WIM 100 East

Iluka Resources Limited

Preliminary Baseline Groundwater Assessment

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Contents

Executive Summary

Iluka Resources Limited holds exploration licences for a number of fine-grained mineral sand deposits that have yet to be developed, including the WIM50, WIM100 and Goschen South deposits. Prior to potential future mining operations at these sites, the groundwater conditions at each site are first to be characterised to inform:

- the development of baseline groundwater monitoring programs
- the risk of potential groundwater impacts during potential future mining operations
- the development of strategies to manage those risks

This report develops a conceptual hydrogeological model for the area surrounding the WIM100 East deposit, incorporates historical groundwater monitoring data and presents the results from sampling of groundwater in the area during November 2017. The aim of the report is to develop an understanding of the baseline groundwater conditions in the assessment area, and to highlight data gaps in the monitoring program that should be targeted during future baseline monitoring.

By building on information available in previous reports, the Victorian State Observation Bore Network, the Victorian Aquifer Framework, historical monitoring from at Iluka's nearby Echo mine site and sampling at 9 bores in November 2017, the following key conclusions have been drawn:

1. Groundwater levels indicate a prevailing groundwater flow in the Loxton Parilla Sands (containing the ore body) to the north, with some flow west to the Douglas Depression, and local groundwater recharge via surface water features. Existing groundwater mapping suggests that groundwater flow towards the Glenelg River only occurs in the area south of Lake Kanagulk and Telangatuk East, however this has not been confirmed by groundwater monitoring in this study and may warrant further assessment.

2. Regionally, groundwater salinity ranges between 3,500 and 13,000 mg/L and as such, will typically need to be protected with respect to segment C of the Groundwaters of Victoria SEPP (EPA, 1997).

3. Groundwater is significantly fresher (less saline) than the typical regional salinity in areas surrounding surface water features (such as the Connangorach Swamp), indicating preferential recent recharge to the Loxton Parilla Sands via such features.

4. Fresher waters in the assessment area have more variable, and generally higher, cation:chloride ratios, likely resulting from the variability of ions in rainfall and in water-rock (soil) interaction near the surface.

5. Regional groundwater is more saline and has lower and less variable cation:chloride ratios than the fresh areas. These observations are consistent with groundwater salinization resulting from evaporation.

6. As fresh groundwater flows down hydraulic gradient, it mixes with more saline regional groundwater resulting in a decline in cation:chloride ratios.

7. A positive correlation is observed between the radioactivity of groundwater (Ra^{226}, Ra^{228} and U^{238}) and salinity, irrespective of the depth and geological formation being monitored. This suggests that the concentration of radionuclides in groundwater in the assessment area may be more closely related to the total concentration of dissolved solids in groundwater than the formation or depth being monitored.

8. While this would suggest that radioactivity may evolve with salts in solution and not sourced from later processes (such as leaching or mixing), the correlation is not an exact fit, is based on a limited data set, and would require ongoing monitoring to confirm.

9. The Victorian Aquifer Framework identifies the Murray Group Limestone or equivalent units in the area. However, bore logs in the vicinity of the ore body do not show a distinct limestone unit. Thus the degree

of connection between the units in the vicinity of the ore and the regional limestone resource is not resolved. Given the use of the Murray Group Limestone for irrigation in the western Murray Basin, this requires further evaluation.

The key data gaps in the current monitoring network identified by this assessment include:

- Temporal variations in groundwater chemistry, which are yet to be characterised within the single monitoring event.
- Confirmation of the existence of Murray Group Limestone near the ore body is needed. This should include determination of the degree of connection (if any) between limestone equivalent units and the limestone groundwater resource that is recognised further west of the site.
- A spatial gap identified in the current monitoring bore network should be filled in order to confirm that the flow and salinity trends identified in this report are occurring around the ore body.

Glossary of terms

BOM – Bureau of Meteorology

EC – Electrical conductivity (measure of salinity)

ET – Evapotranspiration

GDE – Groundwater dependant ecosystem

HM – Heavy Minerals

LPS – Loxton-Parilla Sand

TDS – Total dissolved solids (measure of salinity)

VAF – Victorian Aquifer Framework

VVG – Visualising Victoria's groundwater

WIM – Wimmera (a shorthand notation developed during exploration in the 1980's)

1. Introduction

1.1 Background

Iluka Resources Limited (Iluka) have undertaken a series of operations in the Murray Basin that have included the mining, processing, transport, storage and shipment of mineral sand products. This includes the mining of mineral sand deposits at the Douglas and Echo mine sites near Balmoral in south west Victoria, as well as at the Kulwin and WRP mine sites near Ouyen. These sites have completed their mining phase and are now largely in the rehabilitation phase of their operational lifespan.

