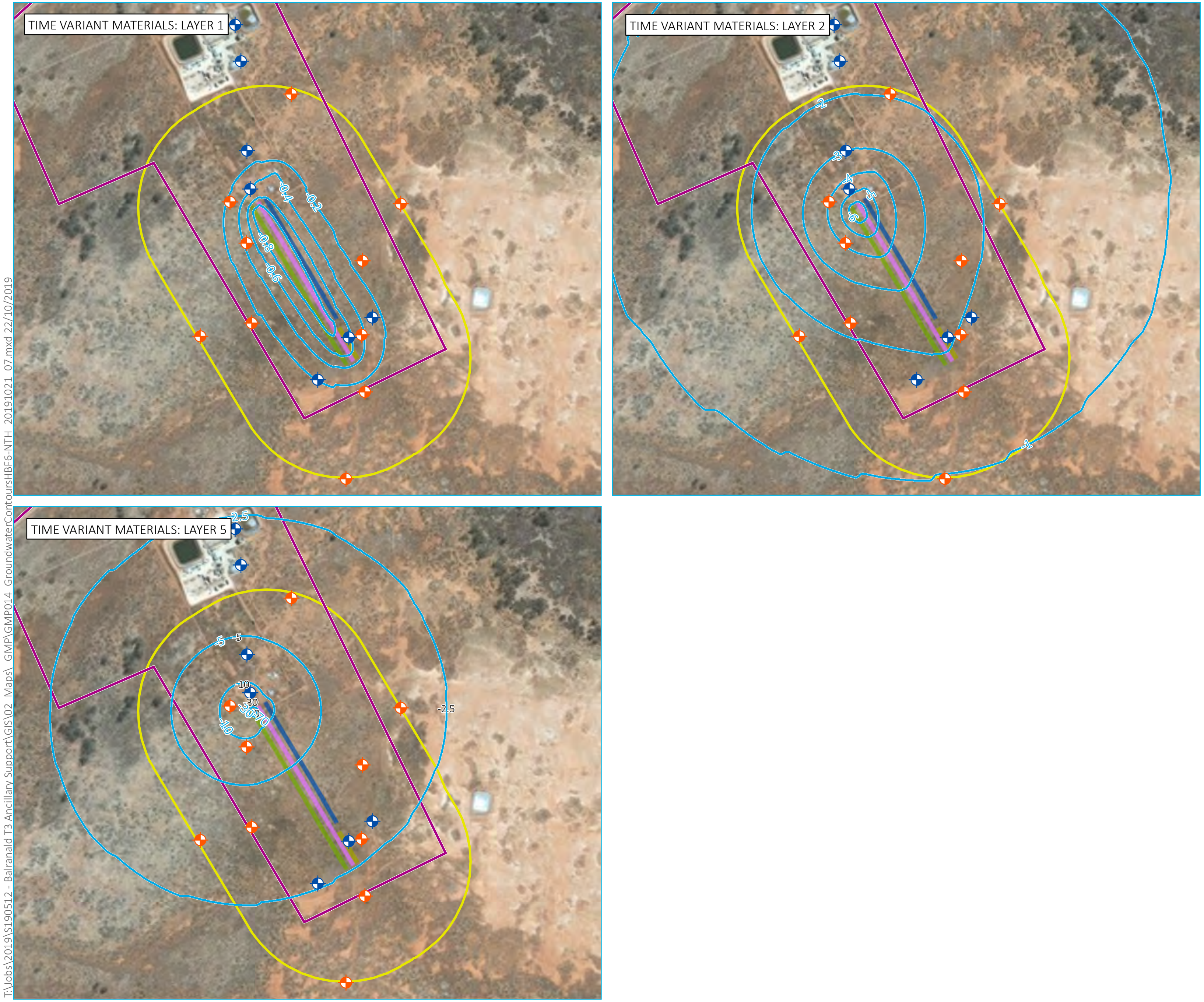
Figure 6.2 Modelled T3 activity hydrographs- HBF and LPS bores



Source: EMM (2019); DFSI (2017)

Groundwater contours at the end of injection at HBF5-MP1

Iluka Resources Limited
Groundwater Management Plan
Figure 6.3



Source: EMM (2019); DFSI (2017)

KEY

- Activity area
- Existing bore
- Proposed new T3 bore
- Mounding contour (m)
- Transition zone boundary
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

Note:
Layer 1 = Upper SFM (water table region)
Layer 2 = Lower SFM (slightly above LPS)
Layer 5 = LPS hosting ore body

0 250 500
m
GDA 1994 MGA Zone 54

Groundwater contours at the end of injection at HBF6-NTH

Iluka Resources Limited
Groundwater Management Plan
Figure 6.4

creating opportunities

7 Trigger action response plans and adaptive management

7.1 Trigger Action Response Plans

The approach to water and environmental management is defined by the Hydrogeological Trigger Action Response Plan (TARP). The recorded data is measured against a range of site specific trigger levels (SSTL) established to protect the groundwater resource as defined in Section 4. The type and urgency of management responses are triggered by SSTLs corresponding to a three-tiered management framework, defined in Table 7.1. This approach will allow for early and rapid intervention of possible groundwater.

Table 7.1 Hydrogeological Trigger Action Response Plan

Operating Range	Management Response
GREEN	The Green operating range indicates normal operation. Observed parameters are below the accepted SSTL range and impacts fall within acceptable limits. No action is required.
YELLOW	The Yellow operating range also indicates normal operating conditions but is designed to inform Iluka of possible future issues to allow time for adequate investigation and/or intervention. Observed parameters are marginally outside the accepted SSTL range, signifying action must be taken within 48 hours of infringement confirmation. Confirmation is defined by: • 24 hours of continuously recorded infringement in autonomous and telemetry collected data; • 2 daily consecutive infringements recorded in for-cause manual sampling; • ensuring pH of the PWD is within the acceptable range of 6.5 – 8.5. Checking both autonomous and field readings is required; and, • additional verification of the data, if required. This allows a suitable timeframe for any local variability associated with small saline slugs, or measurement error, to be delineated and confirmed. Actions associated with the operation of the T3 activity within the yellow monitoring threshold: • increasing monitoring frequency in order to assess trends and understand processes occurring; • revising the accepted SSTL range upon assessment of the impact on environmental values (to be completed with regulator consent); • reducing the mining/backfilling and/or groundwater abstraction rates until infringements are within Green monitoring threshold or have stabilized; and • depending on trends and if the red breaches are imminent, consider remediation action. After 72 hours of continued operation in this threshold from a water quality perspective, a notification report will be forwarded to DPIE Water and NSW EPA, ideally and prior to conditions breaching the Red operating range. Hydraulic breaches against the LPS HOC's are not considered breaches of compliance criteria. *Note, although the TARP only applies to bores located outside of the defined transition zone, all bore locations will be monitored and assessed during site activities as preventative measure to minimise the risk to SSTL breaches.*

Table 7.1 Hydrogeological Trigger Action Response Plan

Operating Range	Management Response
RED	The Red operating range indicates a breach of acceptable operating conditions. Observed parameters are above the Red SSTL, signifying action must be taken 12 hours after infringement confirmation. Infringement confirmation is defined by: • 24 hours of continuously recorded infringement in autonomous and telemetry collected date; • 2 consecutive infringements recorded in manual data; and, • Additional verification of the data, if required. Actions associated with the operation of the T3 activity within the red monitoring threshold, include those listed for the previous tier, with the addition of: • Modifying the T3 operations until infringements are within the Green or Yellow monitoring threshold or have stabilised; • Investigate the cause of the SSTL breach if not adequately understood; and • If necessary, develop and implement strategies to prevent future Red SSTL breaches or to mitigate any impacts caused by the SSTL breach. Iluka are committed to not adversely impacting sensitive receivers including the environment and 3rd party bore owners. If groundwater pressures adversely impact these receptors, make good provisions would apply as defined by the AIP (2012).

Note: The TARP only applies to bores located outside the 300 m buffer zone for the purposes of groundwater quality (see Section 4.2 and 5.2). As detailed in Section 4.1, the TARP does not apply to the HOC associated with the LPS, which will be managed by an adaptive management process.

7.2 Adaptive Management Philosophy

The approach to management of groundwater during T3 activities will be adaptive. The adaptive management approach will allow for the use of the monitoring data to address the risks and impacts to the groundwater system and allow immediate change in management and/or activities as may be required. By incorporating this flexibility into this plan Iluka will be able to adjust the site operations and or monitoring program (such as sampling frequency) in response to information gained from the monitoring data collected during the T3 activities. This is especially the case for developing flexible operational hydraulic triggers, which will vary along the orebody/strike due to the inherent heterogeneity within the subsurface system.

8 References

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Appendix A

Balranald Bulk Samping Activities - Historical Groundwater Assessment and Summary Report (October 2019)

Historical Groundwater Assessment and Summary Report

Bulk Sampling Activity

Prepared for Iluka Resources Limited

October 2019

EMM

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Balranald Bulk Sampling Activities

Historical Groundwater Assessment and Summary Report

Prepared for Iluka Resources Limited
October 2019

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Balranald Bulk Sampling Activities

Historical Groundwater Assessment and Summary Report

Report Number

S180539 RP2

Client

Iluka Resources Limited

Date

22 October 2019

Version

v2 Final

Prepared by

William Bull
Environmental Engineer
22 October 2019

Joel Georgiou
Associate Director
22 October 2019

Approved by

Paul Gibbons
Associate Director
22 October 2019

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1 Introduction

1.1 Document purpose

This historical groundwater assessment and summary report has been prepared to compliment the Groundwater Management Plan (GMP) which aims to manage potential groundwater risks associated with the T3 activity and considers all the requirements outlined by the Development Consent (DP&E 2016). The intent of this report is to summarise the main hydrogeological and hydrogeochemical assessments undertaken to date and address the comments made by the Department of Planning, Industry and Environment – Water (DPIE Water) on the previous GMP (Reference number OUT18/6975). Table 1.1 summarises the review comments received from DPIE Water and the sections within this document which provide information related to these comments.

Table 1.1 DPIE Water comments

Number	Comment	Relevant section
1	Provisions to supply water to potentially impacted parties, if required during the T3 bulk sampling activity, needs to be included within the GMP.	3.6
2	Greater analysis is required to demonstrate how the trigger levels adjacent to the activity protect the regional aquifer and sensitive receptors at some distance from the activity.	4
3	A water balance for groundwater needs to be included within the GMP.	5
4	Baseline groundwater level data should be made available to the department.	3.1
5	Information relating to privately-owned groundwater bores and the on-site production bores 'P2' and 'Karra Bore' needs to be included, such as location, construction, lithology as they are referred to frequently. In addition, a map is required to illustrate the relative location of these bores with respect to the extent of drawdown.	2.1
6	Explanation of how the green trigger levels for water quality were established is required.	3.2
7	Further assurance in the definition of the trigger values of early warning bores is required. Additional analysis is to be included to demonstrate that if trigger levels are managed to, then the impacts to the regional aquifer and sensitive receptors will be protected.	4
8	Include trigger levels and management responses for the Process Water that will be re-injected.	3.4
9	Remediation of the aquifers should be considered as a management response if it is ever required.	3.6
10	Describe how the T3 monitoring program fits into the broader monitoring program – DPIE Water is concerned about the post-activity monitoring frequency.	2.2
11	The GMP will need to be updated prior to the commencement of the full-scale operation in consultation with DPIE Water.	7
12	The department does not accept the changed trigger levels for a number of water quality parameters. All proposed changes to trigger levels must be undertaken in consultation with the Department, as they are part of the GMP.	3.3
13	All monitoring bores must be developed to a standard that allows the collection of water samples that reflect the aquifer. Evidence of adequate bore development must be provided to the Department.	2.3
14	Groundwater sampling methodology is recommended to be added as an appendix of the Groundwater Operating and Management Strategy.	N/A[1]

Table 1.1 DPIE Water comments

Number	Comment	Relevant section
15	Compliance reports on groundwater management should include a summary of the sampling methodology used at each site, and a validation of the monitoring field procedures and data processing quality assurance, quality control programs.	6
16	Consider the monitoring and management of deeper-rooted vegetation in the context of groundwater mounding in the next iteration of the Groundwater Operating Strategy for the full-scale operation.	7
17	It is requested an update to the Groundwater Operating Strategy be provided for comment 6 months prior to commencement of full-scale operations and prior to commencement of other activities that may impact groundwater, eg further bulk sampling activities.	7
18	Where reference is made to groundwater works with Iluka reference numbers for production bores, reinjection bores, reinjection bores, or monitoring bores, a table is requested to include the corresponding licence/approval number under water legislation where applicable.	2.1

Note: 1. To be attached to the GMP, not relevant to this document.

1.2 Overview

On 5th April 2016 Iluka Resources Limited (Iluka) was granted Development Consent under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for a mineral sands mine in south-western New South Wales, known as the Balranald Mineral Sands Project (the Balranald Project). The project was assessed and approved as State Significant Development 5285 (SSD-5285).

The Balranald Project includes construction, mining, primary processing and rehabilitation of two linear mineral sand deposits, known as the West Balranald and Nepean deposits located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald (Balranald town), respectively (Figure 1.1).

The Balranald Project included undertaking a bulk sampling activity (the activity) at the West Balranald deposit to test the selective in-situ removal of up to 100,000 tonnes (t) of ore.

1.3 The activity

The activity is an unconventional mining method to test the selective in-situ removal of mineral ore and reflects a continuation of a smaller bulk sampling activity (known as T1) undertaken by Iluka during Q1-2015 and Q1-2016 in accordance with approval under Part 5 of the EP&A Act from NSW Trade & Investment, Resources & Energy (Reference OUT13/28341 and OUT15/27702).

The activity commenced under SSD-5285 in Q2-2016 and Q3-2016 and successfully extracted approximately 6,400 t of ore from three stopes (referred to as Stopes 1B, 3 and 4) and backfilled approximately 700 t of mining of ore (known as T2). Iluka placed the activity site into care and maintenance during 2017 and 2018 to review the mining and environmental monitoring outcomes.

Iluka now propose to recommence unconventional mining (known as T3) to trial the selective in-situ removal of the remaining 93,600 t of ore approved under SSD-5285. The objectives of T3 are to determine whether the unconventional mining method can:

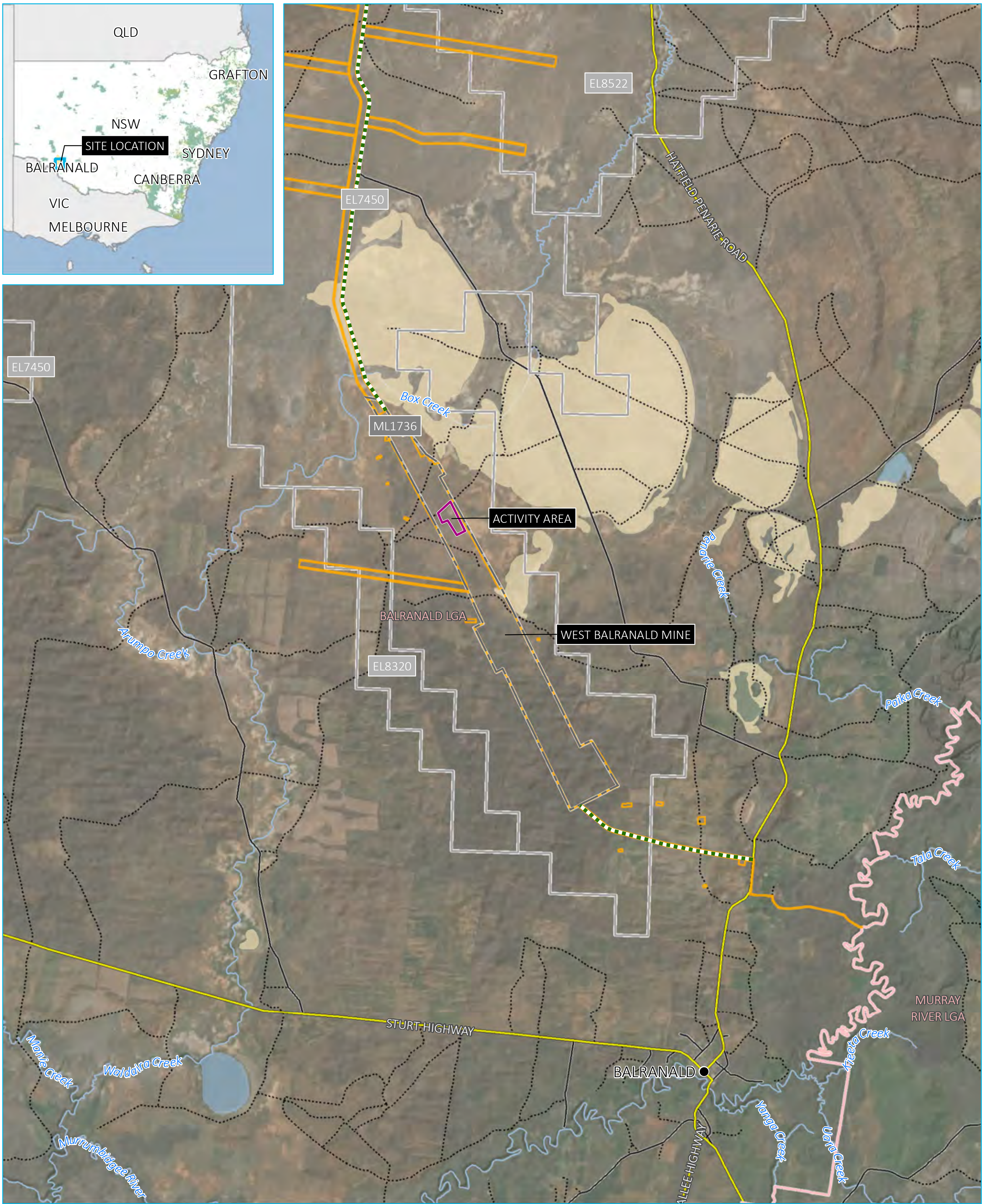
- sustain production over a larger sample set (ie longer and multiple stope length);

- backfill process to deliver a mining by product management strategy; and
- further validate groundwater and subsidence impact response prediction models.

T3 will create up to three additional underground cavities (referred to as Stopes 5, 6 and one of either the remainder of Stope 4, or 3B), each with an approximate volume of 21,000 cubic metres (m^3) in volume, located approximately 65–69 m below the natural surface level. The overburden typically comprises sands, clayey sands and clay layers with minimal or not continuous induration or rock.

The activity site is located entirely within the disturbance footprint of the West Balranald mine, including the area of the open cut pit. As such, all land disturbed by the activity will eventually be subsumed by mining of the West Balranald mine (Figure 1.2).

T3 activities are scheduled to commence in Q4, 2019.



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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 5 10 km

GDA 1994 MGA Zone 54

N

KEY

- Activity area
- Project boundary
- Place
- Access road
- Mining Lease 1736
- Iluka mineral tenement
- Main road
- Local road
- Vehicular track
- Named watercourse
- Perennial lake
- Ephemeral lake
- Local government area

Regional location

Iluka Resources Limited
Groundwater Management Plan
Figure 1.1

EMM
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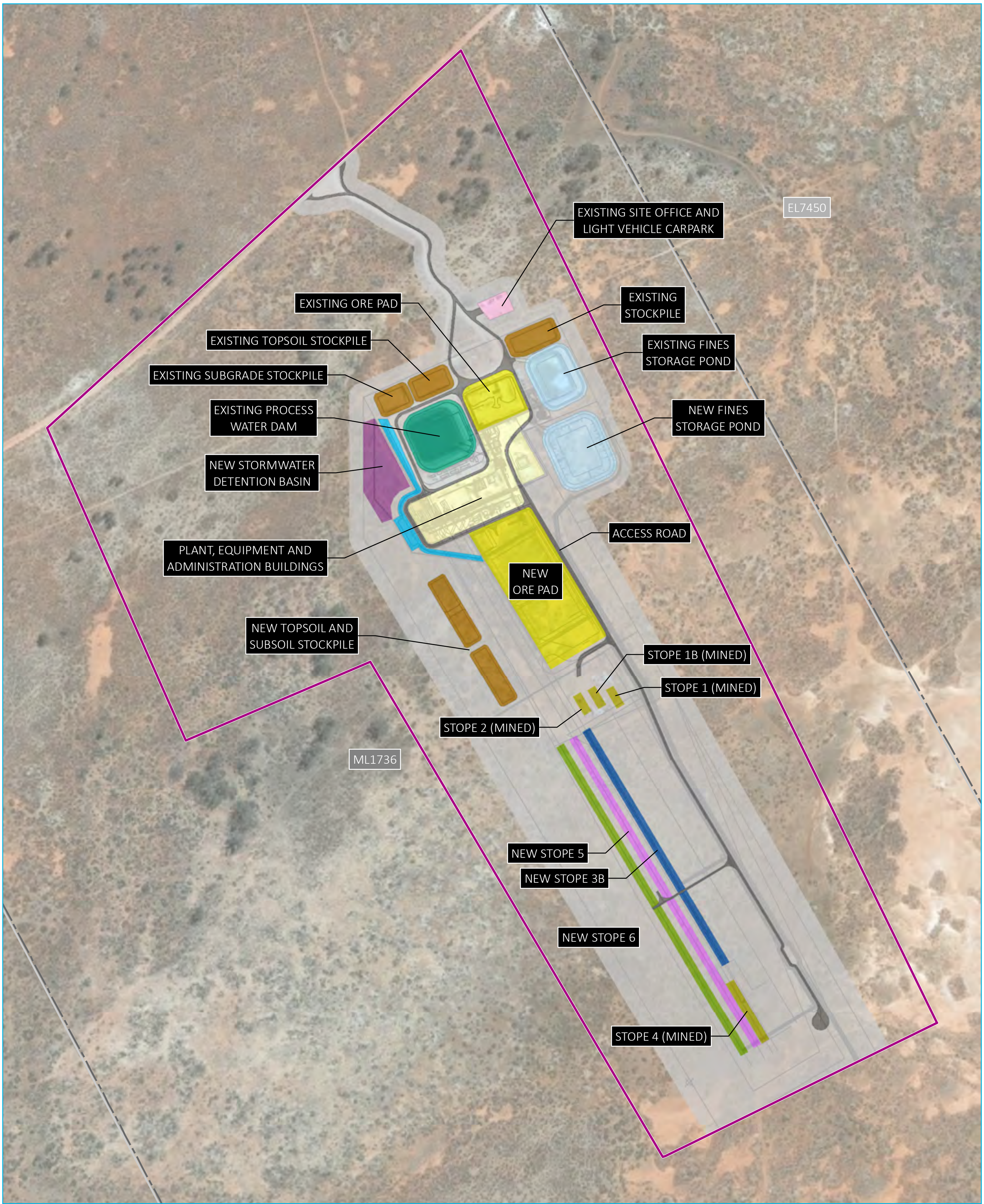

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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 100 200 m
GDA 1994 MGA Zone 54
N

KEY

Activity area
Mining Lease 1736
Iluka mineral tenement

Indicative site layout
Access road
Activity footprint
Existing site office and light vehicle carpark
Fines storage pond
Ore pad
Plant, equipment and administration buildings

Process water dam
Spoon drain
New stormwater detention basin
Stockpile
Stope (mined)
Stope 3B
Stope 5
Stope 6

Site map

Iluka Resources Limited
Groundwater Management Plan
Figure 1.2

creating opportunities

1.4 Mining approach and hydrostratigraphy

The unconventional mining method uses Horizontal Directional Drilling (HDD) principles and remote access to sequentially and at times simultaneously, extract heavy mineral (HM) ore hosted within the Loxton Parilla Sand aquifer (LPS), and hydraulically backfill the tailings slurry into the mine voids. Key components of how the HDD mining method may interact with the local hydrostratigraphy is illustrated in a series of figures for the pre-mining, mining, backfilling and post mining phases below.

1.4.1 Pre-mining

Referring to Figure 1.3:

- the ore is hosted within the marine deposited LPS, generally located below the LPS1 package and within the LPS2 package;
- overlying the LPS is the Shepparton Formation (SFM) which was deposited within a fluvial-lacustrine environment. The SFM consists of sand-clay to clay sediments with bands of fine grained sand. The base of this unit was often defined by a ferricrete/lateritic horizon and bentonite. The unit was consistently 30 to 35 m thick throughout the trial sites;
- high grade ore consisting of predominantly ilmenite, are approximately 5 m thick and are located approximately 70 mBGL; and
- the water table is hosted within the SFM at approximately 14 mBGL. The LPS potentiometric surface is also measured at around 14 mBGL, and thus the LPS is confined at the Site.

1.4.2 Mining phase

Referring to Figure 1.4:

- increased pressure within the LPS may occur during the mining phase, a consequence of injecting high pressure water into the mine stope to facilitate the mining process. The pressure increase and subsequent recovery, is likely to be rapid due to the confining nature of the LPS aquifer; and
- pressure responses within the SFM should remain insignificant if a sufficient aquitard exists between the SFM and the underlying LPS. However, pressure increases within the SFM could occur in areas where a hydraulic connection occurs between the SFM and underlying LPS aquifer.

1.4.3 Backfill phase

Referring to Figure 1.5:

- backfilling activities may result in significant pressure responses within the LPS, a consequence of injecting tailings into the mined cavity initially, with pressure responses propagating throughout the aquifer thereafter. The amount of pressure build-up is also dependant on the aquifers transmissivity, which may vary significantly along the strike;

- backfilling activities should not result in significant pressure responses within the SFM if a sufficient aquitard exists between the SFM and LPS. This is generally represented by multiple clay horizons within the SFM itself and commonly by a highly plastic clay unit located at the base of the SFM which represents naturally occurring bentonite along with the occasional ferricrete; and

- pressure responses (both drawdown to supply process water and mounding due to mining / backfilling) are expected to be rapid, due to the confining and semi-confining nature of the LPS and SFM respectively.

1.4.4 Post-mining phase

Referring to Figure 1.6, the post mining pressure responses within the LPS are expected to recover to, or close to, the pre-mining groundwater pressure levels. Depending on the level of backfilling achieved and thus the in-situ material density of the final stopes, final LPS groundwater pressures in close proximity of the stopes may be more subdued than the pre-mining levels. This would be caused by an area of the LPS which would exhibit higher transmissivities and larger porosity, compared to its pre-mining state.

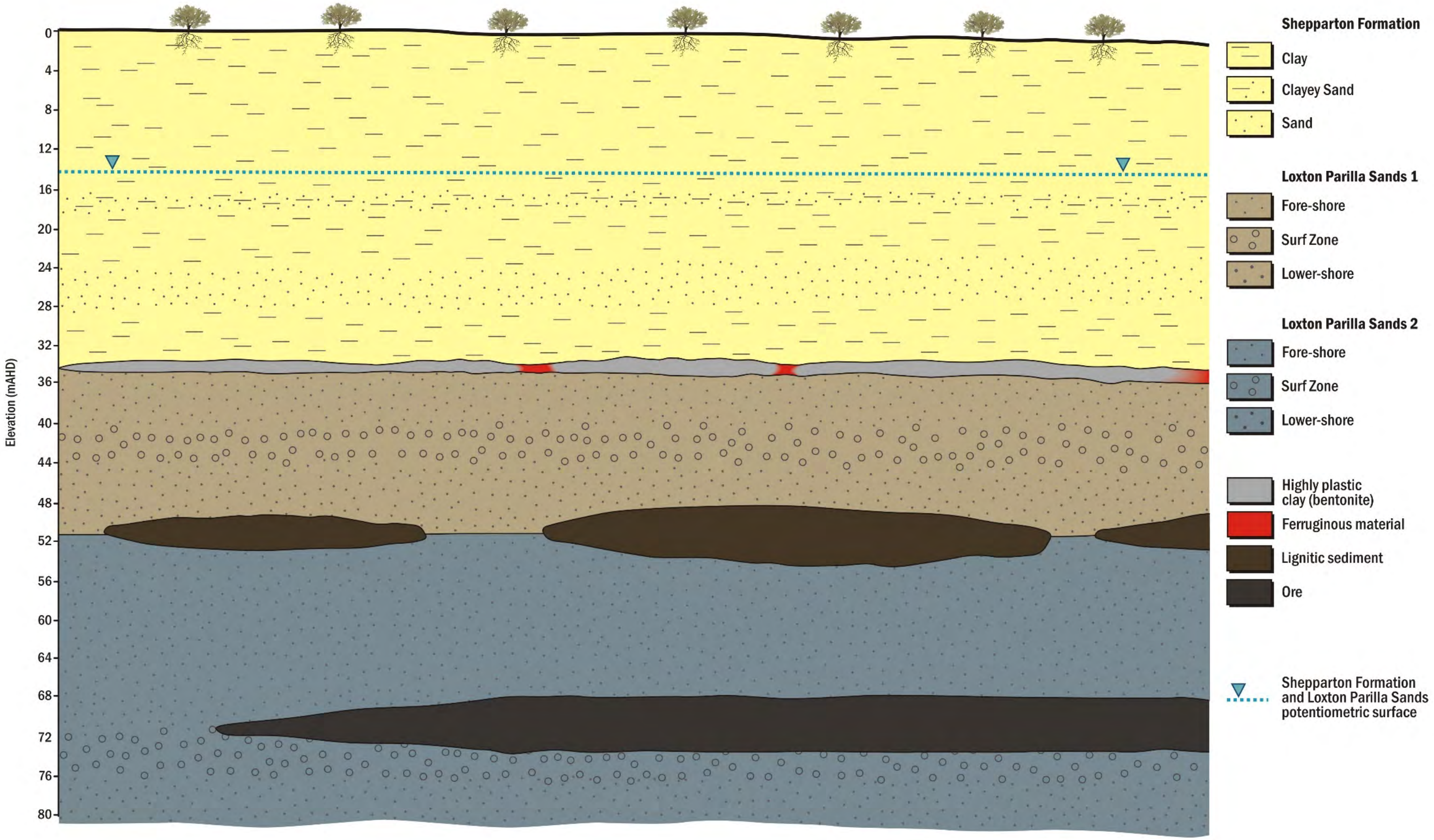


Figure 1.3 Hydrostratigraphy and pre-mining conditions

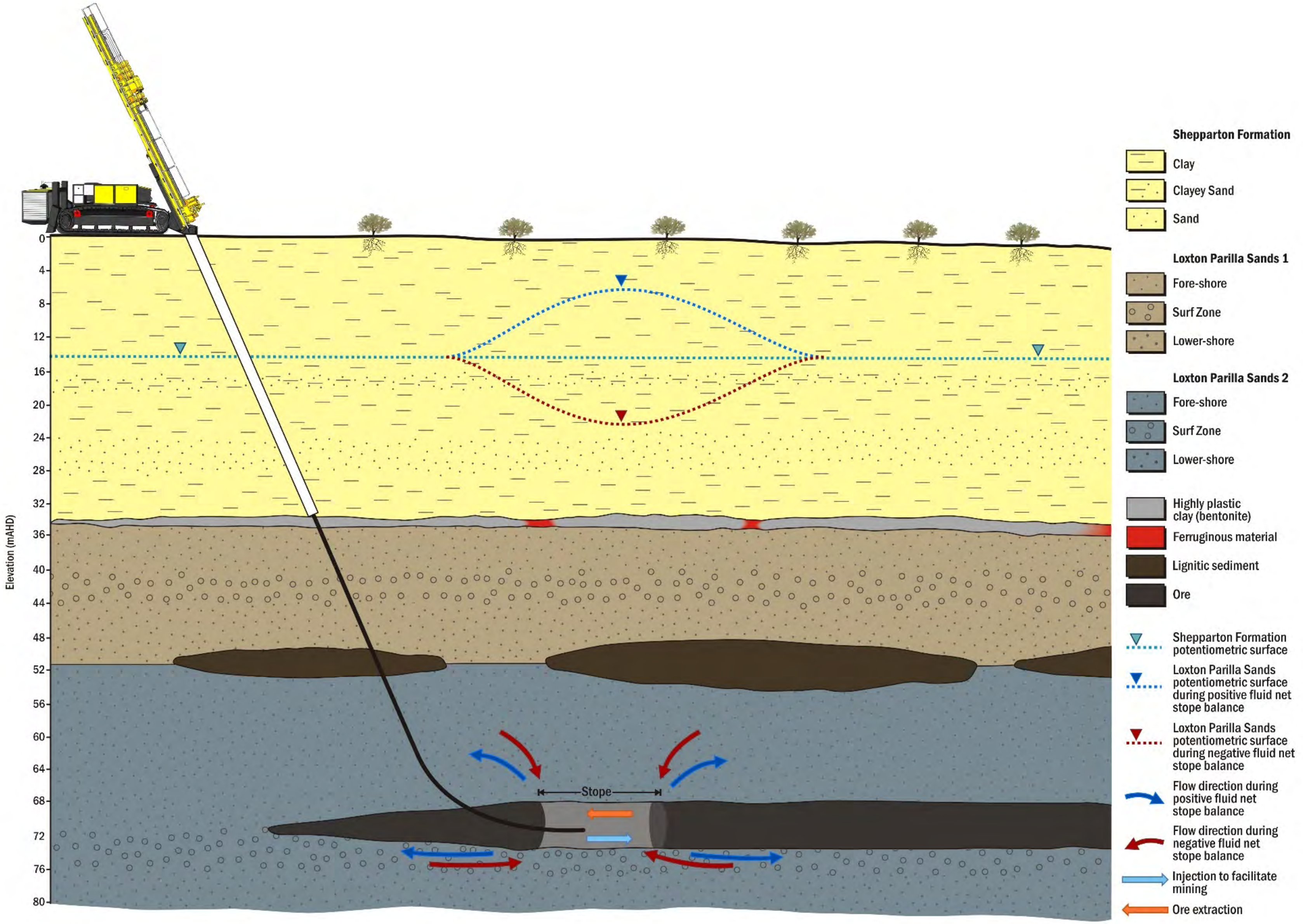


Figure 1.4 Mining phase

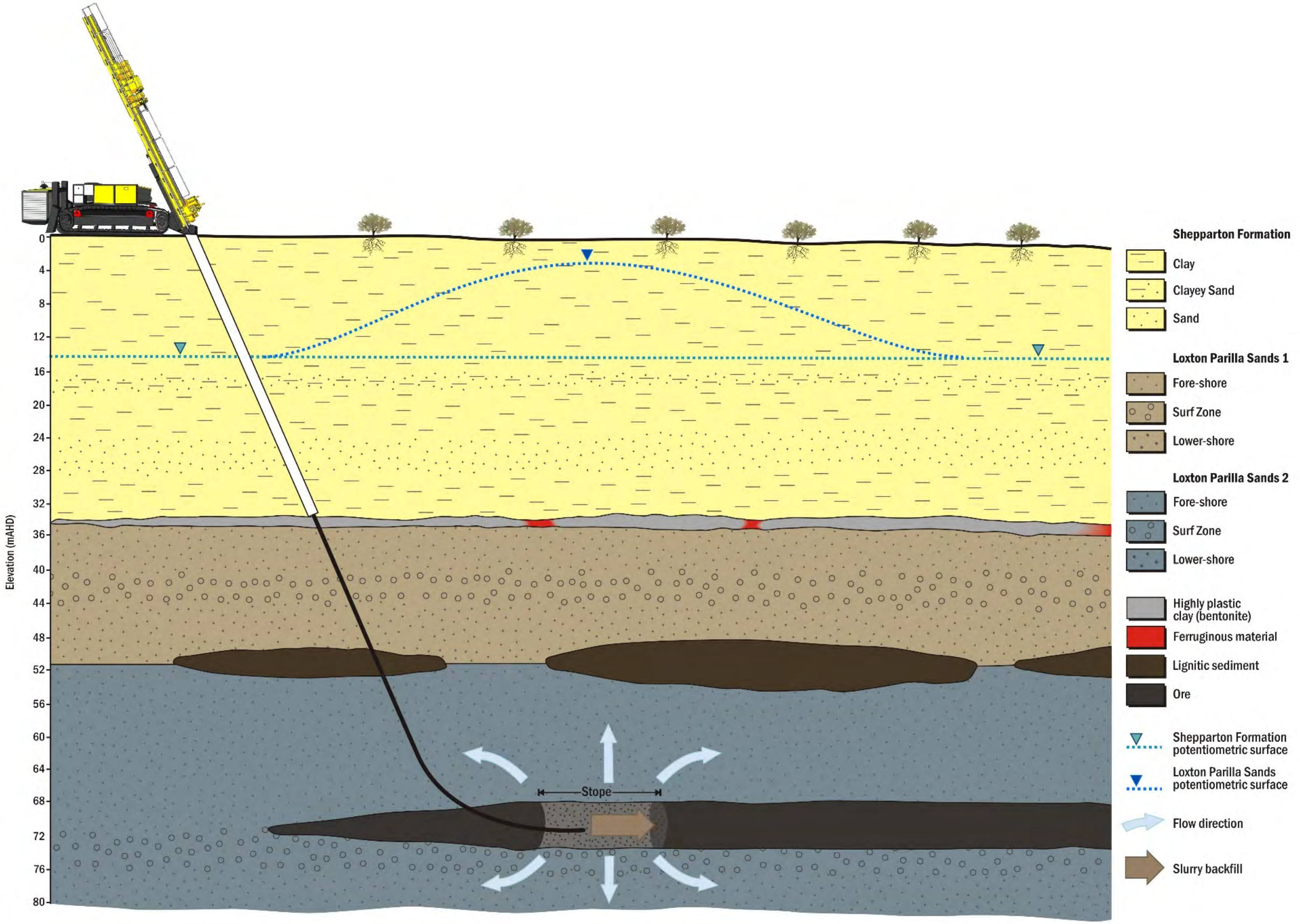


Figure 1.5 Backfill phase

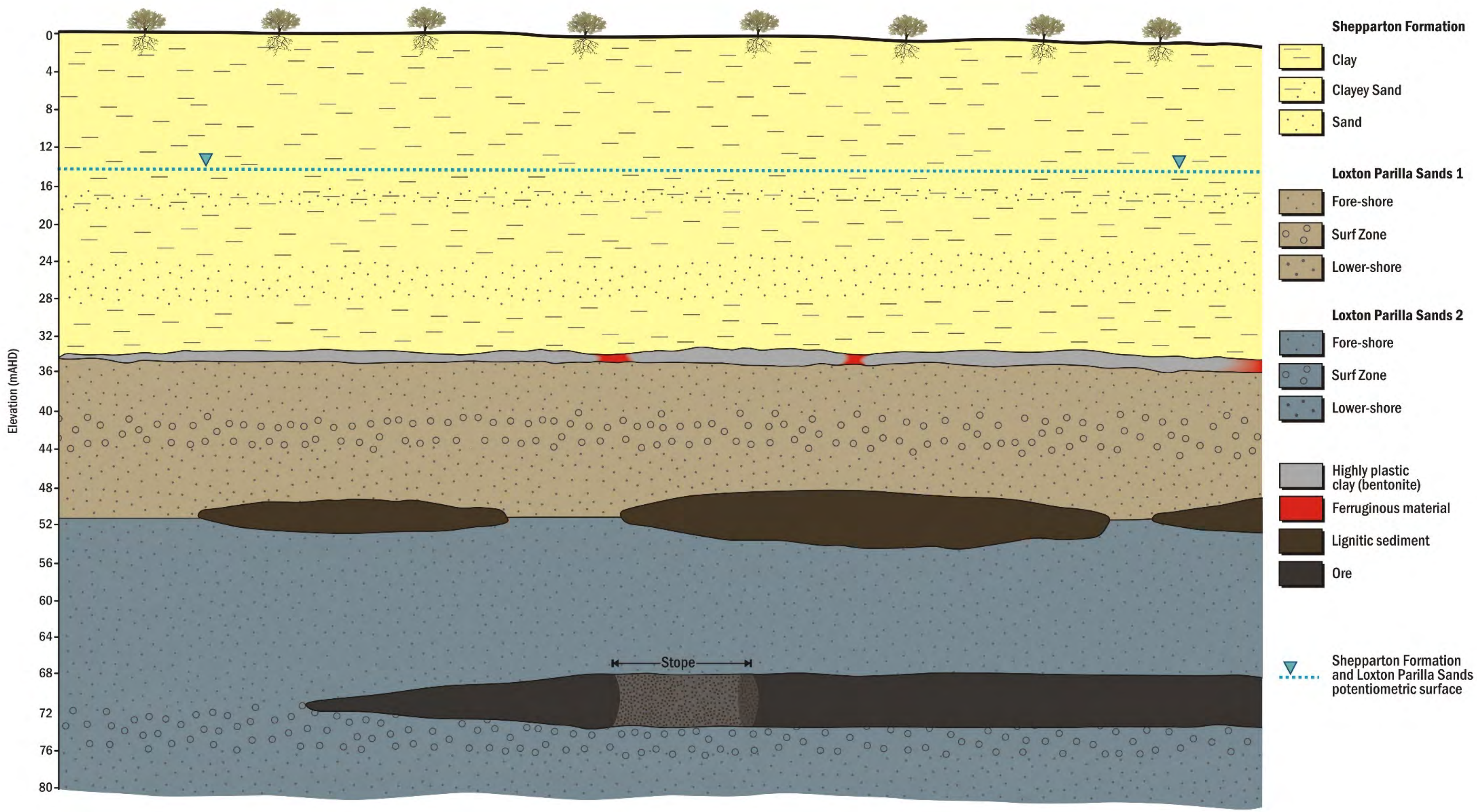


Figure 1.6 Post mining conditions

1.5 Planned T3 schedule

Figure 1.2 shows the planned site layout for the T3 activity. The largest changes to the T3 site layout compared to T2 includes:

- a new fines storage pond;
- a new larger sand and ore pad; and
- the inclusion of stope 5 and stope 6.

A preliminary mining and backfill schedule is shown in Figure 1.7 below, with the following noted:

- Stope 5 and 6 are the planned stopes to be mined and backfilled. Stope 3B will be a contingency;
- each stope measures approximately 500 m long and between 10 to 20 m wide;
- stopes will be mined over an approximate period of 7 weeks, assuming no operational delay;
- mining will occur from the south to north per stope, and the expected order is shown in Figure 1.7;
- hydraulic backfilling of tailings will commence after approximately 10 weeks of site operation; and require approximately 10 weeks to complete; and
- total site preparation, mining and backfill period will last approximately 20 weeks, again assuming no operational delays.

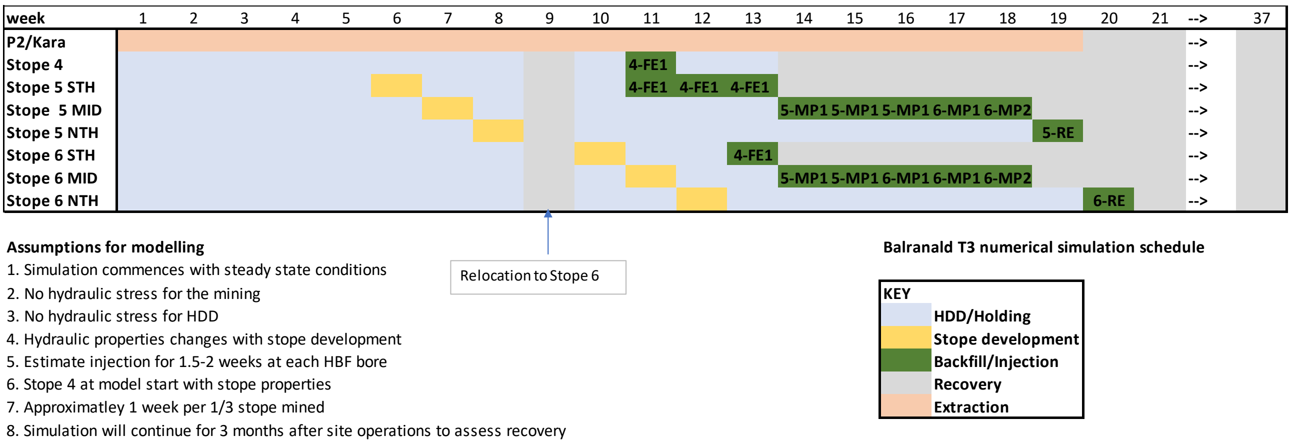


Figure 1.7 Preliminary mining schedule for T3 trial

2 Monitoring Bore Network

2.1 Overview

The existing Balranald bore network, including near-mining monitoring bores, regional monitoring bores, third party bores and process water abstraction bores is listed in Table 2.1. To meet the monitoring objectives for the T3 trial (outlined in Section 2.2), installation of some additional monitoring bores is proposed as outlined in Table 2.2., Figure 2.1 and Figure 2.2 show the broader Balranald monitoring network which are sampled as part of the groundwater monitoring events (GMEs), and the local T3 monitoring network respectively. The planned hydraulic backfill (HBF) bores for the T3 trial are also included in Table 2.2 and Figure 2.2.