Iluka also holds exploration licences for a number of fine-grained mineral sand deposits within the southern Murray Basin that have yet to be developed, including the WIM50, WIM100 and Goschen South deposits.

Prior to potential future mining operations, the baseline groundwater conditions at each site requires characterisation. This will allow the identification of any groundwater risks, inform the management of those risks, and, the assessment of any potential future groundwater impacts.

This report provides a preliminary assessment of the baseline groundwater conditions at the WIM100 East site and reviews the existing groundwater monitoring network. The report is intended to inform future groundwater risk/impact assessments and identify any additional groundwater monitoring that may be required to accurately inform such assessments.

1.2 Scope

This report aims to provide a preliminary characterisation of the baseline groundwater conditions around the WIM100 and WIM50 deposit areas in order to inform future groundwater monitoring programs and/or future groundwater risk/impact assessments by:

- Characterising the regional and local geological / hydrogeological units and thicknesses
- Reviewing the physical characteristics of hydrogeological units (i.e. hydraulic conductivity and storativity)
- Evaluating groundwater levels and flow directions
- Assessing groundwater quality and chemistry
- Reviewing the current groundwater monitoring network with respect to the above

The report will subsequently highlight any gaps in the current groundwater monitoring network that may be prioritised in future network augmentations.

2. Site overview

This section briefly considers the topography, major surface water features and climate. The purpose of the section is not to fully itemise or characterise these features, which may be the subject for later, more detailed, assessment, but to provide a level of context for the subsequent groundwater assessment. As such, further commentary around the effect that topography, surface water and climate have with respect to groundwater trends will be discussed later in Sections 5 and 6.

2.1 Location and topography

The WIM100 and WIM50 deposits are located approximately 40 km south east of Horsham. The general area being assessed as part of this study is defined by the black outline in Figure 2-1, however considerations beyond this boundary have been made throughout various sections of the report.

The topography at the site is relatively flat and sloping to the north, from around 170 m AHD in the south of the assessment area to around 140 m AHD in the north of the assessment area.

The Black Range is a topographic high point of >400 mAHD to the south east of the assessment area, and the northern trending Douglas Depression forms a topographic low along the western boundary of the study area.

2.2 Surface water

The major surface water bodies proximal to the assessment area include a series chain of lakes and swamps through the Douglas Depression, most of which are saline (DEDJTR, 2017). These are comprised of White Lake, Brooskbys Swamp, Centre and North Lake, Lake Bow, Clear Lake and Boundary Swamp among others, and run along the western boundary of the assessment area.

To the north of the assessment area, a number of creeks including Noradjuha Creek, Natimuk Channel and Darragan Creek drain to the north, forming series of minor tributaries to the Wimmera River.

The Toolondo Reservoir (also known as Lake Toolondo) is an off-stream reservoir and trout fishery in the south of the assessment area. The reservoir receives inflows from a small catchment to the west of the Black Ranges via Mt Talbot Creek. The reservoir is the terminal discharge point of Mt Talbot Creek and its only discharge is via the Rockland Channel to the south.

The Glenelg River is a perennial River in the Glenelg Hopkins Catchment to the south of the assessment area.

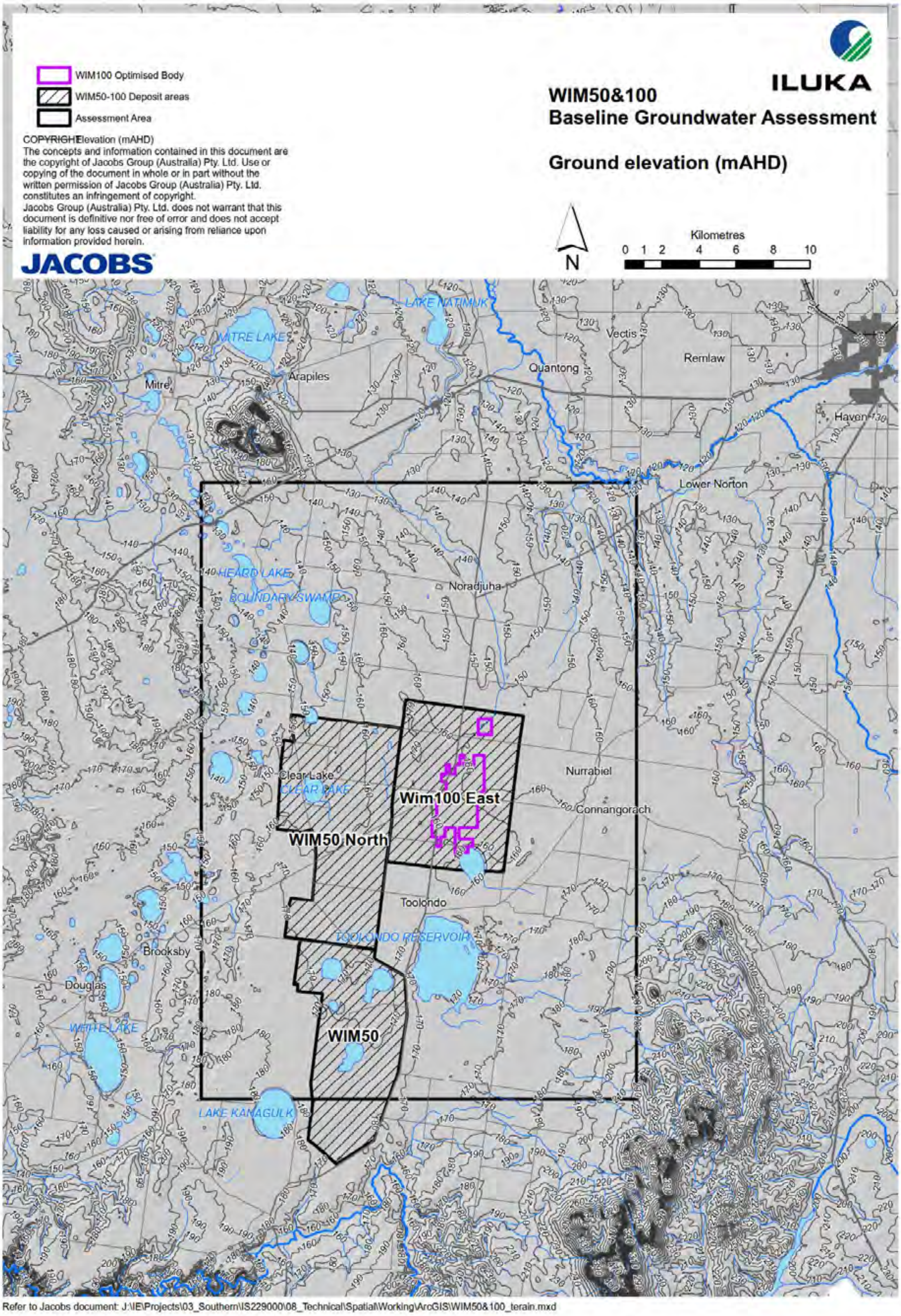

Figure 2-1 Location of assessment area

2.3 Climate

The nearest rainfall gauges to the WIM100 East site are located at Clear Lake (~10 km to the north west of the site) and Telangatuk East (~10 Km to the south east of the site). Monitoring at these gauges indicates an average annual rainfall for the area of 497 mm. Rainfall is lower in summer months, with an average monthly rainfall <30 mm/month between December and March, increasing to >50 mm/month between May and September (Figure 2-2).

The nearest monitoring of evapotranspiration (ET) occurs at Horsham (~40 km to the north east of the site). Monitoring indicates that the average monthly ET ranges from <40 mm/month in June to >200 mm/month between December and February (Figure 2-2). June and July represent the only two months of the year in which average rainfall exceeds ET.

Long-term monitoring of rainfall at Clear Lake and Telangatuk is represented in Figure 2-3. This illustrates the cumulative deviation of rainfall from the long-term mean rainfall, with increasing trends representing periods of above average rainfall and decreasing trends representing periods of below average rainfall. The figure indicates relatively dry conditions between the early and mid-1900s, followed by wetter conditions between the mid 1900's and around the year 2000. Since the year 2000, the area has been subject to a period of reduced rainfall and drying, with brief periods of increased rainfall around 2010 and 2016.

The data illustrated in Figure 2-2 indicates that annual rainfall in the area is relatively stable with respect to ET. Given the observed trends, seasonal rainfall recharge of groundwater appears unlikely to be a dominant process throughout the area. It is instead more likely that regional groundwater levels in the area will respond to long-term shifts in climate, such as those illustrated in Figure 2-3.