The construction details for the production bores, P2 and the Karra Homestead bore, are summarised in Table 2.3 and the lithology logs for these bores are presented in Appendix A.

Table 2.1 Existing monitoring bore network

Well ID	Licence number	Easting	Northing	SFM screen interval (mBGL[1])	LPS screen interval (mBGL)	Category
UGM-M1	60BL216700	723166	6189938	15 - 18	71 - 77	near mining
UGM-M2	60BL216700	723332	6189842	25 - 28	68 - 71	near mining
UGM-M4	60BL216700	723348	6189745	24 - 27	71 - 77	near mining
UGM-M5	60BL216700	723478	6189409	26 - 29	66 - 72	near mining
UGM-M6	60BL216700	723373	6189400	20 - 23	68 - 71	near mining
UGM-M7	60BL216700	723425	6189454	29 - 32	74 - 77	near mining
UGM-M8	60BL216700	723364	6189505	26 - 29	66 - 72	near mining
UGM-M10	60BL216700	723380	6189381	30-33	71 - 77	near mining
UGM-M11	60BL216720	723591	6189038	15 - 18	74 - 77	near mining
UGM-M12	60BL216720	723609	6189009	15 - 18	74 - 77	near mining
UGM-M13	60BL216720	723630	6188974	15 - 18	74 - 77	near mining
UGM-M14	60BL216720	723649	6188941	15 - 18	71 - 77	near mining
UGM-M15	60BL216720	723555	6188886	15 - 18	74 - 77	near mining
GW036673 (1)	n/a	711680	6189281	32 - 37	n/a	regional
GW036866 (1/2)	n/a	734900	6203463	21 - 27	52 - 58	regional
SHOB03	60BL216540	724911	6186351	17 - 23	n/a	regional
SHOB04	60BL216539	723695	6189033	16 - 22	n/a	regional
WB41	60BL216632	720596	6194488	n/a	35 - 77	regional
WB42	60BL216625	720599	6194491	23 - 27	n/a	regional
WBGT3	n/a	724880	6186352	n/a	76 - 82	regional
WBGT4	n/a	723703	6189063	n/a	76 - 82	regional
LPSPB03	60BL216540	724893	6186351	n/a	62 - 72	regional

Table 2.1 Existing monitoring bore network

Well ID	Licence number	Easting	Northing	SFM screen interval (mBGL[1])	LPS screen interval (mBGL)	Category
LPSPB04	60BL216539	723702	6189053	n/a	58 - 70	regional
WB1	60BL216637	730399	6175412	22 - 28	n/a	regional
WB2	60BL216621	730402	6175415	n/a	52 - 100	regional
WB5	60BL216646	730450	6175489	n/a	96 - 102	regional
WB7	60BL216621	729924	6176754	15 - 31	n/a	regional
HD1	n/a	726021	6185781	n/a	225 - 235 (LRG)	third-party
T01	n/a	722791	6201032	n/a	208 - 216 (LRG)	third-party
T02	n/a	729728	6195981	n/a	176.5 - 185 (LRG)	third-party
T03	n/a	732044	6189404	n/a	204 - 210 (LRG)	third-party
Karra Homestead Bore	60WA583109	720430	6188310	n/a	218.3 - 230.3 (LRG)	third-party/process water
P2	60WA583169	723191	6189730	n/a	57 - 81	process water

Notes: 1. mBGL: Metres below ground level
2. SFM: Shepparton Formation Aquifer
3. LPS: Loxton-Parrilla Sands Aquifer
4. LRG: Lower Renmark Group Aquifer

Table 2.2 T3 activity monitoring network

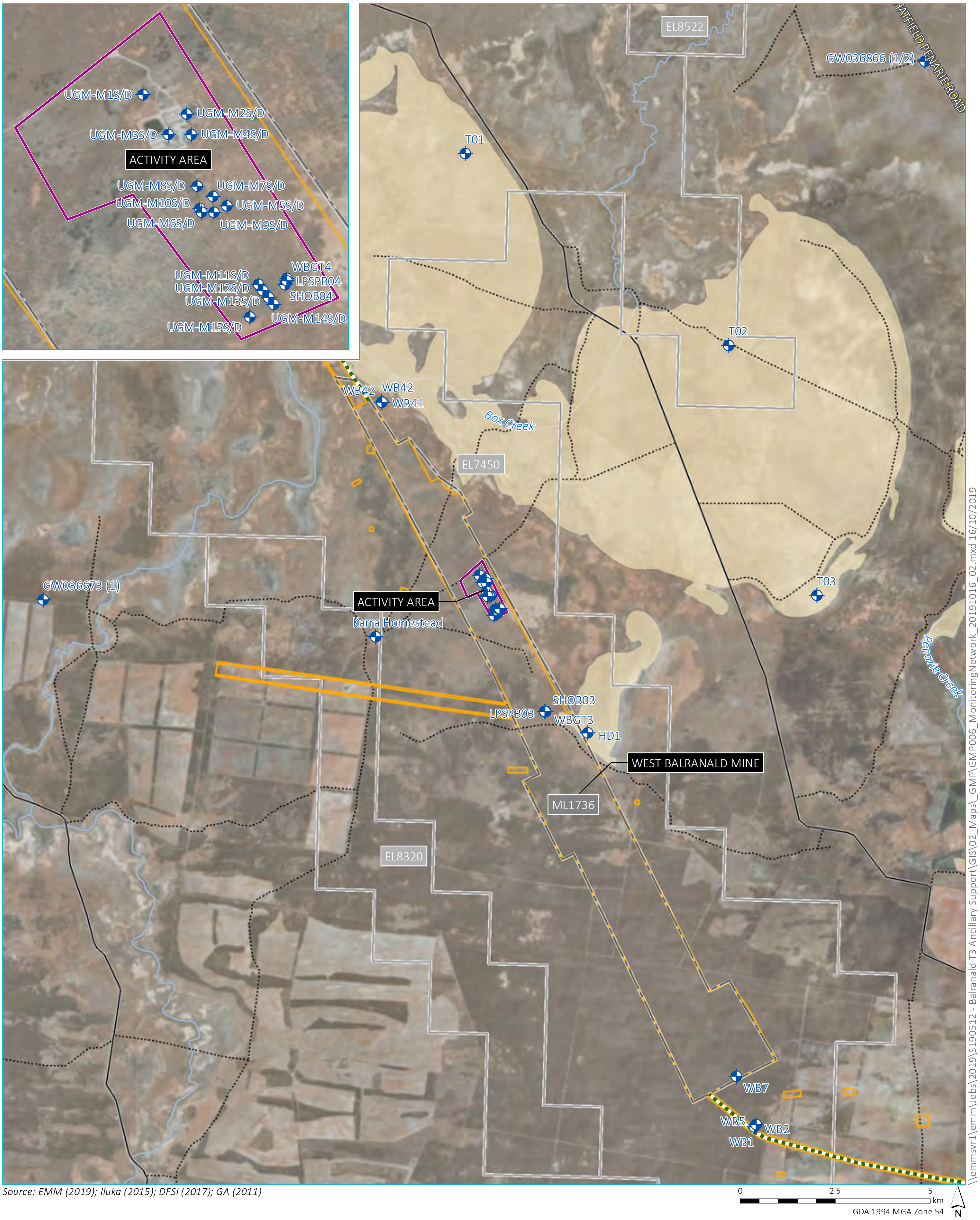
Well ID	Easting (m)	Northing (m)	Status	Screen	SSTL zone
UGM-M01	723217	6189938	existing	SFM/LPS	3 (background)
UGM-M02	723332	6189842	existing	SFM/LPS	3 (background)
UGM-M04	723348	6189745	existing	SFM/LPS	3 (background)
UGM-M06	723373	6189400	existing	SFM/LPS	2 (transition)
UGM-M12	723639	6189000	existing	SFM/LPS	1 (mining)
UGM-M15	723555	6188886	existing	SFM/LPS	2 (transition)
LPSPB04	723702	6189053	existing	LPS	2 (transition)
BH-M16	723484	6189656	new	SFM/LPS	3 (background)
BH-M17	723318	6189364	new	SFM/LPS	2 (transition)
BH-M18	723363	6189255	new	SFM/LPS	2 (transition)
BH-M19	723377	6189038	new	SFM/LPS	2 (transition)
BH-M20	723676	6189207	new	SFM/LPS	2 (transition)
BH-M21	723672	6189008	new	SFM/LPS	2 (transition)
BH-M22	723682	6188854	new	SFM/LPS	2 (transition)
BH-M23	723631	6188619	new	SFM/LPS	3 (background)
BH-M24	723779	6189359	new	SFM/LPS	3 (background)
BH-M25	723238	6189003	new	SFM/LPS	3 (background)
VWP16	723414	6189262	new	SFM	1 (mining)
VWP17	723453	6189284	new	SFM	1 (mining)
VWP18	723466	6189175	new	SFM	1 (mining)
VWP19	723504	6189198	new	SFM	1 (mining)
VWP20	723713	6189335	new	SFM	1 (mining)
VWP21	723517	6189090	new	SFM	1 (mining)
VWP22	723555	6189112	new	SFM	1 (mining)
VWP23	723631	6188902	new	SFM	1 (mining)
VWP24	723668	6188926	new	SFM	2 (transition)
HBF4-FE1	723630	6188994	new	Stope	1 (mining)
HBF5-MP1	723551	6189121	new	Stope	1 (mining)
HBF6-MP1	723450	6189216	new	Stope	1 (mining)
HBF5- North	723399	6189356	New	Stope	1 (mining)
HBF6- North	723381	6189345	new	Stope	1 (mining)

Notes: 1. SFM: Shepparton Formation Aquifer
2. LPS: Loxton-Parilla Sands Aquifer

Table 2.3 Production bore construction details

Bore	Depth (mBGL)	Details
Karra Homestead	0-216.5	177 mm ND[1] blank µPVC
	216.5-218.3	100 mm ND blank µPVC
	218.3-230.3	100 mm ND stainless steel screen
	230.3-239.0	100 mm ND blank µPVC
P2 (PWD Bore)	0-57	300 mm ND CL18 blank µPVC
	57-81	300 mm ND CL18 blank µPVC

Notes: 1. ND = Nominal diameter



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

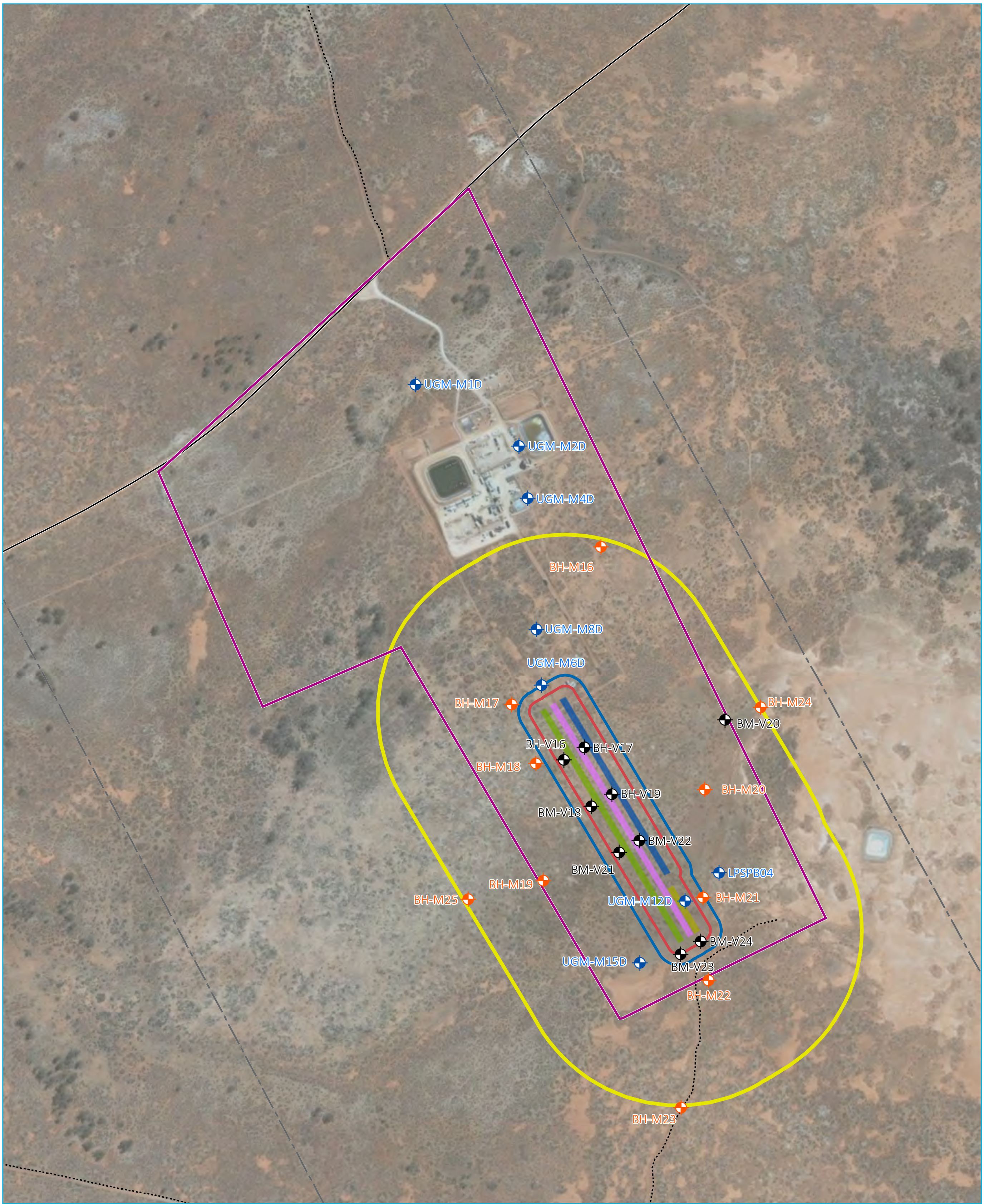
KEY

- Activity area
- Project boundary
- Groundwater bore location
- Access road
- Mining Lease 1736
- Iluka mineral tenement
- Main road
- Local road
- Vehicular track
- Named watercourse
- Ephemeral lake

Balranald monitoring network
(GME and T3 network)

Iluka Resources Limited
Groundwater Management Plan
Figure 2.1

EMM
creating opportunities



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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 100 200 m

GDA 1994 MGA Zone 54

N

KEY

- Activity area
- Proposed new T3 bores
- Proposed new T3 VWPs
- Existing bores
- Local road
- Vehicular track
- Restricted area
- Mining zone boundary
- Transition zone boundary
- Mining Lease 1736
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

T3 activity monitoring site plan

Iluka Resources Limited
Environmental Management Plan
Figure 2.2

EMM
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2.2 Monitoring program

All of the bores on-site (Table 2.1) are monitored biannually in June and December, regardless of site activities, to meet the following objectives:

1. detect and manage potential impacts to sensitive receptors from changes in groundwater levels or quality that may be attributable to Iluka's mining activities, in the context of natural variability and other (non-Iluka) threatening processes; and

2. detect and manage potential impacts to water users in the vicinity of the Balranald project.

Leading up to, during and after the T3 trial, the frequency of monitoring of bores near the bulk sampling activities will be increased to capture any groundwater changes. This monitoring will include the use of automatic water level loggers. An overview of the proposed T3 monitoring program is outlined in Table 2.4. The T3 monitoring program is described in further detail in the T3 GMP (EMM 2019a). The objectives of the T3 monitoring network are to:

1. measure the groundwater pressure and chemical changes along a transect within the LPS during both mining and backfilling periods. This will help with the refinement of hydrogeochemical modelling and the overall understanding of the system;

2. ensure adequate monitoring bores are located within each SSTL zone as described in Section 3.3.1;

3. monitor the groundwater within the SFM along the HDD access holes to ensure the water table elevation does not breach the trigger levels during mining/backfilling periods;

4. measure smaller backfilling periods/rates during times of unforeseen operational challenges;

5. allow for flow net/pressure analysis to be performed radially within the LPS (this is in addition to the transect bores);

6. allow the potential for down-hole geophysical mapping of the mining voids using seismic technology (ie transect bores located either side of the stopes);

7. develop an understanding of operational constraints; and

8. provide a robust dataset which future groundwater modelling can use to assist with the assessing the feasibility of an underground mining method for the Project.

Table 2.4 Proposed T3 monitoring program overview

Suite	Description	Parameters	Frequency
1	Field parameters	Water levels, electrical conductivity (EC), pH, dissolved oxygen, temperature, oxidation reduction potential (redox), ferrous and total Fe.	Pre- and post-trial, daily for bore transects adjacent to active mining and backfill periods, fortnightly for other bore locations.
2	Major ions	Ca, Mg, Na, K, SO_2-, $SO4^{2-}$, Cl, alkalinity (bicarbonate, carbonate, hydroxide and total as $CaCO_3$.	Pre- and post-trial, and monthly during the trial. Aim to collect water samples at bore transects at times adjacent to active backfill periods.
3	Leading indicators	Al, Mg, S, Cl:SO_4, ferrous and total Fe.	As for Suite 2
4	Radionuclides	U, Ra-226 and Ra-228	Pre- and post-trial

2.3 Bore development procedures

All of the bores installed on-site have been developed in accordance with the NUDLC (2012) guidelines to ensure any groundwater samples are representative of the local aquifer, and in order to reach maximum production/injection capacity for extraction and injection bores, the latter associated with previous conventional water disposal trials. This was achieved using jetting, surging and airlifting techniques to improve near-bore permeability and reduce entry losses, as well as removing muds, silts, sands and other potential contaminants introduced during the bore construction process.

The double surge block with air technique was employed to develop all production and injection bores across the broader Balranald site, due to the longer screened intervals in these bores. This technique allowed the screens to be developed in 1 m segments. Instead of trying to develop the entire screen length at once, the energy could be concentrated to effectively develop short intervals one at a time.

Monitoring bores were developed using water jetting, airlifting and surging techniques with the following equipment:

- a rig-mounted 650 cubic feet per minute (cfm) compressor, generally used for the larger diameter (50 mm) and deeper monitoring bores; and
- a trailer-mounted 190 cfm air compressor used for the shallower (32 mm) monitoring bores.

For all bores (injection, production and monitoring), development continued until field water quality parameters had stabilised and the sand content within a 20 L sample was less than a quarter of a teaspoon.

Where bores had lower than expected yields, were showing unexpected water quality exceedances, or otherwise showed signs of poor bore development, action was taken to re-develop the bores.

Anomalous water quality exceedances were observed post-T2 trial in some monitoring bores screened in the SFM adjacent to Stope 4. These exceedances were likely due to the small diameter bore casing (ie 32 mm ND) which is difficult to develop through airlifting combined with the installed screen being within the SFM, which is a poor aquifer and thus does not readily transmit large volumes of water to enter the screen during development. Water samples from these bores had been observed to have high turbidity, high alkaline pH and elevated concentrations of various dissolved and total metals, which were possibly reflective of the drilling fluids used during installation. These conditions were not observed in other bores, suggesting they had been sufficiently developed.

The bores showing abnormal measurements were subsequently developed further. Bore re-development took place during the December 2018/January 2019 groundwater monitoring event, prior to sampling. The bores were developed using dedicated tubing and the process involved the removal of accumulated sediment and groundwater from both the bore and the surrounding aquifer. A minimum of five bore volumes were removed during development, consistent with industry standards. Following each bore volume, field parameters were recorded using a calibrated water quality meter. Bore development continued until the field water quality parameters had stabilised (ie within 3% EC, 0.05 pH, 10% DO, 10 mV redox and 0.5°C temperature) and/or turbidity was reduced (ie the extracted groundwater was generally clear and free of suspended solids). The field sheets produced during the development of these bores are presented in Appendix C. As a result of this development, the following changes in water quality were observed (EMM 2019b):

- UGM-M12S: the dissolved molybdenum concentration went from 0.026 mg/L in July 2018 (exceeding the yellow trigger level) to 0.01 mg/L in January 2019 (below the yellow trigger level);
- UGM-M13S: the dissolved calcium concentration decreased from above the red trigger level (1410 mg/L in July 2018) to below the yellow trigger level (1030 mg/L in January 2019);
- UGM-M11S: the dissolved uranium concentration decreased from 0.066 mg/L in July 2018 (exceeding the yellow trigger level) to 0.064 mg/L in January 2019 (below the yellow trigger level); and
- UGM-M4D: the dissolved bismuth concentration decreased from 0.015 mg/L in July 2018 (above the yellow trigger level) to <0.002 mg/L in January 2019 (below the yellow trigger level).

3 Proposed T3 SSTL Framework

3.1 Baseline data

Baseline data has been collected from existing near-mining, third-party and regional monitoring bores within a 3 km radius of the site prior to commencement of the bulk sampling activities. The baseline data was collected from 2011–2015 and used to summarise the local groundwater chemistry surrounding the site. Table 3.1, Table 3.2, and Table 3.3 present statistical analyses summarising the baseline groundwater chemistry of the SFM, the LPS, and the Lower Renmark Group (LRG) respectively. As local third-party groundwater users predominately utilise the LRG for irrigation purposes, the ANZECC (2000) trigger values for irrigation are displayed in these tables for comparison purposes only.

The raw dataset used to create these tables is presented in Appendix B.

Table 3.1 Shepparton Formation: groundwater quality statistical summary

Statistic	pH	Total Alkalinity (mg/L $CaCO_3$)	Total Dissolved Solids (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO_4 (mg/L)	Cl (mg/L)	Al (mg/L)	As (mg/L)	Cu (mg/L)	Fe (mg/L)	Li (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Sr (mg/L)	U (mg/L)	Zn (mg/L)
Number	96	95	96	96	96	96	96	96	96	96	27	96	93	96	96	27	27	96	96	96
Minimum	3.85	177	19700	340	710	6800	19	1800	12300	0.003	0.001	<LOR	0.003	0.010	<LOR	<LOR	<LOR	7.320	<LOR	0.003
Lower Fence[1]	6.16	223	19700	340	710	6800	19	1800	12300	0.003	0.001	<LOR	0.003	0.010	0.001	0.001	0.001	9.213	<LOR	0.003
Quartile 1 (25th percentile)	6.85	328	33675	502	1200	9088	35	3600	15575	0.005	0.001	0.005	0.240	0.061	0.093	0.002	0.005	14.950	0.003	0.020
Median	7.13	359	39650	598	1530	11200	42	4245	20200	0.025	0.004	0.012	0.630	0.088	0.270	0.004	0.010	16.950	0.012	0.033
Quartile 3 (75th percentile)	7.30	398	43650	657	1750	13000	66	4801	23000	0.050	0.010	0.018	3.570	0.1218	0.591	0.010	0.017	18.775	0.025	0.072
Upper Fence[2]	7.98	503	57200	890	2550	16200	113	6603	30500	0.118	0.024	0.038	8.565	0.211	1.338	0.022	0.035	24.513	0.059	0.151
Maximum	8.10	570	57200	1100	2550	16200	115	9309	30500	28.90	0.028	0.071	10.400	0.368	6.200	0.053	0.057	32.900	0.229	0.244
IQR[3]	0.46	70	9975	155	550	3913	31	1201	7425	0.045	0.009	0.013	3.330	0.060	0.498	0.008	0.012	3.825	0.023	0.053
Number of Upper Outliers[4]	2	4	0	2	0	0	1	8	0	19	2	2	2	6	15	1	3	2	9	3
Number of Lower Outliers[5]	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
ANZECC[6]	4 - 9	N/A	5 000	N/A	N/A	N/A	N/A	N/A	N/A	5	0.1	0.2	N/A	2.5	0.2	0.01	0.2	N/A	0.01	2

Notes:
1. Lower fence is defined as the 25th percentile minus 1.5 multiplied by the IQR;
2. Upper fence is defined as the 75th percentile plus 1.5 multiplied by the inter IQR;
3. IQR = Inter Quartile Range, which represents 50% of the data between the 25th and 75th percentile (ie. IQR = Q3-Q1);
4. Upper outliers are defined as data that fall between the upper fence and the maximum;
5. Lower outliers are defined as data that fall between the lower fence and the minimum; and
6. ANZECC (2000) guideline value for irrigation and general water use.

Table 3.2 Loxton Parilla Sands: groundwater quality statistical summary

Statistic	pH	Total Alkalinity (mg/L $CaCO_3$)	Total Dissolved Solids (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	Cl (mg/L)	Al (mg/L)	As (mg/L)	Cu (mg/L)	Fe (mg/L)	Li (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Sr (mg/L)	U (mg/L)	Zn (mg/L)
Number	173	173	173	173	173	173	173	173	173	173	36	173	164	173	173	36	36	173	173	173
Minimum	6.19	207	8870	105	225	3200	10	500	5240	0.005	<LOR	<LOR	0.025	0.017	0.064	<LOR	<LOR	2.990	<LOR	0.003
Lower Fence[1]	6.30	252	8870	105	225	3200	10	500	5240	0.005	0.001	<LOR	0.025	0.017	0.064	0.001	0.001	2.990	<LOR	0.003
Quartile 1 (25th percentile)	6.93	376	18500	276	594	5330	31	991	10000	0.005	0.001	0.003	0.450	0.087	0.220	0.001	0.001	6.260	<0.001	0.013
Median	7.16	427	33000	368	1100	9000	40	2460	16600	0.025	0.001	0.005	1.370	0.112	0.427	0.001	0.002	9.480	0.003	0.029
Quartile 3 (75th percentile)	7.35	458	38000	556	1420	11000	52	3680	19400	0.050	0.008	0.008	4.120	0.155	0.620	0.003	0.004	14.600	0.005	0.080
Upper Fence[2]	7.98	582	48200	848	2659	14200	84	6170	26000	0.118	0.018	0.016	9.625	0.257	1.220	0.006	0.009	27.110	0.012	0.181
Maximum	8.40	914	48200	848	1930	14200	110	6170	26000	0.340	0.045	0.058	12.300	0.279	1.650	0.010	0.010	33.300	0.027	1.100
IQR[3]	0.42	83	19500	280	826	5670	21	2689	9400	0.045	0.007	0.006	3.670	0.068	0.400	0.002	0.003	8.340	0.005	0.068
Number of Upper Outliers[4]	10	16	0	0	0	0	5	0	0	22	2	9	4	1	11	4	4	1	30	19
Number of Lower Outliers[5]	1	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANZECC[6]	4 - 9	N/A	5 000	N/A	N/A	N/A	N/A	N/A	N/A	5	0.1	0.2	N/A	2.5	0.2	0.01	0.2	N/A	0.01	2

Notes:
1. Lower fence is defined as the 25th percentile minus 1.5 multiplied by the IQR;
2. Upper fence is defined as the 75th percentile plus 1.5 multiplied by the inter IQR;
3. IQR = Inter Quartile Range, which represents 50% of the data between the 25th and 75th percentile (ie. IQR = Q3-Q1);
4. Upper outliers are defined as data that fall between the upper fence and the maximum;
5. Lower outliers are defined as data that fall between the lower fence and the minimum; and
6. ANZECC (2000) guideline value for irrigation and general water use.

Table 3.3 Lower Renmark Group: groundwater quality statistical summary

Statistic	pH	Total Alkalinity (mg/L $CaCO_3$)	Total Dissolved Solids (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	Cl (mg/L)	Al (mg/L)	As (mg/L)	Cu (mg/L)	Fe (mg/L)	Li (mg/L)	Mn (mg/L)	Mo (mg/L)	Ni (mg/L)	Sr (mg/L)	U (mg/L)	Zn (mg/L)
Number	209	32	117	58	58	58	58	55	51	47	21	21	42	21	51	21	21	15	14	1
Minimum	5.70	379	2490	21	28	793	16	1	1180	<LOR	<LOR	<LOR	0.009	0.041	0.006	<LOR	<LOR	0.818	<LOR	<LOR
Lower Fence[1]	6.72	379	2490	21	28	793	16	1	1180	<LOR	0.001	0.001	0.009	0.041	0.006	0.001	0.001	0.818	<LOR	<LOR
Quartile 1 (25th percentile)	7.29	400	3570	35	47	1073	23	1	1570	0.020	0.001	0.001	0.330	0.051	0.014	0.001	0.001	0.958	0.001	<LOR
Median	7.50	432	4349	40	59	1235	27	1	1840	0.050	0.001	0.001	0.660	0.060	0.020	0.001	0.001	1.160	0.001	<LOR
Quartile 3 (75th percentile)	7.67	445	5675	53	70	1565	29	2	2400	0.115	0.001	0.002	1.533	0.075	0.038	0.001	0.001	1.940	0.001	<LOR
Upper Fence[2]	8.24	511	8833	81	104	2304	37	4	3645	0.256	0.001	0.003	3.336	0.111	0.075	0.001	0.001	2.830	0.001	<LOR
Maximum	9.63	603	10265	120	160	2530	49	35	4280	1.980	0.006	0.003	7.390	0.158	0.091	0.001	0.004	2.830	0.001	<LOR
IQR[3]	0.38	45	2105	18	23	493	6	1	830	0.095	0.000	0.001	1.203	0.024	0.025	0.000	0.000	0.983	0.000	<LOR
Number of Upper Outliers[4]	5	2	2	3	8	4	7	9	7	5	5	0	2	2	4	0	3	0	0	0
Number of Lower Outliers[5]	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
ANZECC[6]	4 - 9	N/A	5 000	N/A	N/A	N/A	N/A	N/A	N/A	5	0.1	0.2	N/A	2.5	0.2	0.01	0.2	N/A	0.01	2

Notes:
1. Lower fence is defined as the 25th percentile minus 1.5 multiplied by the IQR;
2. Upper fence is defined as the 75th percentile plus 1.5 multiplied by the inter IQR;
3. IQR = Inter Quartile Range, which represents 50% of the data between the 25th and 75th percentile (ie. IQR = Q3-Q1);
4. Upper outliers are defined as data that fall between the upper fence and the maximum;
5. Lower outliers are defined as data that fall between the lower fence and the minimum; and
6. ANZECC (2000) guideline value for irrigation and general water use.

3.2 SSTL derivation

3.2.1 Hydraulic Operating Conditions

The Hydraulic Operating Conditions (HOCs) were previously referred to as site specific trigger levels (SSTLs) within the T2 GMP (Iluka, 2016) and are detailed in Table 3.4. The HOCs represent the historical maximum pressures that have been experienced within the aquifers without any adverse impacts being observed. As the T3 site activities progress, it is envisaged that the HOCs will be progressively updated as part of Iuka's adaptive management philosophy.

HOCs were derived using aquifer-specific methodologies. For the overlying SFM aquifer, HOCs were derived based on the rooting depths of nearby vegetation. Away from the Murrumbidgee River and the associated floodplain region, vegetation relies predominantly on rainfall and soil water storage within the SFM, with root system depths around 5 mBGL as determined by Jacobs (2014) and CDM-Smith (2015). Due to the high salinity of groundwater in the SFM aquifer, groundwater level rise into the root zone should be avoided. The HOC range has therefore been defined to allow a 1 to 3 m buffer below rooting depth. Temporary dewatering within the SFM and LPS is not deemed to adversely impact this groundwater system and an HOC has not been set for this scenario.

Water level trigger levels for the LPS aquifer have been defined for the upper-most facie of this unit, which lies directly below the SFM. These HOCs have been set to avoid over-pressurising, and thus compromising, the integrity of the SFM layer, but more specifically, the bentonite clay layer existing at the base of the SFM. These conservative HOCs were based on past hydrogeological field programs which involved large scale reinjection activities (Iluka 2015; Iluka 2016) as discussed below.

Long term trial (LTT) reinjection activities were undertaken at Balranald in 2014, as part of the conventional open cut and EIS studies. The reinjection trial consisted of pumping of up to 50 L/s from a production bore site, transferring the water seven km through a pipeline and reinjecting the water across an injection borefield. Twelve injection bores were installed within the LPS. Reinjection commenced in late May 2014 and continued for approximately six weeks. Referring to Figure 3.1 and Figure 3.2, the following observations were made:

- throughout the trial, the injection bores operated at a hydraulic head between 80 and 90 mAHD screened across the LPS, which translated to an approximate artesian pressure of 20 to 30 meters above ground surface (shown as a black dash line on each hydrograph). The 20 m artesian head, which has been converted from the pressure gauge readings recorded from the injection headworks, represented the operational threshold set on the injection wellfield and has since been adopted for the unconventional trials. An example of the time-series pressures recorded at one of the injection bores in shown in Figure 3.1 for injection well WBIW07A;

- all hydrographs derived from data loggers, installed within the dip-tubes of the injection bores, correlate closely with the hydrographs developed from the manually-recorded data. Manual recorded data are shown as blue circles on the WBIW07A and WBMW11 plots (Figure 3.1);

- WBMW11D is a monitoring well installed near the centre of the injection borefield. The response measured here showed the largest mounding response within the LPS aquifer of approximately 11 m, which is located 38 m south of the injection well field. The response within the overlying SFM at this location was insignificant, as indicated by the WBMW11S series;

- referring to the nested Vibrating Wire Piezometer (VWP) and well site, WBMW10, all hydrographs showed a static response, which confirms, a) that no impacts were occurring within the SFM based on VWP P4 (installed at 34 mBGL) and VWP P5 (installed 44 mBGL), and b) no impact occurred within the deeper Olney Formation based on the manual measured data (WBMW10D_MAN) and the diver logger data taken from the well screen. The Olney groundwater levels are measured at approximately 60 mAHD, compared to the SFM with groundwater levels measured at approximately 50 mAHD; and

- Figure 3.2 shows a hydrogeological cross section through the LTT injection borefield, including main stratigraphic units and the groundwater pressures recorded within the main aquifers of interest including the SFM, LPS and the deeper Olney Formation, part of the LRG.

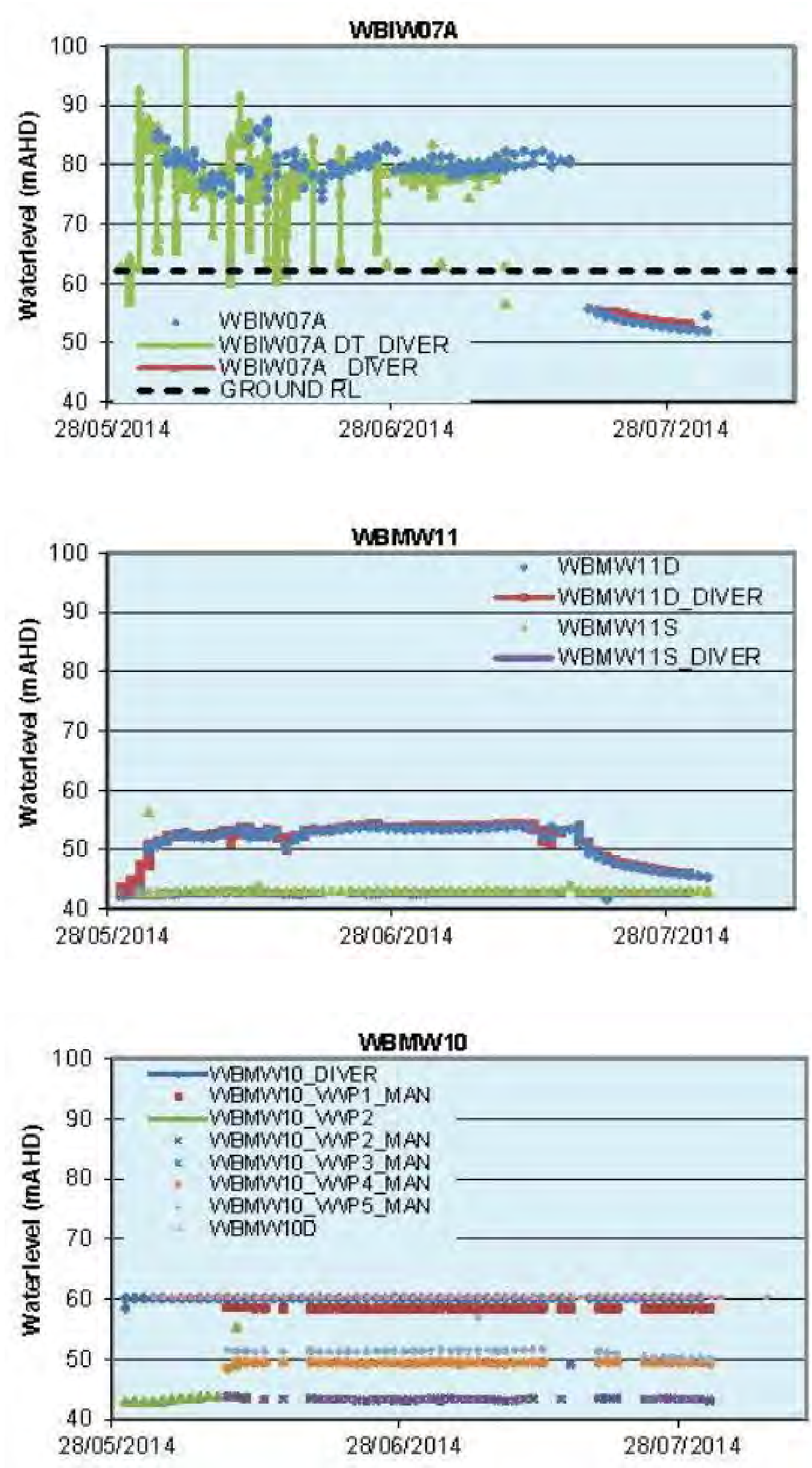


Figure 3.1 **Example hydrographs from Balranald LTT injection borefield (Iluka, 2015)**

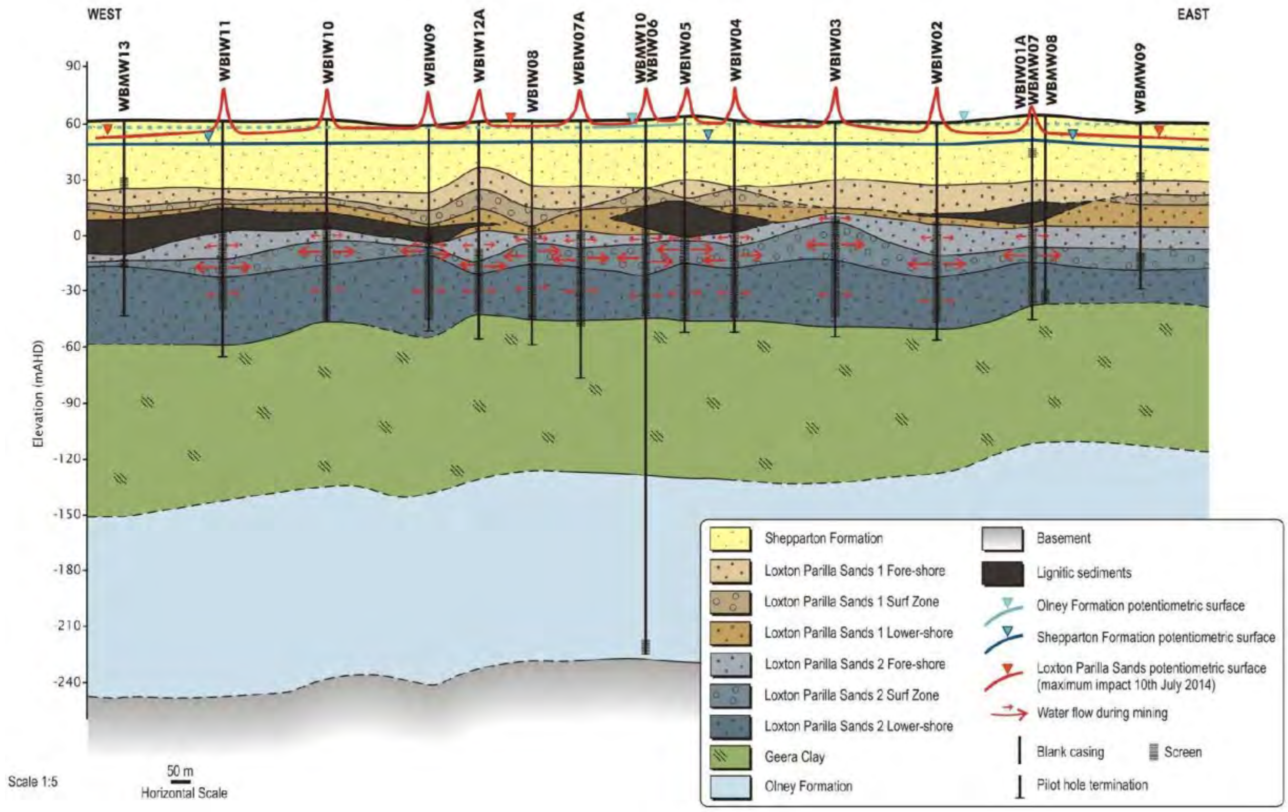


Figure 3.2 Hydrogeological cross-section through Balranald's LTT injection borefield (Iluka, 2015)

Possible hydrostatic loading effects in the LRG aquifer due to the pressurisation of the overlying LPS aquifer mean that groundwater level and hydraulic pressure responses cannot be used to set trigger levels or hydraulic conditions for the LRG (Iluka 2015). Therefore, water quality SSTLs are deemed more appropriate in determining the management response to monitoring thresholds. HOCs for dewatering within the LRG aquifer are provided in Table 3.4 for indicative purposes only.

Table 3.4 Initial hydraulic operational conditions

Parameters	Shepparton Aquifer			Loxton Parilla Sands Aquifer			Lower Renmark Group Aquifer		
	Green	Yellow	Red	Green	Yellow	Red	Green	Yellow	Red
Depth to groundwater (mounding response)	>8 mBGL[1]	≤ 8 to > 6 mBGL	≤ 6 mBGL	< 15 mAGL[2]	≥ 15 to < 20 mAGL	≥ 20 mAGL	N/A	N/A	N/A
Depth to groundwater (dewatering response)	N/A	N/A	N/A	N/A	N/A	N/A	≤ 8 mBGL[1]	> 8 to ≤ 10 mBGL	> 10 mBGL

Notes: 1. mBGL: metres below ground level; and
2. mAGL: metres above ground level.

3.2.2 Groundwater quality SSTLs

The groundwater quality SSTLs are defined in the T3 GMP (Iluka 2019) and were derived on a per-aquifer basis using the baseline data summarised in Section 3.1. The analytes with assigned trigger levels have been defined as either 'direct risk' or 'indirect risk' analytes, with the following definitions:

- Direct risk: potential contaminant species which would present a potential adverse risk to the beneficial use of the aquifer (if realised); and

- Indirect risk: chemical species which are indicative of a change to the chemistry of the groundwater system and do not present an adverse risk to the beneficial use of the aquifer.

The green, yellow and red SSTLs have been defined for both risk categories based on the statistical summary shown in Section 3.1 as follows:

i Direct risk

- the green SSTL indicates normal operations and incorporates all values less than the yellow management response;

- the SSTL for a yellow management response in defined as the upper fence multiplied by 1.1; and

- the SSTL for a red management response is defined as the upper fence multiplied by 1.25.

ii Indirect risk

- the green SSTL indicates normal operations and incorporates all values less than the yellow management response;

- the SSTL for a yellow management response in defined as the upper fence multiplied by 1.25; and

- the SSTL for a red management response is defined as the upper fence multiplied by 1.5.

For both risk categories, the upper fence is defined as the 75th percentile of the baseline data plus 1.5 multiplied by the interquartile range (IQR; which is the difference between the 75th and 25th percentiles) and represents the upper limit of statistically significant data in the baseline dataset. The upper fence and IQR values for each analyte in each aquifer are defined in Table 3.1 through to Table 3.3. For instances where there were insufficient baseline data or analyses were below the LOR, the ANZECC (2000) long-term trigger value (LTV) and short-term trigger value (STV) for sensitive tolerant species have been adopted as the yellow and red SSTLs respectively. Where the ANZECC (2000) irrigation guideline values were of poorer quality than the baseline conditions, the ANZECC LTV was adopted as the red SSTL.

SSTLs are not defined for organic carbon, zirconium and particular bacteriological species, as the toxicity of these parameters is deemed low and the analysis is primarily for Iluka's operational information.

3.3 Proposed SSTL updates

3.3.1 Chemical SSTL zones

To reflect the expected changes to the groundwater system surrounding the stopes during bulk sampling activities, chemical SSTL zones have been proposed. These chemical SSTL zones are summarised in Table 3.5 and focus on protecting the beneficial use of the groundwater system down-gradient from the mining site. The zoned approach represents a significant upgrade compared to the previous T2 GOMS (Iluka, 2016).

These SSTL zones are based on hydrogeochemical modelling, completed by LWC (2017b), that suggests large groundwater quality changes could be observed within 20 m of the stope edges, which will then dissipate to background conditions within a 300 m buffer zone from the stope edges. A detailed overview of the geochemical modelling results and further justification for the chemical SSTL zones is provided in Section 4. Using these SSTL zones, only bores falling outside of the 300 m transition zone will be considered for compliance monitoring; termed the background zone. Bores within the transition zone will be monitored to provide a leading indicator of responses outside of the transition zone, but do not need to adhere to the SSTL management and mitigation measures. Bores located within the mining zone will be monitored to assess immediate changes to the aquifer and assist with understanding potential hydrogeochemical processes associated with mining and backfill activities.

Table 3.5 Zoned hydrogeochemical SSTL framework

Groundwater Monitoring Zone	Purpose	Details
Zone 1 Mining Zone	Operational	Adjacent and surrounding the actual mining area. Includes the stope areas plus a 20 m buffer. Required to understand immediate changes to groundwater quality and pressure. Large changes relative to baseline conditions, are expected in this zone and represent the source location of both pressure and geochemical changes. Provide a leading indicator to potential responses within Zone 2.
Zone 2 Transition Zone	Operational	Non mining area and represents the zone between 20 m and 300 m from the stope edges. Data and trends within this zone are used to understand aquifer responses at various locations away from the stopes, during mining and backfill. Provide a leading indicator to potential responses within Zone 3.
Zone 3 Background Zone	Compliance	Non mining area and represents the zone beyond 300 m from the stope edges. Bores located in this zone are part of the EPA Licence and will therefore be required to adhere to the nominated SSTL's and associated compliance reporting.

3.3.2 Bore-specific trigger updates

Bores UGM-M1S, UGM-M6S, UGM-M9S, UGM-M2D, UGM-M4D and the Karra Homestead bore were found to have naturally elevated concentrations of certain analytes, causing them to breach the set SSTLs even though measurements were within the baseline range for each bore. To reduce false-positive breaches, trigger levels in these bores have been redefined for those analytes that are naturally elevated. These revised SSTLs were calculated using the same method outlined in Section 3.2, but using only the baseline data from the bore showing naturally elevated analyte concentrations, instead of data from every bore in the same aquifer. The revised SSTLs are summarised in Table 3.6. The baseline data used for these calculations are presented in Appendix B.

Table 3.6 Revised SSTLs for groundwater quality

Aquifer	Bore ID	Analyte	Previous SSTL			Redefined SSTL		
			Green	Yellow	Red	Green	Yellow	Red
SFM	UGM-M9S	TDS	<64,474	≥64,474	>73,266	<72,270	≥72,270	>81,125
	UGM-M1S	Molybdenum	<0.024	≥0.024	>0.028	<0.0583	≥0.0583	>0.662
	UGM-M1S	Total aluminium	<0.129	≥0.129	>5	<0.583	≥0.583	>0.662
	UGM-M6S					<0.0572	≥0.0572	>0.65
LPS	UGM-M2D	Total aluminium	<0.129	≥0.129	>5	<0.594	≥0.594	>0.675
	UGM-M4D					<0.44	≥0.44	>0.50
LRG	Karra Homestead	Zinc	LOR	>LOR	>2	<0.3113	≥0.3113	>0.353

3.4 PWD SSTLs

The pH of the water stored in the PWD controls geochemical processes in the aquifer once introduced. Due to this, the water quality within the PWD is subject to the monitoring schedule outlined in the T3 GMP (EMM 2019a), which includes weekly monitoring of field parameters. To prevent a change in the local groundwater chemistry as a result of the bulk sampling trial, the pH of the process water will be maintained between 6.5 and 8.5. If necessary, the process water pH will be adjusted by dosing tailings with lime during mining and backfill activities. The pH of the PWD will be monitored remotely via sensors installed on the off-take line and alert staff to dose as required.

3.5 T2 groundwater modelling

The Balranald MOD 1 groundwater modelling component comprised of developing a numerical groundwater flow model to simulate the responses observed during the T2 activities undertaken in 2016. The model was developed as a "cookie cut" from the existing regional-scale impact assessment model developed in support of the Balranald Project EIS for conventional open-cut mining. This calibrated and peer reviewed regional model was considered a well-tested and efficient starting framework for simulating the unconventional mining trials.

The model was created in Groundwater Vistas v7, using MODFLOW-USG to simulate groundwater flow. The domain measured 13 km east-west and 14 km north-south with model origin at MGA coordinates 716,000 mE, 6,183,000 mN in zone 54. Cell spacing was set regionally at 200 m x 200 m, refined using smoothed quadtree refinement down to 6.25 m x 6.25 m at stopes and locations of pumping.

Records of the T2 mining trial schedule were analysed against measured groundwater level data to match observed responses to groundwater extraction for water supply and pumping associated with mining and backfilling process. Modelling the stresses necessitated a transient model run comprised of 60 stress periods. Extraction from the P2 bore for water supply was simulated at 30 L/s for all identified times of operation. Water injection rates for mining were known for two events, and inferred for all others, averaging 110 kL/hour. Backfilling events had more detailed records, including percentage solid content of injected slurry ranging between 20% and 40%. Removing the solid content from the slurry left calculated water injection rates between 102 kL/hour and 180 kL/hour.

Modifications to the model, relative to the regional EIS model, were made to represent void properties in the stopes created by the mining/ore extraction process. Zones of hydraulic conductivity of 100,000 m/day were applied over the extent of each stope in model layer 5, corresponding to the portion of Loxton Parilla Sands located between the two surf zone facies. Increased vertical connection was also simulated above the stope and into the lower portions of the SFM. In summary, a good calibration between measured and modelled drawdown/mounding responses was achieved. The T2 calibrated model forms the basis of T3 trial assessment modelling and is detailed in Section 4.5.

3.6 Management responses

It is unlikely that there will be any responses to third-party water users from T3 operations and extraction at P2 in the LPS. No third-party users of water from the LPS have been identified. The Geera Clay, which underlies the LPS is demonstrated to be extensive in this region (Jacobs, 2015). The hydraulic conductivity of the Geera Clay is estimated at 4×10^{-4} m/d, which contrasts the LPS at between 2 m/d and 5 m/d. When there is at least a two-order magnitude contrast in hydraulic conductivity between hydrogeologic units then contact can be considered a no flow boundary (Freeze and Witherspoon, 1967). Moreover, the T2 trial produced no impact to water levels in the LRG when P2 was used for extraction. Consequently, there are no foreseeable hydraulic or hydrochemical impacts to third party users associated with the operations in the LPS.

Water extracted from Karra Homestead bore in the LRG is license-limited to 150 ML, operated under water allocation licence (WAL) No. 31101. Monitoring and provisions are available from Iluka to ameliorate any impacts to third party if they occur. A single site selected for bulk sampling activities between the 1 km and 3 km radius of the mining operation is specific to third party impact detection and provides early warning for Iluka to halt extraction and investigate responses further. Third-party water users have been identified as HD1 (although Iluka own this property), T01, T02 and T03. The closest user to Karra Homestead is HD1 at approximately 6.2 km. The estimated maximum drawdown at HD1 attributed to pumping 1.25 ML/d for 120 days (full entitlement) at Karra Homestead is less than 0.015 m when modelled analytically using the Theis solution (Theis 1935) for confined aquifer drawdown prediction. The remaining third-party users are between 11 km and 12 km from Karra Homestead with drawdown predictions of less than 0.01 m. Further assessment of potential impacts from geochemical and numerical modelling are documented in Sections 4.3 and 4.5 respectively, while Section 4.6 assesses these predicted impacts against the Aquifer Interference Policy (AIP, 2012). The AIP defines the regime for considering impacts of aquifer interface activities on the water resources of NSW and outlines the policy and information requirements for the collation and preparation of an EIS.

In the event that a management response is required, the trigger action response plan (TARP) will be in effect and is outlined in Table 3.7.

3.6.1 SSTL exceedances

Management responses to SSTL exceedances are based on a three-tiered management framework, which is detailed in the T3 GMP (EMM 2019a). If the groundwater quality or level in a bore outside of the 300 m transition zone exceeds the trigger levels defined in Section 3.2 and meets the confirmation criteria described in the T3 GMP, a management response will be implemented based on the SSTL tier exceeded (green, yellow or red). This approach allows for early and rapid intervention of any adverse groundwater effects. The management response for each exceedance tier is summarised in Table 3.7.

Table 3.7 Hydrogeological trigger action response plan

Operating Range	Management Response
GREEN	The Green operating range indicates normal operation. Observed parameters are below the accepted SSTL range and responses fall within acceptable limits. No action is required.
YELLOW	The Yellow operating range also indicates normal operating conditions but is designed to inform Iluka of possible future issues to allow time for adequate investigation and/or intervention. Observed parameters are marginally outside the accepted SSTL range, signifying action must be taken within 48 hours of infringement confirmation. Confirmation is defined by: 24 hours of continuously recorded infringement in autonomous and telemetry collected data; 2 daily consecutive infringements recorded in for-cause manual sampling; ensuring pH of the PWD is within the acceptable range of 6.5 – 8.5. Checking both autonomous and field readings is required; and, additional verification of the data, if required. This allows a suitable timeframe for any local variability associated with small saline slugs, or measurement error, to be delineated and confirmed. Actions associated with the operation of the T3 activity within the yellow monitoring threshold: increasing monitoring frequency in order to assess trends and understand processes occurring; revising the accepted SSTL range upon assessment of the impact on environmental values (to be completed with regulator consent); reducing the mining/backfilling and/or groundwater abstraction rates until infringements are within Green monitoring threshold or have stabilized; and depending on trends and if the red breaches are imminent, consider remediation action. After 72 hours of continued operation in this threshold from a water quality perspective, a notification report will be forwarded to DPIE Water and NSW EPA, ideally and prior to conditions breaching the Red operating range. Hydraulic breaches against the LPS HOC's are not considered breaches of compliance criteria. *Note, although the TARP only applies to bores located outside of the defined transition zone, all bore locations will be monitored and assessed during site activities as preventative measure to minimise the risk to SSTL breaches.*

Table 3.7 Hydrogeological trigger action response plan

Operating Range	Management Response
RED	The Red operating range indicates a breach of acceptable operating conditions. Observed parameters are above the Red SSTL, signifying action must be taken 12 hours after infringement confirmation. Infringement confirmation is defined by: 24 hours of continuously recorded infringement in autonomous and telemetry collected date; 2 consecutive infringements recorded in manual data; and, Additional verification of the data, if required. Actions associated with the operation of the T3 activity within the red monitoring threshold, include those listed for the previous tier, with the addition of: Modifying the T3 operations until infringements are within the Green or Yellow monitoring threshold or have stabilised; Investigate the cause of the SSTL breach if not adequately understood; and If necessary, develop and implement strategies to prevent future Red SSTL breaches or to mitigate any impacts caused by the SSTL breach. Iluka are committed to not adversely impacting sensitive receivers including the environment and 3rd party bore owners. If groundwater pressures adversely impact these receptors, make good provisions would apply as defined by the AIP (2012).

4 T2 Trial Assessment

4.1 T2 trial results

Upon completion of the T2 trial, LWC (2017a) was engaged to review the groundwater pressure and chemical results collected during the mining and backfilling trials. The main findings of this report were:

- the pressure responses measured in the LPS were greater than those measured in the SFM during mining periods, as expected;
- the pressure responses measured during backfilling were larger within the SFM, suggesting that backfilling is not discrete between the two aquifers;
- hydraulic exceedances were measured at two SFM monitoring bores, UGM-M7S and UMG-M5S, which breached the 'red' and 'yellow' trigger zones respectively during backfilling periods. These exceedances only occurred over a matter of hours before subsiding to background levels;
- given the position of the monitoring infrastructure in relation to the stopes, there is the potential that the mounding measured during backfilling could have been locally greater than the data suggested;
- although the exact reason behind the SFM pressure changes remains unknown, conceivable reasons include:
  - backpressure, with fluid taking the path of least resistance and travelling up the decline between the horizontal directional drill casing and borehole, eventually releasing into the SFM during net positive stope pressure periods. This may have been a possibility during the Stope 1 backfilling trials, however the casing was grouted into place during the Stope 1B trials, which would have minimised this effect;
  - a sink hole that developed at Stope 3 between the mining and backfilling periods, promoting greater connection between the LPS and overlying SFM;
  - the T2 stope areas had a higher density of monitoring bores, dual nested VWPs, extensiometers, RF Id tags and water monitoring bores that may have resulted in increased connectivity; and/or
  - naturally widespread preferential pathways between the LPS and SFM aquifers.

Another reason which may have caused potential breaches in the SFM bores, albeit artificial, is that both piezometers are installed within the one borehole. This relies on the driller to ensure that an intact seal is installed within the bore annulus between the deeper LPS screen and the shallower SFM screen. Iluka are planning to install deep and shallow piezometers within separate boreholes for locations closer to the stope as part of the T3 activities.

The assessment of the T2 chemical results suggested:

- no chemical SSTL exceedances or significant trends in the chemical data were identified within the LPS or the overlying SFM during the T2 activities;
- the range in acidity from the mined material is dependent on the moisture content and the duration of oxidation (ie the duration of the exposure to the environment);
- based on the calculated rates of acidity generation where no neutralisation of mined materials occurs, acidification will always occur within the LPS. Stockpiling, even for short periods, will still result in acidification of the reinjected slurry if not treat prior;

- modelling infers that a notable amount of low pH slurry was potentially introduced to the LPS system during backfilling periods, despite the absence of measurable changes; and

- the on-site backfill tests were short, lasting only 4-5 hours. Groundwater was sampled from the available monitoring bores both 7 and 11 days after the on-site backfill tests had been completed, which is potentially too late to measure any changes in groundwater pH.

From the assessment of the T2 results, it was recommended that future bulk sampling events should have groundwater monitoring bores within a useful proximity of the active stope so that any short-term groundwater chemistry and pressure responses can be detected. These bores should be monitored on a regular basis, including during and immediately before and after mining/backfilling activities have ceased. These bores would be monitored in addition to background bores, which are needed to ensure regional impact distances are understood. It was also recommended that the backfill material be neutralised to avoid oxidation and acid generation. These considerations are further documented in the T3 GMP (EMM, 2019).

The assessment concluded that no permanent alteration of the groundwater system can be delineated as a result of the T2 bulk sampling activities.

4.2 Post-T2 groundwater monitoring

Since the completion of the T2 trial, a total of five groundwater monitoring events have taken place from November 2016 to December 2018. The groundwater level and quality data collected during these events was assessed by EMM (2019) in support of the 2018 Annual Compliance Report for submission to the NSW EPA. This report made the following conclusions:

- the post-T2 groundwater levels were within historical ranges, suggesting that any localised pressure responses caused during the T2 trial have subsided and re-equilibrated with the regional system;

- various groundwater quality exceedances in different analytes have been observed over time, but most of these have been once-off, irregular ‘yellow’ trigger level exceedances that have returned to the ‘green’ trigger level zone in subsequent monitoring events;

- it is noted that values falling between the ‘yellow’ and ‘red’ trigger levels are still considered to be within normal operating conditions, and that the ‘yellow’ trigger level exists to allow for adequate investigation time and potential intervention before species reach the ‘red’ trigger level. Due to this, it is expected that analytes will occasionally be measured above the yellow trigger level as a result of natural variation. Without evidence of an increasing trend in the exceeding analytes, these exceedances have been attributed to natural geochemical processes, rather than past bulk sampling studies;

- bores UGM-M11 through to UGM-M15 were installed after the SSTLs were set and were only sampled once prior to the post-T2 trial groundwater monitoring event. Therefore, it is possible that quality exceedances observed in these bores are representative of normal conditions in the area where these bores are installed, and modified trigger levels for some parameters should be considered on a spatial basis;

- insufficient purging of the groundwater in the bores before sampling could have contributed to some historically observed quality exceedances (as described in Section 2.3); and

- if the observed groundwater quality exceedances were being caused by acidification, it would be expected that pH and alkalinity would decrease, while TDS concentrations would increase. None of the bores which had exceedances were found to have a concurrent downwards pH or alkalinity trend, or an increase in TDS. Due to this, it is unlikely that acidification of the groundwater occurred at these sites, causing metal mobilisation.

4.3 T3 geochemical modelling

LWC (2017b) assessed the potential geochemical responses on the LPS aquifer as a result of several hypothetical T3 backfilling regimes. As the ore being extracted on-site contains reactive sulphide minerals, there is the potential for acid and metalliferous drainage to be generated during the bulk sampling activities. The ore, ore processing streams and process by-products will be exposed to atmospheric conditions prior to backfilling/reinjection, and therefore will have the potential to affect the groundwater system through oxidation and subsequent metal mobilisation.

Predictive assessments were undertaken using a range of backfilling conditions, stockpiled by-product exposure times, backfilling rates, as well as accounting for various blending ratios. The geochemical modelling, which used the Geochemist Work Bench (GWB) modelling suite, indicated the following:

- depending on the stockpile duration of the process by-products prior to backfilling, the pH of the solution phase of the backfill material is expected to fall between pH 6 and 3. The pH of the material when first extracted is 6.4;
- if no pH adjustments are performed on the by-products prior to backfilling, groundwater pH responses within the LPS aquifer are expected to occur up to several hundred metres from the stopes, depending on the stockpile duration. An example of one of the modelled scenarios showing the pH trend along a typical flow path away from a stope during backfill is shown in Figure 4.1 to demonstrate this;
- longer stockpiling periods, such as during the start-up of operations, are predicted to result in larger groundwater impacts due to prolonged oxidation and subsequently lower pH of the backfill material; and
- adjusting the pH of the backfill material via dosing with lime or similar substances will mitigate groundwater impacts related to low pH and thus any potential metal mobilisation.

Modelling of the different life-of-mine operating scenarios found that pH dosing can effectively buffer any pH related groundwater impacts. When the backfill material is adjusted to pH 6 via dosing, the pH of the LPS aquifer was predicted to reach a minimum of pH 6.25, from an original pH of 6.4. When the pH of the backfill material was increased to 7, the groundwater pH did not decrease below 6.35.

For the T3 trials, the pH of the process water dam will be maintained between 6.5 and 8.5 through lime dosing, which will help manage the pH of tailings prior to backfilling. Therefore, it is expected that minimal pH and metal mobilisation related impacts will be observed in the LPS aquifer as a result of the T3 bulk sampling activities.

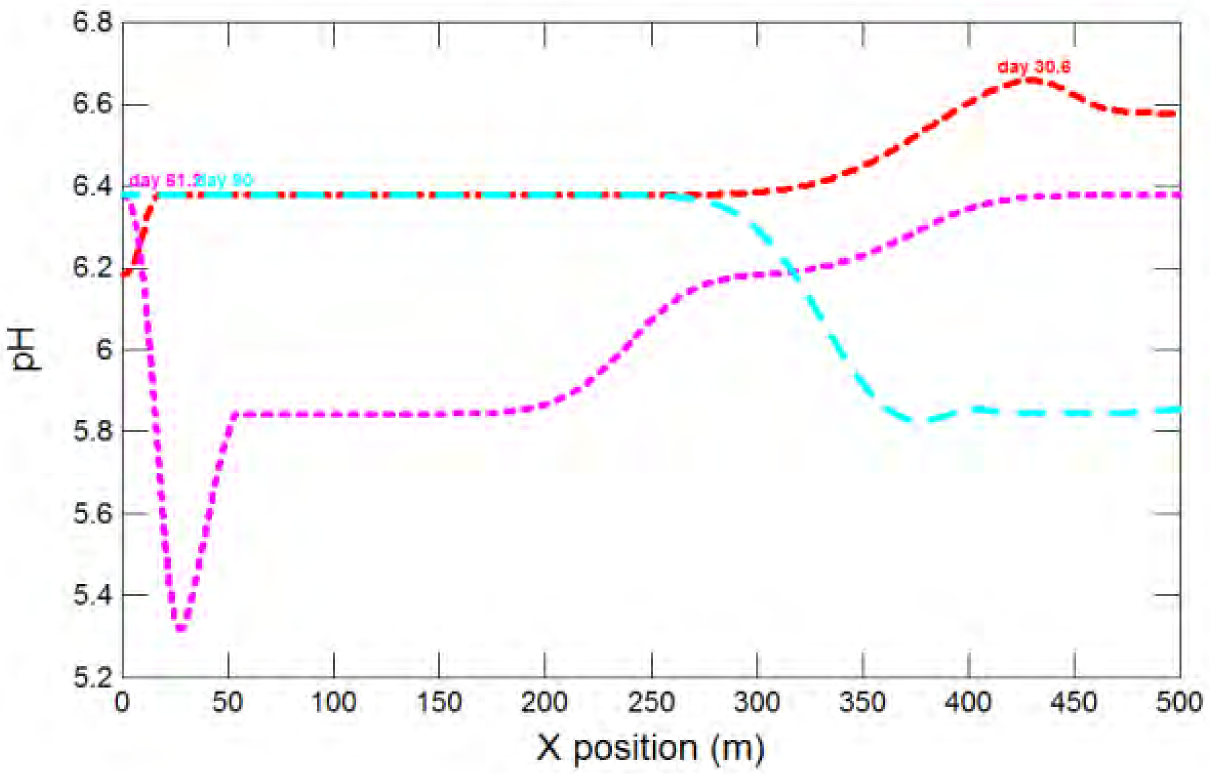


Figure 4.1 One-dimensional flow and pH trend along the flow-path for a typical backfill scenario (after LWC 2017b)

4.4 Justification of zoned SSTLs

The zoned hydrogeochemical SSTL framework (described in Section 3.3.1) was developed following the T2 trial to more accurately classify groundwater quality exceedances in the area surrounding the bulk-sampling activities. This framework considers the results gathered during the T2 trial and from the subsequent geochemical modelling.

The zoned approach acknowledges that groundwater changes are likely to occur at distances closer to the bulk-sampling area. Under current conditions and assumptions, groundwater chemical processes are expected to continually reduce pH and alkalinity and increase dissolved metals in the mining zone and to a lesser degree within the transition zone (up to 20 and 300 m from the stope edges respectively). Due to this, continual breaches against the SSTLs are expected to occur in these zones. However, for distances beyond 300 m from the stope edges, both natural attenuation and higher alkalinity is expected to reduce the effects of such processes. Compliance with SSTLs is expected to be adhered to at bores located beyond the 300 m transition zone, termed the background zone. Therefore, as the SSTLs were set using baseline data from each aquifer, it is expected that groundwater quality will be within baseline ranges outside of the transition zone and hence will not pose a risk to any receptors at distances from the bulk sampling activity.

The zoned SSTL framework additionally enables an adaptive approach whereby the SSTL zonation can be reviewed and potentially updated throughout the mining life based on improved understanding of the site and/or changes to the mining rate or hydrogeological conditions.

4.5 Updated T3 MODFLOW modelling approach

The T3 trial predictive groundwater modelling simulations adopt the T2 calibrated parameter set. Model parameters and external boundaries are congruent with the regional EIS model except for the mined stope voids and the aquifer properties associated with potential failure zones above the stopes. Connection between the LPS and SFM was enhanced in the model, albeit limited to the zones above the simulated stopes in order to achieve an acceptable history match with the field observations from the T2 trial. Results from the T2 seismic survey revealed voids/deformation extending upwards towards the shallower depths above stope 4 which potentially exacerbate the mounding observed in the SFM during backfill. Changes to hydraulic parameters are expected given the disruption to the porous matrix in sediments adjacent to the stope void. This same approach was used in the T3 simulations to ensure that any potential response to the porous matrix capable of transmitting water to the upper SFM was captured. Stope voids were simulated as regions of high hydraulic conductivity to reflect expected aquifer conditions post-mining.

Figure 4.2 shows the model domain in vertical exaggeration viewed from the southern end. It covers an area 14 km N-S by 13 km E-W with the T3 trial occupying approximately a 2 km square region in the middle. The grid is refined to 6.25 m cells through all layers encompassing the T3 trial location (center of domain) to facilitate better resolution of the hydraulic gradients expected during backfilling. The layering, relative thickness and hydraulic conductivities of the hydrostratigraphic units are presented in the top-right. The LRG (yellow) is at the base of the model overlain by the Geera Clay (white). The LPS (green) has surf zone depositional environments (light blue) represented as separate layers. It is these layers in the middle of the model that are targeted for mining and will be subjected to injection from backfilling. The top two layers comprise the SFM (dark blue). The location of bores in the model are highlighted (bright green). The majority of the monitoring bores are screened in both the SFM and the LPS.

The proposed new monitoring bore network (Figure 2.2) is included in the model with specific focus on detecting the extent of mounding in the SFM, intrusion of hypersaline water into the LRG and any potential impacts to third party bores in the LRG. The T2 trial demonstrated that the mining process had minor hydraulic responses in comparison to backfill process. Accordingly, the T3 numerical simulations focused primarily on the responses during backfilling. The estimated schedule for backfill operations provided by Iluka comprised approximately 10 weeks of 12-hour shifts, running 7 days a week for backfilling. The schedule remains preliminary and served as a guide for timing of stresses to the system. To ensure a conservative assessment in the numerical model of the potential responses to the LPS and SFM, simulations for investigating drawdown from extraction and mounding from injection were separated to ensure that neither process mitigated the responses of the other.

T2 simulations required increased vertical conductance through all modelled aquifer layers in the vicinity of above the stopes in order to achieve suitable calibration. Some change to hydraulic parameters is expected given the disruption to the porous matrix in sediments adjacent to the stope void. This same approach was used in the T3 simulations to ensure that any potential fracturing capable of transmitting water to the upper SFM was captured. Stope voids were simulated as regions of high conductivity and increased storage to reflect the expected aquifer conditions post mining. For the sake of brevity, only those results pertinent to the responses assessed by the groundwater model are presented and discussed.

4.5.1 Simulation period

As discussed above, extraction from the P2 and Karra Homestead bore was simulated separately to backfilling to allow for a conservative (and separate) assessment of both drawdown and mounding effects respectively. Simulation assumed a 10-week mining period followed by a 10-week backfill period. Extraction at P2 and Karra is simulated as continuous for the entire 20-week period of site works. Backfilling simulations include only 10 weeks of injection along the mined stopes. The simulation period continues for a further three months post-backfill with no further stresses in order to observe the system recovery.

4.5.2 Simulation extraction

Water used on site was extracted from the P2 bore screened within the LPS with some extraction from Karra Homestead bore from the LRG used for dust suppression. The conservative approach used by the numerical simulation assumed that the total annual entitlement from P2 and Karra was extracted during the 20 weeks. This results in approximately 30 L/s from P2 and 6 L/s for Karra for the total duration of all siteworks (20 weeks). The extraction rates are in excess of what is realistic for the period given capacity on site to hold water and the general requirements for dust suppression.

4.5.3 Simulation injection

Injection associated with backfilling is simulated using a constant rate of 150 m^3/hr. In reality, 30% of the volume will be solid but EMM's approach assumes all fluid. Injection occurs in 12-hour time blocks for a period of 10 weeks. Given the rapid recovery of the LPS identified from previous site trials, a decision was made to explicitly simulate the 12-hour working day shifts where injection would occur as the intermediate recovery periods may help mitigated long-term mounding.

4.5.4 Other system stresses and boundaries

Evapotranspiration and recharge for the region was set at the rates used in the regional model. The external boundaries are simulated as head dependent boundary conditions, which were informed by the head distribution from the regional EIS model.

4.5.5 Mounding results

Assessment to the LPS and SFM responses are provided as hydrographs and plots of mounding contours. For the sake of brevity, only those results pertinent to the mounding responses are presented and discussed. The effect of drawdown from extraction is discussed in section 4.6.1.

Excessive and sustained mounding in the SFM may threaten local vegetation if the high salinity reaches the root zone identified as 3 mBGL. Surface level in the vicinity of the backfilling bores is ~ 64 mAHD. Groundwater levels in the SFM exceeding 56 mAHD are therefore considered in yellow SSTL and levels in excess of 61 mAHD in red SSTL. Maximum mounding is expected in the vicinity of the final injection bore along each stope because of the reduction in stope conductivity. However, it is also possible for equivalent mounding to occur at any point during backfill if the stope collapses, thereby reducing the void space for injection. The implication here is that while bore HBF6-NTH and bore HBF5-NTH present the greatest risk to mounding in excess of a red SSTL along each stope, the possibility remains for equivalent mounding responses at all injection points. Both HBF6-NTH and bore HBF5-NTH bores are the northern most injection point along each stope. The general procedure for planned backfilling operations is from South to North.

The attached hydrographs show the predicted mounding in the SFM and the LPS at monitoring bores across the site. The modelling approach considered three scenarios to represent a range of possible void characteristics:

1. Open stope: The stope is modelled with the void represented by high hydraulic conductivity that remains consistent during all backfill operations;

2. Closing stope: Void hydraulic conductivity is linearly reduced throughout backfilling to below background properties at the completion of operations. This represents a void that is progressively backfilled with tailings; and

3. Partially closed stope: Initial void hydraulic conductivity is halved compared to the proceeding scenarios and linearly reduced such that background value is achieved prior to injection at the rig end. This scenario represents a scenario whereby the void is progressively backfilled with tailings, but also experiences a further loss of permeability due to caving.

Hydrograph plots shown in Figure 4.3 show the hydraulic head behavior in the LPS and SFM under each scenario. The graphs are presented in a sequence of increasing distance from the stope focusing on the LPS then the SFM and Table 4.1 summarises the bore locations which are assessed below and their distance from the nearest stope. BH-M12 is within the mining zone closest to the stopes. BH-M17 and BH-M19 are within the transition zone. BH-M25 is on the boundary of the mixing zone while UGM-M2 is approximately 200 m outside the mixing zone. The SFM hydrographs are for the water table and are not representative of the responses that could occur in the lower portions of the Shepperton Formation located approximately 30 mBGL.

Mounding within the LPS is greatest at the locations of injection (eg hydrographs for HBF6-NTH and HBF4-FE1) but recovers rapidly due to the high hydraulic conductivity of the aquifer. This is evident by the rapid recovery to baseline hydraulic heads at the cessation of backfill. It is noteworthy that the hydrographs are conservative in that they plot peak points only and exclude the effects of daily recovery in the LPS between the scheduled 1- hour work shifts.

Table 4.1 Bore locations relative to stopes

Bore	Screen	Distance to nearest stope (m)	Nearest Stope
HBF6-NTH	LPS (stope)	0	6
HBF5-MP1	LPS (stope)	0	5
HBF4-FE1	LPS (stope)	0	4
UGM-M12S	SFM	25	6
UGM-M12D	LPS	25	6
BH-M17S	SFM	75	6
BH-M17D	LPS	75	6
BH-M19S	SFM	125	6
BH-M19D	LPS	125	6
BH-M25S	SFM	250	6
BH-M25D	LPS	250	6
UGM-M2S	SFM	350	
UGM-M2D	LPS	350	

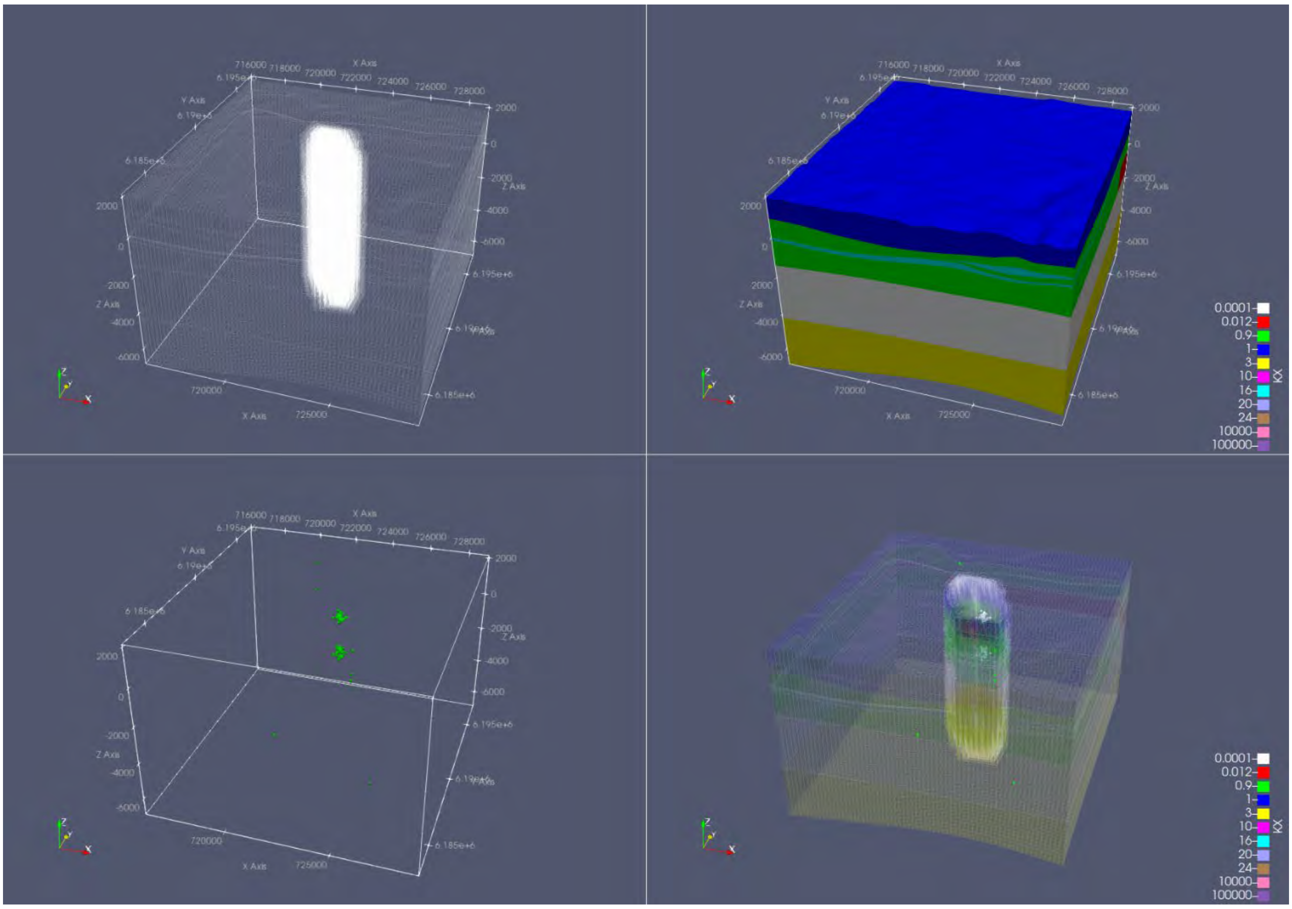


Figure 4.2 Vertically exaggerated model domain (z axis multiplied by 30)

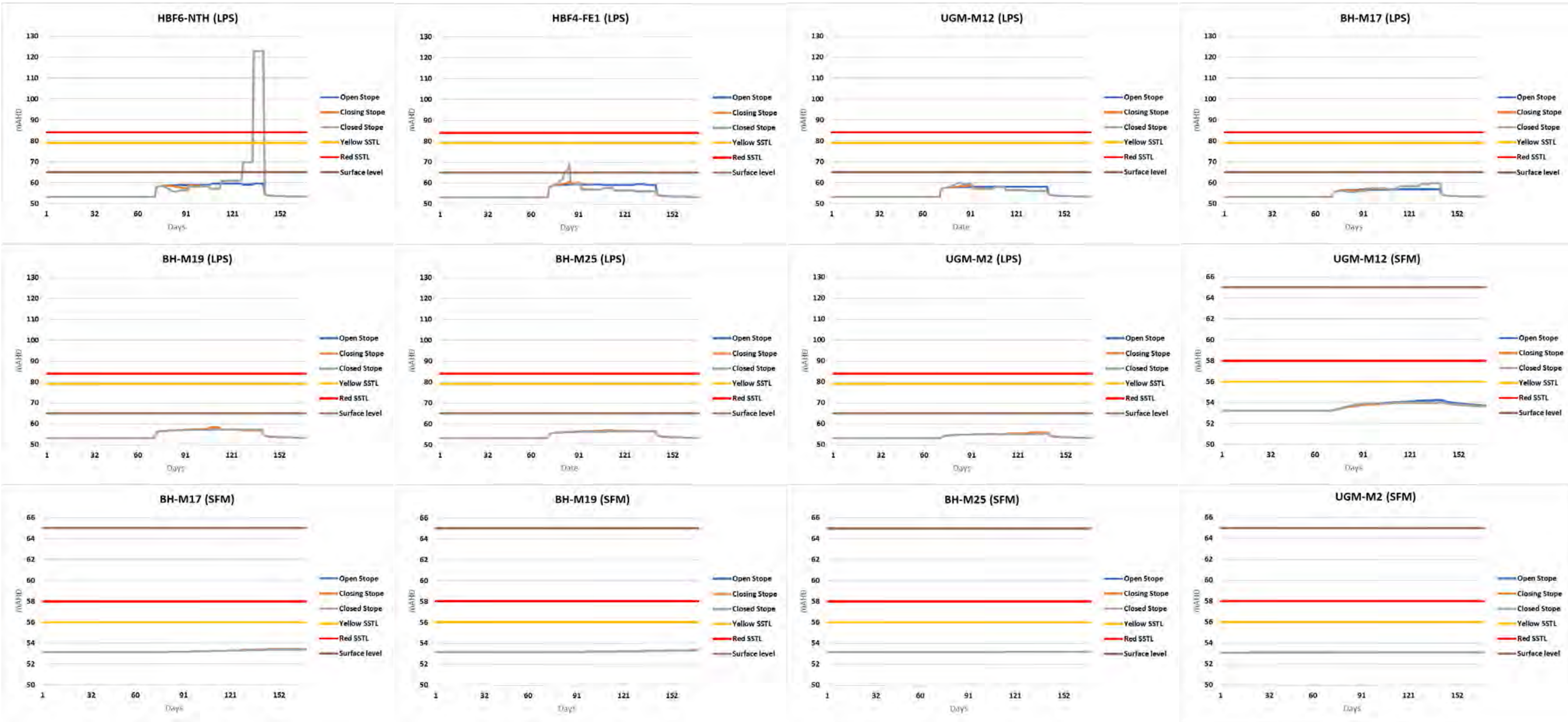


Figure 4.3 Hydrographs for modelled monitoring bores and selected injection points.

There is significant uncertainty associated with the predicted mounding within the SFM and LPS caused by the T3 activity. Characteristics contributing to uncertainty include:

1. Stope conditions prior to commencement of backfill:

    a) a large relatively open stope will facilitate backfill with minimal observable mounding initially because there is a large highly conductive void space available, which facilitates rapid propagation of pressure along the stope; and

    b) a stope that has collapsed will have reduced void space and less ability to propagate pressure, which may result in large mounding responses very early in the backfill process.

2. Integrity of the aquifer material above the stopes post-mining:

    a) if the aquifer material above the stopes remains cohesive then mounding responses in the SFM are likely to remain minimal during backfill. There is a naturally occurring bentonite layer at the base of the Shepperton which confines the LPS, facilitating potential artesian conditions during backfilling; and

    b) enhanced permeability of the bentonite layer above the mined stope will promote rapid mounding in the SFM. Enhance permeability may occur for multiple reasons including slumping, weakening of material above the stope due to pressurisation during backfilling, historical exploration drilling and leakage around the annulus of monitoring and/or injection/mining bores.

3. Extraction at P2 could potentially mitigate the mounding from backfilling, depending on timing and extraction rate from this bore. From a conservative perspective, the use of P2 is assumed to have occurred prior to backfilling activities and thus no mitigation of mounding pressures is simulated.

Regardless of the inherent uncertainty in the current model, the prediction results still give some valuable insights to how the system may behave during the T3 activity. Referring to Figure 4.4 to Figure 4.6, notable responses are summarised below, and site staff should be aware of such possible processes during the trial:

- the hydrographs show mounding in the SFM and LPS at specific bore locations. The three horizontal lines represent the surface level (brown), yellow (yellow) and red (red) SSTLs. The “open”, “closing” and “closed” scenarios reflect different stope behaviour during backfill, with increasing difficulty of returning tailings to the voids. Backfill starts 10 weeks after siteworks commence. Note some scenarios overlie each other;

- the hydrographs identify maximum mounding in the LPS at the points of injection. The hydrographs of monitoring points in the SFM are in order of increasing distance from the stope (refer Figure 2.2). Groundwater pressure increases within the SFM appear minimal despite significant hydraulic heads being simulated within the LPS, notably at HBF6-NTH;

- the modelled hydrographs also suggest that backfilling may cause less mounding response at the beginning of the backfill schedule, as indicated by responses simulated at HBF4-FE1, compared to the responses simulated at the end of the backfill schedule as indicated at HBF6-NTH. The modelled responses assume a constant backfill rate and may be required to reduce over time, as void spaces reduce and become increasingly filled with tailings. As it stands, the model suggests that a variable rate may be required to manage the pressures within an acceptable range;

- there appears to be very little East-West lateral propagation of mounding in the upper SFM (Figure 4.4 and Figure 4.5, Layer 1) away from the stopes. The mounding propagation migrates along the stope in line with the regional gradient, which is from South-East to North-West. Mounding may show greater lateral extent in the upper SFM within the angle of draw of the void due to loss of cohesion in the overlying aquifer material;

- mounding associated with backfilling may appears to have limited observable effect at the water table with increasing distance from the stope;
- the lower portion of the SFM (Figure 4.4 and Figure 4.5, Layer 2) shows greater response to the injection occurring in the LPS;
- there is potential for excessive mounding in the LPS (Figure 4.6) if the stope voids collapse or have reduced conductivity from backfilling (See Time Variant Material plots). Continued injection into a low conductivity stope could result in head pressures tens of meters above ground level. Regardless of stope initial behaviour, these conditions are very likely in the final stages of the backfill. Careful monitoring of the VWP responses and bores located in close proximity of the stopes should provide adequate warning of rapidly increasing mound trends;
- there is no observable impact to third party bore users extracting from the LRG. Full annual entitlement extraction Karra Homestead bore during 5 months of siteworks may cause <0.1 m drawdown at HD1; and
- there are no identified GDEs that could be impacted by drawdown or mounding from the T3 activity.

The numerical model will be validated/re-calibrated with actual site-based data post completion of the T3 trial, prior to use to inform LOM operations and impact assessments.

1.2 The Aquifer Interference Policy and minimal impact considerations

From an NSW regulatory perspective, the minimal impact considerations are a series of thresholds that define minimal impacts from aquifer interference activities. There are two levels of minimal impact considerations specified in the Australian Interference Policy (AIP), being Level 1 and Level 2. If the predicted impacts are less than the threshold level specified by the Level 1, then these impacts are acceptable under the AIP. Where the predicted impacts are greater than the Level 1 minimal impact considerations, then additional investigations are required to fully assess and manage these predicted impacts. If the investigations conclude that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, then those impacts will be considered acceptable.

Table 4.2 compares the potential project impacts with the minimal impact considerations for less productive western Murray porous rock water sources, which is appropriate for Balranald's site based aquifers. A location of the various groundwater sources within the relevant Water Sharing Plan (WSP) and approximate location of the T3 project are shown in Figure 4.7.