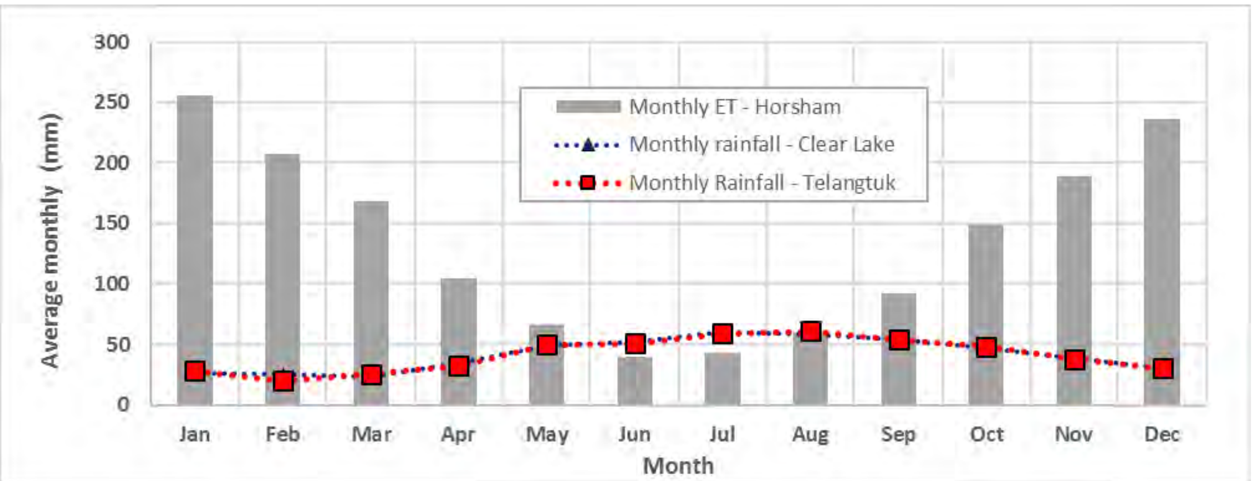

Figure 2-2 Average monthly rainfall and evapotranspiration

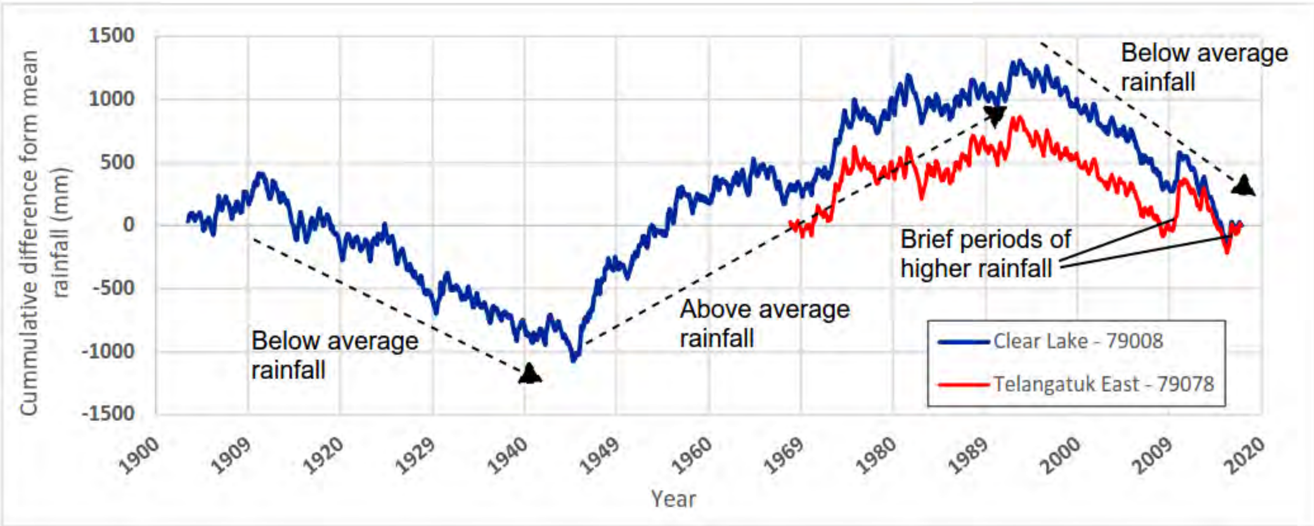

Figure 2-3 Cumulative deviation from the long-term mean rainfall for two rainfall stations within the study area

2.4 Key materials reviewed

A number of works programs and studies have been conducted around the WIM100 East assessment area that pre-date the commencement of this assessment. The information and findings disseminated throughout the reports and studies have been incorporated into the subsequent sections.

The regional geological conceptualisation of the area was assimilated from Evans and Kellett (1989), Birch (2003) and Cartwright and Weaver (2005). Mapping and interpretation of the surface geology of the area was based on VandenBerg (1997) and DELWP (2014).

The formation of mineral sand deposits was informed by Farrell et al. (2001), Whitehouse (2009) and Roy et al. (2000) as well as additional material provided by Iluka.