Table 4.2 Minimal impact considerations – less productive porous rock water sources

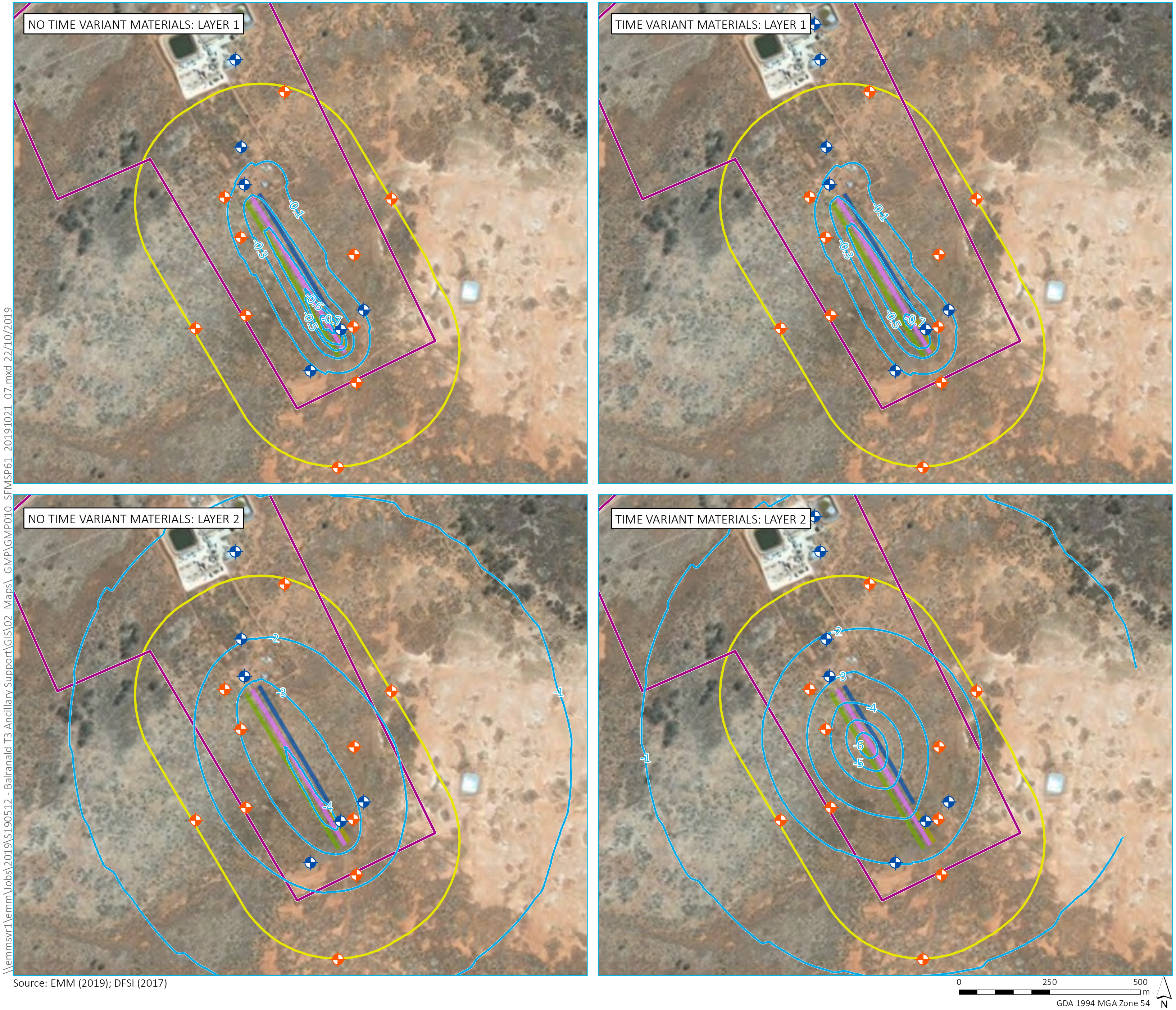
Water Sharing Plan (WSP013): The NSW Murray Darling Basin Porous Rock Groundwater Sources	
Aquifer	**Western Murray Porous Rock (Shepparton Formation, Loxton Parilla Sand and Renmark Group)**
Category	**Less productive**
Level 1: Minimal Impact Considerations	**Preliminary assessment**
Water table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan **or** A maximum of a 2 m decline cumulatively at any water supply work.	The model shows that water table mounding associated with T3 stope void backfill does not extend past the model domain and there are no GDE's or high priority culturally significant sites within the boundary of the model. **Conclusion:** No water table impacts to GDEs No water table impacts to Culturally Significant Sites No water table declines exceeding 2 meters from any water supply work
Water pressure A cumulative pressure head decline of not more than a 2 m decline, at any water supply work	Numerical modelling of the T3 trial shows a maximum of 0.1 m decline for 36 days for a single third-party water user which remains well below 2 meters. **Conclusion:** No water pressure impact
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity	The water used in the T3 trial is hypersaline water extracted from the LPS. There is presently no known beneficial use for this water in the region close to the trial site. There is no expected impacts to the less saline water of the LRG due to its hydraulic isolation caused by the presence of thick Geera Clay. **Conclusion:** No water quality impact

1.2.1 Impact assessment to 3rd party bores

The third-party bores closest to the trial site are T01, T02, T03 and HD1 (see Table 2.1). Apart from HD1, all third-party bores are at distances greater than the modelled domain. All bores are screened within the LRG and could potentially be impacted by extraction from the Karra Homestead bore. A simulation comprising a full extraction of annual entitlement at Karra during the T3 trial showed that the expected responses to third party bores T01, T02 and T03 are negligible (< 0.05 m). The maximum drawdown predicted at HD1 is 0.1 m at the cessation of site works. The model shows complete drawdown recovery within a period 56 days. The clay sediments of the Geera Clay formation prevent drawdown and mounding within the LRG from impacting the LPS and vice versa; in other words, they are hydraulically isolated as far as T3 activities are concerned.

1.2.2 Impact assessment to environmental receptors

Notwithstanding the root zones of vegetation, there are no environmental receptors that are a cause for concern within the vicinity of the trial. The numerical model used to predict the mounding from backfill show minimal (< 0.01 m in the LPS) hydraulic effects at the model boundaries. There is potential for significant mounding directly above the stope void but this will be avoided with the combination of planned monitoring strategy and the SSTLs.



KEY
- Activity area
- Existing bores
- Proposed new T3 bores
- Mounding contour (m)
- Transition zone boundary
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

Note:
Layer 1 = Upper SFM (water table region)
Layer 2 = Lower SFM (slightly above LPS)

Source: EMM (2019); DFSI (2017)

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Shepperton Formation groundwater contours at the end of injection at HBF5-MP1

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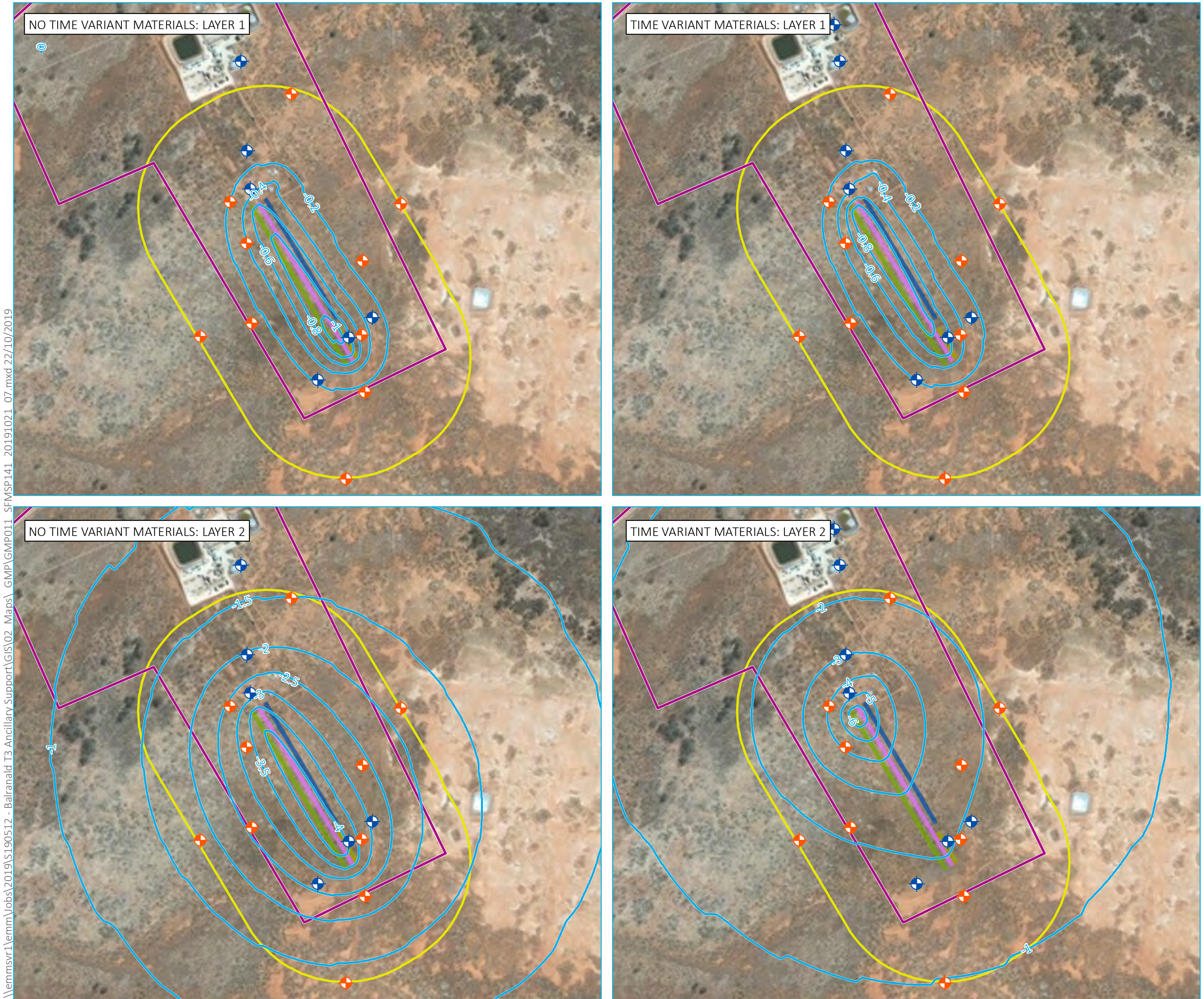
Groundwater Assessment Report
Figure 4.4

EMM
creating opportunities



0 250 500 m
GDA 1994 MGA Zone 54
N

Source: EMM (2019); DFSI (2017)

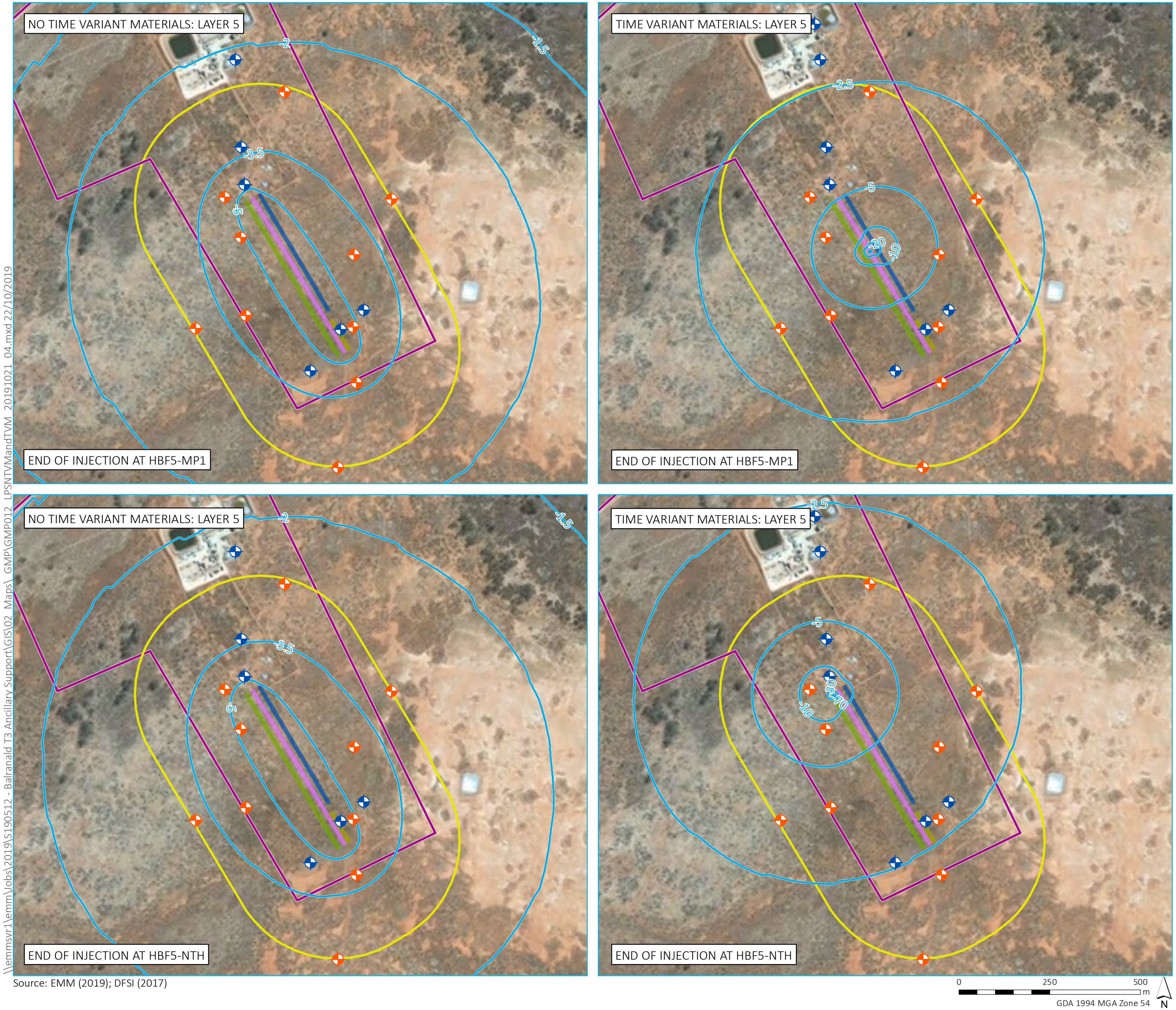
KEY
- Activity area
- Existing bores
- Proposed new T3 bores
- Mounding contour (m)
- Transition zone boundary
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

Note:
Layer 1 = Upper SFM (water table region)
Layer 2 = Lower SFM (slightly above LPS)

Shepperton Formation groundwater contours at the end of injection at HBF6-NTH

Iluka Resources Limited
Groundwater Assessment Report
Figure 4.5

EMM
creating opportunities



KEY

- Activity area
- Existing bores
- Proposed new T3 bores
- Mounding contour (m)
- Transition zone boundary
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

Note:
Layer 5 = LPS hosting ore body

Source: EMM (2019); DFSI (2017)

Loxton-Parilla Sands
groundwater contours

Iluka Resources Limited
Groundwater Assessment Report
Figure 4.6

EMM
creating opportunities

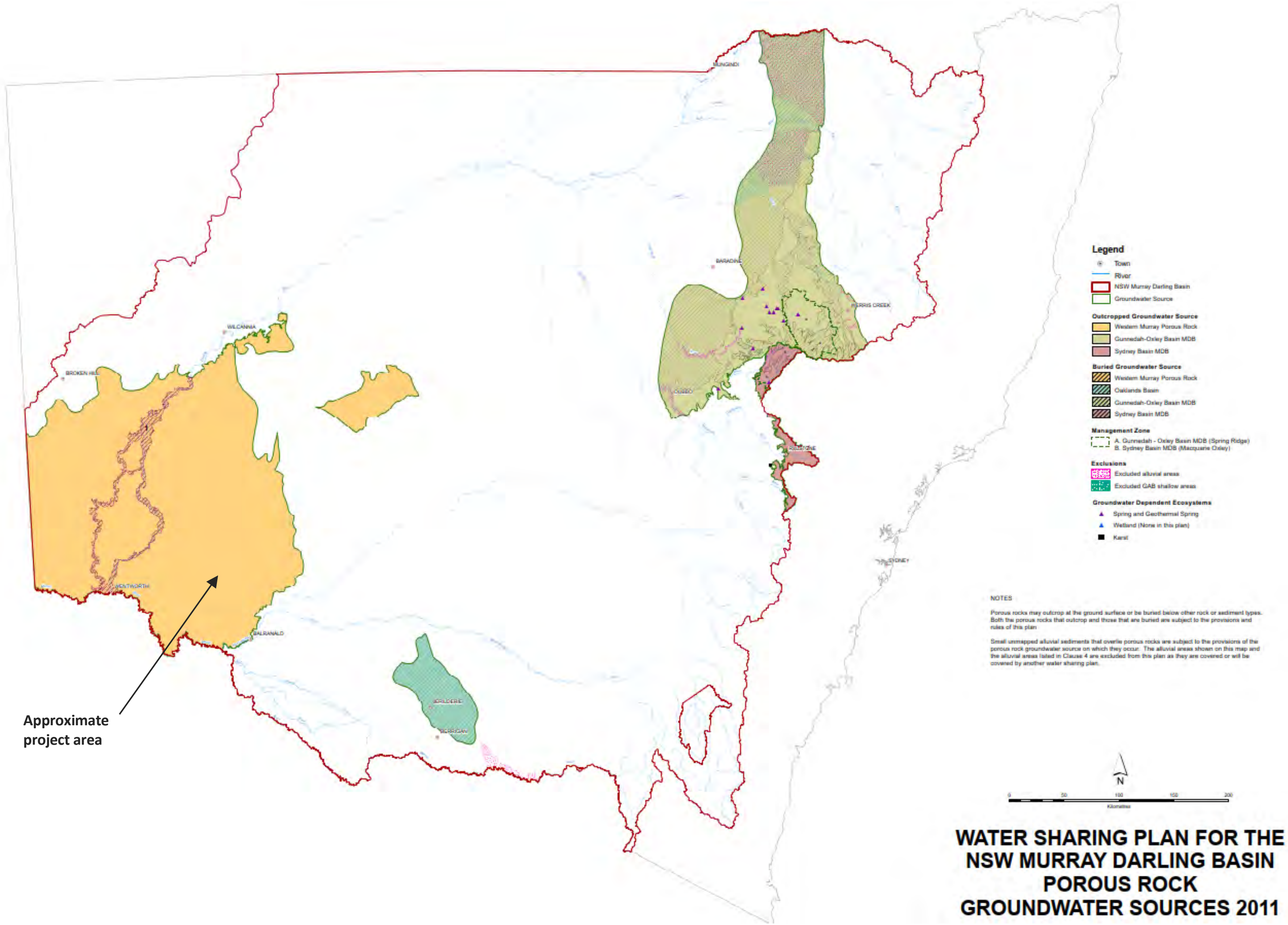


Figure 4.7 Water Sharing Plan for the NSW Murray Darling Basin porous rock groundwater resources

5 Water Balance

Water used at the trial site will comprise volumes extracted from existing production bores. This includes the PWD bore, P2, screened within the LPS and the Karra Homestead bore screened within the deeper LRG (Figure 2.1). Direct rainfall interception and runoff by the PWD is expected to be negligible given the size of the dam. However, some loss due to evaporation from the PWD is expected to contribute to makeup water demand. The water pumped from the Karra Homestead bore is considered a loss because it will be used primarily for dust suppression and stockpile management.

The mining method extracts and injects water sequentially during ore removal with some water lost to the mined cavity in the process. There is also a small volume of water sourced from the PWD that is lost at the screening plant. The volume of water used during backfilling is expected to be the primary use of water from the PWD, which will be sourced from the P2 bore. Despite large volumes associated with injection during backfilling, net groundwater use in the LPS is expected to be negative. A Water Trade for 2019-2021 was secured at 2350 ML previously and was assigned to the Water Access License (WAL) 31102. Abstraction from the LRG has a limit of 150 ML secured via Water Trade for 2019-2021 and was assigned to WAL 31101.

Presently, the available data for water use is in flow rates associated with the mining process. This makes a volumetric water balance problematic until the new mine operations plan is finalised. Accordingly, the site water balance in Table 5.1 is based on an estimated percentage use of licensed extraction informed by flow rates associated with the mining process and should therefore be considered preliminary. Make-up water requirements are a percentage of the loss from the LRG.

The flow rate demand required for mining, plant and backfill activities have been estimated as 527, 219 and 116 m^3/hr respectively.

Table 5.1 Site water balance (to/from aquifer)

Extraction:	**Volume (ML)**	**Percent of licensed extraction**
From LPS	2350	100
From LRG	150	100
Injection:		
Into LPS	-2040	87
Into LRG	0	0
Residual:		
LPS loss	310	13
LRG loss	150	100

6 GME and compliance reports

6.1 Sampling methodology

All post-T2 groundwater monitoring events have been undertaken by LWC, Iluka's current field sampling consultant. The sampling methodology used is described in Table 6.1. A data quality assessment carried out by LWC (2019) found that the data collected is suitable to be used as a basis of interpretation of potential impacts beneath the Site; an acceptable degree of field and laboratory QA/QC was collected and reported, providing confidence in the accuracy and precision of all reported results.

Data collected pre, during and post T3 activities will be undertaken using similar methodologies and are further discussed in the GMP (EMM 2019a).

Table 6.1 LWC (2019) groundwater sampling methodology

Activity	Details
Water level measurement	Monitoring bores were gauged for water level elevations using a calibrated electronic water level probe prior to the commencement of sampling. Water levels were gauged from the top of the casing.
Well purging and sampling	All groundwater monitoring bores were purged using industry standard low-flow sampling techniques with dedicated LDPE Teflon tubing used per location. The low-flow sampling method included placement of the pump at the midpoint of the slotted screen interval and pumping at a flow rate such that the groundwater did not decline significantly (greater than 10 cm). Each bore was pumped at a flow rate less than 0.5 L/min, which is within the recommended range in industry standard guidelines (0.1 to 0.5 L/min). Groundwater elevation gauging during sampling was undertaken to ensure groundwater extracted from the bore was fresh groundwater obtained from the adjacent formation and not stagnant water contained in the bore. Note that T01, T02, T03, HD1 and the Karra Homestead bore are permanently equipped with pumps, tubing and associated headworks. The existing pump setup on these bores was used for purging and sampling. The discrete process water samples taken from the PWD were obtained using a dedicated disposable bailer.
Field parameters	Prior to collection of field parameters, a flush-through of groundwater entering the tubing material was undertaken and was conservatively based on an assumption of 1 litre per 10 metres of tubing. Measurement of field water quality parameters was undertaken until the parameters had stabilised (ie within 3% EC, 0.05 pH, 10% DO, 10mV redox and 0.5C temperature). Parameter measurements were obtained every 5 minutes until field parameters had stabilised over two consecutive readings, after which sampling proceeded. A minimum of four readings were undertaken at each monitoring bore. Field chemical parameters were recorded to ensure stable geochemical conditions existed prior to the collection of the groundwater sample. Field tests for ferrous and total iron were undertaken at each location using a DR900 handheld colorimeter. The pH, redox, electrical conductivity, dissolved oxygen and temperature metres were calibrated prior to the commencement of purging (ie at the start of each day) and recorded into a calibration record book.

Table 6.1 LWC (2019) groundwater sampling methodology

Activity	Details
Decontamination procedure	Decontamination of all groundwater sampling equipment between locations was performed using the following procedure: • decontaminate equipment away from the sampling location; • wash with Decon 90 or similar decontaminant solution and rinse; • triple wash with laboratory supplied clean deionised water; and • air dry the equipment (if possible) before use in sampling. The flow cell for measuring field parameters was also rinsed with clean water between locations.
Sample method and preservation	Targeted monitoring bores were purged and sampled using dedicated low-flow LDPE Teflon tubing (per monitoring bore). Following stabilisation of field parameters, samples were placed into laboratory supplied bottles containing appropriate preservatives for the required analytical tests. Groundwater samples analysed for heavy metals/metalloids and ferrous/ferric iron were filtered in the field using dedicated 0.45 µm filters for each sample, prior to being placed into a pre-acidified container. Samples were immediately chilled and stored at a temperature of 4°C or less prior to transit to the laboratory.
Analytical laboratories	Groundwater samples were placed in laboratory cleaned bottles containing appropriate preservatives, and then placed into a chilled esky for transport to the primary laboratory, Australian Laboratory Services Pty Ltd (ALS). Intra-duplicate and inter-duplicate groundwater samples were also collected and sent to ALS and Eurofins- MGT Pty Ltd (MGT) another NATA registered laboratory. Laboratory limits of reporting were below the adopted relevant guideline values for each targeted analysis.
Quality assurance/quality control	QA/QC samples were collected and analysed in accordance with Australian Standard and NEPM (1999 – amended 2013). QA/QC samples collected for quality control purposes included the following: • intra-laboratory field duplicates; • inter-laboratory field triplicates; and • rinsate blanks (pump equipment only) per each day of sampling to ensure appropriate decontamination processes occurred. The frequency of QA/QC samples included the following: • 1 in 20 groundwater samples are required for intra- and inter-laboratory field duplicate analysis; and • 1 rinsate blank from the decontaminated pump obtained for key water quality analytes (heavy metals) per day.
Sample nomenclature	Sampling nomenclature was consistent with the previous monitoring bore nomenclature.
Field records/documentation	During each monitoring event: • Groundwater elevations were recorded for each targeted monitoring event; • Field purge and sampling sheets were filled in per bore per monitoring event; and • Chain of custody documentation for all samples were sent to the laboratory to be maintained for quality assurance checking.

6.2 QA/QC procedures

Quality assurance/quality control (QA/QC) measures are activities undertaken to demonstrate the accuracy and precision of the monitoring program. Quality control (QC) consists of the steps Iluka and their consultants will take to determine the validity of specific sampling and analytical procedures. Quality assurance (QA) generally refers to Iluka's broad plan for maintaining quality in all aspects of the work program. The reliability of and confidence in the data collected on-site is determined through the following quality controls:

- routine and regular equipment maintenance, checks and calibrations;
- internal data validation; and
- external data validation.

All QA/QC results will be assessed both by Iluka and their consultants to inform the overall adequacy and reliability of each parameter to meet the monitoring program objectives.

6.2.1 Equipment maintenance, checks and calibrations

Any down-hole sensors will be calibrated prior to use, according to the manufacturer's recommendations. At a minimum, any down-hole sensors will be calibrated again post-trial to assess any potential deviation. Field meters used to measure water levels, pH, EC, ORP, ferrous iron and ferric iron will be calibrated daily. The calibrations will be carried out using standards and buffers that reflect the likely range of measurement.

The requirement for recalibration during the trial will be assessed as needed based on any observed measurement drift, measurement error, equipment malfunction, or discrepancy with manually collected field data. At a minimum, each sensor will be calibrated according to the guidance provided by the instrument manufacturer. When not in use, equipment will be stored and maintained according to the manufacturer's guidance.

All calibrations will be recorded in an electronic calibration log that will include the sensor number (or serial number) and the measured parameter both before and after calibration. This log will allow detection of possible instrument issues over time and serve as a reference to increase data confidence should future validation be required.

All equipment will be cleaned routinely as part of the calibration and maintained according to the manufacturer's specifications or more frequently as required.

6.2.2 Internal data validation

Internal data validation procedure will be performed by Iluka staff and their nominated consultants and will include the following:

- Field blanks: at a minimum, one field blank will be collected per batch of groundwater samples analysed;
- Field duplicates: at a minimum, one duplicate sample will be collected and analysed for selected parameters per batch of groundwater samples or per 20 samples. In addition, a minimum of two duplicate samples will be collected and analysed by a different external laboratory for groundwater samples collected before and after the bulk sampling activities;
- Spike samples: used for investigative purposes, as required. The concentration of the standard used, and amount of standard addition will be determined based on the parameter and/or test method in question;

- Manual groundwater level measurements to verify the data collected by the automatic water level loggers; and

- Manual discrete water quality measurements to verify laboratory derived data.

The internal QA/QC procedures followed during the post-T2 groundwater monitoring events are summarised in Table 6.1.

In addition to validation processes related to water quality, the following routine procedures will also be undertaken:

- manual groundwater level measurements compared to downloaded logger data from both down-hole logger sensors and VWPs; and

- measured water abstraction volumes and calculated rates.

6.2.3 External data validation

External checks are performed by non-Iluka personnel such as an external monitoring contractor or the analytical laboratory. Iluka and/or nominated consultants will select one or more laboratories that are accredited by the Australian National Association of Testing Authorities (NATA). As such, each laboratory selected operates according to the guidelines described in ISO/IEC 17025 – "General requirements for the competence of calibration and testing laboratories". Iluka will review the external laboratory QA/QC program as part of the laboratory selection process.

External laboratories should provide a QA/QC report with each batch of samples given. To avoid data entry errors, the laboratory should transcribe all data reports electronically. The external QA/QC procedures followed during the post-T2 groundwater monitoring events are summarised in Table 6.1.

7 Closing

A summary of the main hydrogeological, hydrogeochemical and other assessments performed to date has concluded the following:

- all of the groundwater monitoring bores on-site have been adequately developed;
- if the process water is buffered appropriately, minimal pH and metal mobilisation related impacts should be observed in the surrounding groundwater following reinjection events;
- maintaining process water at a pH of between 6.5 and 8.5 will be sufficient to buffer the potentially acid forming ore;
- with appropriate buffering, groundwater quality should reach background levels within a 300 m radius from the edge of the active stope, based on preliminary geochemical modelling;
- no permanent alteration of the groundwater system can be delineated as a result of the previous T2 bulk sampling activities;
- an estimated 13% of the groundwater extracted from the LPS will be consumed during the T3 trial due to process losses;
- it is unlikely that there will be any impact to third-party water users from T3 operations due to water extraction from the LPS at bore P2, or extraction from the LRG at the Karra Homestead bore;
- there are presently no identified GDEs that will be impacted by theT3 trial;
- despite enhanced vertical connection between the LPS and SFM, T3 models show small mounding responses in the upper SFM at the water table, when injecting into large stopes at the start of backfill;
- void properties have a significant effect on mounding behaviour in both the SFM and LPS; and
- the final stages of backfill along each stope represent the greatest risk for excessive mounding due to reduction in the volume of the stope void.

It is acknowledged that monitoring and management of deeper-rooted vegetation in the context of groundwater mounding should be included in the GMP for full-scale operation. For the planned T3 trial, however, the monitoring and management of this vegetation is not applicable, as it is associated with the Black Box community and the river floodplain, which are located sufficiently far from the trial site that they will not be impacted. Consideration of this vegetation will be included in the GMP for full-scale operation, which will be updated prior to commencement in consultation with DPIE Water.

It is noted that the updated GMP is required to be submitted to DPIE Water 6 months prior to commencement of other activities that may impact groundwater, such as further bulk sampling activities or mine commencement. Based on current planning, horizontal directional drilling is scheduled to begin in March 2020, following by bulk sampling from June 2020.

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Appendix A

Bore Lithology Logs

A.1 Karra Homestead Bore

Table A.1 Karra Homestead Bore lithology log

Depth (mBGL)	Unit	Description
0-6	Shepparton Formation	Clay: Light brown. Moderate-high plasticity
6-7	Shepparton Formation	(As above) Ferruginous clay. Light grey and red 50-50%
7-11	Shepparton Formation	Silty Clay: Grey and light brown, trace red-brown
11-13	Shepparton Formation	Silty Clay: Mottled grey and light brown, increasing red-brown, trace yellow-brown. Moderate-low plasticity
13-18	Shepparton Formation	Clayey Silt: Light grey and red-brown. Silt, trace medium quartz, subrounded-subangular, moderate-high sphericity
18-21	Shepparton Formation	Ferruginous Sand/Silty Sand: Light grey and red-brown. Silt-medium grains, subangular-subrounded, moderate sphericity, moderately sorted. Trace clay
21-22	Shepparton Formation	Sand: Clear, light grey, light red-brown. Very fine-medium <1mm, subangular, moderate sphericity, well sorted. Minor cemented quartz grains, light grey
22-24	Shepparton Formation	(As above) Overall increase in grain size, medium <2mm
24-25	Shepparton Formation	Sand (as in 21-22m): Increase in red-brown grains. Cemented pieces, mostly light grey. Increase in size of cemented pieces
25-26	Shepparton Formation	Sand: Clear, light grey, orange-brown. Fine-medium, subangular-subrounded, moderate sphericity, well sorted. Minor cemented sand (less than interval above). Most pieces 5mm
26-27	Shepparton Formation	Sand: Light grey, trace red-brown. Fine-medium, subangular-subrounded, moderate sphericity, well sorted. Minor cemented sand
27-29	Shepparton Formation	(As above) with trace yellow-brown
29-30	Shepparton Formation	Sand: Light grey, orange-brown, trace yellow brown. Very fine-medium, subangular, poor-moderate sphericity, well sorted. Smaller pieces of cemented sand.
30-31	Shepparton Formation	(As above) Trace red-brown. Cemented/semi-cemented pieces are silt instead, not sand. Increase in size of silt pieces, mostly ~1cm
31-33	Shepparton Formation	Indurated Sand: Light grey, minor red-brown. Medium grains, subrounded-subangular, moderate sphericity
33-34	Shepparton Formation	Clay: Light grey-light brown. Moderate plasticity
34-35	Loxton Parilla Sands	Sandy Clay: Light grey, light brown. Trace cemented sand pieces. Trace medium clear quartz grains, trace very fine-fine sand, rounded, moderate-high sphericity
35-36	Loxton Parilla Sands	Silty Clay: Light grey. Low plasticity
36-41	Loxton Parilla Sands	Sand: Light grey, light brown, trace red-brown. Medium grained quartz, subrounded, well sorted, clear, moderate-high sphericity. ~50% yellow-stained grains
41-43	Loxton Parilla Sands	(As above) minor yellow-brown

Table A.1 Karra Homestead Bore lithology log

Depth (mBGL)	Unit	Description
43-44	Loxton Parilla Sands	Sand (as in 36-41m) increase in quartz sand. Trace maghemite - dark brown/black, dull, no metallic lustre, platy, crumbles easily, dark brown streak, magnetic
44-45	Loxton Parilla Sands	Sand: Light grey, clear. Fine-medium grains, subrounded, moderate sphericity, well sorted. Trace light grey clay, very low plasticity
45-46	Loxton Parilla Sands	(As above) overall more yellow. Trace dark brown
46-48	Loxton Parilla Sands	Sand: Light-dark grey. Medium grains (overall coarser than previous interval), subrounded, moderate sphericity, well sorted
48-49	Loxton Parilla Sands	(As above) trace dark red-brown
49-50	Loxton Parilla Sands	Sand: Light grey, minor red-brown, trace dark grey. Medium grains (finer than above), subrounded, moderate sphericity, well sorted. Trace clay
50-51	Loxton Parilla Sands	Sand: Light-dark grey, trace red-brown and dark brown. Medium, subrounded, well sorted quartz sand. Trace clay. Trace indurated dark brown silt. Trace maghemite specks
51-53	Loxton Parilla Sands	Sand: Dark-light grey, trace black specks. Medium grains, subrounded, moderate sphericity, moderately sorted. Trace clay and silt
53-54	Loxton Parilla Sands	(As above) no silt/clay
54-55	Loxton Parilla Sands	Sand: Dark-light grey, minor black, trace red-brown. Fine-medium, trace coarse <2mm, subrounded, moderate-high sphericity. Trace hard silcrete pieces, cream-coloured. Trace cemented pieces. Black specks throughout
55-59	Loxton Parilla Sands	Sand: Dark-light grey, minor black, trace dark brown and yellow-brown. Fine-medium grains, high sphericity, well sorted. Trace hard light grey clay
59-60	Loxton Parilla Sands	(As above) overall increase in grain size (medium). No clay present. Trace red-brown <5%
60-61	Loxton Parilla Sands	Sand: Light-dark grey, black, trace red-brown. Very fine-medium, subangular-subrounded, moderate sphericity, poorly sorted. Trace maghemite
61-62	Loxton Parilla Sands	Sand: Dark-light grey, brown, trace black. Very fine-medium, subrounded, moderate sphericity, moderately sorted, polished
62-64	Loxton Parilla Sands	(As above) trace orange-brown grains. Trace light grey clay
64-67	Loxton Parilla Sands	Sand: Dark-light grey, black, trace red-brown. Very fine-medium, subangular-subrounded, moderate-low sphericity, poorly sorted. Maghemite and black specks. At 65-66m, less fine grains
67-69	Loxton Parilla Sands	Sand: Dark-light grey, trace black. Very fine-medium grains, subangular-subrounded, moderate sphericity, moderately sorted
69-72	Loxton Parilla Sands	(As above) with light grey clay
72-73	Loxton Parilla Sands	Sand: Dark grey, black, trace red-brown. Very fine, minor medium <2mm, subrounded, moderate-high sphericity, moderately sorted. Abundance of black, carbonaceous. Trace HM
73-74	Loxton Parilla Sands	Sand: Dark grey, black. Very fine-medium grains, subrounded, moderate-high sphericity, poorly sorted. Black clumps ~5mm. Less HM than above. Mica

Table A.1 Karra Homestead Bore lithology log

Depth (mBGL)	Unit	Description
74-77	Loxton Parilla Sands	Sand: Black, dark grey. Carbonaceous. Very fine and medium quartz, rounded, high sphericity. Mica, trace HM
77-80	Loxton Parilla Sands	Silty Sand: Light grey, light brown, trace black silt. Silt-very fine and medium grains, subangular, low-moderate sphericity, poorly sorted. Quartz held together in a cemented silt matrix. Trace light grey clay
80-81	Loxton Parilla Sands	Sandy Silt: Dark grey, black. Silt, minor medium ~<1mm quartz. Black and grey silt. Mica
81-83	Loxton Parilla Sands	(As above) with trace red-brown
83-85	Loxton Parilla Sands	Silty Sand: Dark grey, minor black. Silt-medium (trace) subrounded, moderate sphericity grains. At 84-85m, trace light grey clay
85-86	Loxton Parilla Sands	Sandy Silt: Dark-light grey, trace black. Silt-very fine/fine grains. Trace light grey clay
86-88	Loxton Parilla Sands	Silty Sand: Dark grey, trace black. Silt-fine sand. Trace cemented sand. Trace mica
88-89	Loxton Parilla Sands	Silt: Dark grey, minor black. Trace yellow-stained grains. (Red-brown throughout sample due to contamination with surface)
89-90	Loxton Parilla Sands	(As above) trace light grey clay - mudstone
90-91	Loxton Parilla Sands	Silty Sand: Dark grey, minor clear, black. Silty-medium grains, subrounded, moderate sphericity, poorly sorted. Trace light grey hard clay
91-92	Loxton Parilla Sands	Silt (as in 89-90m): increase in black silt clumps
92-94	Loxton Parilla Sands	Silt: Dark grey, black 50-50%. Abundance in silty black clumps. Trace light grey hard clay - mudstone. Trace medium quartz grains, clear and opaque
94-96	Loxton Parilla Sands	Silt: Dark grey
96-97	Loxton Parilla Sands	Silt: Dark grey. Trace medium-fine grains, subrounded-subangular, moderate sphericity
97-101	Loxton Parilla Sands	Silt: Dark grey, black. Trace medium quartz, clear, yellow, light grey. Trace white-light grey low plasticity clay
101-102	Loxton Parilla Sands	Sandy Silt: Dark grey, black. Medium clear grains, subrounded, moderate sphericity, well sorted. Trace orange-yellow quartz grains
102-103	Loxton Parilla Sands	Silt (as in 97-101m)
103-104	Loxton Parilla Sands	Sandy Silt (as in 101-102m)
104-107	Geera Clay	Silt: Dark grey, black, trace light grey. Silt, trace medium quartz, subrounded, moderate sphericity. Trace light grey clay pieces, very low plasticity, disperses easily. At 105-107m, red-brown and yellow-brown clumps present
107-108	Geera Clay	Silt: Dark grey, black, trace red/yellow-brown. Minor medium quartz, angular-subrounded, moderate sphericity, moderately sorted. Trace low plasticity clay
108-109	Geera Clay	Clayey Silt: Dark grey, black, trace light grey and yellow-brown. Minor low plasticity clay. Trace medium quartz grains

Table A.1 Karra Homestead Bore lithology log

Depth (mBGL)	Unit	Description
109-110	Geera Clay	Silt: Dark grey, black. Trace medium quartz, subangular
110-111	Geera Clay	Silt: Dark grey, trace light grey, black. Minor low plasticity clay. Trace medium quartz <0.5mm
111-112	Geera Clay	(As above) less clay
112-115	Geera Clay	Silt: Dark grey, black. Minor quartz, medium <1mm, subrounded, moderate sphericity, poorly sorted. Amount of quartz increasing with depth. At 114-115m, yellow-brown silty clump. Trace shell fragments?
115-116	Geera Clay	(As above) less medium quartz. Trace red silty clump
116-117	Geera Clay	Silt: Dark grey, black. Trace medium quartz grains. Trace dark grey clay
117-118	Geera Clay	(As above) Trace medium-coarse grains, subangular-subrounded
118-119	Geera Clay	Silt (as in 116-117m)
119-120	Geera Clay	Silt: Dark grey, black. Minor light grey clay, low plasticity
120-122	Geera Clay	Silt: Dark grey, black. Minor medium quartz <1mm, clear and yellow-orange, subangular, moderate sphericity, poorly sorted. Amount of quartz increasing with depth (at 121-122m). Trace red silt
122-123	Geera Clay	Silt: Dark grey, black. Minor quartz, clear, opaque and yellow/orange. Trace red silt
123-124	Geera Clay	Silt: Dark grey, black. Minor medium quartz, clear, yellow, red grains, subangular-subrounded, moderate sphericity, poorly sorted. Trace white-grey clay. Trace mica
124-125	Geera Clay	Silt (as in 122-123m): trace white-grey clay, low plasticity
125-127	Geera Clay	Silt (as in 123-124m)
127-128	Geera Clay	Silt: Dark grey, black. Minor clear, yellow, red quartz grains. Medium <1mm, subangular-subrounded, moderate sphericity, moderately sorted
128-129	Geera Clay	(As above) quartz grains are more angular (subangular) and poorly sorted
129-130	Geera Clay	Silt: Dark grey, black. Minor white-grey clay with low plasticity. Trace medium <1mm quartz grains, subangular-subrounded, moderate sphericity, moderately sorted. Trace light yellow/cream cemented quartz grains - silcrete?
130-131	Geera Clay	Silt: Dark grey, black, minor red. Minor quartz grains, medium <2mm, subangular-subrounded, poorly sorted. Trace white-grey clay with low plasticity
131-132	Geera Clay	(As above) quartz grains <1mm
132-142	Geera Clay	Silt (as in 130-131m)
142-144	Geera Clay	Clayey Silt/Silty Clay: 50-50%. Dark grey and light grey-white. Medium plasticity. Trace quartz grains
144-145	Geera Clay	(As above) with trace red silt
145-146	Geera Clay	Clay: Dark grey and light grey-white. Trace medium quartz grains. Clay medium-high plasticity. Trace bright blue embedded in clay
146-149	Geera Clay	(As above) no bright blue present

Table A.1 Karra Homestead Bore lithology log

Depth (mBGL)	Unit	Description
149-150	Geera Clay	Silty Clay: Dark grey. Low plasticity. Minor light grey-white clay. Minor medium quartz grains, angular, low sphericity, poorly sorted
150-151	Geera Clay	Silty Clay: Dark grey, minor white. Minor quartz grains, medium, subangular, low-moderate sphericity, poorly sorted
151-154	Geera Clay	Clay (as in 145-146m). Dark grey. Calcareous - reacts with HCl. At 152-154m, silt increasing with depth
154-157	Geera Clay	Clayey Silt: Dark grey, black. Trace white clay. Trace iron-stained quartz grains, medium, subangular-subrounded, moderate sphericity. Clay, low plasticity. Trace pale blue (Glauconite? Contamination?). Calcareous, reacts with HCl
157-160	Geera Clay	(As above) overall increase in grain size of quartz, still medium. No trace of blue. Calcareous, small shell visible
160-168	Olney Formation	Sandy Silt: Dark grey, clear, white, trace red. Silt-medium grains, rounded, moderate-high sphericity, poorly sorted. White shell fragments, calcareous
168-170	Olney Formation	(As above) with trace light grey low plasticity clay. At 169-170m, clay content increasing with depth
170-178	Olney Formation	Sandy Silt: Dark grey, trace red silt/quartz. Silt-medium grains, rounded, moderate sphericity, poorly sorted. Trace light grey low plasticity clay. Trace white calcareous fragments, reacts with HCl
178-179	Geera Clay	Silty Clay: Very dark grey, light grey. Medium plasticity clay. Trace quartz grains, and calcareous fragments
179-180	Geera Clay	Sandy Silty Clay: Very dark grey. Low-medium plasticity. Trace medium quartz grains, trace calcareous fragments
180-181	Geera Clay	(As above) with light grey low plasticity clay
181-182	Geera Clay	Sandy Silty Clay (as in 179-180m): Decrease in amount of quartz grains. Trace light grey clay low plasticity
182-183	Geera Clay	Sandy Silty Clay: Dark grey, black, trace light grey low plasticity clay. Medium quartz grains <1mm, trace coarse, subangular, moderate sphericity, poorly sorted. Trace calcareous fragments
183-185	Geera Clay	(As above) no coarse quartz grains
185-186	Geera Clay	Silt: Dark grey, minor/trace black, trace light grey clay. Trace calcareous fragments
186-187	Geera Clay	(As above) trace quartz
187-191	Geera Clay	Sandy Silty Clay (as in 183-185m). At 189-191m, trace red
191-194	Geera Clay	Silt: Dark grey and black, trace orange, clear and opaque quartz grains. Trace light grey clay. Trace calcareous fragments
194-205	Olney Formation	Silty Sand: Dark grey, black. Fine grains, trace medium, trace orange-red. Trace light grey low plasticity clay. Trace calcareous fragments
205-210	Olney Formation	(As above) increase in clay (minor)
210-214	Olney Formation	Silty Sand: Dark-light grey. Fine-medium grains. Trace light grey low plasticity clay

Table A.1 Karra Homestead Bore lithology log

Depth (mBGL)	Unit	Description
214-215	Olney Formation	(As above) increase in clay. Trace calcareous fragments
215-223	Olney Formation	Silty Sand (as in 210-214m)
223-224	Olney Formation	Sand: Light-dark grey. Fine-coarse grains, subangular, low sphericity, poorly sorted
224-229	Olney Formation	(As above) Trace orange. Less fine grains. Trace mica
229-239	Olney Formation	(As above) trace light grey clay. Increase in coarse grains. At 233-239m, clay and silt content increasing with depth

A.2 P2 Bore

Table A.2 P2 Bore lithology log

From (mBGL)	To (mBGL)	Unit	Description
0	1	Shepparton Formation	Silty Clay: Pale red- grey, low plasticity.
1	3	Shepparton Formation	Clay: Pale grey- red, low plasticity. @ 2-3m high plasticity.
3	8	Shepparton Formation	Silty Clay: Light grey, trace orange. Very low plasticity. @ 4m trace red. @ 5-8m low- medium plasticity.
8	9	Shepparton Formation	Ferruginous Clay: As above, increase in red (50%).
9	11	Shepparton Formation	Ferruginous Clay: As above, increase in yellow (trace), medium plasticity.
11	15	Shepparton Formation	Clay: Light grey, medium plasticity.
15	17	Shepparton Formation	Clay: Pale brownish grey, low plasticity.
17	20	Shepparton Formation	Clay: Light grey and red and yellow mottled silty clay, low plasticity.
20	21	Shepparton Formation	Silty Clay: As above, increase in red silt (minor).
21	22	Shepparton Formation	Clayey Sand: Clear, light grey, fine, well sorted, moderately polished, moderate sphericity, sub angular- sub rounded. Trace orange grains.
22	28	Shepparton Formation	Ferruginous Clayey Sand: As above, minor yellow-orange.
28	29	Shepparton Formation	Ferruginous Clayey Sand: As above, predominantly orange, minor clear, very fine-fine,trace medium, moderately sorted, sub angular- sub rounded, moderate sphericity.
29	34	Shepparton Formation	Clay: Yellowish grey, low plasticity. @ 32m decrease in yellow.

Table A.2 P2 Bore lithology log

From (mBGL)	To (mBGL)	Unit	Description
34	35	Shepparton Formation	Clay: As above, negligible yellow.
35	37	Shepparton Formation	Clay: Brownish grey, low plasticity, trace lightly cemented Ferruginous fine sand.
37	40	Loxton Parilla Sands	Sand: Clear, light grey, orange, trace dark brown lightly cemented clumps, very fine and fine, sub angular- sub rounded, moderate sphericity, moderately- well sorted.
40	41	Loxton Parilla Sands	Silty Clay: Light grey, low plasticity.
41	47	Loxton Parilla Sands	Sand: Clear, light grey, orange, trace dark brown lightly cemented clumps, very fine and fine, sub angular- sub rounded, moderate sphericity, moderately- well sorted.
47	54	Loxton Parilla Sands	Sand: As above, trace dark grey/black grains (carbonaceous), very fine.
54	56	Loxton Parilla Sands	Sand: clear, light grey, light grey, light brown. Trace dark grey, dark brown, black. Fine-medium (<1mm), sub angular, moderately sorted, moderate sphericity.
56	63	Loxton Parilla Sands	Sand: As above, grain size decrease, fine, well sorted.
63	71	Loxton Parilla Sands	Sand: As above, + brown silt (trace). @ 64m very fine- medium, trace HM, mica, predominantly very fine. Moderately sorted. HM increasing with depth. @ 66m, no medium grains, well sorted.
71	77	Loxton Parilla Sands	Sand: As above, grain size increase, HM decrease, silt decrease. Grains medium (0.5- 1mm), moderately- well sorted. @ 76m grain size decrease, trace very fine.
77	80	Loxton Parilla Sands	Silty Sand: Grey-brown, very fine sand and brown silt. Trace HM.
80	85	Loxton Parilla Sands	Silty Sand: As above, + trace grey, low plasticity clay.

Appendix B

Baseline Data (2011 – 2015)

Table A-3 Raw groundwater chemistry dataset

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
WB1	29/11/2013	SFM	6.81	397	27700	502	933	7960	38	1870	12800	0.176	5.92	0.02		0.009	0.102			9.84	0.002	0.029
WB1	2/03/2014	SFM	6.66	376	24700	474	946	7970	39	1890	13000	0.163	5.49	0.005		0.006	0.13			10.2	0.001	0.015
WB1	24/05/2014	SFM	6.99	385	24200	482	985	8000	39	1920	13000	0.159	5	0.05		0.005	0.075			9.94	<0.01	0.025
WB1	27/08/2014	SFM	8.1	520	25000	400	810	6800	73	1921.922	13000	0.22	6.9	0.125		0.0025	0.097			10	< 0.025	0.035
WB1	19/11/2014	SFM	6.98	374	27100	442	967	7860	32	1860	15700	0.264	5.46	0.025		0.005	0.09			9.72	<0.050	0.0125
WB1	11/02/2015	SFM	7.04	418	26900	449	870	6980	28	1910	12800	0.167	4.28	0.025		0.006	0.097			8.29	<0.005	0.0125
WB1	19/05/2015	SFM	7.05	415	24800	461	818	6890	35	1860	13100	0.174	7.54	0.005		0.0005	0.078			15.6	0.001	0.054
WB1	3/08/2015	SFM	6.95	416	22400	453	930	7350	36	1800	12800	0.14	4.29	0.005		0.004	0.096			9.09	<0.001	0.065
WB20	2/12/2013	SFM	7.13	476	46400	586	1880	14800	105	8720	20600	0.094	0.79	0.01		0.02	0.061			17.9	0.169	0.022
WB20	4/03/2014	SFM	7.71	525	46200	546	1950	13300	115	8920	19900	0.061	0.6	0.005		0.023	0.054			21.4	0.229	0.08
WB20	2/06/2014	SFM	7.35	510	41600	476	1850	13300	104	8340	19700	0.067	0.55	0.005		0.023	0.064			18.4	0.181	0.244
WB20	25/08/2014	SFM	7.7	570	43000	490	1400	14000	110	9309.309	21000	0.09	1.5	0.25	0.008	0.005	0.053	0.002	0.012	18	0.2	0.069
WB20	18/11/2014	SFM	7.33	466	53900	512	2010	14100	111	8730	23300	0.116	0.99	0.07		0.018	0.054			16.9	0.161	0.031
WB20	10/02/2015	SFM	6.98	493	47500	528	1880	13600	97	8170	19600	0.084	0.83	0.025	0.011	0.017	0.055	0.002	0.012	16.8	0.126	0.0125
WB20	20/05/2015	SFM	7.49	486	42700	501	1860	13100	93	8500	20300	0.066	0.39	0.005		0.0005	0.033			26.4	0.157	0.029
WB20	5/08/2015	SFM	7.17	430	42000	498	1750	12200	90	7780	20400	0.032	<0.05	0.025	0.025	0.033	0.076	0.001	0.012	17.8	0.085	0.098
WB38	8/01/2014	SFM	7.22	383	41100	657	1530	12600	31	4650	21100	0.012	<0.05	0.02		0.012	0.094			15.1	0.011	0.022
WB38	5/03/2014	SFM	7.28	381	41000	730	1750	13000	45	4240	21200	0.013	<0.50	0.005		0.018	0.121			19.7	0.013	0.131
WB38	25/05/2014	SFM	7.45	383	38300	653	1540	10400	40	4250	21000	<0.010	<0.50	0.005		0.005	0.075			16.3	0.012	0.025
WB38	22/08/2014	SFM	7.6	-	41000	600	1200	13000	42	4204.204	23000	< 0.05	< 0.5	0.25		0.005	0.12			17	< 0.05	0.029
WB38	21/11/2014	SFM	7.26	370	43600	636	1540	12100	36	4130	21700	0.02	0.12	0.025		0.011	0.128			15.1	0.012	0.068
WB38	12/02/2015	SFM	7.3	396	41800	622	1420	12500	34	4010	20800	0.045	<0.25	0.025		0.018	0.109			14.4	0.008	0.074
WB38	7/08/2015	SFM	7.31	409	43200	562	1350	11400	34	4380	19600	0.006	<0.25	0.025		0.014	0.084			13.1	0.007	0.064
WB42	9/01/2014	SFM	7.03	343	36200	681	1460	10900	30	4130	17900	0.276	1.13	0.01		0.012	0.094			13.6	0.004	0.013
WB42	5/03/2014	SFM	7.13	346	36200	781	1710	11400	45	4280	17900	0.496	1.81	0.005		0.016	0.121			20.2	<0.010	0.112
WB42	25/05/2014	SFM	7.34	342	35300	630	1440	11600	36	3880	18100	0.38	1.35	0.005		0.005	0.077			17.2	<0.010	0.025
WB42	22/08/2014	SFM	7.5	-	37000	610	1100	11000	37	3903.904	20000	0.48	1.7	0.25		0.005	0.12			16	< 0.05	0.019
WB42	22/11/2014	SFM	7.19	328	39200	657	1450	10400	35	3720	19300	0.418	1.29	0.025		0.009	0.122			16.5	<0.005	0.035
WB42	12/02/2015	SFM	7.29	358	38500	673	1410	11500	34	3820	18300	0.466	1.11	0.025		0.048	0.104			14.8	<0.005	0.22
WB42	7/08/2015	SFM	7.22	372	36500	595	1290	9880	35	3880	17100	0.42	<0.005	0.025		0.0025	0.085			13.1	<0.005	0.0125
SHOB03	3/12/2013	SFM	6.63	345	34600	595	1530	11400	49	3840	18100	0.612	2.44	0.005		0.071	0.159			16.3	0.002	0.09
SHOB03	4/03/2014	SFM	6.73	345	36200	626	1590	10400	53	3870	17600	0.796	3.57	0.005		0.02	0.145			19.9	<0.010	0.095
SHOB03	12/06/2014	SFM	7.11	284	39900	485	1440	11000	64	4870	20100	0.179	<0.50	0.005		0.021	0.127			16.6	0.02	0.072
SHOB03	25/08/2014	SFM	7.3	-	38000	490	1200	12000	61	5705.706	21000	0.1	< 0.5	0.25	0.001	0.015	0.14	0.004	0.004	18	< 0.05	0.12
DUP2	25/08/2014	SFM	7.3	-	40000	510	1200	13000	60	5705.706	22000	0.11	< 0.5	0.25		0.012	0.13			18	< 0.05	0.11
DUP2	25/08/2014	SFM	6.94	234	39600	488	1480	11800	56	5320	20000	0.124	0.55	0.005	0.002	0.026	0.141	0.006	0.003	15.3	0.019	<0.050
SHOB03	18/11/2014	SFM	6.9	270	44700	473	1410	11400	43	5850	23300	0.094	0.26	0.22		0.034	0.114			15.9	<0.050	0.091
SHOB03	10/02/2015	SFM	6.98	354	37400	582	1530	10500	41	3720	17700	0.588	0.38	0.025	0.001	0.019	0.148	0.005	0.002	14.3	0.007	0.032
SHO B03	20/05/2015	SFM	7.01	366	36300	580	1540	10600	43	3790	14400	0.616	0.31	0.005		0.013	0.083			22.4	0.005	0.048
SHO B03	5/08/2015	SFM	6.93	357	34600	531	1480	10400	42	4040	19900	0.486		0.005		0.034	0.086			16	0.005	0.06
SHOB04	3/12/2013	SFM	7.25	324	50400	608	1670	16100	27	5250	28300	0.006	<0.05	0.005		0.026	0.105			16.2	0.055	0.021
SHOB04	5/03/2014	SFM	7.31	322	47400	657	1810	15100	33	5300	28100	0.011	<0.50	0.005		0.025	0.096			19.7	0.057	0.093

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
SHOB04	25/05/2014	SFM	7.52	361	46200	602	1740	13200	31	5030	25700	<0.010	<0.50	0.005		0.013	0.061			16.5	0.059	0.025
SHOB04	22/08/2014	SFM	7.6	350	50000	570	1300	16000	36	4804.805	29000	< 0.05	< 0.5	0.25		0.017	0.097			17	0.057	0.053
SHOB04	21/11/2014	SFM	7.29	307	57200	657	1850	15100	34	4970	30500	0.022	0.22	0.025		0.015	0.104			15.7	0.058	0.03
SHOB04	12/02/2015	SFM	7.38	327	50000	596	1690	16200	25	4990	25200	0.046	<0.25	0.025		0.026	0.089			15.5	0.047	0.034
SHOB04	6/08/2015	SFM	7.26	336	52700	562	1650	15000	30	5320	28600	<0.005	<0.25	0.025		0.032	0.078			13.8	0.044	0.046
GW036673-1	26/11/2013	SFM	6.69	187	50200	646	1510	13000	54	4660	24600	4.92	5.73	0.005		0.019	0.141			18.2	<0.001	0.055
GW036673-1	28/02/2014	SFM	6.55	177	44100	633	1590	13600	46	4590	26000	4.67	8.28	0.005		0.016	0.164			19.1	<0.001	0.039
GW036673-1	22/05/2014	SFM	6.88	189	42600	645	1700	14000	54	4610	23700	5.01	5.92	0.05		0.014	0.078			19.2	<0.010	0.025
GW036673-1	19/11/2014	SFM	6.79	190	51500	660	1730	14700	47	3970	26200	5.07	5.71	0.025		0.014	0.106			16.9	<0.050	0.055
GW036673-1	14/02/2015	SFM	6.85	194	46500	651	1570	14300	40	4690	23000	4.91	2.73	0.025		0.024	0.122			18.1	<0.005	0.072
GW036673 - 1	29/05/2015	SFM	7.43	201	44800	602	1470	13200	39	4550	25800	6.2	5.53	0.025		0.017	0.141			23.9	<0.005	0.084
GW036673 - 1	10/08/2015	SFM	7.25	194	49600	656	1550	14500	53	3740	26400	6.02		0.025		0.018	0.114			18.7	<0.005	0.118
GW036866-1	27/11/2013	SFM	7.06	392	22400	340	738	7760	19	2140	13200	0.25	0.63	0.005		0.009	0.105			9.47	0.002	0.01
GW036866-1	26/02/2014	SFM	7.01	383	19700	358	791	7750	22	1970	12400	0.199	0.77	0.01	0.01	0.007	0.112	0.01	0.01	9.54	0.002	0.006
GW036866-1	23/05/2014	SFM	7.28	418	25700	368	812	8060	22	2080	12400	0.25	0.77	0.05		0.005	0.065			9.7	<0.01	<0.005
GW36866-1	24/08/2014	SFM	7.6	440	24000	360	710	7400	25	2132.132	13000	0.22	0.74	0.25		0.005	0.077			9.4	< 0.05	0.016
GW036866-1	23/11/2014	SFM	7.13	407	24900	364	743	7170	21	2060	13200	0.23	0.7	0.025		0.006	0.087			9.18	<0.005	0.03
GW036866-1	12/02/2015	SFM	7.17	400	23100	358	723	7600	20	2070	12300	0.754	0.87	0.025		0.018	0.088			9.21	<0.005	0.033
GW036866-1	24/05/2015	SFM	7.52	417	23200	342	753	7620	22	2240	13700	0.398	0.14	0.005		0.004	0.042			10.9	0.002	0.03
GW036866-1	8/08/2015	SFM	7.16	417	25700	343	721	7260	22	2230	12300	0.224	0.61	0.005		0.008	0.057			7.32	0.001	0.032
GW040247-1	25/11/2013	SFM	3.85	<1	50000	586	1700	10500	95	3030	22500	2.34	10.4	28.9		0.009	0.368			19.6	0.006	0.053
GW040247-1	25/02/2014	SFM	4.3	<1	40700	648	1940	11800	91	2980	22300	2.91	7.52	6.73		0.026	0.308			21.4	0.002	0.08
GW040247-1	22/05/2014	SFM	3.92	<1	41500	622	1850	13600	92	3060	22400	2.79	5.59	9.25		0.014	0.203			20.3	<0.01	0.025
GW040247-1	15/08/2014	SFM	3.9	-	41000	590	1200	13000	87	3003.003	25000	2	6.6	7.9		0.0005	0.26			18	< 0.005	0.078
GW040247-1	25/11/2014	SFM	3.94	<1	47000	646	1880	11400	86	3220	25200	3.29	6.61	7.18		0.02	0.314			19.1	<0.005	0.124
GW040247-1	14/02/2015	SFM	3.98	<1	43400	674	1850	12000	82	2940	22000	3.19	4.95	6.43		0.025	0.3			19.2	<0.005	0.094
GW040247-1	21/05/2015	SFM	3.97	<1	41300	565	1640	10400	34	3200	26500	3.73	9.84	7.66		0.007	0.206			32.9	0.002	0.14
GW040247-1	10/08/2015	SFM	4.07	<1	39100	659	1770	11700	102	3240	25500	3.57		12.2		0.017	0.283			18.5	<0.005	0.165
GW036862-1	7/12/2013	SFM	6.77	347	32200	785	1790	9150	35	4820	14700	0.425	<0.05	0.005		0.026	0.06			16.7	0.031	0.028
GW036862-1	27/02/2014	SFM	6.83	349	30300	796	1900	9640	40	4800	15700	0.42	0.2	0.005		0.013	0.067			17	0.031	0.009
GW036862-1	23/05/2014	SFM	7.07	350	30200	699	1640	8370	35	4780	14600	0.446	<0.5	0.005		0.012	0.037			17.3	0.033	0.025
GW36862-1	24/08/2014	SFM	7.3	-	32000	710	1200	8100	35	4504.505	15000	0.73	< 0.5	0.25		0.005	0.025			17	< 0.05	0.034
GW036862-1	24/11/2014	SFM	7.04	337	34100	736	1680	8400	32	4990	15200	0.572	<0.25	0.025		0.035	0.045			15.5	0.026	0.038
GW036862-1	16/02/2015	SFM	7.01	369	33600	708	1580	8360	30	4730	14400	0.6	<0.25	0.1		0.024	0.045			15.7	0.022	0.096
GW036862-1	25/05/2015	SFM	7.24	373	33300	754	1660	8520	36	4770	14800	0.571	0.24	0.005		0.002	0.024			19.8	0.031	0.01
GW036862-1	11/08/2015	SFM	7.52	375	32900	718	1520	8310	38	4950	14500	0.535	0.2	0.005	0.003	0.008	0.031	0.002	0.005	13.7	0.028	0.031
N27	4/03/2014	SFM	6.71	330	39700	832	2550	10800	110	4240	20000	0.627	4.85	0.05		0.014	0.067			22.4	0.016	0.025
N27	14/06/2014	SFM	7.23	344	45200	578	2050	10400	95	4300	21200	0.663	3.31	0.05	0.01	0.012	0.066	0.01	0.01	18.7	0.012	0.025
N27	23/08/2014	SFM	7.3	-	42000	590	1400	12000	81	4200	22000	0.63	3.4	0.25		0.005	0.069			18	< 0.05	0.018
N27	23/11/2014	SFM	6.75	325	43800	639	2090	10800	83	4290	21300	0.395	3.42	0.025		0.01	0.07			16.5	0.012	0.041
N27	4/03/2015	SFM	6.96	357	46100	594	2010	11600	85	4230	20700	0.321	3.96	0.025		0.012	0.064			17.8	0.011	0.036
N27	28/05/2015	SFM	7.16	360	40100	656	2290	11800	78	4220	21800	0.346	2.08	0.025		0.0025	0.056			22	0.012	0.148
N27	9/08/2015	SFM	6.82	347	42000	552	1900	10000	72	4350	19200	0.348	3.16	0.0025		0.0025	0.058			17	0.011	0.0125

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
UGM-M1 S		SFM	8.1	-	41846	1100	800	10000	110	4200	24000	0.055	0.06	< 0.01	0.006	0.0005	0.1	0.053	0.016	20	0.024	0.0025
UGM-M2 S		SFM	6.86	-	36949	610	1100	9400	61	4800	23000	0.067	0.12	< 0.01	0.006	0.0005	0.04	0.005	0.057	17	0.0078	0.016
UGM-M4 S		SFM	7.66	-	34969	580	1000	10000	45	4200	20000	0.28	0.61	< 0.01	0.021	0.0005	0.01	0.008	0.019	14	0.015	0.0025
UGM-M5 S		SFM	6.39	300	38501	650	1500	12000	42	4500	23000	0.035	< 0.05	< 0.01	0.001	0.001	0.052	0.001	0.022	21	0.0059	0.019
UGM-M6 S		SFM	6.34	-	39803	570	1200	9200	47	4500	21000	0.001	< 0.05	< 0.01	0.001	0.0005	0.065	0.001	0.051	18	0.0082	0.015
UGM-M7 S		SFM	7.89	230	37928	810	1600	11000	48	4500	22000	0.18	0.28	< 0.01	0.005	0.0005	0.05	0.003	0.012	17	0.012	0.0025
UGM-M8 S		SFM	6.43	250	38968	660	1500	12000	40	4800	23000	0.1	< 0.05	< 0.01	0.002	0.004	0.025	0.001	0.049	20	0.0053	0.037
UGM-M9 S		SFM	7.98	220	51197	900	1900	15000	55	5700	29000	0.15	< 0.05	< 0.01	0.004	0.002	0.14	0.002	0.017	22	0.013	0.0025
UGM-M10 S		SFM	6.75	-	34265	480	1100	8900	58	3900	20000	0.58	4.8	< 0.01	0.028	0.0005	0.058	0.002	0.018	15	0.0038	0.011
WB2	29/11/2013	LPS	6.84	427	20100	333	653	6420	34	1010	10800	0.184	<0.05	0.01		0.007	0.12			6.72	0.0005	0.006
WB2	2/03/2014	LPS	6.86	432	19000	293	659	6040	33	974	10800	0.156	0.18	0.005		0.004	0.147			6.64	0.0005	0.019
WB2	24/05/2014	LPS	7.2	462	18500	298	691	6350	33	969	10700	0.139	<0.5	0.05		0.005	0.092			6.78	0.005	0.025
WB2	27/08/2014	LPS	8.1	-	19000	270	550	5100	64	960.961	10000	0.17	0.09	0.125		0.0025	0.11			6.7	0.0125	0.031
WB2	19/11/2014	LPS	7.23	421	19700	287	636	5960	29	877	12300	0.15	0.42	0.025		0.0025	0.099			6.11	0.025	0.0125
WB2	11/02/2015	LPS	7.25	445	20000	283	572	5330	25	896	10200	0.108	<0.25	0.025		0.006	0.095			5.68	0.0025	0.0125
WB2	19/05/2015	LPS	7.43	470	18800	276	613	5720	29	912	10800	0.108	0.09	0.005		0.0005	0.082			9.82	0.0005	0.012
WB2	3/08/2015	LPS	7.14	464	18700	275	594	5500	32	873	10400	0.084	0.06	0.005		0.004	0.104			5.96	0.0005	0.0025
WB5	29/11/2013	LPS	6.85	421	22100	364	757	6910	37	1200	11800	0.328	1.37	0.01		0.005	0.124			7.43	0.0005	0.007
WB5	2/03/2014	LPS	6.79	413	20600	325	764	6630	36	1170	11800	0.285	1.35	0.005		0.004	0.153			7.39	0.0005	0.044
WB5	3/06/2014	LPS	7.26	425	22300	312	785	6710	33	1170	11600	0.312	1.41	0.05		0.005	0.152			7.78	0.005	0.025
WB5	27/08/2014	LPS	8.1	-	21000	300	650	6000	62	1171.171	12000	0.37	1.2	0.125	0.001	0.0025	0.12	0.001	0.004	7.9	0.0125	0.11
WB5	20/11/2014	LPS	6.91	409	22500	336	743	6360	36	1140	11900	0.29	0.95	0.025		0.007	0.13			8.15	0.0025	0.035
WB5	11/02/2015	LPS	7.18	439	23000	347	762	6510	38	1130	11300	0.233	0.77	0.025	0.001	0.0025	0.105	0.001	0.006	6.57	0.0025	0.0125
WB5	26/05/2015	LPS	7.14	456	19900	334	794	6970	33	1150	12000	0.29	1.02	0.005		0.0005	0.072			8.66	0.0005	0.008
WB5	3/08/2015	LPS	7.01	450	20200	319	735	6270	35	1110	11500	0.217	0.74	0.005	0.001	0.004	0.108	0.001	0.003	7.28	0.0005	0.018
WB6	2/12/2013	LPS	6.74	412	23900	319	690	6670	36	1070	11000	0.518	0.2	0.01		0.005	0.112			7.2	0.0005	0.008
WB6	2/03/2014	LPS	6.79	416	19600	280	702	6350	34	999	10900	0.449	0.16	0.005		0.004	0.131			7.14	0.0005	0.01
WB6	24/05/2014	LPS	7.12	414	19000	266	690	6270	32	987	11000	0.426	<0.05	0.05		0.005	0.078			7.02	0.005	0.025
WB6	26/08/2014	LPS	8.1	-	19000	260	570	5400	60	990.991	10000	0.57	0.15	0.125		0.0025	0.1			7	0.0125	0.028
WB6	20/11/2014	LPS	6.96	409	21600	278	633	5720	31	934	11200	0.4	0.12	0.025		0.0025	0.112			6.26	0.0025	0.0125
WB6	11/02/2015	LPS	7.19	444	21200	294	643	5890	27	924	10500	0.38	<0.25	0.025		0.0025	0.095			5.78	0.0025	0.0125
WB 6	29/05/2015	LPS	7.73	457	18400	285	637	6000	34	915	10700	0.396	0.13	0.01		0.001	0.047			8	0.0005	0.013
WB6	4/08/2015	LPS	7.16	456	19000	274	631	5720	32	901	10600	0.34	0.12	0.005		0.005	0.089			6.41	0.0005	0.024
WB7	28/11/2013	LPS	6.33	248	45100	702	1820	12500	72	4580	25000	0.972	0.74	0.005		0.058	0.115			19.2	0.013	0.093
WB7	2/03/2014	LPS	6.19	238	41700	715	1870	12400	47	6170	24300	0.973	1.26	0.005		0.01	0.136			18.8	0.011	0.018
WB7	24/05/2014	LPS	6.51	244	39700	688	1900	14200	56	4510	21800	1	1.02	0.05		0.005	0.067			19.6	0.012	0.025
WB7	26/08/2014	LPS	8	-	41000	640	1600	12000	110	4804.805	23000	1.4	3.3	0.125		0.0025	0.11			19	0.0125	0.05
WB7	20/11/2014	LPS	6.3	242	44700	707	1760	11800	51	4450	24700	1.03	1.03	0.025		0.01	0.115			17.8	0.008	0.038
WB7	11/02/2015	LPS	6.56	258	48200	716	1820	11900	44	4150	22700	1.03	1.2	0.025		0.008	0.097			16.8	0.008	0.026
WB 7	29/05/2015	LPS	7.14	265	43700	687	1760	12200	44	4440	24200	1.2	1.59	0.025		0.0025	0.093			22.5	0.009	0.03
WB7	4/08/2015	LPS	6.47	261	40300	668	1710	11200	47	4310	21700	1.11	1.11	0.01		0.001	0.074			15.3	0.01	0.062
WB8	28/11/2013	LPS	7.07	496	18800	290	621	6820	32	892	11100	0.112	0.15	0.005		0.0005	0.12			6.5	0.0005	0.0025
WB8	3/03/2014	LPS	7.07	471	18800	336	707	6600	36	841	10700	0.108	<0.05	0.005	0.001	0.003	0.134	0.001	0.003	7.43	0.0005	0.005

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
WB8	24/05/2014	LPS	7.2	456	18500	310	697	6510	33	893	10500	0.108	<0.05	0.05		0.005	0.082			6.75	0.005	0.025
WB8	26/08/2014	LPS	7.8	-	19000	280	550	5200	60	870.8709	10000	0.13	< 0.05	0.125	0.001	0.0025	0.1	0.002	0.002	6.8	0.0125	0.005
WB8	20/11/2014	LPS	7.08	515	22000	295	606	5610	29	863	11000	0.153	0.11	0.025		0.0025	0.113			6.85	0.0025	0.0125
WB8	11/02/2015	LPS	7.05	518	20700	316	661	6040	28	856	10400	0.114	0.27	0.025	0.001	0.0025	0.091	0.001	0.002	5.71	0.0025	0.0125
WB 8	29/05/2015	LPS	7.78	508	21100	285	625	5810	39	839	10700	0.117	<0.05	0.02		0.0005	0.036			7.84	0.0005	0.013
WB8	4/08/2015	LPS	7.18	507	17600	281	597	5500	31	850	10700	0.109	0.06	0.005		0.003	0.082			6.49	0.0005	0.019
WB17	9/01/2014	LPS	6.53	363	44100	640	1820	13000	46	4400	24500	0.32	3.87	0.005		0.01	0.197			14.1	0.002	0.261
WB17	3/03/2014	LPS	6.64	360	42000	674	1870	12500	60	3980	24400	0.57	5.26	0.05		0.005	0.209			20.4	0.005	0.524
WB17	3/06/2014	LPS	7	401	44800	579	1730	12900	49	3970	23100	0.401	5.28	0.05		0.005	0.279			16.5	0.005	0.566
WB17	25/08/2014	LPS	7.2	-	41000	600	1300	13000	59	3903.904	24000	0.52	5.2	0.25		0.005	0.23			16	0.025	1.1
WB17	18/11/2014	LPS	6.84	357	47300	633	1930	13900	54	3610	25400	0.464	4.33	0.025		0.01	0.21			16.1	0.025	0.031
WB17	10/02/2015	LPS	6.52	399	43200	610	1700	12400	47	3900	22100	0.427	3.78	0.025		0.017	0.217			14.7	0.0025	0.0125
WB17	26/05/2015	LPS	6.93	403	42500	539	1570	12900	51	3970	26000	0.493	5.24	0.025		0.0025	0.191			19.7	0.0025	0.039
WB17	4/08/2015	LPS	6.75	374	34100	550	1590	11300	48	3780	25000	0.458		0.025		0.0025	0.16			13.5	0.0025	0.025
WB18	2/12/2013	LPS	6.69	361	37000	625	1480	13000	46	3700	19300	0.502	11.9	0.01		0.024	0.182			14.4	0.001	0.087
WB18	4/03/2014	LPS	6.73	360	36600	645	1700	11600	56	3630	18300	0.604	12.3	0.05		0.014	0.15			16.9	0.005	0.399
WB18	12/06/2014	LPS	7.09	388	36000	482	1370	10300	52	3610	19400	0.673	8.84	0.05		0.012	0.213			14.2	0.005	0.055
WB18	25/08/2014	LPS	7.3	-	37000	500	1100	11000	45	3603.604	20000	0.62	3.1	0.25		0.013	0.16			14	0.025	0.27
WB18	18/11/2014	LPS	7.03	361	38800	540	1530	11600	50	3820	21900	0.514	1.37	0.07		0.018	0.155			14.2	0.025	0.048
WB18	10/02/2015	LPS	6.71	392	34500	526	1400	10600	41	3500	17800	0.536	5.83	0.025		0.014	0.162			13.2	0.005	0.04
WB18	20/05/2015	LPS	7.2	400	35200	541	1460	10800	39	3670	18700	0.517	10.2	0.005		0.001	0.106			20.2	0.004	0.042
WB18	5/08/2015	LPS	7	408	34100	488	1320	9740	40	3530	17800	0.47	3.05	0.005		0.007	0.11			14.6	0.0005	0.069
WB28	3/12/2013	LPS	6.84	412	38800	565	1490	12500	46	4200	20800	0.505	1.56	0.005	0.002	0.009	0.174	0.001	0.001	14	0.002	0.051
WB28	5/03/2014	LPS	6.9	413	40100	594	1620	11600	53	4340	20200	0.698	2.12	0.05		0.016	0.15			17.8	0.005	0.184
WB28	3/06/2014	LPS	7.3	402	41900	472	1500	12200	41	4060	21100	0.553	2.34	0.05	0.002	0.005	0.2	0.001	0.001	14.6	0.005	0.127
WB28	22/08/2014	LPS	7.4	-	40000	490	1200	12000	50	4204.204	22000	0.64	2.2	0.25		0.005	0.16			13	0.025	0.18
WB28	21/11/2014	LPS	6.91	395	37900	550	1580	11600	47	4060	20500	0.557	6.33	0.025	0.001	0.008	0.15	0.001	0.001	13.8	0.0025	0.56
WB28	17/02/2015	LPS	7.34	413	38000	539	1480	11400	47	4230	21400	0.563	1.6	0.025		0.009	0.159			13.9	0.0025	0.0125
LPSPB04	8/08/2015	LPS	7.04	440	41100	471	1400	11100	42	4180	18800	0.575	1.66	0.25		0.0025	0.118			11.5	0.0025	0.041
WB40	8/01/2014	LPS	7.03	364	36800	653	1360	10300	29	4100	17900	0.318	1.5	0.01		0.013	0.119			14.7	0.0005	0.041
WB40	5/03/2014	LPS	7.11	366	36400	682	1480	10900	40	3740	17000	0.506	1.91	0.05		0.015	0.137			18.9	0.005	0.157
WB40	3/06/2014	LPS	7.43	368	37600	618	1460	10600	32	3710	18100	0.466	2.08	0.05		0.005	0.183			17.2	0.005	0.1
WB40	22/08/2014	LPS	7.5	-	37000	630	1100	12000	41	3903.904	21000	0.56	1.9	0.25		0.005	0.13			16	0.025	0.13
WB40	21/11/2014	LPS	7.14	363	38500	643	1440	10600	34	3710	18800	0.441	2.01	0.025		0.01	0.138			15.2	0.0025	0.0125
WB40	12/02/2015	LPS	7.22	384	37400	646	1360	11000	32	3670	17400	0.41	1.26	0.025		0.018	0.128			14.5	0.0025	0.043
WB40	7/08/2015	LPS	7.21	400	36200	593	1320	10100	36	3840	17100	0.452	1.49	0.025		0.009	0.102			12.7	0.0025	0.036
WB41	9/01/2014	LPS	6.96	355	31500	706	1500	10900	33	3900	17300	0.29	0.79	0.005		0.008	0.112			14.3	0.0005	0.038
WB41	5/03/2014	LPS	7.08	357	35100	667	1440	10200	40	3490	17500	0.526	1.56	0.05		0.015	0.156			19.8	0.005	0.154
WB41	3/06/2014	LPS	7.71	363	37900	598	1400	10100	32	3620	17700	0.436	1.56	0.05		0.005	0.143			15.9	0.005	0.082
WB41	22/08/2014	LPS	7.5	-	38000	600	1100	11000	36	3903.904	20000	0.57	1.8	0.25		0.005	0.13			16	0.025	0.097
WB41	22/11/2014	LPS	7.2	351	38200	648	1420	10000	36	3450	18200	0.457	1.15	0.025		0.009	0.149			16.1	0.0025	0.03
WB41	12/02/2015	LPS	7.22	374	35100	635	1330	10500	31	3480	17200	0.439	0.98	0.025		0.017	0.131			14.8	0.0025	0.0125
WB41	7/08/2015	LPS	7.22	390	37700	590	1300	9730	39	3680	16600	0.463		0.025		0.0025	0.111			13.1	0.0025	0.0125

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
GW036866-2	27/11/2013	LPS	7.15	454	13600	191	400	4960	20	1320	8010	0.597	0.81	0.01		0.007	0.086			4.93	0.0005	0.031
GW036866-2	26/02/2014	LPS	7.15	451	13600	151	400	4100	19	1240	7370	0.227	0.1	0.01		0.004	0.089			5.31	0.0005	0.141
GW036866-2	4/06/2014	LPS	7.6	475	13900	182	410	4300	20	1200	7420	0.319	0.85	0.05		0.005	0.075			5.16	0.005	0.069
GW36866-2	24/08/2014	LPS	7.8	-	14000	200	390	4200	20	1291.291	7500	0.38	0.87	0.25		0.005	0.067			5.1	0.025	0.18
GW036866-2	24/11/2014	LPS	7.44	426	13400	187	410	4260	20	1230	7820	0.432	1.78	0.025		0.005	0.069			5.27	0.0025	0.058
GW036866-2	13/02/2015	LPS	7.36	475	12800	188	393	4440	18	1220	7260	0.41	1.41	0.025		0.014	0.076			5.16	0.0025	0.063
GW036866-2	24/05/2015	LPS	7.58	475	13700	191	407	4490	20	1260	7580	0.393	2.73	0.005	0.007	0.0005	0.035	0.004	0.001	5.88	0.0005	0.024
GW036866-2	8/08/2015	LPS	7.31	485	14300	176	384	4150	20	1260	7220	0.336	0.43	0.005		0.003	0.051			4.21	0.0005	0.029
GW036673-2	26/11/2013	LPS	6.7	233	43200	572	1380	11400	56	3550	19900	1.33	4.63	0.005	0.006	0.009	0.107	0.004	0.004	14.8	0.0005	0.024
GW036673-2	28/02/2014	LPS	6.59	227	36200	521	1380	10800	44	3740	19200	1.33	4.53	0.005		0.008	0.119			14.9	0.0005	0.0025
GW036673-2	5/06/2014	LPS	7.08	235	38200	500	1440	10900	40	3350	18600	1.37	5.6	0.05		0.005	0.092			15	0.005	0.069
GW036673-2	19/11/2014	LPS	6.84	230	39600	542	1480	11700	45	3510	22000	1.55	4.21	0.025		0.008	0.088			14.9	0.0025	0.0125
GW036673-2	14/02/2015	LPS	6.92	242	37700	556	1430	12000	40	3350	18500	1.39	3.9	0.025		0.019	0.088			14.3	0.0025	0.038
GW036673 - 2	29/05/2015	LPS	7.45	250	39600	520	1340	11000	41	3470	19100	1.65	4.84	0.025		0.0025	0.098			18.5	0.0025	0.118
GW036673 - 2	10/08/2015	LPS	7.28	247	40500	559	1400	11900	55	3740	19100	1.65		0.025		0.0025	0.086			14.2	0.0025	0.05
GW040247-2	25/11/2013	LPS	6.34	207	39900	836	1640	10100	72	2740	21600	0.986	5.69	0.04		0.007	0.18			19.7	0.0005	0.011
GW040247-2	25/02/2014	LPS	6.46	208	37200	652	1680	9450	55	2540	19700	0.96	5.82	0.02		0.008	0.185			20.4	0.0005	0.006
GW040247-2	22/05/2014	LPS	6.73	208	35400	810	1760	10800	72	2600	19700	1.11	5.5	0.05		0.005	0.107			20.5	0.005	0.058
GW040247-2	15/08/2014	LPS	6.5	-	39000	820	1300	11000	82	2762.763	22000	1.3	6.2	0.025		0.0005	0.098			18	0.0025	0.31
GW040247-2	25/11/2014	LPS	6.83	220	41900	848	1800	10600	61	2770	22900	1.2	6.21	0.34		0.009	0.164			19.6	0.0025	0.045
GW040247-2	14/02/2015	LPS	6.79	220	39000	820	1660	10400	54	2620	19400	1.11	5.46	0.3		0.018	0.155			18.9	0.0025	0.029
GW040247-2	21/05/2015	LPS	6.83	222	37500	737	1500	9310	<10	2750	19600	1.25	9.68	0.01		0.001	0.114			33.3	0.001	0.02
GW040247-2	10/08/2015	LPS	7.11	220	41200	819	1610	10200	72	2860	19600	1.06		0.025		0.0025	0.131			18.2	0.0025	0.046
GW036868-1	23/11/2013	LPS	7.2	840	8870	105	225	3200	12	830	5240	0.147	0.26	0.005		0.003	0.028			2.99	0.025	0.017
GW036868-1	26/02/2014	LPS	7.16	861	10600	120	291	4100	13	927	5890	0.214	0.5	0.01		0.005	0.03			3.72	0.025	0.133
GW036868-1	23/05/2014	LPS	7.36	861	11000	132	299	3970	12	993	5840	0.194	0.54	0.005		0.003	0.023			3.6	0.027	0.0025
GW036868-1	26/08/2014	LPS	8.2	-	10000	120	230	3500	31	900.9009	5600	0.23	0.64	0.125	0.001	0.0025	0.028	0.001	0.002	3.4	0.0125	0.026
GW036868-1	20/11/2014	LPS	7.19	814	10500	133	273	3580	12	926	6180	0.221	0.55	0.025	0.001	0.0025	0.033	0.001	0.002	3.66	0.016	0.0125
GW036868-1	16/02/2015	LPS	7.32	889	9820	121	246	3590	10	885	5540	0.191	0.37	0.005		0.002	0.023			3.49	0.022	0.021
GW036868-1	22/05/2015	LPS	7.52	886	10000	118	247	3570	11	887	5600	0.22	0.52	0.005		0.0005	0.017			3.85	0.02	0.023
GW036868-1	5/08/2015	LPS	7.32	914	10200	125	259	3400	13	898	5760	0.197		0.005		0.003	0.019			3.56	0.017	0.025
GW036868-2	23/11/2013	LPS	6.98	430	16700	290	560	5260	32	624	9960	0.064	0.17	0.01		0.002	0.111			5.71	0.0005	0.0025
GW036868-2	26/02/2014	LPS	6.99	436	15100	295	633	5260	30	619	8680	0.08	0.59	0.01		0.003	0.119			6	0.0005	0.0025
GW036868-2	5/06/2014	LPS	7.39	442	16500	248	530	4760	25	564	9000	0.082	0.54	0.05		0.005	0.104			5.8	0.005	0.127
GW036868-2	26/08/2014	LPS	8.1	-	16000	230	440	5200	45	600.6006	10000	0.098	0.47	0.125		0.0025	0.1			5.9	0.005	0.004
GW036868-2	22/11/2014	LPS	7.13	425	16400	266	513	4730	25	589	9490	0.127	0.5	0.025		0.0025	0.107			6.38	0.0025	0.027
GW036868-2	16/02/2015	LPS	7.24	460	15900	251	486	4850	22	578	9050	0.104	<0.25	0.025		0.012	0.098			5.66	0.0025	0.042
GW036868-2	22/05/2015	LPS	7.43	462	14700	275	528	5060	26	578	9190	0.08	0.07	0.005		0.001	0.057			6.49	0.0005	0.008
GW036868-2	5/08/2015	LPS	7.24	466	16100	259	523	4680	27	571	9110	0.076		0.005		0.003	0.066			5.77	0.0005	0.012
GW036868-3	24/11/2013	LPS	6.85	458	19500	352	665	6220	33	1110	11100	0.332	1.19	0.005		0.003	0.099			7.61	0.003	0.0025
GW036868-3	26/02/2014	LPS	7.01	436	14900	241	483	4280	25	641	8560	0.218	1.1	0.005		0.003	0.125			5.8	0.0005	0.099
GW036868-3	23/05/2014	LPS	7.28	437	14100	247	494	4620	27	535	8220	0.204	1.11	0.005		0.002	0.09			5.51	0.0005	0.089
GW036868-3	26/08/2014	LPS	8.2	-	14000	230	390	4500	37	510.5105	8700	0.24	1.2	0.125		0.0025	0.11			5.2	0.0125	0.34