The development of the hydrogeological conceptualisation of the area has involved the review of numerous works including Smart (1991), McAuley (1992), Smart (2001a, 2001b, 2001c), Judkins (2001), URS (2008, 2009) and CDM Smith (2014). These works have subsequently been built on using resources such as the Victorian Aquifer Framework (GHD, 2012), Victorian water table mapping DELWP (2014) and the Atlas of Groundwater Dependant Ecosystems database (BOM, 2016).

3. Geology

The WIM 100 East assessment area is located towards the south western edge of the Murray (Geological) Basin. The basin is an intra-cratonic basin extending over 300 000 km^2 in New South Wales, Victoria and South Australia (Birch, 2003). The formation of the basin is the result of basement subsidence following the break-up of Gondwana, and the subsequent periods of marine transgression and regression during the Tertiary period. The basin comprises up to ~600 m of marine, coastal and continental sediments that is underlain by Palaeozoic basement rocks, and surrounded by low mountain ranges of the same age.

More locally, the WIM 100 East area is bound to the south and east by the Devonian Rocklands Rhyolite, Silurian marine and fluvial deposits of the Grampians Group, Ordovician intrusive granites and Cambrian sandstone, siltstone and schist grade metamorphics, among others (VandenBerg, 1997).

The Murray Basin includes three sub-basins or provinces, including the Riverine, Scotia, and Mallee-Limestone provinces, which are separated by basement ridges (Cartwright and Weaver, 2005). The Scotia province occupies the most arid part of the basin to the east and south of the barrier range in South Australia and New South Wales (Evans and Kellett, 1989). The Riverine Province is a relatively flat area consisting of alluvial floodplains in the eastern side of the Murray Basin, and is bounded to the west by the Neckarboo Ridge. The Riverine province is dominated by the Renmark Group, Calivil Formation and Shepparton Formation.

The WIM 100 East assessment area falls within the Mallee-Limestone Province, which lies to the west of the Neckarboo Ridge in western Victoria and South Australia. The major geological units in the Mallee-Limestone Province are listed below from oldest to youngest, with their stratigraphic relationship illustrated in Figure 3-1:

- Renmark Group
- Ettrick Formation, Winambool Formation and Geera Clay
- Murray Group Limestone
- Loxton-Parilla Sands
- Shepparton Formation

The Renmark Group forms the basal unit lying unconformably above the basement throughout most of the Murray Basin. The unit was formed in a fluvial-lacustrine setting in the early to mid-Tertiary period and is comprised of gravel, quartz sand, silt and clay (Birch, 2003).

The deposition of the Ettrick Formation, Winambool Formation and Geera Clay represent a period of mid-Tertiary marine transgression in which terrestrial deposition was replaced with marine shelf and lagoonal deposition. The result of the transgression was the formation of marl, carbonaceous silts and clays, and some minor sands and gravels.

The Murray Group Limestone was deposited during the final stages of the Mid-Tertiary marine transgression, resulting in the formation of highly fossiliferous limestones and calcareous sandstones. Subsequent marine regression during the Late-Tertiary period saw the formation of shallow marine clays and marls termed the Bookpurnong Formation, that unconformably overlie the Murray Group Limestone.

The Loxton-Parilla Sands (LPS) were formed during a period of rapid marine transgression in the Late-Tertiary period. The sands represent beach, dune and back barrier-lagoonal depositional settings and cover a significant portion of the Murray Basin. These are locally represented by poorly sorted, micaceous fine to grit sized sands. The LPS host the heavy mineral (HM) deposits that are the target for mining in this area and so is the geological unit of most interest for this baseline assessment.

The Shepparton Formation is comprised of non-marine sands and clays deposited from the Late-Tertiary and Quaternary periods after marine regression. It is poorly consolidated and forms the surface unit through much of the central and eastern portions of the Murray Basin.