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
GW036868-3	22/11/2014	LPS	7.2	436	14300	242	452	4160	25	510	8480	0.22	1.05	0.025		0.0025	0.121			5.37	0.0025	0.063
GW36868-3	16/02/2015	LPS	7.22	454	14400	229	433	4310	23	508	7930	0.224	0.98	0.025		0.012	0.118			5.32	0.0025	0.531
DUP4	16/02/2015	LPS	7.26	447	13200	227	432	4330	24	500	8030	0.227	0.94	0.025		0.012	0.107			4.91	0.0025	0.557
DUP4	16/02/2015	LPS	8.1	-	15000	240	440	4200	30	510	8300	0.2	1.1	0.025		0.0005	0.1			4.8	0.0025	0.53
GW036868-3	22/05/2015	LPS	7.45	456	13900	258	487	4700	28	516	8330	0.206	1.12	0.005		0.0005	0.069			5.92	0.0005	0.01
GW036868-3	5/08/2015	LPS	7.09	490	19400	324	704	5720	27	1210	10900	0.304	0.43	0.005		0.003	0.058			8.65	0.001	0.017
N7	8/12/2013	LPS	6.86	455	34300	404	1450	11700	66	2470	18200	0.144	3.79	0.005	0.001	0.006	0.188	0.003	0.004	9.26	0.002	0.016
N7	28/02/2014	LPS	6.77	451	33000	368	1260	10100	64	2490	18200	0.143	4.3	0.005		0.007	0.219			9.36	0.002	0.006
N7	2/06/2014	LPS	7.2	458	36000	363	1300	10100	68	2480	17800	0.123	4.28	0.05	0.001	0.005	0.197	0.003	0.006	9.48	0.005	0.025
N7	23/08/2014	LPS	7.3	-	35000	380	1100	11000	72	2552.553	21000	0.18	5.7	0.25	0.001	0.005	0.17	0.001	0.001	9.5	0.025	0.029
N7	23/11/2014	LPS	6.95	442	36100	377	1330	10100	71	2390	18300	0.169	3.96	0.025	0.001	0.007	0.176	0.001	0.001	9.8	0.0025	0.06
N7	4/03/2015	LPS	7.18	485	35500	366	1270	10100	75	2460	18000	0.135	4.04	0.06		0.01	0.155			8.47	0.0025	0.0125
N7	23/05/2015	LPS	7.3	489	35600	376	1270	10400	68	2470	17700	0.138	4.03	0.025	0.001	0.0025	0.129	0.001	0.001	8.98	0.0025	0.072
N7	9/08/2015	LPS	6.91	498	33300	356	1240	10100	70	2500	16600	0.142	4.02	0.025		0.0025	0.157			9.66	0.0025	0.054
N10	8/12/2013	LPS	6.91	657	37200	518	1520	12000	77	2650	19000	0.321	5.39	0.005	0.01	0.006	0.212	0.01	0.01	11.5	0.003	0.04
N10	1/03/2014	LPS	6.94	655	35000	463	1300	10200	74	2680	18100	0.326	6.44	0.005		0.007	0.239			12	0.003	0.13
N10	2/06/2014	LPS	7.28	690	36500	460	1420	10800	77	2640	18700	0.317	5.46	0.05		0.005	0.198			11.2	0.005	0.166
N10	23/08/2014	LPS	7.5	-	37000	470	1100	11000	80	2672.673	21000	0.39	7.3	0.25		0.005	0.18			12	0.025	0.21
DUP1	23/08/2014	LPS	7.6	-	35000	470	1100	11000	80	2672.673	20000	0.4	7.6	0.25		0.005	0.17			12	0.025	0.18
DUP1	23/08/2014	LPS	7.19	681	37500	461	1320	10100	96	2500	18200	0.379	7.34	0.05		0.017	0.181			10.8	0.005	0.127
N10	23/11/2014	LPS	7.04	633	38200	495	1420	10600	85	2520	19300	0.307	5.96	0.025		0.008	0.188			11.1	0.0025	0.036
N10	4/03/2015	LPS	7.26	690	40800	458	1380	11500	86	2610	19000	0.321	6.08	0.025		0.01	0.167			11.8	0.0025	0.028
N10	23/05/2015	LPS	7.37	718	35700	574	1610	13000	92	2630	18800	0.317	6.22	0.025		0.0025	0.145			11.9	0.0025	0.0125
N10	9/08/2015	LPS	7	725	38300	437	1270	10100	80	2770	17700	0.311		0.025		0.0025	0.164			11.8	0.0025	0.038
DUP3	9/08/2015	LPS	7.03	717	34500	446	1280	10400	75	2680	17200	0.318	6.97	0.025		0.0025	0.169			12.3	0.0025	0.036
N28	8/12/2013	LPS	6.93	457	19400	352	895	6510	43	1670	10500	0.961	0.21	0.01		0.008	0.092			7.76	0.0005	0.091
N28	1/03/2014	LPS	6.8	426	19200	354	828	5690	42	1820	10100	1.09	0.23	0.005		0.006	0.107			8.24	0.0005	0.174
N28	2/06/2014	LPS	7.21	419	21700	342	864	5820	39	1930	10600	1.07	<0.50	0.05		0.005	0.106			8.75	0.005	0.466
N28	23/08/2014	LPS	7.4	-	22000	360	800	5900	39	2102.102	11000	1.2	< 0.5	0.25		0.005	0.087			8.9	0.025	0.36
N28	23/11/2014	LPS	6.95	393	22600	378	898	5740	40	1950	11100	1	0.57	0.025		0.005	0.089			8.74	0.0025	0.0125
N28	4/03/2015	LPS	7.04	422	19200	350	855	6260	45	1980	10900	1.11	<0.25	0.025		0.007	0.082			8.76	0.0025	0.0125
N28	28/05/2015	LPS	7.29	440	21200	349	853	5720	38	2030	11300	1.23	0.1	0.005		0.002	0.044			10.5	0.0005	0.006
DUP2	28/05/2015	LPS	7.36	441	20200	330	812	6020	40	2040	11400	1.2	0.1	0.005	0.001	0.0005	0.045	0.004	0.001	10.5	0.0005	0.005
DUP2	28/05/2015	LPS	7.2	-	22000	430	950	5000	49	2040	10000	1.2	0.1	0.005		0.0005	0.07			8.2	0.0001	0.0025
N28	9/08/2015	LPS	6.93	430	22500	350	863	5720	40	2100	10600	1.04		0.005	0.01	0.0005	0.031	0.01	0.01	7.07	0.0005	0.008
DUP4	9/08/2015	LPS	6.99	437	23200	349	855	5700	39	2100	10600	1.03	0.07	0.005		0.0005	0.059			6.98	0.0005	0.007
GW036674-1	7/12/2013	LPS	6.82	431	15800	206	507	4940	28	1340	8620	0.566	1.37	0.005		0.009	0.084			4.78	0.0005	0.306
GW036674-1	27/02/2014	LPS	6.87	427	14400	201	517	4900	31	1260	8170	0.582	1.68	0.005		0.006	0.096			5.1	0.0005	0.272
GW036674-1	4/06/2014	LPS	7.35	427	15400	200	508	4610	30	1240	8130	0.567	1.38	0.05		0.005	0.083			5.08	0.005	0.08
GW36674-1	24/08/2014	LPS	7.4	-	16000	220	480	4500	31	1321.321	8200	0.68	1.9	0.25		0.005	0.076			4.9	0.025	0.53
GW036674-1	24/11/2014	LPS	7.06	412	15000	216	506	4720	30	1270	8430	0.665	1.72	0.025		0.007	0.079			5.24	0.0025	0.049
GW036674-1	16/02/2015	LPS	7.08	450	15200	204	486	4740	29	1250	8000	0.58	1.39	0.025		0.014	0.08			4.59	0.0025	0.066
GW36674-1	25/05/2015	LPS	7.31	452	15700	228	523	5050	33	1300	8370	0.689	1.66	0.005		0.0005	0.038			5.92	0.0005	0.013

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
GW36674-1	11/08/2015	LPS	7.63	454	15600	210	463	4730	36	1330	8210	0.614		0.005		0.003	0.056			4.21	0.0005	0.019
UGM-M1 D		LPS	8.4	-	35000	550	1000	9500	62	3900	19000	0.33	< 0.5	0.05	0.018	0.0005	0.12	0.003	0.002	13	0.0014	0.0025
UGM-M2 D		LPS	7.4	-	38000	440	1100	8700	58	3900	21000	0.74	5.4	0.005	0.045	0.0005	0.13	0.003	0.001	13	0.0043	0.007
UGM-M4 D		LPS	7.3	-	38000	540	1100	9600	70	3900	21000	0.62	4.2	0.005	0.015	0.0005	0.17	0.002	0.001	14	0.0023	0.013
UGM-M5 D		LPS	7.4	390	38000	470	1200	12000	40	3900	19000	0.64	5.4	0.005	0.002	0.001	0.17	0.001	0.001	16	0.00052	0.01
UGM-M6 D		LPS	8	-	38000	450	1100	9400	41	3900	21000	0.55	4.9		0.001			0.001	0.002			
UGM-M7 D		LPS	7.4	380	38000	520	1300	9700	44	3900	19000	0.6	3.9		0.005			0.005	0.005			
UGM-M8 D		LPS	7.5	420	33000	540	1500	10000	50	3900	20000	0.61	5.9	0.005	0.007	0.0005	0.15	0.001	0.002	13	0.0011	0.013
UGM-M9 D		LPS	7.5	420	38000	440	1200	9800	39	3900	18000	0.82	3.7	0.005	0.001	0.0005	0.17	0.001	0.001	15	0.0016	0.007
UGM-M10 D		LPS	7.4	-	37000	450	1100	9000	51	3900	21000	0.53	3.4	0.005	0.011	0.0005	0.14	0.001	0.002	13	0.0005	0.007
GW036673(3)	19/09/2012	LRG	7.53		5478								0.009							6.72	<0.001	
GW036673(3)	22/09/2012	LRG	7.29		4270								0.024							6.64	<0.001	
GW036673(3)	27/10/2012	LRG	7.3		3640								0.023							6.78	<0.01	
GW036673(3)	15/12/2012	LRG	7.76		3090								0.119							6.7	< 0.025	
GW036673(3)	19/12/2012	LRG	7.8	440	3500	38	56	1300	24	1	2200									6.11	<0.050	
GW036673(3)	15/01/2013	LRG	7.8	400	4100	55	68	1500	24	1	2600									5.68	<0.005	
GW036673(3)	15/04/2013	LRG	7.8	380	3300	38	53	1100	19	1	1800									9.82	<0.001	
GW036673(3)	15/05/2013	LRG	7.8	400	2800	35	46	1100	23	1	1700									5.96	<0.001	
GW036673(3)	15/07/2013	LRG	8	435	4110	41	62	1310	27		1840		0.39							7.43	<0.001	
GW036673(3)	25/07/2013	LRG	7.67	437	4930	42	61	1320	26	6	1810		0.7							7.39	<0.001	
GW036673(3)	15/09/2013	LRG	7.65	436	4800	41	62	1310	27		1800		0.92							7.78	<0.010	
GW036673(3)	19/09/2013	LRG	7.8												0.002			0.001	0.002	7.9	< 0.025	
GW036674(3)	6/09/2012	LRG	7.9	380	5500	120	160	1700	43		3200	0.04		0						8.15	<0.005	0
GW036674(3)	22/09/2012	LRG	7.5		10265															6.57	<0.005	
GW036674(3)	22/09/2012	LRG	7.9		4365															8.66	<0.001	
GW036674(3)	22/09/2012	LRG	7.66		4474															7.28	<0.001	
GW036674(3)	27/10/2012	LRG																		7.2	<0.001	
GW036674(3)	15/12/2012	LRG	7.55	390	6010	71	94	1950	47	8	3530	0.026	3.65	0.03						7.14	<0.001	
GW036674(3)	21/12/2012	LRG	7.63	382	2790	34	48	831	27	2	1230	0.022	1.26	0.02						7.02	<0.01	
GW036674(3)	15/01/2013	LRG	7.48	412	4880	48	63	1550	30	1	2130	0.006	0.49	0.03						7	< 0.025	
GW036674(3)	15/04/2013	LRG	7.47	395	4090	34	52	1210	24	2	1630	0.014	0.07	0.02						6.26	<0.005	
GW036674(3)	15/05/2013	LRG	7.46	407	3250	31	45	970	28	1	1480	0.012	0.33							5.78	<0.005	
GW036674(3)	15/07/2013	LRG	7.26																	8	<0.001	
GW036674(3)	22/07/2013	LRG	7.5																	6.41	<0.001	
GW036674(3)	7/12/2013	LRG	7.55																	19.2	0.013	
GW036674(3)	7/12/2013	LRG	7.76	598	6350	63	134	2240	26	35	4280	0.082	3.11	0.38	0.001			0.001	0.001	18.8	0.011	
GW036674(3)	1/02/2014	LRG	7.9																	19.6	0.012	
GW036674(3)	27/02/2014	LRG	7.66												0.001			0.001	0.001	19	< 0.025	
GW036674(3)	25/05/2014	LRG	7.6																	17.8	0.008	
GW036674(3)	1/08/2014	LRG	7.5																	16.8	0.008	
GW036674(3)	1/11/2014	LRG	7.97	444	2990	21	31	947	19	1	1710	0.025	1.74	0.27						22.5	0.009	
GW036674(3)	1/02/2015	LRG	7.76	432	3180	29	31	1000	20	1	1770	0.015	1.74	0.06						15.3	0.01	
GW036674(3)	1/05/2015	LRG	7.7	440	3560	38	61	1290	29	1	2150	0.011	0.59	0.11						6.5	<0.001	

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
GW036674(3)	1/08/2015	LRG	7.43																	7.43	<0.001	
GW036790(3)	15/04/2013	LRG	7.03																	6.75	<0.01	
GW036790(3)	15/05/2013	LRG	7.94																	6.8	< 0.025	
GW036866(4)	6/09/2012	LRG	7.77																	6.85	<0.005	
GW036866(4)	22/09/2012	LRG	7.25																	5.71	<0.005	
GW036866(4)	23/09/2012	LRG	7.37																	7.84	<0.001	
GW036866(4)	27/10/2012	LRG	7.38																	6.49	<0.001	
GW036866(4)	15/12/2012	LRG	7.4																	14.1	0.002	
GW036866(4)	21/12/2012	LRG	7.5																	20.4	<0.010	
GW036866(4)	15/01/2013	LRG																		16.5	<0.010	
GW036866(4)	15/04/2013	LRG																		16	< 0.05	
GW036866(4)	15/05/2013	LRG																		16.1	<0.050	
GW036866(4)	15/06/2013	LRG	6.73																	14.7	<0.005	
GW036866(4)	25/07/2013	LRG	7.04																	19.7	<0.005	
GW036866(5)	6/09/2012	LRG	7.85																	13.5	<0.005	
GW036866(5)	22/09/2012	LRG	7.93																	14.4	0.001	
GW036866(5)	23/09/2012	LRG	7.64																	16.9	<0.010	
GW036866(5)	27/10/2012	LRG	7.69																	14.2	<0.010	
GW036866(5)	15/12/2012	LRG																		14	< 0.05	
GW036866(5)	21/12/2012	LRG																		14.2	<0.050	
GW036866(5)	15/01/2013	LRG	7.44																	13.2	0.005	
GW036866(5)	15/04/2013	LRG	7.35																	20.2	0.004	
GW036866(5)	15/05/2013	LRG	7.63																	14.6	<0.001	
GW036866(5)	15/07/2013	LRG																		14	0.002	
GW036866(5)	25/07/2013	LRG	7.19																	17.8	<0.010	
GW036866(5)	6/12/2013	LRG	7.52	383	6440	78	101	2100	40	21	3740	0.026	1.26	0.1						14.6	<0.010	
GW036866(5)	6/12/2013	LRG	7.88	446	3570	40	58	1200	29	2	1960	0.01	0.14	0.05	0.002			0.001	0.001	13	< 0.05	
GW040247(4)	22/03/2012	LRG	7.51	413	3750	44	60	1030	26	7	1760	0.038	2.11	0.24						13.8	<0.005	
GW040247(4)	23/03/2012	LRG	7.45	379	4060	36	46	862	25	1	1360	0.024	0.62	0.03						13.9	<0.005	
GW040247(4)	6/09/2012	LRG	7.57	445	4340	48	79	1380	29	3	2160	0.088	1.42	0.05						11.5	<0.005	
GW040247(4)	27/10/2012	LRG	7.72	603	9940	66	128	2480	28	5	4090	0.091	1.67	0.6						14.7	<0.001	
GW040247(4)	15/01/2013	LRG	7.89	446	3110	22	30	960	19	1	1480	0.02	0.93	0.06						18.9	<0.010	
GW040247(4)	15/04/2013	LRG	7.71	439	3310	30	28	996	19	1	1570	0.015	1.33	0.02						17.2	<0.010	
GW040247(4)	15/05/2013	LRG	7.53	407	3930	35	46	1020	27	1	1670	0.016	0.33							16	< 0.05	
GW040247(4)	25/11/2013	LRG	7.13																	15.2	<0.005	
GW040247(4)	25/11/2013	LRG	7.36												0.006			0.001	0.004	14.5	<0.005	
GW040247(4)	1/02/2014	LRG	7.9																	12.7	<0.005	
GW040247(4)	25/02/2014	LRG	7.78												0.005			0.001	0.001	14.3	<0.001	
GW040247(4)	22/05/2014	LRG	7.2																	19.8	<0.010	
GW040247(4)	1/08/2014	LRG	7.49																	15.9	<0.010	
GW040247(4)	1/11/2014	LRG	7.28																	16	< 0.05	
GW040247(4)	1/02/2015	LRG	7.40																	16.1	<0.005	
GW040247(4)	1/05/2015	LRG	7.30																	14.8	<0.005	

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
GW040247(4)	1/08/2015	LRG	7.6																	13.1	<0.005	
HD1	1/01/2011	LRG	7.43																	4.93	<0.001	
HD1	3/01/2011	LRG	7.35																	5.31	<0.001	
HD1	27/07/2011	LRG																		5.16	<0.010	
HD1	31/07/2011	LRG	6.57																	5.1	< 0.05	
HD1	3/08/2011	LRG	7.24																	5.27	<0.005	
HD1	22/09/2012	LRG	7.16																	5.16	<0.005	
HD1	23/09/2012	LRG	7.71																	5.88	<0.001	
HD1	15/12/2012	LRG	7.67																	4.21	<0.001	
HD1	19/12/2012	LRG	5.7																	14.8	<0.001	
HD1	15/01/2013	LRG	7.23																	14.9	<0.001	
HD1	15/04/2013	LRG	6.91																	15	<0.010	
HD1	15/05/2013	LRG	6.96																	14.9	<0.050	
HD1	15/06/2013	LRG	7.04																	14.3	<0.005	
HD1	20/06/2013	LRG	6.92																	18.5	<0.005	
HD1	15/09/2013	LRG	7.14																	14.2	<0.005	
HD1	25/09/2013	LRG	6.99												0.001			0.001	0.001	19.7	<0.001	
HD1	2/12/2013	LRG	6.7																	20.4	<0.001	
HD1	2/12/2013	LRG	8.17												0.001			0.001	0.001	20.5	<0.01	
HD1	1/02/2014	LRG	8.89																	18	< 0.005	
HD1	4/03/2014	LRG	9.63												0.001			0.001	0.001	19.6	<0.005	
HD1	12/06/2014	LRG	8.22																	18.9	<0.005	
HD1	1/08/2014	LRG	8.24																	33.3	<0.002	
HD1	1/11/2014	LRG	7.1																	18.2	<0.005	
HD1	1/02/2015	LRG	6.82																	2.99	0.025	
HD1	1/05/2015	LRG	6.95																	3.72	0.025	
HD1	1/08/2015	LRG	7.04																	3.6	0.027	
Karra Homestead	1/11/2014	LRG	7.3																	3.4	< 0.025	
Karra Homestead	1/02/2015	LRG	8.52																	3.66	0.016	
Karra Homestead	1/08/2015	LRG	8.53																	3.49	0.022	
T01	1/01/2011	LRG	7.01																	3.85	0.02	
T01	3/01/2011	LRG	7.17																	3.56	0.017	
T01	20/09/2012	LRG	7.16																	5.71	<0.001	
T01	27/10/2012	LRG	7.24																	6	<0.001	
T01	15/12/2012	LRG	7.8																	5.8	<0.010	
T01	15/01/2013	LRG	7.27																	5.9	< 0.025	
T01	15/04/2013	LRG	7.23																	6.38	<0.005	
T01	15/05/2013	LRG	7.47		4670	54	65	1400	28	1	2180	0.006	0.47							5.66	<0.005	
T01	15/06/2013	LRG	7.5		4090	38	55	1170	22	2	1680	0.017	0.2	0.12						6.49	<0.001	
T01	18/06/2013	LRG	7.43		3290	34	47	956	26	1	1470	0.016	0.32							5.77	<0.001	
T01	15/09/2013	LRG	7.61		4690	42	60	1150	28	1	1960	0.011	0.48	0.01						7.61	0.003	
T01	20/09/2013	LRG	7.2												0.001			0.001	0.001	5.8	<0.001	
T01	28/11/2013	LRG	7.5																	5.51	<0.001	

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
T01	28/11/2013	LRG	7.21												0.001			0.001	0.001	5.2	< 0.025	
T01	1/03/2014	LRG	7.25																	5.37	<0.005	
T01	1/03/2014	LRG	7.14												0.001			0.001	0.001	5.32	<0.005	
T01	12/06/2014	LRG	7.32																	4.91	<0.005	
T01	1/08/2014	LRG	7.41		7600	57	127	2410	22	1	3900	0.07	1.57	0.12						4.8	< 0.005	
T01	1/11/2014	LRG	7.49		3500	47	70	1120	26	1	1570	0.04	1.98	0.37						5.92	<0.001	
T01	1/02/2015	LRG	7.5		6700	70	94	2080	40	1	3610	0.028	1.01	0.21						8.65	0.001	
T01	1/05/2015	LRG	7.73		3480	28	30	1140	21	1	1480	0.027	1.41	0.18						9.26	0.002	
T01	1/08/2015	LRG	7.43		3640	27	28	1100	20	1	1480	0.07	2.18	0.06						9.36	0.002	
T02	1/01/2011	LRG	7.47		2800	39	49	818	27	1	1240	0.038	0.84	0.04						9.48	<0.010	
T02	3/01/2011	LRG	7.8		4290	46	70	1420	30	1	2000	0.068	1.66	0.08						9.5	< 0.05	
T02	20/09/2012	LRG	7.19																	9.8	<0.005	
T02	27/10/2012	LRG	7.44																	8.47	<0.005	
T02	15/12/2012	LRG	7.44																	8.98	<0.005	
T02	15/01/2013	LRG	7.51																	9.66	<0.005	
T02	15/04/2013	LRG	7.44																	11.5	0.003	
T02	15/05/2013	LRG	7.2																	12	0.003	
T02	15/06/2013	LRG	7.72		6390	65	93	1990	44	7	3710	0.06	7.39	1.98		0.075	0.001			11.2	<0.010	
T02	18/06/2013	LRG	7.6		5020	54	69	1570	30	2	2690	0.009	0.39	0.03		0.043	0.002			12	< 0.05	
T02	15/09/2013	LRG	7.79		3980	38	57	1230	24	1	1880	0.018	0.15	0.06		0.047	0.002			12	< 0.05	
T02	20/09/2013	LRG	7.73		3580	35	50	1080	28	1	1570	0.016	0.2	0.02	0.001	0.047	0.002	0.001	0.002	10.8	<0.010	
T02	28/11/2013	LRG	7.6		2530	37	49	854	27	1	1320	0.031	0.56	0.05		0.046	0.001			11.1	<0.005	
T02	28/11/2013	LRG	7.81		3800	40	59	1270	30	1	1940	0.013	0.41	0.05	0.001	0.06	0.001	0.001	0.001	11.8	<0.005	
T02	1/03/2014	LRG	7.37		6530	112	152	2090	49	1	3680	0.04		0.05						11.9	<0.005	
T02	6/03/2014	LRG	7.38												0.001	0.158	0.001	0.001	0.001	11.8	<0.005	
T02	12/06/2014	LRG	7.55		4440	51	68	1800	26	1	2860	0.007		0.02						12.3	<0.005	
T02	1/08/2014	LRG	7.62													0.057	0.001			7.76	<0.001	
T02	1/11/2014	LRG	7.6		3440	32	47	1340	16	1	2020	0.018		0.03						8.24	<0.001	
T02	1/02/2015	LRG	7.67													0.056	0.001			8.75	<0.010	
T02	1/05/2015	LRG	7.41		3210	33	46	1200	23	1	1700	0.017		0.02						8.9	< 0.05	
T02	1/08/2015	LRG	7.63													0.06	0.001			8.74	<0.005	
T03	1/01/2011	LRG	7.42		2490	38	42	866	26	2	1180	0.038		0.13						8.76	<0.005	
T03	3/01/2011	LRG	7.27													0.051	0.002			10.5	<0.001	
T03	20/09/2012	LRG	7.58		4400	47	59	1220	30	1	1990	0.009		0.02						10.5	<0.001	
T03	27/10/2012	LRG	7.51													0.072	0.002			8.2	0.0001	
T03	15/12/2012	LRG	7.47		3400	34	31	1070	19	2	1570	0.008		0.05						7.07	<0.001	
T03	21/12/2012	LRG	7.36													0.041	0.001			6.98	<0.001	
T03	15/01/2013	LRG	7.58		6790	57	129	2530	21	8	4280	0.071		0.08						4.78	<0.001	
T03	15/04/2013	LRG	7.49													0.072	0.002			5.1	<0.001	
T03	15/05/2013	LRG	7.24	427	4604.6															5.08	<0.010	
T03	15/06/2013	LRG	7.2	-	6445.4															4.9	< 0.05	
T03	18/06/2013	LRG	7.33	412	7567.3															5.24	<0.005	
T03	15/09/2013	LRG	7.47	450	6470	93	143	1980	41	1		0.036		0.03		0.147	0.003			4.59	<0.005	

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
T03	20/09/2013	LRG	7.59	452	6520	45	117	2470	22	1		0.075		0.17	0.001	0.079	0.002	0.001	0.001	5.92	<0.001	
T03	28/11/2013	LRG	6.99	454	2633.15															4.21	<0.001	
T03	28/11/2013	LRG	7.42		5577.65										0.001			0.001	0.001			
T03	1/03/2014	LRG	7.53		4314.7																	
T03	6/03/2014	LRG	7.48		3885.05										0.001			0.001	0.001			
T03	12/06/2014	LRG	7.48		4670	55	68	1630	28	1		0.006		0.01		0.054	0.002					
T03	1/08/2014	LRG	7.27		2800	32	42	793	24	6		0.034		0.04		0.055	0.001					
T03	1/11/2014	LRG	7.69		4190	42	62	1290	28	1		0.011		0.01		0.098	0.001					
T03	1/02/2015	LRG	7.61		3920	38	56	1240	22	1		0.02		0.01		0.073	0.001					
T03	1/05/2015	LRG	7.56		3140	36	50	1080	27	1		0.018		0.01		0.076	0.002					
T03	1/08/2015	LRG	7.33		6441.5																	
WB100	27/10/2012	LRG	7.22		2611.05																	
WB100	15/12/2012	LRG	7.49		7508.15																	
WB100	20/12/2012	LRG	6.47		4077.45																	
WB100	15/01/2013	LRG	6.96		5050.5																	
WB100	15/04/2013	LRG	6.82		4020.25																	
WB100	15/05/2013	LRG	6.64		3566.55																	
WB100	15/07/2013	LRG	7.64		4586.4																	
WB100	23/07/2013	LRG	7.17		2678																	
WB100P	19/09/2012	LRG	7.4		6399.9																	
WB100P	22/09/2012	LRG	7.46		5647.85																	
WB100P	15/12/2012	LRG	7.5		4451.85																	
WB100P	20/12/2012	LRG	7.54		3939.65																	
WB100P	15/04/2013	LRG	7.59		7481.5																	
WB100P	15/05/2013	LRG	7.69		4571.45																	
WB100P	15/07/2013	LRG	7.2		2750.15																	
WB100P	25/07/2013	LRG	7.42		6535.1																	
WB100P	15/09/2013	LRG	7.47		5675.15																	
WB100P	24/09/2013	LRG	7.55		4485.65										0.001			0.001	0.001			
WB100P	30/11/2013	LRG	7.5		4004.65																	
WB100P	30/11/2013	LRG	7.61		6078.15										0.001			0.001	0.001			
WB100P	1/03/2014	LRG	7.5		8054.15																	
WB100P	2/03/2014	LRG	7.79		4564.95										0.002			0.001	0.001			
WB100P	24/05/2014	LRG	7.32		4083.3																	
WB100P	1/08/2014	LRG	7.53		7650.5																	
WB100P	1/11/2014	LRG	7.63		5775.9																	
WB100P	1/02/2015	LRG	7.63		4564.95																	
WB100P	1/05/2015	LRG	7.55		4083.3																	
WB100P	1/08/2015	LRG	7.76		6345.3																	
WB102	27/10/2012	LRG	8.3		7650.5																	
WB102	15/12/2012	LRG	7.6		4571.45																	
WB102	20/12/2012	LRG	7.27		2629.25																	
WB102	15/01/2013	LRG	7.4		6610.5																	

Well ID	Date	Screened Aquifer	pH	Total Alkalinity	TDS	Ca	Mg	Na	K	SO4	Cl	Mn	Fe	Al	As	Cu	Li	Mo	Ni	Sr	U	Zn
WB102	15/04/2013	LRG	7.59		5562.05																	
WB102	15/05/2013	LRG	7.58		4348.5																	
WB102	15/07/2013	LRG	7.46		3899.35																	
WB102	26/07/2013	LRG	7.48		7695.35																	
WB103	27/10/2012	LRG	7.75		4622.8																	
WB103	15/12/2012	LRG	7.29		2598.05																	
WB103	15/01/2013	LRG	7.27		6581.9																	
WB103	15/04/2013	LRG	7.77		5485.35																	
WB103	15/05/2013	LRG	7.8		4276.35																	

Appendix C

Bore Development Field Sheets

Well Development Purge Sheets

General Information	
Client:	Iluka Resources Limited
Job Number:	CP-01-26
Project:	Balranald Mineral Sands Mining Project
Program:	December 2018 - Groundwater and Surface Water Monitoring
Location:	Balranald, New South Wales

Bore Information			
Well ID No.	SHOB04	Aquifer Unit	Shepparton Formation
Depth to Groundwater (m-TOSC):	—	Well depth (m-PVC)	23m
Depth to Groundwater (mPVC):	14.32	Bore Radius (m)/ PVC Casing Radius (m)	0.107 / 0.025
Depth to Groundwater (m-BGL):	—	Screen Interval (m)	17-23m
Gatic Cover: Y / N	Standpipe: Y / N	Bore Condition (integrity of casing/ well caps etc):	

Equipment Calibration Information	
Chem Kit Number/ Type: YSI	Chem Kit Calibrated: Y / N
Comments: Rental Rental	Signed Off By:

Weather Conditions	
Rain: None	Wind Direction: NE
Temperature: 24°C	Wind Speed: low
Cloud Cover: 90%	Upwind Activities: Site /Agri

Sampling Methodology					
Sampling Method (Circle):	Disposable Bailer	Waterra Tubing/ Footvalve	Low Flow Sampling	Passive Sampler	Existing Tubing used
Equipment (Circle):	Disposable	Dedicated Tubing	Decontaminated		Tubing left in Well

Trigger Levels

Bore Volume Calculation:

$$PV = [(H \times \pi \times r^2) + 0.2(h \times \pi \times (R^2 - r^2))] \times 1000$$

where H = height of water column (m) R = Bore Radius (m)

h = thickness of saturated filterpack (m) r = PVC Radius (m)

$PV = [(8.68\pi 0.025^2) + 0.2(6.08\pi(0.107^2 - 0.025^2))] \times 1000$

$= 57.8$ L

Low Flow Methodology:

The low flow pump is to be positioned at the mid-point of the saturated well screen. Between sampling locations, dedicated LDPE tubing and internal pump bladders are to be used with the pump decontaminated using Decon90 (decontamination solution) and rinsed through twice, once with tap water and then with distilled water. The water level is to be measured during the micro purging so as to ensure that the water level does not fall by more than 10 cm and that water is being sampled from the targeted depth. This is required to ensure groundwater extracted from the well is fresh groundwater obtained from the adjacent formation and not stagnant water contained in the well water column. Field chemical parameters are to be recorded every five minutes or the time taken to remove one volume of the flow through the cell (whichever is greater) and at least 1 bore volume (screened interval only) should be removed before sampling (if conditions are suitable).

Purging Information

Date: 16/12/18		Name: R Martin / J Rohrlach					
Start Time: 9.05		Finish Time 10.44			Pump Depth —		
Purge Volume (L) 58		No times purged 5			Pump Speed —		
Time	Volume Removed (L)	pH	E.C. (µS/cm or mS/cm)	Redox (mV)	Temp (°C)	Water Level (mPVC)	Appearance (Colour, Turbidity, Odour and Appearance of a Sheen)
9.21	58	7.49	62,090	16.6	20.4	—	Moderate turbidity, yellow/brown
9.34	58	7.52	63,709	29.7	21.6	—	" "
9.52	58	7.55	63,632	25.9	21.4	—	low to mod turbidity, clear to brown
10.25	58	7.55	68,109	18.1	21.4	—	low turbidity, clear, no odours / sheen
10.44	58	7.50	64,965	17.6	21.8	—	" " "

Purging should continue until measurements for pH are within 0.05 pH unit, EC is within 3%, Redox is within 10mV and Temperature is within 0.5 degC of the previous set of parameters.

Field Iron Test Results	
Ferrous Iron (mg/L):	
Total Iron (mg/L):	
Total - Ferrous = Ferric Iron (mg/L):	

Sampling Notes

Purger/ Sampler Name: J Rohrlach	Signature	Date / /
Checked by: E Picken	Signature EP	Date 10/2/19

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Well Development Purge Sheets

General Information	
Client:	Iluka Resources Limited
Job Number:	CP-01-26
Project:	Balranald Mineral Sands Mining Project
Program:	December 2018 - Groundwater and Surface Water Monitoring
Location:	Balranald, New South Wales

Bore Information			
Well ID No.	UGM-14S	Aquifer Unit	Shepparton Formation
Depth to Groundwater (m-TOSC):	-	Well depth (m-PVC)	18.0m
Depth to Groundwater (mPVC):	13.504	Bore Radius (m)/ PVC Casing Radius (m)	0.107 / 0.016
Depth to Groundwater (m-BGL):	-	Screen Interval (m)	15-18m
Gatic Cover: Y / N	Standpipe: Y / N	Bore Condition (integrity of casing/ well caps etc):	Good

Equipment Calibration Information	
Chem Kit Number/ Type: YSI	Chem Kit Calibrated: Y / N
Comments: Rental	Signed Off By:

Weather Conditions			
Rain:	None	Wind Direction:	NE
Temperature:	23°C	Wind Speed:	low
Cloud Cover:	95%	Upwind Activities:	site / ag

Sampling Methodology					
Sampling Method (Circle):	Disposable Bailer	Waterra Tubing/ Footvalve	Low Flow Sampling	Passive Sampler	Existing Tubing used
Equipment (Circle):	Disposable	Dedicated Tubing	Decontaminated		Tubing left in Well

Trigger Levels

Bore Volume Calculation:

$$PV = [(H \times \pi \times r^2) + 0.2(h \times \pi \times (R^2 - r^2))] \times 1000$$

where H = height of water column (m) R = Bore Radius (m)
h = thickness of saturated filterpack (m) r = PVC Radius (m)

$PV = [(4.496\pi 0.016^2) + 0.2(3.0 \pi (0.107^2 - 0.016^2))] \times 1000$

$= 24.71$ L

Low Flow Methodology:
The low flow pump is to be positioned at the mid-point of the saturated well screen. Between sampling locations, dedicated LDPE tubing and internal pump bladders are to be used with the pump decontaminated using Decon90 (decontamination solution) and rinsed through twice, once with tap water and then with distilled water. The water level is to be measured during the micro purging so as to ensure that the water level does not fall by more than 10 cm and that water is being sampled from the targeted depth. This is required to ensure groundwater extracted from the well is fresh groundwater obtained from the adjacent formation and not stagnant water contained in the well water column. Field chemical parameters are to be recorded every five minutes or the time taken to remove one volume of the flow through the cell (whichever is greater) and at least 1 bore volume (screened interval only) should be removed before sampling (if conditions are suitable).

Purging Information

Date: 15/12/18	Name: R Martin / J Rohrlach		
Start Time: 10.45	Finish Time 13.28	Pump Depth	-
Purge Volume (L) 25	No times purged 5	Pump Speed	

Time	Volume Removed (L)	pH	E.C. (µS/cm or mS/cm)	Redox (mV)	Temp (°C)	Water Level (mPVC)	Appearance (Colour, Turbidity, Odour and Appearance of a Sheen)
11.26	25	7.64	62,939	-18.9	21.0	-	high turbidity, brown, no odours/sheen
12.20	25	7.70	65,695	4.3	24.3	-	" " "
12.54	25	7.67	63,519	3.4	23.4	-	" " "
13.14	25	7.61	69,028	11.0	21.1	-	medium to high turb, becoming clearer
13.28	25	7.61	68,776	12.6	21.6	-	low to medium turbidity, no odours/sheen

Purging should continue until measurements for pH are within 0.05 pH unit, EC is within 3%, Redox is within 10mV and Temperature is within 0.5 degC of the previous set of parameters.

Field Iron Test Results

Ferrous Iron (mg/L):	
Total Iron (mg/L):	
Total - Ferrous = Ferric Iron (mg/L):	

Sampling Notes

Purger/ Sampler Name: J Rohrlach	Signature	Date / /
Checked by: E Picken	Signature	Date 10/2/19

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Well Development Purge Sheets

General Information	
Client:	Iluka Resources Limited
Job Number:	CP-01-26
Project:	Balranald Mineral Sands Mining Project
Program:	December 2018 - Groundwater and Surface Water Monitoring
Location:	Balranald, New South Wales

Bore Information			
Well ID No.	UGM-13S	Aquifer Unit	Shepparton Formation
Depth to Groundwater (m-TOSC):	—	Well depth (m-PVC)	18.0 m
Depth to Groundwater (mPVC):	13.366	Bore Radius (m)/ PVC Casing Radius (m)	0.107 / 0.016
Depth to Groundwater (m-BGL):	—	Screen Interval (m)	15 - 18 m
Gatic Cover: Y / N	Standpipe: Y / N	Bore Condition (integrity of casing/ well caps etc):	Good / no well cap.

Equipment Calibration Information		Weather Conditions	
Chem Kit Number/ Type: YSI	Chem Kit Calibrated: Y / N	Rain: none	Wind Direction: NE
Comments: Rental	Signed Off By:	Temperature: 18°C	Wind Speed: low
		Cloud Cover: 90%	Upwind Activities: site / agric.

Sampling Methodology					
Sampling Method (Circle):	Disposable Bailer	Waterra Tubing/ Footvalve	Low Flow Sampling	Passive Sampler	Existing Tubing used
Equipment (Circle):	Disposable	Dedicated Tubing	Decontaminated		Tubing left in Well

Trigger Levels

Bore Volume Calculation:

$$PV = [(H \times \pi \times r^2) + 0.2(h \times \pi \times (R^2 - r^2))] \times 1000$$

where H = height of water column (m) R = Bore Radius (m)

h = thickness of saturated filterpack (m) r = PVC Radius (m)

PV = [(4.634 π 0.016²) + 0.2(3 π 0.107² - 0.025²))] × 1000

= 24.8 L

Low Flow Methodology:

The low flow pump is to be positioned at the mid-point of the saturated well screen. Between sampling locations, dedicated LDPE tubing and internal pump bladders are to be used with the pump decontaminated using Decon90 (decontamination solution) and rinsed through twice, once with tap water and then with distilled water. The water level is to be measured during the micro purging so as to ensure that the water level does not fall by more than 10 cm and that water is being sampled from the targeted depth. This is required to ensure groundwater extracted from the well is fresh groundwater obtained from the adjacent formation and not stagnant water contained in the well water column. Field chemical parameters are to be recorded every five minutes or the time taken to remove one volume of the flow through the cell (whichever is greater) and at least 1 bore volume (screened interval only) should be removed before sampling (if conditions are suitable).

Purging Information

Date: 16/12/18	Name: R Martin / J Rohrlach			
Start Time: 7.39	Finish Time 8.32	Pump Depth —		
Purge Volume (L) 25	No times purged 5	Pump Speed —		

Time	Volume Removed (L)	pH	E.C. (µS/cm or mS/cm)	Redox (mV)	Temp (°C)	Water Level (mPVC)	Appearance (Colour, Turbidity, Odour and Appearance of a Sheen)
7.52	25	8.33	50,876	17.7	19.0	—	high turbidity, brown, organic odour, no sheen
8.01	25	8.20	57,848	14.8	19.6	—	" " "
8.10	25	8.14	58614	12.9	19.7	—	med to high turbidity, cream/brown organic odour
8.21	25	8.10	59159	12.0	19.5	—	becoming clearer, low to moderate turbidity, slight organic odour
8.32	25	8.05	60888	6.7	19.7	—	" " "

Purging should continue until measurements for pH are within 0.05 pH unit, EC is within 3%, Redox is within 10mV and Temperature is within 0.5 degC of the previous set of parameters.

Field Iron Test Results

Ferrous Iron (mg/L):	
Total Iron (mg/L):	
Total - Ferrous = Ferric Iron (mg/L):	

Sampling Notes

Purger/ Sampler Name: J Rohrlach	Signature	Date / /
Checked by: E Picken	Signature EP	Date 10/2/19

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Well Development Purge Sheets

General Information	
Client:	**Iluka Resources Limited**
Job Number:	**CP-01-26**
Project:	**Balranald Mineral Sands Mining Project**
Program:	**December 2018 - Groundwater and Surface Water Monitoring**
Location:	**Balranald, New South Wales**

Bore Information			
Well ID No.	UGM-12S	**Aquifer Unit**	Shepparton Formation
Depth to Groundwater (m-TOSC):	—	Well depth (m-PVC)	18.0m
Depth to Groundwater (mPVC):	13.492	Bore Radius (m)/ PVC Casing Radius (m)	
Depth to Groundwater (m-BGL):	—	Screen Interval (m)	15-18m
Gatic Cover: Y / N	Standpipe: Y / N	Bore Condition (integrity of casing/ well caps etc):	Good

Equipment Calibration Information		Weather Conditions	
Chem Kit Number/ Type: YSI	Chem Kit Calibrated: Y / N	Rain: None	Wind Direction: NE
Comments: Rental	Signed Off By:	Temperature: 19°C	Wind Speed: low
		Cloud Cover: 90%	Upwind Activities: site/agri

Sampling Methodology						
Sampling Method (Circle):	Disposable Bailer	Waterra Tubing/ Footvalve	Low Flow Sampling	Passive Sampler		Existing Tubing used
Equipment (Circle):	Disposable	Dedicated Tubing	Decontaminated			Tubing left in Well

Trigger Levels

Bore Volume Calculation:

$$PV = [(H \times \pi \times r^2) + 0.2(h \times \pi \times (R^2 - r^2))] \times 1000$$

where H = height of water column (m) R = Bore Radius (m)

h = thickness of saturated filterpack (m) r = PVC Radius (m)

PV = [(4.508π0.016²) + 0.2 (3π 0.1072² − 0.016²))] ×1000

= 24.72 L

Low Flow Methodology:

The low flow pump is to be positioned at the mid-point of the saturated well screen. Between sampling locations, dedicated LDPE tubing and internal pump bladders are to be used with the pump decontaminated using Decon90 (decontamination solution) and rinsed through twice, once with tap water and then with distilled water. The water level is to be measured during the micro purging so as to ensure that the water level does not fall by more than 10 cm and that water is being sampled from the targeted depth. This is required to ensure groundwater extracted from the well is fresh groundwater obtained from the adjacent formation and not stagnant water contained in the well water column. Field chemical parameters are to be recorded every five minutes or the time taken to remove one volume of the flow through the cell (whichever is greater) and at least 1 bore volume (screened interval only) should be removed before sampling (if conditions are suitable).

Purging Information

Date: 15/12/18	Name: R Martin / J Rohrlach		
Start Time: 9.00	Finish Time 12.48	Pump Depth —	
Purge Volume (L) 25	No times purged 5	Pump Speed —	

Time	Volume Removed (L)	pH	E.C. (µS/cm or mS/cm)	Redox (mV)	Temp (°C)	Water Level (mPVC)	Appearance (Colour, Turbidity, Odour and Appearance of a Sheen)
9.50	25	7.84	46,033	-0.3	17.5	—	high turbidity, grey, no odours/sheen
10.23	25	7.83	56,015	-6.3	20.8	—	" " "
11.42	25	7.75	60,488	-10.0	20.9	—	moderate to high turbidity, grey, no odours/sheen
12.34	25	7.77	61,355	13.5	20.9	—	moderate turbidity, becoming clearer
12.48	25	7.73	61,607	7.9	20.9	—	low to moderate turbidity, becoming clear, no odours/sheen

Purging should continue until measurements for pH are within 0.05 pH unit, EC is within 3%, Redox is within 10mV and Temperature is within 0.5 degC of the previous set of parameters.

Field Iron Test Results

Ferrous Iron (mg/L):	
Total Iron (mg/L):	
Total - Ferrous = Ferric Iron (mg/L):	

Sampling Notes

Purger/ Sampler Name: J Rohrlach	Signature	Date / /
Checked by: E Picken	Signature EP	Date 10/2/19

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Well Development Purge Sheets

General Information	
Client:	Iluka Resources Limited
Job Number:	CP-01-26
Project:	Balranald Mineral Sands Mining Project
Program:	December 2018 - Groundwater and Surface Water Monitoring
Location:	Balranald, New South Wales

Bore Information			
Well ID No.	UGM-11S	Aquifer Unit	Shepparton Formation
Depth to Groundwater (m-TOSC):	-	Well depth (m-PVC)	18
Depth to Groundwater (mPVC):	13.58	Bore Radius (m)/ PVC Casing Radius (m)	0.107 / 0.016
Depth to Groundwater (m-BGL):	-	Screen Interval (m)	15-18 m
Gatic Cover: Y / N	Standpipe: Y / N	Bore Condition (integrity of casing/ well caps etc):	Good

Equipment Calibration Information		Weather Conditions			
Chem Kit Number/ Type: YSI	Chem Kit Calibrated: Y / N	Rain:	None	Wind Direction:	NE
Comments: Rental	Signed Off By:	Temperature:	18 °C	Wind Speed:	low
		Cloud Cover:	90%	Upwind Activities:	site / agri.

Sampling Methodology

Sampling Method (Circle):	Disposable Bailer	Waterra Tubing/ Footvalve	Low Flow Sampling	Passive Sampler	Existing Tubing used
Equipment (Circle):	Disposable	Dedicated Tubing	Decontaminated		Tubing left in Well

Trigger Levels

Bore Volume Calculation:

$$PV = [(H \times \pi \times r^2) + 0.2(h \times \pi \times (R^2 - r^2))] \times 1000$$

where H = height of water column (m) R = Bore Radius (m)
h = thickness of saturated filterpack (m) r = PVC Radius (m)

$PV = [(4.42 \pi\, 0.016^2) + 0.2(3 \pi\, 0.107^2 - 0.016^2))] \times 1000$

$= 24.65$ L

Low Flow Methodology:
The low flow pump is to be positioned at the mid-point of the saturated well screen. Between sampling locations, dedicated LDPE tubing and internal pump bladders are to be used with the pump decontaminated using Decon90 (decontamination solution) and rinsed through twice, once with tap water and then with distilled water. The water level is to be measured during the micro purging so as to ensure that the water level does not fall by more than 10 cm and that water is being sampled from the targeted depth. This is required to ensure groundwater extracted from the well is fresh groundwater obtained from the adjacent formation and not stagnant water contained in the well water column. Field chemical parameters are to be recorded every five minutes or the time taken to remove one volume of the flow through the cell (whichever is greater) and at least 1 bore volume (screened interval only) should be removed before sampling (if conditions are suitable).

Purging Information

Date: 15/12/18 — Name: R Martin / J Rohrlach
Start Time: 8.28 — Finish Time: 11.57 — Pump Depth: -
Purge Volume (L): 25 — No times purged: 5 — Pump Speed: -

Time	Volume Removed (L)	pH	E.C. (µS/cm or mS/cm)	Redox (mV)	Temp (°C)	Water Level (mPVC)	Appearance (Colour, Turbidity, Odour and Appearance of a Sheen)
8.43	25	7.33	44,889	16.7	19.8	13.98	high turbidity, brown, no odours/sheen
9.15	25	7.40	56,587	-3.0	19.6	13.81	medium turbidity, cream, no odours/sheen
10.08	25	7.43	60,700	-1.4	20.8	13.55	low to medium turbidity, water is becoming clear
10.49	25	7.52	63,011	-7.6	20.8	13.55	low turbidity, no odours/sheen
11.57	25	7.48	63,812	-12.2	20.5	13.53	" " "

Purging should continue until measurements for pH are within 0.05 pH unit, EC is within 3%, Redox is within 10mV and Temperature is within 0.5 degC of the previous set of parameters.

Field Iron Test Results

Ferrous Iron (mg/L):	
Total Iron (mg/L):	
Total - Ferrous = Ferric Iron (mg/L):	

Sampling Notes

Purger/ Sampler Name: J Rohrlach	Signature	Date	/ /
Checked by: E Picken	Signature	Date	10/2/19

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Appendix B

GME hydrographs (2016-2019)

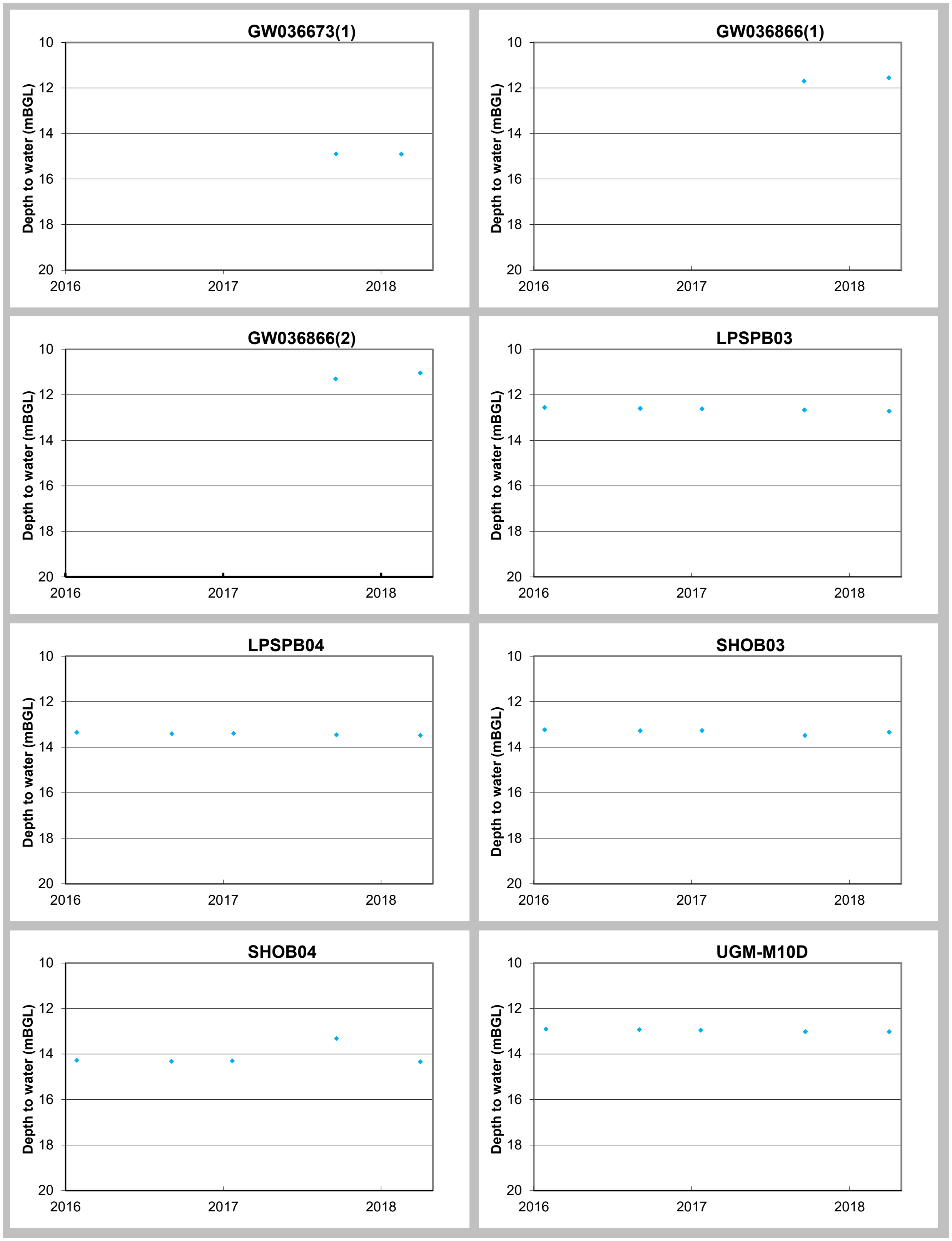


Figure A1 Balranald hydrographs

T:\Jobs\2018\S180539 - Iluka provisional support Balranald 2019\Technical studies\Groundwater\Data\EMM Processed Data\[Balranald_GME hydrographs.xlsm]Fig1

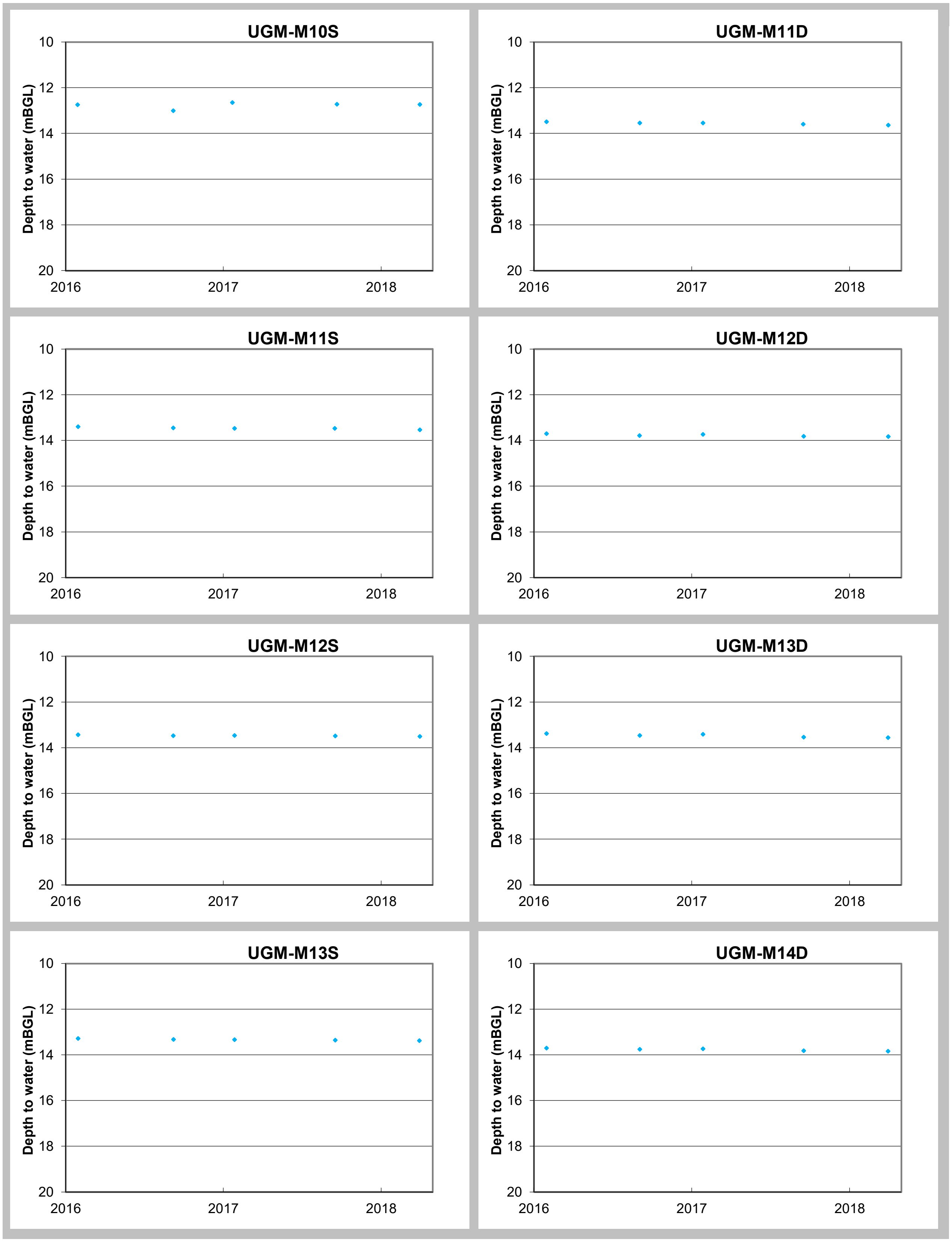


Figure A2 Balranald hydrographs

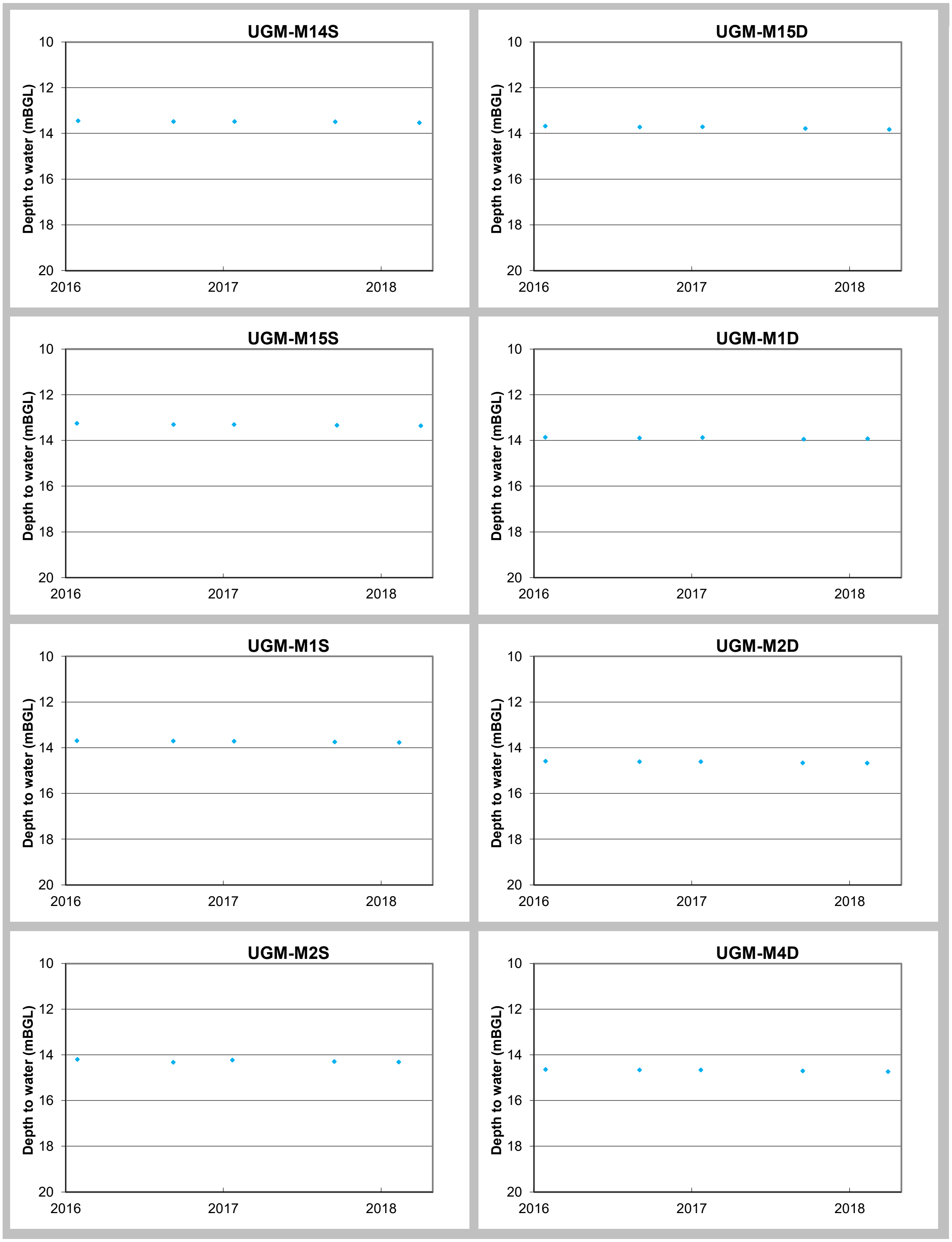


Figure A3 Balranald hydrographs

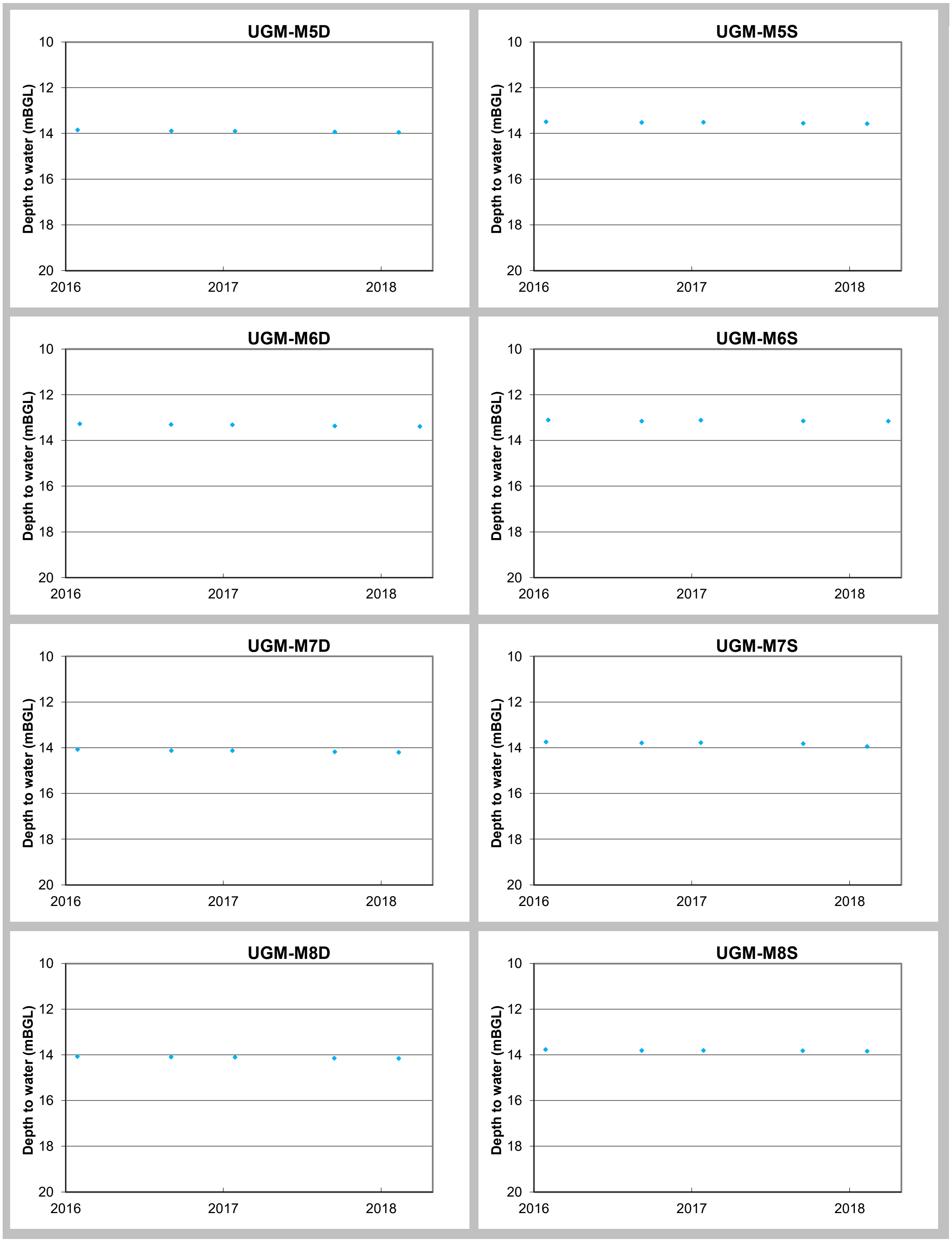


Figure A4 Balranald hydrographs

T:\Jobs\2018\S180539 - Iluka provisional support Balranald 2019\Technical studies\Groundwater\Data\EMM Processed Data\[Balranald_GME hydrographs.xlsm]Fig4

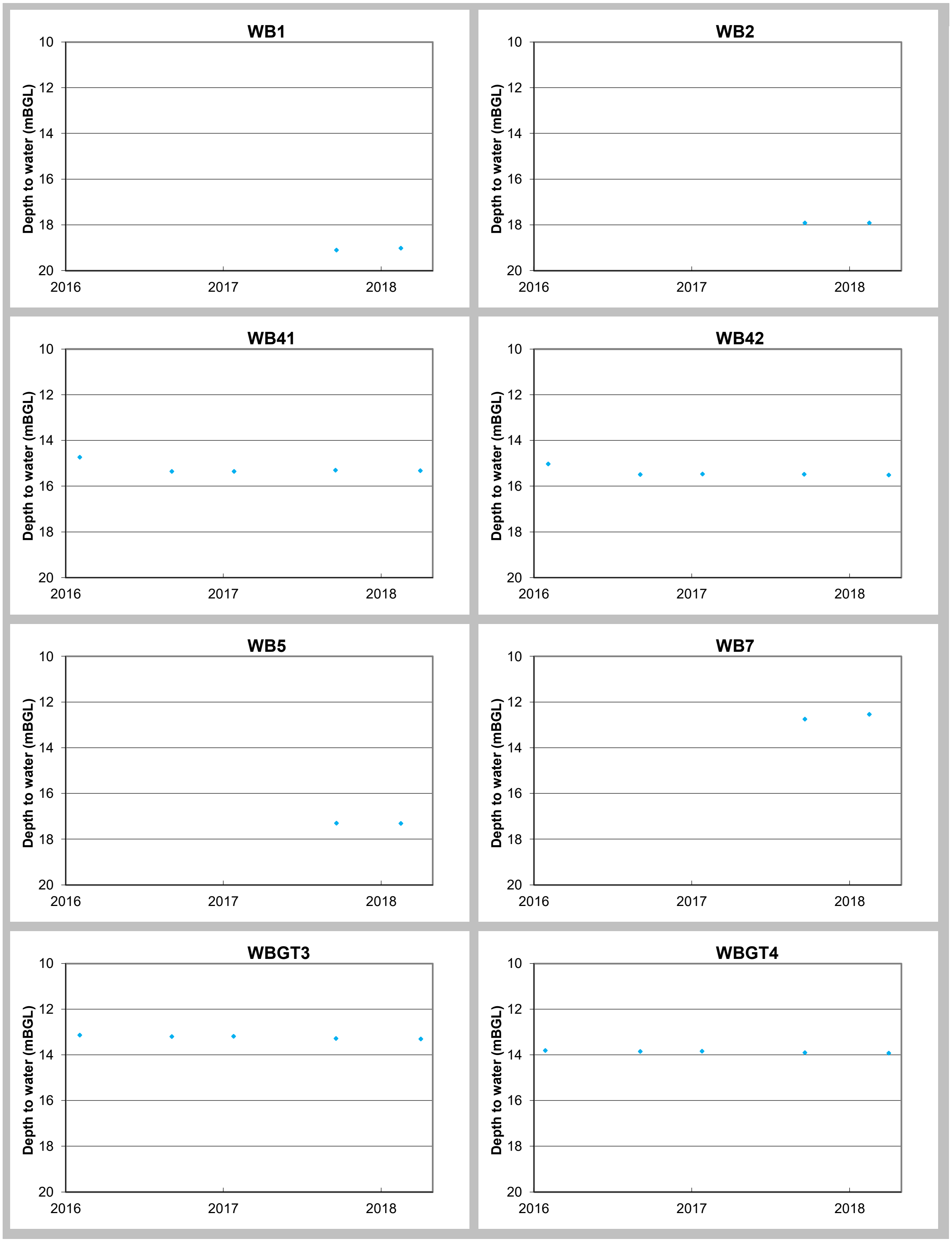
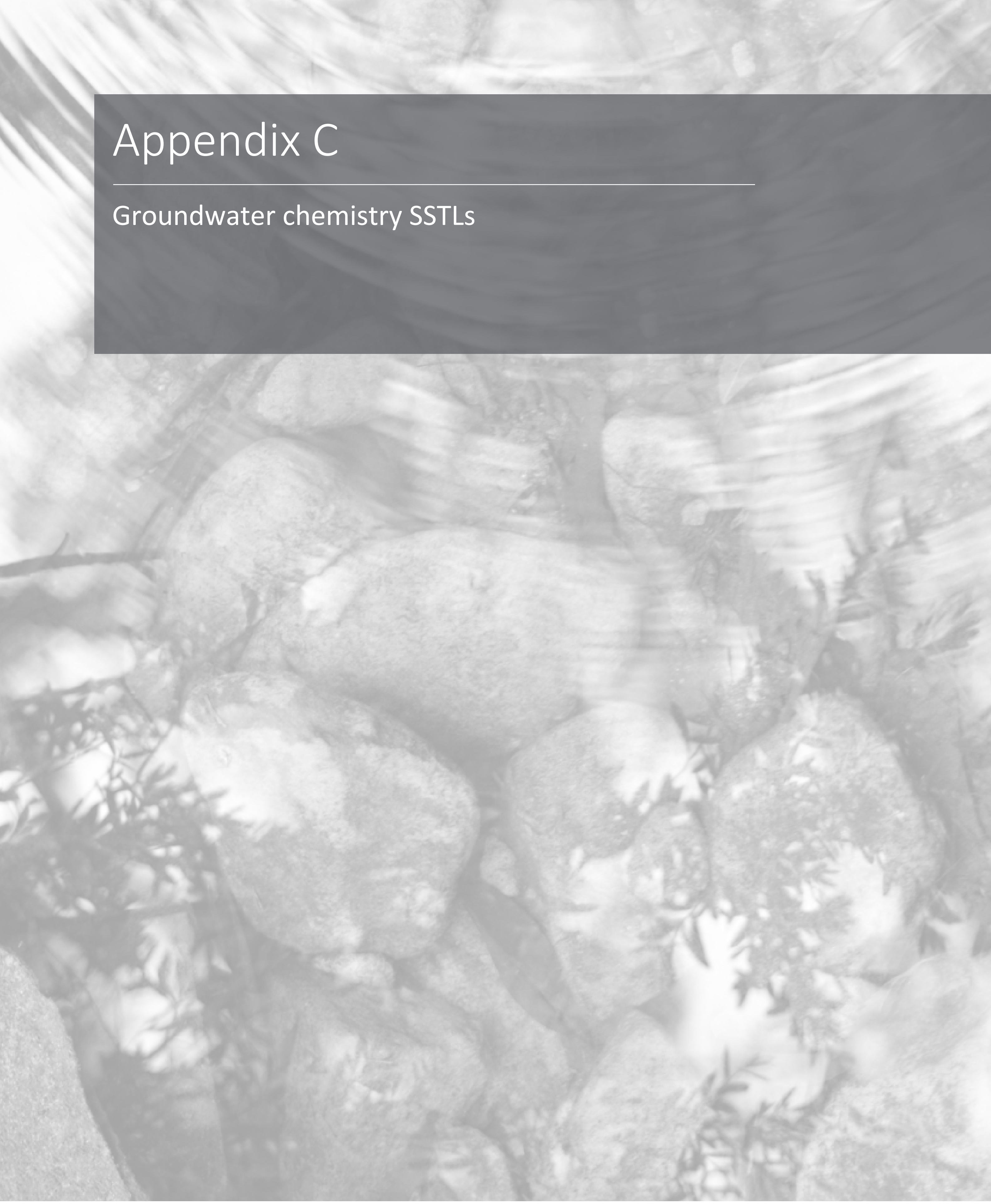


Figure A5 Balranald hydrographs

T:\Jobs\2018\S180539 - Iluka provisional support Balranald 2019\Technical studies\Groundwater\Data\EMM Processed Data\[Balranald_GME hydrographs.xlsm]Fig5

Appendix C

Groundwater chemistry SSTLs



C.1 Field water quality SSTLs

The SSTLs that are applied to field water quality parameters are outlined in Table C.1.

Table C.1 Field parameter water quality SSTLs

Water Quality Parameter	Shepparton Formation			Loxton Parilla Sands Aquifer			Lower Renmark Group Aquifer		
	Green	Yellow	Red	Green	Yellow	Red	Green	Yellow	Red
pH Upper	<8.78	<8.78	>9	<8.78	≥8.78	>9	≤8.24	>8.24	>9
pH Lower	>5.60	>5.60	<4	>5.73	≤5.73	<4	≥6.11	<6.11	<4
EC (mS/cm)	<99.191	<99.191	>112.717	<113.808	≥113.808	>129.328	<14.948	≥14.948	>16.986
Total Iron	<9.422	<9.422	>10.706	<10.588	≥10.588	>12.031	<3.670	≥3.670	>4.170

C.2 Laboratory water quality SSTLs

The SSTLs that are applied to the results of laboratory analysed water quality samples are shown in Table C.2.

Table C.2 Laboratory water quality SSTLs

Water Quality Parameter	Shepparton Formation			Loxton Parilla Sands Aquifer			Lower Renmark Group Aquifer		
	Green	Yellow	Red	Green	Yellow	Red	Green	Yellow	Red
Indirect – Adverse Risk to Beneficial Users									
Total Alkalinity (mg/L CaCO3)	<628	≥628	>754	<727	≥727	>823	<639	≥639	>767
Calcium (mg/L)	<1,112	≥1,112	>1,335	<1,220	≥1,220	>1,464	<101	≥101	>121
Magnesium (mg/L)	<3,219	≥3,219	>3,863	<3,324	≥3,324	>3,989	<130	≥130	>156
Sodium (mg/L)	<23586	≥23586	>28303	<24381	≥24381	>29258	<2880	≥2880	>3456
Potassium (mg/L)	<141	≥141	>169	<105	≥105	>126	<47	≥47	>56
Sulphate (mg/L)	<8254	≥8254	>9905	<9642	≥9642	>11570	<4	≥4	>5
Chloride (mg/L)	<42672	≥42672	>51206	<41875	≥41875	>50250	<4556	≥4556	>5468
Direct – Adverse Risk to Beneficial Users									
pH Upper	<8.78	≥8.78	>9	<8.78	≥8.78	>9	≤8.24	>8.24	>9
pH Lower	>5.60	≤5.60	<4	>5.73	≤5.73	<4	≥6.11	<6.11	<4
Total Alkalinity (mg/L CaCO3)	<628	≥628	>754	<727	≥727	>873	<639	≥639	>767
Total Dissolved Solids	<64474	≥64474	>73266	<73975	≥73975	>84063	<9716	≥9716	>11041
Al (mg/L)	<0.129	≥0.129	5	<0.129	≥0.129	5	<0.283	≥0.283	5
Ag (mg/L)	<0.01	≥001	>0.05	<0.01	≥0.01	>0.05	<0.01	≥0.01	>0.05
As (mg/L)	<0.026	≥0.026	>0.1	<0.020	≥0.02	>0.1	LOR	LOR	>0.1
B (mg/L)	<0.5	≥0.5	>1.0	<0.5	≥0.5	≥1.0	<0.5	≥0.5	>1.0

Table C.2 Laboratory water quality SSTLs

Water Quality Parameter	Shepparton Formation			Loxton Parilla Sands Aquifer			Lower Renmark Group Aquifer		
	Green	Yellow	Red	Green	Yellow	Red	Green	Yellow	Red
Be (mg/L)	<0.1	≥0.1	>0.5	<0.1	≥0.1	>0.5	<0.1	≥0.1	>0.5
Bi (mg/L)	<0.01	≥0.01	>0.05	<0.01	≥0.01	>0.05	<0.01	≥0.01	>0.05
Cd (mg/L)	<0.01	≥0.01	>0.05	<0.01	≥0.01	>0.05	<0.01	≥0.01	>0.05
Co (mg/L)	<0.05	≥0.05	>0.1	<0.05	≥0.05	>0.1	<0.05	≥0.05	>0.1
Cr (mg/L)	<0.1	≥0.1	>1.0	<0.1	≥0.1	>1.0	<0.1	≥0.1	>1.0
Cu (mg/L)	<0.042	≥0.042	>0.2	<0.018	≥0.018	>0.2	<0.004	≥0.004	>0.2
F (mg/L)	<1.0	≥1.0	>2.0	<1.0	≥1.0	>2.0	<1.0	≥1.0	>2.0
Fe (mg/L	<9.422	≥9.422	>10.706	<10.588	≥10.588	>12.031	<3.670	≥3.670	>4.170
Li (mg/L)	<0.233	≥0.233	>2.5	<0.283	≥0.283	>2.5	<0.122	≥0.122	>2.5
Mn (mg/L)	<1.472	≥1.472	>1.673	<1.342	≥1.342	>1.525	<0.0822	≥0.082	>0.093
Mo (mg/L)	<0.024	≥0.024	>0.028	<0.007	≥0.007	>0.01	LOR	≥LOR	>0.01
Ni (mg/L)	<0.038	≥0.038	>0.2	<0.009	≥0.009	>0.2	LOR	≥LOR	>0.2
Pb (mg/L)	<2.0	≥2.0	>5.0	<2.0	≥2.0	>5.0	<2.0	≥2.0	>5.0
Sb (mg/L)	<0.01	≥0.01	>0.05	<0.01	≥0.01	>0.05	<0.01	≥0.01	>0.05
Se (mg/L)	<0.02	≥0.02	>0.05	<0.02	≥0.02	>0.05	<0.02	≥0.02	>0.05
Sr (mg/L)	<29.964	≥26.964	>30.641	<29.821	≥29.821	>33.888	<3.755	≥3.755	>4.267
Th (mg/L)	<0.01	≥0.01	>0.1	<0.01	≥0.01	>0.1	<0.01	≥0.01	>0.1
U (mg/L)	<0.065	≥0.065	>0.073	<0.013	≥0.013	>0.015	<0.001	>LOR	>0.01
V (mg/L)	<0.1	≥0.1	>0.5	<0.1	≥0.1	>0.5	<0.1	≥0.1	>0.5
Zn (mg/L)	<0.166	≥0.166	>2	<0.199	≥0.199	>2	LOR	>LOR	>2
Ra-226 (Bq/L)	N/A		≥5	N/A		≥5	N/A		>5
Ra-228 (Bq/L)	N/A		≥2	N/A		≥2	N/A		≥2
N- Species	<5	≥5	>25	>5	≥5	>25	>5	≥5	>25
Total Recoverable Hydrocarbons (TPH)	N/A		≥0.3	N/A		≥0.3	N/A		≥0.3

Appendix D

EMM Standard Operating Procedures

SOP001_Groundwater Sampling_ Micro-purge Pump

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2 September 2019

Subject: Standard Operating Procedure (SOP001) Sampling Groundwater using Micro-purge pump

1 Purpose and Scope

To instruct field staff on how to collect representative site-specific groundwater samples from the aquifer formation, with minimal disturbance to the water column.

This Field Instruction (FI) describes the methodology for the collection of groundwater samples using a bladder pump (low flow technique). This procedure should be read in conjunction with the following Australian/New Zealand Standards:

- AS NZS 5667.1.1998 – Water Quality Sampling – Part 1 Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples; and
- AS NZS 5667.11,1998 – Water quality - Sampling guidance on sampling of groundwaters.

2 Responsibilities

Role	Responsibility
Fieldwork Staff	To apply the methods detailed in this FI. To ensure equipment is in good working order prior to use, is maintained according to supplier's advice and is appropriately calibrated or verified, have a basic understanding of common faults and field-based repairs. Any faults shall be reported to the Project Manager (PM) or the equipment supplier as soon as they are identified. To ensure Quality Assurance/Quality Control and Health and Safety Compliance.
Project Manager	Define the objectives and appropriate methodology to field staff prior to mobilisation into the field. The Project Manager should check (or designate another to check) the gauging data recorded by the fieldwork staff for anomalies such as measurements inconsistent with historical groundwater level fluctuations or well construction records. To ensure Quality Assurance/Quality Control and Health and Safety Compliance.
Office HSE Advisor	The Office Health, Safety and Environment (HSE) Advisor is an assigned person in each office and is responsible for reviewing and approving Health, Safety and Environment (HSE) Plans, monitoring the implementation of HSE Plans, interface with PMs in matters of health and safety, investigating reports of incidents or accidents.

3 Equipment and Materials

3.1 Equipment

Equipment required to complete this task includes:

- Low Flow (Bladder) Pump Casing;
- wire hanger;
- control box;
- compressor (air or CO_2 gas cylinder, regulator and hose);
- water quality meter and flow-through-cell; and
- oil-water interface meter or electronic dip meter drawdown meter.

Optional or supplemental equipment:

- Lower Explosive Limit (LEL) Detector; and
- Photo Ionisation Detector (PID).

For remote sites consideration should be given to providing a backup set of equipment, if the cost of remobilisation is high, and there is no access to technical repair facilities.

3.1.1 Water Level Meter

A water level meter, also called electric dip meter, is used to measure the depth to standing water. Where non-aqueous phase liquid (NAPL) is expected or suspected to be present in groundwater wells an oil/water interface meter should be used. A beeping sound is made when the electronic dip meter intersects the standing water level.

3.1.2 Drawdown Meter

A drawdown meter works differently to a water level meter: it makes a beeping sound when exposed to air and is silent in water. The probe should be locked in place in the water column above the pump inlet approximately 10 cm below the pre-pumping water level. As the water level drops during pumping the probe will beep when it is exposed to air. The probe can then be lowered until the beeping stops and the process repeated. The water levels will be recorded against time during the pumping on the field sheets.

3.1.3 Oil/Water Interface Meter

The oil/water interface probe should be used where light non-aqueous phase liquid (LNAPL) or dense non-aqueous phase liquid (DNAPL) are expected or suspected to be present in the wells. The probe emits two different sounds for distinguishing the depth to NAPL (continuous tone) and the standing water level (short beeping). Because LNAPL floats on top of water, the continuous tone will occur typically before the beeping tone; with DNAPL, the continuous tone would occur towards the base of the well, after the beeping tone of the water column. As the water level drops during pumping the probe will stop beeping when it is exposed to air. The probe can then be lowered until the beeping starts to gauge water level and the process repeated. The water levels will be recorded against time during the pumping on the field sheets.

3.1.4 Water Quality Meter

A water quality meter will typically comprise instrument probes to measure electrical conductivity (EC), pH, temperature, oxidation reduction potential (ORP) and dissolved oxygen (DO). Common water quality meters include YSI and TPS FLMV. When renting a water quality meter, the rental company should supply a calibration certificate indicating that the equipment has been cleaned, calibrated and is ready for use. Ensure that a flow-through cell is included with the water quality meter.

3.1.5 Low Flow Pump Casing/Wire Hanger

Casing which is lowered down the well to pump groundwater. Holds the bladder that is used to pump water, one bladder is used per well and replaced during decontamination. The pump is connected to both the discharge line and airline. Both these lines must be securely in place with a tight seal for the pump to work properly. The pump contains o-rings that must be checked each time before the pump is used, for if one is missing or worn the pump will not operate properly.

A wire cable/hanger is connected to the pump from the surface, to hold the pump in place as a safe guard to stop it falling down the well. The D-bolt on the hanger should be checked between each well during the decontamination process to prevent it from loosening and dropping the pump down the well.

3.1.6 Low Flow Control Box

Used to control the rate at which water is pumped (Cycle per Minute) and the pressure that the water is pumped out of the well. The control box (shown in Figure 1) may contain a compressor or is connected to the gas cylinder through the hose and regulator, and also the pump through the air line. Low flow controller may be connected via 12v cables to a battery.

Figure 1 **Low Flow Control Box**

3.1.7 Compressor, Gas Cylinder, Regulator & Hose (if required)

CO_2 gas cylinder can be used to pump groundwater. This is connected to a regulator and regulator is connected to the hose.

Note the pressure on the gas bottle. A full gas bottle should read 5,000 kpa (1,900 psi) and will allow you to sample approximately 20 wells (varying with well depth). If the bottle reads 500 kpa or less it should be marked empty and replaced.

Compressors can be either battery powered or powered using a combustion engine, make sure the pressures are appropriately controlled and that a clear knowledge of operation and the HSEP reflects compressor use prior to mobilization.

3.1.8 Photo Ionisation Detector (PID)

Refer to Operating a Photo-Ionisation Detector (PID), for applicability, operation and calibration of a PID.

3.1.9 Lower Explosive Limit (LEL) Detector

Refer to Operating a Lower Explosive Limit (LEL), for applicability, operation and calibration of a LEL.

3.2 Materials

Materials and consumables that may be required to complete this task include:

- Tubing – air and discharge line (enough metres for all wells including spares)
- Appropriate buckets (based on COPC)
- Potable water
- Deionised water
- Scrubbing brush
- Paper towel
- Steel brush
- Permanent Marker Pens (thick and thin)
- Scissors / tube cutters
- Funnel
- Ice / ice blocks
- Alcohol wipes
- Adjustable spanner
- Stericup filters or in-line filters (if required for COPCs)
- Tools for opening well gatic (eg hammer, screwdriver)
- Hex keys
- Spare O-rings and hex bolts
- Phosphate free detergent (eg Decon 90)
- Wastewater container (ie jerry can)
- Laboratory supplied sampling containers
- Laboratory supplied rinsate water
- Low-flow bladders (1 per well with spares)
- Garbage bags
- Field book
- Esky
- Nitrile gloves
- Duct tape
- Hand pump (if Stericup filters are used)

4 Background

The objective of groundwater sampling is to obtain water samples that best represent natural undisturbed hydrogeological conditions. Low flow sampling is one of the techniques used to achieve this. It works by lowering the pump to a specified depth in the bore screen, thus pumping water coming into the bore from the aquifer, to achieve representative samples of the aquifer with minimal disturbance to the standing water in the well.

Before commencing low flow sampling, some important factors should be considered including, the method used historically on the site for sample collection. The groundwater characteristics may take some time to stabilise after installation and development of new wells. Refer to SOP002 and SOPXXX for further information regarding the monitoring well installation and development.

Pumping should be done in a manner that minimises stress (drawdown) to the system to the extent practical.

6 Fieldwork Instruction

(PRINT THIS SECTION FOR USE IN THE FIELD)

Any variations to this Fieldwork Instruction required to meet project specific objectives should be identified by the Project Manager prior to fieldworks and an amended uncontrolled instruction provided to fieldwork staff.

Variations made in the field by fieldwork staff should be documented in the site notes and communicated to the Project Manager.

6.1 Decontamination

The equipment (low flow pump/interface probe) shall be decontaminated prior to use and between sampling each surface sample location by the following procedure.

1. Wipe the probe and measuring tape (the length that comes into contact with groundwater) using disposable alcohol wipes. Dispose of the alcohol wipes into a contaminated waste bag.

2. Empty pump bladder and leftover groundwater in waste water container using a funnel.

3. Wash the low flow pump, suspension wire, probe and associated tape using a scrubbing brush in a bucket with a solution of potable water and detergent (phosphate free and biodegradable, e.g. Decon 90).

4. Rinse the low flow pump, probe, wire and tape with potable water in another bucket.

5. Final rinse of all apparatus using deionised water in a spray bottle/bucket or directly from the deionized water container.

6. The wash solution needs to be renewed when the decontamination process becomes ineffective, e.g. product on the probe after rinsing or sheen in the wash solution buckets.

6.2 Low Flow Groundwater Sampling

- YSI model WQMs should be turned on 30 minutes before sampling to allow sensors to stabilise. Ensure protective covers are removed from probe;

- Check the pressure on the gas cylinder – a full cylinder should read initially on the regulator 5000 kpa; and

- Check for leakage of CO_2 or air in the system, if identified immediately turn off CO_2/compressor and undertake repair/change equipment with apparatus isolated and de-energized.

1. The wells on the site least likely to be contaminated should be targeted first so as to reduce the risk of potential cross contamination between sample locations.

2. (If using CO_2) Connect gas cylinder/compressor to regulator, the regulator to hose and the hose to the control box.

3. Turn on the gas/start compressor, control box and Water Quality Meter (WQM).

4. Ensure pump casing and hanger cable have been decontaminated. Install new disposable bladder in pump, check o-rings are all in place correctly and undamaged. Connect hanger cable to pump casing, ensuring d-bolt is tightly secured.

5. Connect the tubing line to the pump casing, discharge line (larger diameter) and air line (thinner diameter). If using twin tubing (joined tubing), ensure the excess glue has been removed from tubing line using scissors or tube cutters before connecting to pump and controller to prevent damage to inlets and o-rings. Once connected pull on the tubing to test they are secure.

6. Open the monitoring well cover by (a) unlocking the flush mount well gatic with a hex key or (b) lifting the hinge lid on the monument/stick up well cover or (c) removing the lid on any other well cover as required (e.g. quarter turn well covers).

Caution	**Monitoring well covers can cut/injure hands. Use cut resistant gloves to open well covers. Be careful for wells with positive pressure (such as landfill leachate bores that could pop off the loosened well cap. Keep body parts clear of well when opening).** **Biological hazards (eg spiders, ants) may be present within gatic covers, exercise caution when opening wells. Wear gloves and remove cobwebs before placing hands into the well.**

7. Remove the well cap (e.g. J-plug), PVC end cap, torque cap.

Caution	**High concentrations of vapours can build up in the well and be released into the breathing zone when the well cap is removed. Implement appropriate work space monitoring (eg LEL, PID, colorimetric gas detection tubes) and HSE procedures (eg maintain appropriate fire extinguishers in work area) prior to removal of well cap.**

8. Measure the SWL in the well with the interface probe. This depth will be taken as the original SWL on your purging sheet.

9. Wells should be gauged prior to the commencement of any sampling, where possible.

10. Lower pump into well slowly to avoid water column disturbance (pump should not be lowered to the bottom of well as this could cause resuspension of solids which will have collected at the bottom of the well). Lower tubing and wire carefully together to prevent tangling which can lead to the pump becoming lodged in the well. Review each well completion log to select the depth to which the pump inlet will be set. The pump should be positioned dependent on the contaminant of concern or to target high permeability zones. Where this is not known, the pump inlet should be located approximately in the middle of the screened interval so as not to disturb the bottom of the well and allow for sufficient water above the pump. Ensure the hanger cable is tight and that the cable reel has been locked in place. The depth of the pump inlet can be measured by using the interface probe/water meter to measure the depth to the top of the pump. Record depth to pump on purging sheet.

11. Attach the tubing airline to the control box (see Figure 1). Attach discharge line (larger diameter) to the flow cell in the bottom outlet to allow flow cell to fill with water before discharge. Place flow cell into a bucket to ensure overflow from discharge is contained.

12. Remeasure the SWL in the well or use the drawdown meter to monitor any drawdown during pumping.

13. The difference in depth between the SWL recorded before the pump was lowered into the well and after will give a rough estimate of how quick the well will recharge if no historical data is available (the larger the difference in depths the slower the recharge as a general rule).

14. Measure depth to top of pump and record as purging depth on purge sheet. If this is not possible, ie in wells with a diameter greater than 50 mm, an estimate can be made.