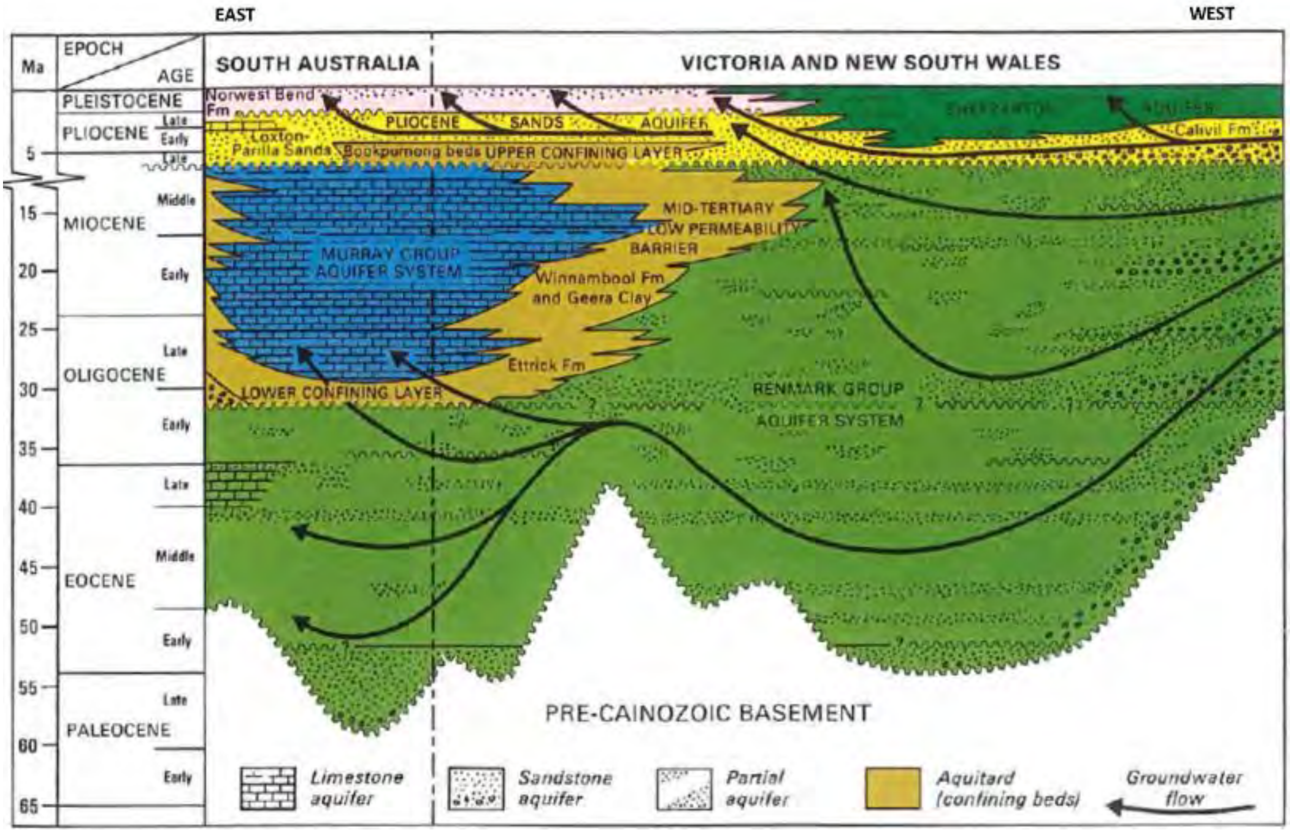

Figure 3-1 Regional stratigraphy of the Murray Basin (after Kellet and Evans, 1989)

4. Mineralisation

This section considers the formation of mineral sands deposits within the Murray Basin and more locally, within the WIM100 East assessment area. The section provides a summary of established models for mineral sand formation based on published works and material provided by Iluka Resources Limited.

The LPS within the Murray Basin host the most significant mineral sands province in Australia (Farrell et al., 2001). Economic heavy mineral mineralisation within the LPS is associated with high clay content and ilmenite, rutile and zircon, as well as cassiterite, chromite, and monazite. Important factors during the formation of mineral sand deposits include the provenance of the sands, their position within the Murray Basin, the energy of their deposition and the localised morphology of the depositional environment (Farrell et al., 2001). The mechanisms responsible for the formation of beach placer deposits are attributed to both marine reworking during transgressive barrier fractionation and littoral bypassing, as illustrated in Figure 4-1.

The WIM100 East site is characterised by “WIM style” deposits. These are generally finer grained in comparison to the above described placer deposits. These form in the low-energy facies of the LPS, including lower-shore and inner-shelf environments. The mechanism for the separation of heavy mineral lenses in this environment are yet to be explained in full, however, the presence of hummocky cross stratification in the WIM150 deposit suggests their development during episodic storm-wave processes, above (but near) storm wave base where depositional rates during storms are high enough to preserve hummocks (Whitehouse, 2009).

Heavy mineral mineralisation at the WIM100 East site is present within the LPS between 130 and 145 mRL, typically around 15 m below the ground surface. These occur within the lowershore facies of the LPS as they overlie clays of the Winnambool/Ettrick/Geera formations. The sands in this area consist of poorly sorted, micaceous fine to grit sized sands with high clay content, overlying stacked units of very fine to fine lowershore sand, in places separated by a thin coarser lens (the surf zone). Iron oxide induration is intense at the contact between the Shepparton and the LPS, and variable within the LPS. Almost all mineralisation is located below the water table (see Section 5).

As discussed above, and illustrated in Figure 4-1 below, the geological process responsible for the formation and concentration of mineral sands within the LPS is variable. This highlights not only the processes responsible for the observed spatial distribution of mineral sands throughout the LPS, but also the potential for grain size and mineralogical variability within the LPS. Such variations in grain size and mineralogy have the capacity to influence groundwater flow patterns and chemistry, and can lead to significant variations in groundwater observations, even when bores are close to each other and screened within the same geological unit.

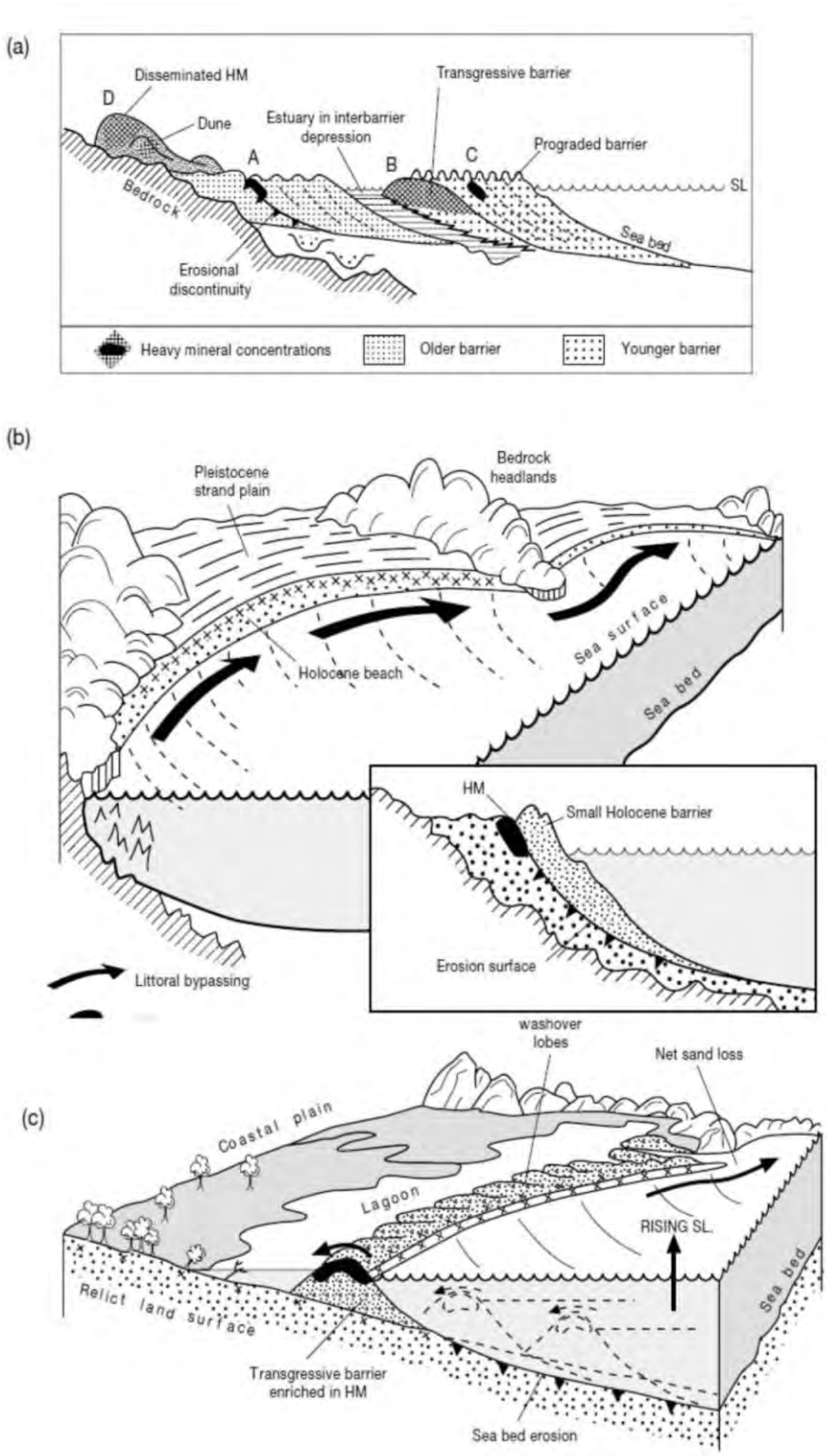

Figure 4-1 Heavy mineral deposits (a) and concentration via littoral bypassing (b) and transgressive barrier fractionation (Roy et al., 2000)

5. Hydrogeological conceptualisation

5.1 Introduction

This section of the report presents a hydrogeological conceptualisation based on literature review and an assessment of pre-existing data and records around the study area. Later sections in the report (Sections 6 and 7) present recent and new groundwater data that has been collected specifically for this study. This section sets the scene for the more recent data collation.