15. For CO_2 setup - Set the air pressure on the gas cylinder regulator and control box throttle to required pressure. Using the formula Purging Depth (1 metre = 1 psi) + 10 psi = Air Pressure e.g. 15m depth = (15x1) +10 = 25. The pressure should be slightly greater on the gas cylinder regulator compared to the control throttle. Watch the rate at which water is discharged and adjust pressure as necessary.

16. Review previous sampling sheets to obtain an idea of the appropriate pumping rate. Set the controller to the estimated flow rate or if unknown start on 100 ml/min (CPM 1). One cycle yields approximately 100 ml of water. Groundwater flow should be between 0.1-0.4 L/ min.

17. For O2 setup – set the fill and discharge times. Discharge times are the time it takes to squeeze the bladder and fill time is the time allowed for the bladder to refill. Fill and discharge rates depend on hydrostatic pressure (i.e. water above the pump). The airline pressure gauge should not exceed the equivalent depth to water 1 PSI = 0.7 m of water.

18. Review previous sampling sheets to obtain an idea of the appropriate flow rate. If discharge falls off before the discharge cycle is complete, the discharge time can be lowered. If drawdown is significant, fill time can be increased.

19. Start the pump. Allow purged water to overflow (into a container) the flow-through cell before starting to take water quality parameter readings and standing water level readings, once this occurs take readings every three minutes (where sampling rate is 100ml/minute or more) or five minutes (if flow rate is less than 100 ml/minute).

20. Fill in data on CPM or fill/discharge rate, SWL readings and water quality parameters on the field purging sheet.

1. The drawdown should not exceed 10 cm difference from the original SWL at any time. However, it is more important that the groundwater quality parameters stabilise before sampling. If the drawdown is dropping continuously lower the flow rate to see if the SWL will stabilise. Once the SWL stabilises wait for three successive stable parameter readings before sampling (at 3 to 5 minute interval between each successive reading).

Caution	**If you are still getting drawdown with the very low pump rates, contact PM for advice.**

22. Once field parameters have stabilised samples can be collected (a minimum of 1 L of groundwater should be removed prior to sampling). The water quality parameters are considered stable when for three successive readings the parameters are within the following: ±10% Dissolved Oxygen; ±3% Electrical Conductivity; ±0.05 pH; ±10 mV Redox Potential; and ±0.2°C Temperature. Pay attention to water quality parameters and check that readings are as expected based on site knowledge and chemistry. Issues often occur with WQMs. Parameters can also be easily recorded incorrectly if the wrong units or parameter is referenced. Taking time to set-up WQM display screen with the required parameters and units may help as parameters that are not recorded (e.g. salinity) are not displayed. Contact PM and/or equipment supplier if unsure of readings or experiencing issues with WQM.

23. If water quality parameters have changed significantly since last GME call the PM.

24. Maintain the same pumping rate for sampling. Disconnect the pump's tubing from the flow-through-cell so that the samples are collected from the pump's discharge tubing. Air pressure on the gas cylinder can be turned down so samples can be filled with minimal turbulence (if applicable).

25. Fill samples over a bucket/basin to minimise spillage.

26. Store samples in esky with sufficient ice or ice bricks. Ice should form a bed beneath samples and cover samples. Glass vials and bottles should be stored in bubble wrap and eskies should not be over-filled.

27. Turn the controller off. Remove the pump from the monitoring well. Decontaminate the pump and probe following steps decontamination steps in section **6.1** and dispose of the tubing, bladder and other waste. The flow-through cell doesn't need to be rinsed between wells (unless a sheen, strong hydrocarbon odour or sediment is noticed to keep it in good working condition). Water quality sensors should be rinsed with tap water.

- If SWL varied during purging, measure the SWL after sampling to ensure that levels did not exceed 10 cm difference from the original SWL.

- If this is the last well for the day, or before a break, the gas line should be turned off and de- pressurised before leaving by turning the gas off at the cylinder and running the controller through one or two cycles. All caps should be replaced on the WQM.

28. Replace cap on well, lock gatic. Check area for anything left behind before leaving.

7 Troubleshooting

7.1 Water isn't discharging from the pump:

- Check gas bottle is not empty/compressor is operating.

- Check air pressure gauges on the gas bottle and controller are at appropriate levels (if applicable).

- Re-connect air hose to compressor to ensure there isn't a leak.

- Remove pump from well.

- Check water and air lines connecting pump to ensure there isn't a leak.

- Check o-rings are in place in pump; replace any worn o-rings.

- Check bladder hasn't broken and is in good condition.

- Decon or clean pump and inlet to remove sediment.

7.2 There are air bubbles (observed audibly from the well head) in the water discharge tube:

- O-rings are missing or worn, check and replace if needed.

- Air line connecting to pump is leaking causing water bubble in discharge line, re-connect both air and water tubes connecting to pump.

- Bladder is missing or not sealed.

7.3 The water level keeps fluctuating up and down rapidly:

- O-rings are missing or worn, check and replace if needed.

- Air line connecting to pump is leaking causing water to bubble in well, re-connect both air and water tubes connecting to pump.

- Bladder is missing or not sealed.

8 References

AS/NZ 5667.1:1998 Water Quality – Sampling, Part 1: Guidance on the Design of Sampling Programs, Sampling Techniques and the Preservation and Handling of Samples, Standards Australia, NSW

AS/NZ 5667.11:1998 Water Quality – Sampling, Part 11: Guidance on Sampling of Groundwaters, Standards Australia NSW

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NEPC 1999: National Environment Protection (Assessment of Site Contamination) Measure (NEPM) (as amended 2013), Low flow (minimal drawdown) ground-water sampling procedures (Puls, R.W. and Barcelona, M.J. 1996). EPA Ground Water Issue, EPA/540/S- 95/504, Washington, National Environment Protection Council (December 1999);

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EMM 2019, Groundwater Monitoring Well Installation SOP002

SOP006_Groundwater Sampling_ HydraSleeve

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18 September 2019

Subject: Standard Operating Procedure (SOP006) Sampling Groundwater using a HydraSleeve

1 Introduction

The HydraSleeve is classified as a no-purge (passive) grab sampling device, meaning that it is used to collect groundwater samples directly from the screened interval of a well without having to purge the well prior to sample collection. When it is used as described in this Standard Operating Procedure (SOP), the HydraSleeve causes no drawdown in the well (until the sample is withdrawn from the water column) and only minimal disturbance of the water column, because it has a very thin cross section and it displaces very little water (<100 ml) during deployment in the well. The HydraSleeve collects a sample from within the screen only. It excludes water from any other part of the water column in the well through the use of a self- sealing check valve at the top of the sampler. It is a single-use (disposable) sampler that is not intended for reuse, so there are no decontamination requirements for the sampler itself.

The use of no-purge sampling as a means of collecting representative groundwater samples depends on the natural movement of groundwater (under ambient hydraulic head) from the formation adjacent to the well screen through the screen. Robin and Gillham (1987) demonstrated the existence of a dynamic equilibrium between the water in a formation and the water in a well screen installed in that formation, which results in formation-quality water being available in the well screen for sampling at all times. No-purge sampling devices like the HydraSleeve collect this formation-quality water as the sample, under undisturbed (non- pumping) natural flow conditions. Samples collected in this manner generally provide more conservative (i.e., higher concentration) values than samples collected using well-volume purging, and values equivalent to samples collected using low-flow purging and sampling (Parsons, 2005).

2 Applications of the HydraSleeve

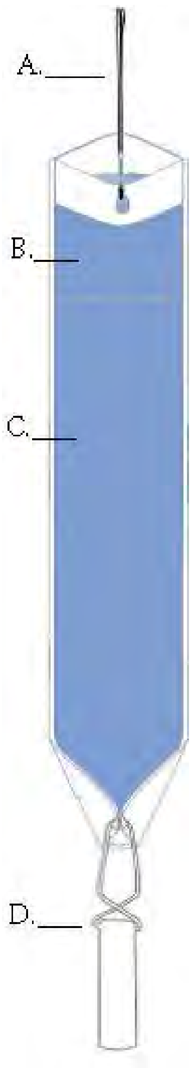
The HydraSleeve can be used to collect representative samples of groundwater for all analytes (volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), common metals, trace metals, major cations and anions, dissolved gases, total dissolved solids, radionuclides, pesticides, PCBs, explosive compounds, and all other analytical parameters).

Designs are available to collect samples from wells from 1” inside diameter and larger. The HydraSleeve can collect samples from wells of any yield, but it is especially well-suited to collecting samples from low-yield wells, where other sampling methods can’t be used reliably because their use results in dewatering of the well screen and alteration of sample chemistry (McAlary and Barker, 1987).

The HydraSleeve can collect samples from wells of any depth, and it can be used for single- event sampling or long-term groundwater monitoring programs. Because of its thin cross section and flexible construction, it can be used in narrow, constricted or damaged wells where rigid sampling devices may not fit. Using multiple

HydraSleeves deployed in series along a single suspension line or tether, it is also possible to conduct in-well vertical profiling in wells in which contaminant concentrations are thought to be stratified.

As with all groundwater sampling devices, HydraSleeves should not be used to collect groundwater samples from wells in which separate (non-aqueous) phase hydrocarbons (ie gasoline, diesel fuel or jet fuel) are present because of the possibility of incorporating some of the separate-phase hydrocarbon into the sample.



3 Description of the HydraSleeve

The basic HydraSleeve (Figure 1) consists of the following components*:

- A suspension line or tether (A), attached to the spring clip or directly to the top of the sleeve to deploy the device into and recover the device from the well. Tethers with depth indicators marked in 1-foot intervals are available from the manufacturer.

- A long, flexible, 4-mil thick lay-flat polyethylene sample sleeve (C) sealed at the bottom (this is the sample chamber), which comes in different sizes, as discussed below with a self-sealing reed-type flexible polyethylene check valve built into the top of the sleeve (B) to prevent water from entering or exiting the sampler except during sample acquisition.

- A reusable stainless-steel weight with clip (D), which is attached to the bottom of the sleeve to carry it down the well to its intended depth in the water column. Bottom weights available from the manufacturer are 0.75” OD and are available in a variety of sizes. An optional top weight may be attached to the top of the HydraSleeve to carry it to depth and to compress it at the bottom of the well (not shown in Figure 1).

- A discharge tube that is used to puncture the HydraSleeve after it is recovered from the well so the sample can be decanted into sample bottles (not shown).

- Just above the self-sealing check valve at the top of the sleeve are two holes which provide attachment points for the spring clip and/or suspension line or tether. At the bottom of the sample sleeve are two holes which provide attachment points for the weight clip and weight.

* Other configurations such as top weighted assemblies, Super/SkinnySleeves, Speedbags, and W3Hybrids are available.

Note: The sample sleeve and the discharge tube are designed for one-time use and are disposable. The spring clip, weight and weight clip may be reused after thorough cleaning. Suspension cord is generally disposed after one use although, if it is dedicated to the well, it may be reused at the discretion of the sampling personnel.

4 Selecting the HydraSleeve size to meet the site-specific sampling objectives

It is important to understand that each HydraSleeve is able to collect a finite volume of sample because, after the HydraSleeve is deployed, you only get one chance to collect an undisturbed sample. Thus, the volume of sample required to meet your site-specific sampling and analytical requirements will dictate the size of HydraSleeve you need to meet these requirements.

Table 1 Dimensions and volumes of HydraSleeve models

Diameter	Volume	Length	Lay-Flat Width	Filled Diameter
2-inch HydraSleeves				
Standard 600 ml HydraSleeve	~600 ml	30”	2.5”	1.4”
Standard 1 L Hydrasleeve	~ 1 L	38”	3”	1.9”
Super/SkinnySleeve 1 L	~1 L	38”	2.5”	1.5”*
Super/SkinnySleeve 1.5 L	~1.5 L	52”	2.5”	1.5”*
Super/SkinnySleeve 2 L	~2 L	66”	2.5”	1.5”*
4-Inch HydraSleeve				
Standard 2.5 L	~2 L	38”	4”	2.7”

* outside diameter on the Heavy Duty Universal Super/SkinnySleeve is 1.5” however when using with schedule 40 hardware the OD of the assembly will be 1.9”

It's also recommended that you size the diameter of the HydraSleeve according to the diameter of the well (ie use 2-inch HydraSleeves in 2-inch wells). Using smaller sleeves in larger diameter wells (ie 2-inch HydraSleeves in 4-inch wells) will result in a longer fill rate and will require special retrieval instructions (explained later).

The volume of sample collected by the HydraSleeve varies with the diameter and length of the HydraSleeve. Dimensions and volumes of available HydraSleeve models are detailed in Table 1.

HydraSleeves can be custom-fabricated by GeoInsight in varying diameters and lengths to meet specific volume requirements. HydraSleeves can also be deployed in series (i.e., multiple HydraSleeves attached to one tether) to collect additional sample to meet specific volume requirements, as described below.

If you have questions regarding the availability of sufficient volume of sample to satisfy laboratory requirements for analysis, it is recommended that you contact the laboratory to discuss the minimum volumes needed for each suite of analytes. Laboratories often require only 10% to 25% of the volume they specify to complete analysis for specific suites of analytes, so they can often work with much smaller sample volumes that can easily be supplied using a HydraSleeve.

5 HydraSleeve deployment

5.1 Information Required Before Deploying a HydraSleeve

Before installing a HydraSleeve in any well, you will need to know the following:

- the inside diameter of the well;
- the length of the well screen;
- the water level in the well;
- the position of the well screen in the well; and
- the total depth of the well.

The inside diameter of the well is used to determine the appropriate HydraSleeve diameter for use in the well. The other information is used to determine the proper placement of the HydraSleeve in the well to collect a representative sample from the screen (see HydraSleeve Placement, below), and to determine the appropriate length of tether to attach to the HydraSleeve to deploy it at the appropriate position in the well.

Most of this information (with the exception of the water level) should be available from the well log; if not, it will have to be collected by some other means. The inside diameter of the well can be measured at the top of the well casing, and the total depth of the well can be measured by sounding the bottom of the well with a weighted tape. The position and length of the well screen may have to be determined using a down-hole camera if a well log is not available. The water level in the well can be measured using any commonly available water-level gauge.

5.2 HydraSleeve Placement

The HydraSleeve is designed to collect a sample directly from the well screen. It fills by pulling it up through the screen a distance equivalent to the length of the sampler when correctly sized to the well diameter. This upward motion causes the top check valve to open, which allows the device to fill. To optimise sample recovery, it is recommended that the HydraSleeve be placed in the well so that the bottom weight rests on the bottom of the well and the top of the HydraSleeve is as close to the bottom of the well screen as possible. This should allow the sampler to fill before the top of the device reaches the top of the screen as it is pulled up through the water column and ensure that only water from the screen is collected as the sample. In short-screen wells, or wells with a short water column, it may be necessary to use a top-weight on the HydraSleeve to compress it in the bottom of the well so that, when it is recovered, it has room to fill before it reaches the top of the screen.

Example

2" ID PVC well, 50' total depth, 10' screen at the bottom of the well, with water level above the screen (the entire screen contains water).

Correct Placement (figure 2): Using a standard HydraSleeve for a 2" well (2.5" flat width/1.5" filled OD x 30" long, 600 ml volume), deploy the sampler so the weight (a 5 oz., 2.5" long weight with a 2" long clip) rests at the bottom of the well. The top of the sleeve is thus set at ~34" above the bottom of the well. When the sampler is recovered, it will be pulled upward approximately 30" before it is filled; therefore, it is full (and the top check valve closes) at approximately 64" (5.3 feet) above the bottom of the well, which is well before the sampler reaches the top of the screen. In this example, only water from the screen is collected as a sample.

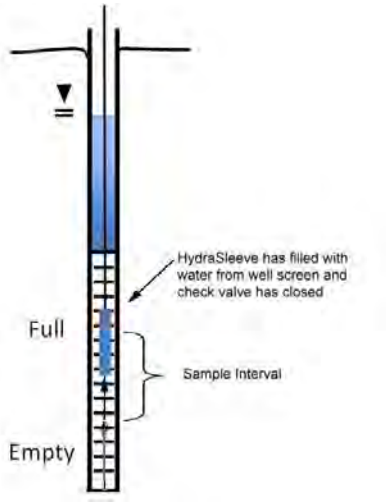


Figure 2 Correct placement of HydraSleeve

Incorrect Placement (figure 3): If the well screen in this example was only 5' long, and the HydraSleeve was placed as above, it would not fill before the top of the device reached the top of the well screen, so the sample would include water from above the screen, which may not have the same chemistry.

The solution? Deploy the HydraSleeve with a top weight, so that it is collapsed to within 6" of the bottom of the well.

When the HydraSleeve is recovered, it will fill within 36" (3 feet) from the bottom of the well, or 2-feet before the sampler reaches the top of the screen, so it collects only water from the screen as the sample.

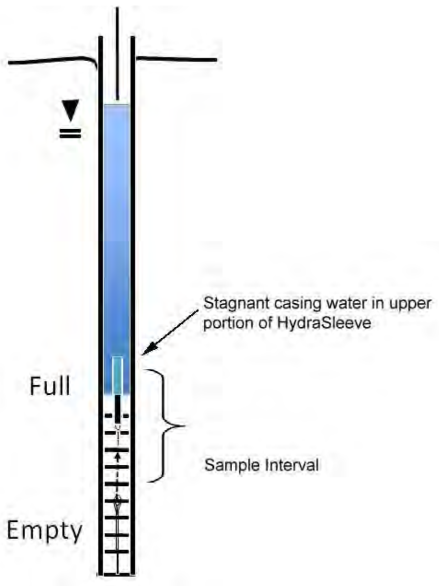


Figure 3 Incorrect placement of HydraSleeve

This example illustrates one of many types of HydraSleeve placements. More complex placements are discussed in a later section.

Note: Using smaller diameter HydraSleeves (2-inch) in larger diameter wells (4-inch) causes a slower fill rate. Special retrieval methods are necessary if this is your set up (shown later in this document).

6 Procedures for sampling with the HydraSleeve

Collecting a groundwater sample with a HydraSleeve is usually a simple one-person operation.

Note: Before deploying the HydraSleeve in the well, collect the depth-to-water measurement that you will use to determine the preferred position of the HydraSleeve in the well. This measurement may also be used with measurements from other wells to create a groundwater contour map. If necessary, also measure the depth to the bottom of the well to verify actual well depth to confirm your decision on placement of the HydraSleeve in the water column.

Measure the correct amount of tether needed to suspend the HydraSleeve in the well so that the weight will rest on the bottom of the well (or at your preferred position in the well).

Make sure to account for the need to leave a few feet of tether at the top of the well to allow recovery of the sleeve.

Note: Always wear sterile gloves when handling and discharging the HydraSleeve.

6.1 Assembling the Basic HydraSleeve*

1. Remove the HydraSleeve from its packaging, unfold it, and hold it by its top.

2. Crimp the top of the HydraSleeve by folding the hard polyethylene reinforcing strips at the holes.

3. Attach the spring clip to the holes to ensure that the top will remain open until the sampler is retrieved.

4. Attach the tether to the spring clip by tying a knot in the tether.

Note: Alternatively, if spring clips are not being utilized, attach the tether to one (NOT both) of the holes at the top of the Hydrasleeve by tying a knot in the tether.

1. Fold the flaps with the two holes at the bottom of the HydraSleeve together to align the holes and slide the weight clip through the holes.

2. Attach a weight to the bottom of the weight clip to ensure that the HydraSleeve will descend to the bottom of the well.

*See Super/SkinnySleeve assembly manual and HydraSleeve Field Manual for other assembly instructions.

6.2 Deploying the HydraSleeve

1. Using the tether, carefully lower the HydraSleeve to the bottom of the well, or to your preferred depth in the water column

2. During installation, hydrostatic pressure in the water column will keep the self-sealing check valve at the top of the HydraSleeve closed, and ensure that it retains its flat, empty profile for an indefinite period prior to recovery.

Note: Make sure that it is not pulled upward at any time during its descent. If the HydraSleeve is pulled upward at a rate greater than 0.5'/second at any time prior to recovery, the top check valve will open and water will enter the HydraSleeve prematurely.

1. Secure the tether at the top of the well by placing the well cap on the top of the well casing and over the tether.

Note: Alternatively, you can tie the tether to a hook on the bottom of the well cap (you will need to leave a few inches of slack in the line to avoid pulling the sampler up as the cap is removed at the next sampling event).

6.3 Equilibrating the well

The equilibration time is the time it takes for conditions in the water column (primarily flow dynamics and contaminant distribution) to restabilise after vertical mixing occurs (caused by installation of a sampling device in the well).

- Situation: The HydraSleeve is deployed for the first time or for only one time in a well.

  The basic HydraSleeve is very thin in cross section and displaces very little water (<100 ml) during deployment so, unlike most other sampling devices, it does not disturb the water column to the point at which long equilibration times are necessary to ensure recovery of a representative sample.

  In some cases, like when using the Speed Bags, the HydraSleeve can be recovered immediately (with no equilibration time) or within a few hours. In regulatory jurisdictions that impose specific requirements for equilibration times prior to recovery of no-purge sampling devices, these requirements should be followed.

  NOTE: If using top weights additional equilibration time is needed to allow the top weight time to compress the HydraSleeve into the bottom of the well.

- Situation: The HydraSleeve is being deployed for recovery during a future sampling event.

  In periodic (i.e., quarterly, semi-annual, or annual) sampling programs, the sampler for the current sampling event can be recovered and a new sampler (for the next sampling event) deployed immediately thereafter, so the new sampler remains in the well until the next sampling event.

  Thus, a long equilibration time is ensured and, at the next sampling event, the sampler can be recovered immediately. This means that separate mobilizations, to deploy and then to recover the sampler, are not required. HydraSleeves can be left in a well for an indefinite period of time without concern.

6.4 HydraSleeve recovery and sample collection

1. Hold on to the tether while removing the well cap.

2. Secure the tether at the top of the well while maintaining tension on the tether (but without pulling the tether upwards)

3. Measure the water level in the well.

4. Use one of the following 3 retrieval methods. In all 3 scenarios, when the HydraSleeve is full, the top check valve will close. You should begin to feel the weight of the HydraSleeve on the tether and it will begin to displace water. The closed check valve prevents loss of sample and entry of water from zones above the well screen as the HydraSleeve is recovered.

- In one smooth motion, pull the tether up 30”-60" (the length of the sampler) at a rate of about 1foot per second (or faster). The motion will open the top check valve and allow the HydraSleeve to fill (it should fill in about 1:1 ratio or the length of the HydraSleeve if the sleeve is sized to fit the well). This is analogous to coring the water column in the well from the bottom up.
- There are times it is recommended that the HydraSleeve be oscillated in the screen zone to ensure it is full before leaving the screen area. Pull up 1-3 feet, let the sleeve assembly drop back down and repeat 3-5 times before pulling the sleeve to the surface. The collection zone will be the oscillation zone. ***When in doubt use this retrieval method.***
- SpeedBags require check valve activation and oscillation during recovery: When retrieving the SpeedBag, pull up hard 1-2 feet to open the check valve; let the assembly drop back down to the starting point; REPEAT THIS PROCESS 4 TIMES; and then quickly recover the SpeedBag through the well screen to the surface.

5. Continue pulling the tether upward until the HydraSleeve is at the top of the well.
6. Discard the small volume of water trapped in the Hydrasleeve above the check valve by pinching it off at the top under the stiffeners (above the check valve).

6.5 Sample discharge

Note: Sample collection should be done immediately after the HydraSleeve has been brought to the surface to preserve sample integrity. Be sure you have discarded the water sitting above the check valve – see step #6 above.

1. Remove the discharge tube from its sleeve.
2. Hold the HydraSleeve at the check valve
3. Puncture the HydraSleeve at least 3-4 inches below the reinforcement strips with the pointed end of the discharge tube. NOTE: For some contaminants (VOC's/sinkers) the best location for discharge is the middle to bottom of the sampler. This would be representative of the deeper portion of the well screen.
4. Discharge water from the HydraSleeve into your sample containers. Control the discharge from the HydraSleeve by either raising the bottom of the sleeve, by squeezing it like a tube of toothpaste, or both.
5. Continue filling sample containers until all are full.

6.5.1 Measurement of field indicator parameters

Field indicator parameter measurement is generally done during well purging and sampling to confirm when parameters are stable and sampling can begin. Because no-purge sampling does not require purging, field indicator parameter measurement is not necessary for the purpose of confirming when purging is complete.

If field indicator parameter measurement is required to meet a specific non-purging regulatory requirement, it can be done by taking measurements from water within a HydraSleeve that is not used for collecting a sample to submit for laboratory analysis (ie a second HydraSleeve installed in conjunction with the primary sample collection HydraSleeve [see Multiple Sampler Deployment below]).

6.5.2 Alternate deployment strategies

Deployment in Wells with Limited Water Columns

For wells in which only a limited water column needs to be sampled, the HydraSleeve can be deployed with an optional top weight in addition to a bottom weight. The top weight will collapse the HydraSleeve to a very short (approximately 6” to 24”) length, depending on the length and volume of the sampler. This allows the HydraSleeve to fill in a water column only 3’ to 10’ in height (again) depending on the sampler size. Note the SuperSleeves accomplish the same thing but provide greater sample volume at a lower per sample cost.

Multiple Sampler Deployment

Multiple sampler deployment in a single well screen can accomplish two purposes:

1. It can collect additional sample volume to satisfy site or laboratory-specific sample volume requirements.

2. It can be used to collect samples from multiple intervals in the screen to allow identification of possible contaminant stratification.

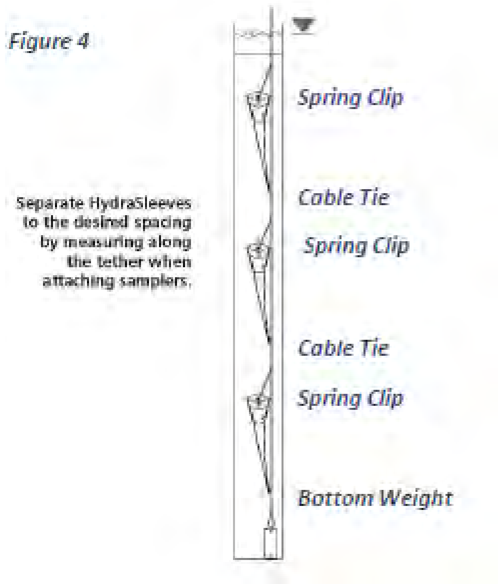


Figure 4 Multiple HydraSleeve deployment

If there is a need for only two samplers, they can be installed as follows. The first sampler can be attached to the tether as described above, a second attached to the bottom of the first using your desired length of tether between the two and the weight attached to the bottom of the second sampler (figure 6). This method can only be used with two samplers; three or more HydraSleeves in tandem need to be attached as described above.

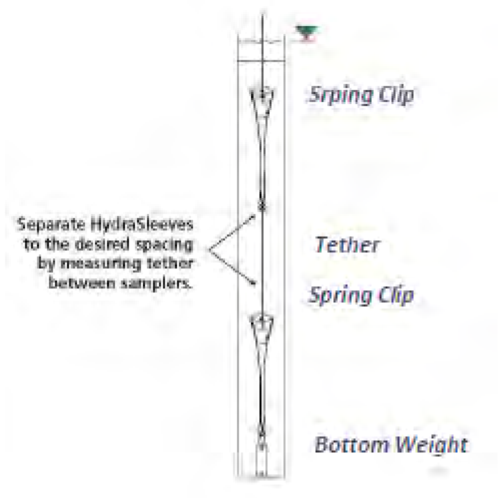


Figure 6 Alternative method for deploying multiple HydraSleeves

In either case, when attaching multiple HydraSleeves in series, more weight will be required to hold the samplers in place in the well than would be required with a single sampler. Recovery of multiple samplers and collection of samples is done in the same manner as for single sampler deployments.

7 Post-sampling activities

The recovered HydraSleeve and the sample discharge tubing should be disposed as per the solid waste management plan for the site. To prepare for the next sampling event, a new HydraSleeve can be deployed in the well (as described previously) and left in the well until the next sampling event, at which time it can be recovered.

The weight and weight clip can be reused on this sampler after they have been thoroughly cleaned as per the site equipment decontamination plan. The tether may be dedicated to the well and reused or discarded at the discretion of sampling personnel.

8 References

McAlary, T. A. and J. F. Barker, 1987, Volatilization Losses of Organics During groundwater Sampling from Low-Permeability Materials, groundwater Monitoring Review, Vol. 7, No. 4, pp. 63-68

Parsons, 2005, Results Report for the Demonstration of No-Purge groundwater Sampling Devices at Former McClellan Air Force Base, California; Contract F44650-99-D-0005, Delivery Order DKO1, U.S. Army Corps of Engineers (Omaha District), U.S. Air Force Center for Environmental Excellence, and U.S. Air Force Real Property Agency

Robin, M. J. L. and R. W. Gillham, 1987, Field Evaluation of Well Purging Procedures, groundwater Monitoring Review, Vol. 7, No. 4, pp. 85-93

SOP007 Bore/well development

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12 September 2019

To: EMM staff
From: Kate Holder
Subject: Bore / well development SOP No.7

Dear team,

1 Introduction

The purpose of bore/ well development is to:

- Rectify drilling damage to the formation by:
  - removing mud filter cake on borehole wall (where mud rotary drilling methods are used); and
  - removing smeared clay/formation material on borehole wall.
- Remove fine grained sediment and drilling fluid from the area immediately surrounding the screen to:
  - increase hydraulic connection to the formation near the borehole to aid water flow towards the bore/ well;
  - eliminate turbidity in future samples; and
  - obtain groundwater samples representative of the formation.

Bores / wells must be developed following installation and prior to groundwater monitoring, aquifer testing or operation. Most development methods reverse flow through the screen to loosen fine-grained materials, draw them out of the area surrounding the screen and rearrange the filter pack and the formation material for greater pumping efficiency. The flow reversals can be induced by surge blocks, bailers, pumps, airlifting with compressed air or by water jetting. Jetting and airlifting are the most effective development methods, especially in larger diameter bores/ wells. To be effective, bore / well development must reach past the screen and the filter /gravel pack to the borehole wall to rectify drilling damage to the formation and to remove any drilling fluids. Development should not be applied to bores/ wells with free product (hydrocarbons), as it may result in the formation of an oil/water emulsion, which can alter the chemistry at the bore/ well for months.

Where possible, bore/ well development should be conducted by the drilling contractor as soon practicable following bore construction. However, this is not always possible.

The following sources were used to prepare the following Standard Operating Procedure:

Sterrett, R. 2007, Groundwater and Wells, 3rd edn, Johnson Screens, United States of America, pp 501-550.

2 Project planning

2.1 Field equipment and supplies

Field equipment for bore development may include the following:

- water level tape /meter or interface probe;
- field water quality meter (YSI 556 Multi Parameter meter or similar);
- calibration solutions (buffer pH 4, 7, 10 solutions; ORP calibration solution; electrical conductivity standard solutions);
- 20 L bucket;
- disposable nitrile gloves;
- tag line;
- clipboard or folder;
- permanent marker and pencils / pens;
- paper towel;
- personal protective equipment.

3 Bore / well development

Bore / well development is performed after the annular seal materials have set/ cured. Development before the annular seal has set may result in the formation of gaps between the filter pack /gravel pack and the annular seal as the filter /gravel pack materials settle and compact. It is useful to collect a sample of the annular seal during installation to be used as a reference for assessing the setting/curing time.

During bore development the following should be recorded:

- initial and final groundwater level measurements;
- airlift yield;
- volume purged; and,
- field water quality parameters, such as temperature, pH and electrical conductivity at regular intervals during the bore / well development process.

The bore screen should be developed in sections, starting at the top of the screen, working down as the sections clear up and the amount of sediment decreases.

The bore is commonly developed until the discharge water is clear or until no further improvement is observed.

Although field parameters are measured during development, they do not indicate development completion; there is no relationship between the stabilisation of field parameters and the objectives of bore development, other than indicating that the drilling water has been removed and formation water is being pumped. However, this is still an important observation.

In addition to recording the initial and final groundwater level, the field hydrogeologist should measure and record the depth to groundwater at the beginning of each shift before recommencing bore development (if the bore development duration extends beyond one shift).

The sections below list some commonly used development techniques in monitoring and production bores.

3.1 Airlift technique (monitoring bores)

Airlifting pumping technique involves the use of an air compressor to alternate lifting the water column to surface for a specified time (typically 10 minutes) and then shutting the compressor off to allow the water column to fall and flow back through the screen (typically 5 minutes). It is advisable to open both valves on the air compressor to relieve back pressure. Airlifting should continue until the pumped water is free of sediment (or as approved by the Project Manager or technical advisor).

Care should be taken to minimise the potential for introducing air or airborne contaminants into the formation. For this reason, the intake of the air compressor must be located upwind of any sources of air contaminants, such as exhaust fumes, and a particulate filter should be utilised. Airlifting should be done through an air–injection pipe (typically 25 mm PVC hose) and a discharge connector, which is secured to the top of the PVC. The air-injector pipe is run down the bore / well to no more than 3 metres above the screen. This prevents oxygenation and introduction of air compressor oils into the formation, which may result in chemical alteration of the sampling zone (Strickland et al, 2009).

Airlift pumping can also be performed with a drilling rig. However, the drilling contractor must conduct the airlifting with care to avoid damaging the bore casing and screens (e.g. damage by lowering to the bottom of the bore and puncturing the bore, or the tool is lowered into the bore at an angle and punctures the casing).

Instantaneous pressure differentials developed during the initial airlift may cause the screen to collapse.

"The casing or screen experiences 1 psi of force for every 2.31 feet of head differential between the inside and outside water level, so a water column differential of 231 feet would exert a pressure of 100 psi at the base of a casing assembly" (Johnson Screens, 2005).

ADVANTAGES

- Well-suited to all types of bore construction.
- The surge action is very effective in rearranging the filter / gravel pack and clearing fines from the bore column due to large amounts of energy available.

DISADVANTAGES

- May alter water chemistry by the introduction of foreign particles from the compressor and oxygen.
- Requires heavy bulky equipment (air compressor or drilling rig).

3.2 Air/ water jetting with jetting tool (production bores)

This method aims to maximise the yield and is typically used in production bores. The drilling contractor should be equipped with a jetting tool, which projects air or water through nozzles. As in Section 3.1, the casing collapse pressure and collapse strength need to be considered when using this methodology, especially if the bore was constructed with PVC.

The procedure for development with a jetting tool is as follows:

1. Review the bore design information.
2. Measure the static groundwater level and total depth of the bore.

3. The jetting tool should be positioned halfway between the static water level and the top of the screen. Airlift to evacuate the water column above the tool. This reduces the differential pressure created between the inside of the screen and the formation, and prevents potential screen collapse. Continue lowering the jetting tool in sections until flow is established with the jetting tool above the top of the screen.

4. Once flow is established, the jetting tool is moved to the top of the screen and lowered at a rate of 0.3 m/min to 0.5 m above the bottom of the screen.

5. The jetting tool is then raised at 1.5 m/min to the starting depth.

6. The jetting tool is then lowered back to 0.5 m above the bottom of the screen.

7. The bore / well is then airlift surged five times at that depth.

8. The jetting tool remains at 0.5 m above the bottom of the bore / well and the entire bore / well is airlifted for at least 30 minutes.
   Sediment testing occur during development. If the amount of sediment in a 20 L bucket is less than the size of a 20 cent piece, the development is complete. Confirmation with the Project Manager or technical advisor should be sought.
   Flow measurements (either using a V-notch weir or conducting a bucket test) and field water quality parameters (temperature, pH, electrical conductivity, dissolved oxygen and oxygen reducing potential) shall be recorded during development and at completion.

9. If development criteria is not met, the process (step 4 to 7) will be repeated. If the amount of sediment in subsequent cycles does not decrease and the water quality parameters are stable, development may be discontinued after consultation with the Project Manager and/ technical advisor.

10. At completion of development, measure and record the final airlift yield and field water quality parameters. Measure the final groundwater level and total depth. A decrease in total depth indicates required additional development time or screen damage.

If possible, pressure transducer data loggers (PTDLs) should be installed in surrounding bore / wells during development. The recorded groundwater elevation data can be used to assess the hydraulic connection and hydraulic parameters.

Once a bore / well is developed by this method, it can be valuable to conduct an airlift recovery test. This involves airlifting at a relatively constant air pressure for a period of time (usually 30 min). Airlift yield (discharge) measurements are recorded at regular intervals while the bore / well is being airlifted. After the airlift period, the air is turned off and the groundwater level recovery is recorded. The simplest way to record the groundwater level recovery is to install a PTDL within the bore / well prior to conducting the airlift recovery test.

3.3 Low yielding bores / monitoring bores

For low-yielding bores, the bore may go dry prior to development completion. If the bore goes dry and does not recover promptly, it is recommended to inject potable water down the bore and commence surging followed by pumping to remove injected water and fines. If a source of potable water is not available, use Waterra tubing with the foot valve deactivated by sealing the foot valve ingress and surge with a surge block followed by pumping to remove fines and formation water.

3.4 Mechanical surging technique

Mechanical surging involves the agitation of the water column in the bore/ well with the up-and-down motion of a plunger-like device, such as a surge block, followed by the removal of sediment brought into the bore by this action through pumping. To effectively surge a bore, apply an up-and-down motion, repeatedly raising and dropping the plunger by about 1 metre. The up-and-down plunging action causes water and fine sediment to flow into and out of the bore / well, agitating and mobilising particles around the screen.

3.4.1 Inertial lift (monitoring bores)

A surge block is a tight-fitting, solid block that is affixed to the end of Waterra tubing and acts as a plunger beneath the groundwater level. The Waterra tubing is equipped with a one-way foot valve, which closes on the "up" cycle, pushing water up to ground surface. Surging should initially be gentle and at a slow rate so that the surge block does not potentially damage the screen through friction. Surging should start at the top of the bore screen to avoid the possibility of “sand-locking” the surge block. The up and down motion can be achieved by hand pumping or by using a Waterra Pump. The use of surge blocks is most effective in 50 mm diameter monitoring bores and is not recommended for larger diameter bores.

Waterra tubing, foot valves and pumps recommended for use at different depth ranges in 50 mm diameter monitoring bores are summarised in Table 1.

Table 1 Recommended tubing, foot valves and pumps

	50 mm diameter Bores with Total Depth < 50 m	50 mm diameter Bores with Total Depth 50 – 90 m
Tubing	5/8” OD x ½” ID High Density Polyethylene Waterra Tubing	1” OD x ½” ID High Density Polyethylene Waterra Tubing
Foot Valve	D-25 Waterra Foot Valve	D-32 Waterra Foot Valve
Pump	Waterra Power Pack (backpac pump)	Waterra Power Pump (large pump)

Note: OD: Outer Diameter; ID: Inner Diameter

ADVANTAGES

- Uses simple, highly portable equipment
- Does not require introduction of foreign fluids
- Effective and relatively inexpensive

DISADVANTAGES

- Not recommended for bores with total depths greater than 90 m
- Not well suited to bores with non-flush casing joints or for bores with an inner diameter greater than 50 mm

3.4.2 Bailer (monitoring bores)

The diameter of a bailer is slightly smaller than the diameter of a 50 mm monitoring bore. The bailer can be used to agitate the water in the bore in a similar manner to a surge block, but less effectively. The bailer is submerged to the top of the screen and pulled up quickly to agitate that portion of the screen. The distance of the pull should be approximately that of the bailer length, usually 1 m. The surging should start at the top of the screen and continue in bailer length intervals towards the bottom. It is recommended to surge the bore using a bailer for 10-20 minutes prior to bailing out the column of water.

ADVANTAGES

- Uses simple, highly portable equipment
- Does not introduce foreign fluids
- Relatively inexpensive

DISADVANTAGES

- Less effective development method compared to using a surge block with Waterra equipment
- Time consuming
- Not recommended for deep bores and bores with deep water columns.
- Not well suited to bores with non-flush casing joints or for bores with inner diameter greater than 50 mm

3.5 Development assisted with chemicals

The use of chemicals in developing a bore / well that will be used to monitor groundwater quality should be avoided if possible; however polyphosphates (a dispersing agent), acids or disinfectants can be used in general bore / well development. Sodium or calcium hypochlorite can be used to break down polymer muds used in drilling. Either of these reagents are usually mixed at a concentration of 1,000 parts per million (ppm) and are injected at a flow rate sufficient to ensure ample mixing of the solution with the drilling mud in the bore. The hypochlorite solution is usually jetted into the bore / well and allowed to react with the drilling fluid for several hours; then the bore / well is developed.

4 Development record

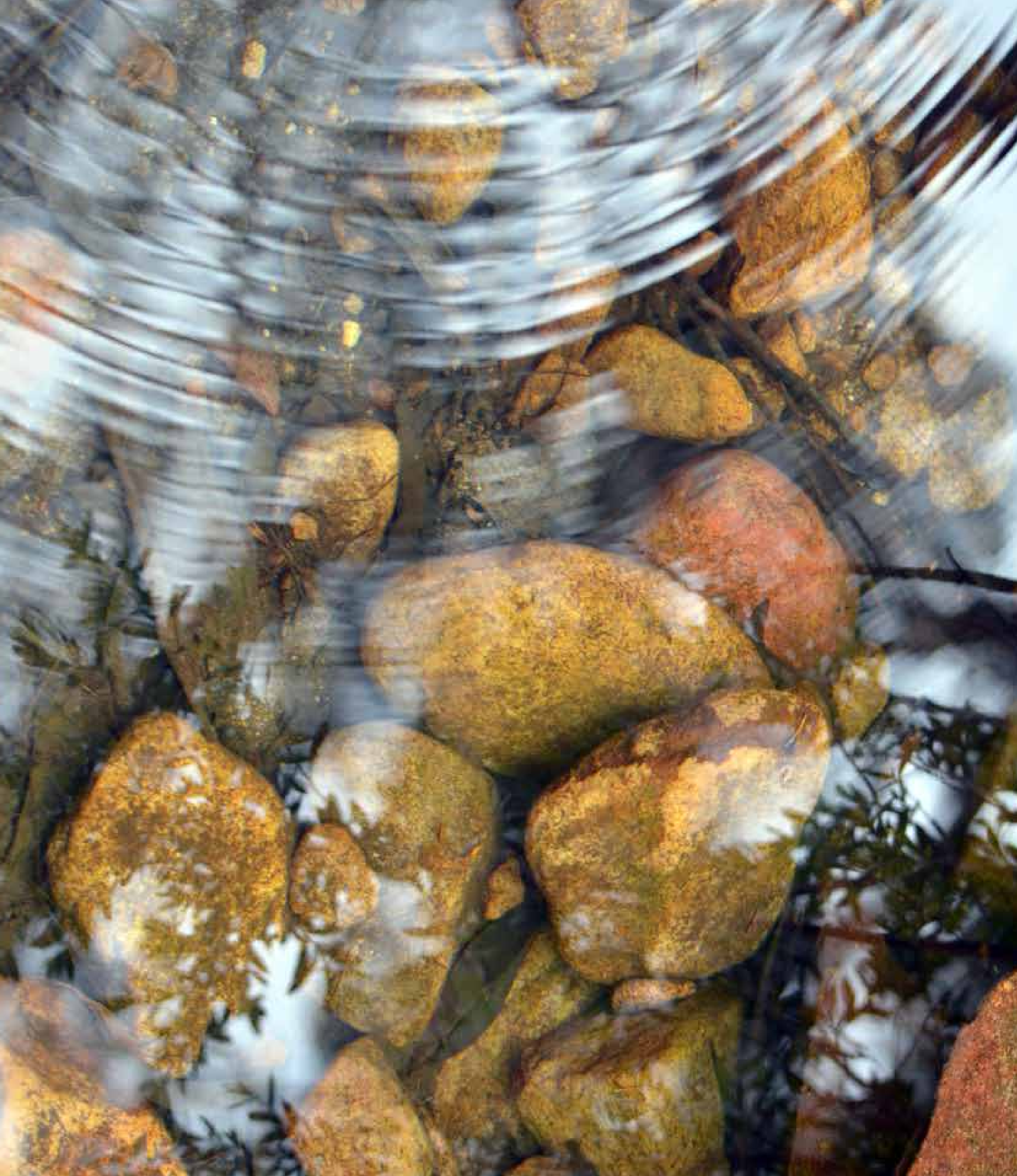
The following should be recorded during bore / well development (see Attachment 1):

- Prior to development:
  - bore ID
  - date
  - total depth
  - screened interval
  - depth to groundwater
- airlift yield
- field water quality parameters
- water clarity should be described in detail and photographed, as that is the main indicator of development completion.
- After to development:
  - final airlift yield
  - field water quality
  - total depth
  - depth to groundwater

The Project Manager / technical advisor may request that a groundwater sample be collected for laboratory analysis following well development.

Project / Borehole						Name				
Date	Depth (m)	Airlift (L/s)	Development volume/time	EC (µS/cm)	TDS (mg/L)	pH	TEMP (°C)	DO (%)	DO (mg/L)	ORP (mV)

Attachment 1: Development Record



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