5.2 Hydrostratigraphy

An initial determination of the hydrostratigraphic units present in the assessment area was based on the 3D aquifer surfaces available in the Victorian Aquifer Framework (VAF) (SKM, 2011; GHD, 2012). The 3D surfaces generated in the VAF define aquifers and aquitards on the basis of their constituent geological components. The VAF is structured such that multiple geological units (e.g. the Warina Sand and Olney Formations) may be amalgamated into hydrogeological units (e.g. the Lower Renmark Group) and finally into an aquifer or aquitard (e.g. the Lower Tertiary Aquifer). The hydrogeological units and constituent formations within the assessment area are detailed in Table 5-1 below.

Table 5-1 Aquifers and constituent hydrogeological units defined within the Victorian Aquifer Framework (units in bold highlight locally dominant units)

Aquifer	Hydrogeological Units
Quaternary Aquifer (QA)	Various/undefined
Upper Tertiary / Quaternary Aquifer (UTQA)	**Shepparton Formation**
Upper Tertiary Aquifer (UTA)	**Loxton Parilla Sand**
	Moorna Formation
	Chowilla Formation
Upper Mid-Tertiary Aquifer (UMTA)	**Murray Group Limestone**
	Nelson Formation
	Glenelg Group
	Duddo Limestone
	Morgan Limestone
	Winnambool formation
Upper Mid-Tertiary Aquitard (UMTD)	**Winnambool formation**
	Geera Clay
	Undifferentiated
Lower Tertiary Aquifer (LTA)	**Renmark Group**
	Warina Sand
	Onley Formation
	White Hills Gravels
Mesozoic and Palaeozoic basement (BSE)	All Palaeozoic basement rocks

An initial review of the VAF has been undertaken in a west to east direction through the centre of the assessment area in as illustrated by the line A-B in Figure 5-1. While the Renmark Group directly overlies the basement within the assessment area, this only occurs to the north of the WIM50-100 deposit area and as such, is not captured in the cross section in Figure 5-1.

The cross section indicates that the basement is overlain by around 20 to 30 m of Upper Mid-Tertiary Aquitard (UMTD - locally the Geera Clay and Winnambool Formation). In the west, this is overlain by 5 to 20 m of Upper Mid-Tertiary Aquifer (UMTA – locally defined by the Murray Group Limestone).

In the east, and above the UMTA in the west, lies the Upper Tertiary Aquifer - UTA (locally defined as the Loxton Parilla Sand). This is typically 30 to 40 m thick and overlain by around 5 m of Upper Tertiary Quaternary Aquifer (UTQA – locally defined by the Shepparton Formation). There are also thin (typically <5m) Quaternary alluvial deposits which occur locally near surface water features.

The Shepparton Formation forms extensive alluvial plains and is the main unconfined aquifer throughout the east of the Murray Basin. However, it is only considered to host the water table in the central and northern region of the Douglas Depression in the Wimmera Region (URS, 2009). As such, the LPS are considered the main unconfined water table aquifer in the assessment area.

Interpretation of drill logs for Iluka's Echo mine project (URS, 2008) towards the east of the assessment area indicates that LPS directly overlie clays (likely to be the Geera Clay), and is consistent with the VAF. This is also consistent with Smart's (2001c) interpretation of drill logs which indicate LPS directly overlying the Geera Clay (Figure 5-3). While Smart's interpretation suggests that this is also the case in the west of the assessment area, the VAF indicates the presence of Murray Group Limestone or equivalent units instead. It may be that there are clays that are depositionally equivalent to the Murray Group Limestone beneath the LPS in the west (perhaps calcareous clays of the Winnambool Formation). It is a recommendation of this assessment that the nature of these clays be resolved.

The availability of deeper drill logs on the VVG in this area is limited. For example, Figure 5-1 illustrates the location of lithological logs in the assessment area and their respective depths. It shows that where the UMTA is expected to occur (and potentially the Murray Group Limestone), only one lithological log >35 m depth is available. This log is from bore 143114, and indicates the presence of sands that transition into grey and black clays with shell fragments between around 20 to 40 m depth. This is where the VAF indicates that presence of UMTA, and suggests that locally the UMTA may be represented by calcareous clays of the Winnambool Formation.

It is unlikely that that a single lithological log to a depth >35 m is sufficient to characterise the extent and nature of the UMTA underlying the WIM50-100 deposit and its surrounds. Given the use of the Murray Group Limestone for irrigation in the western Murray Basin, the nature of the UMTA should be further investigated via the drilling of additional bore holes if no existing data can be found to resolve the matter.

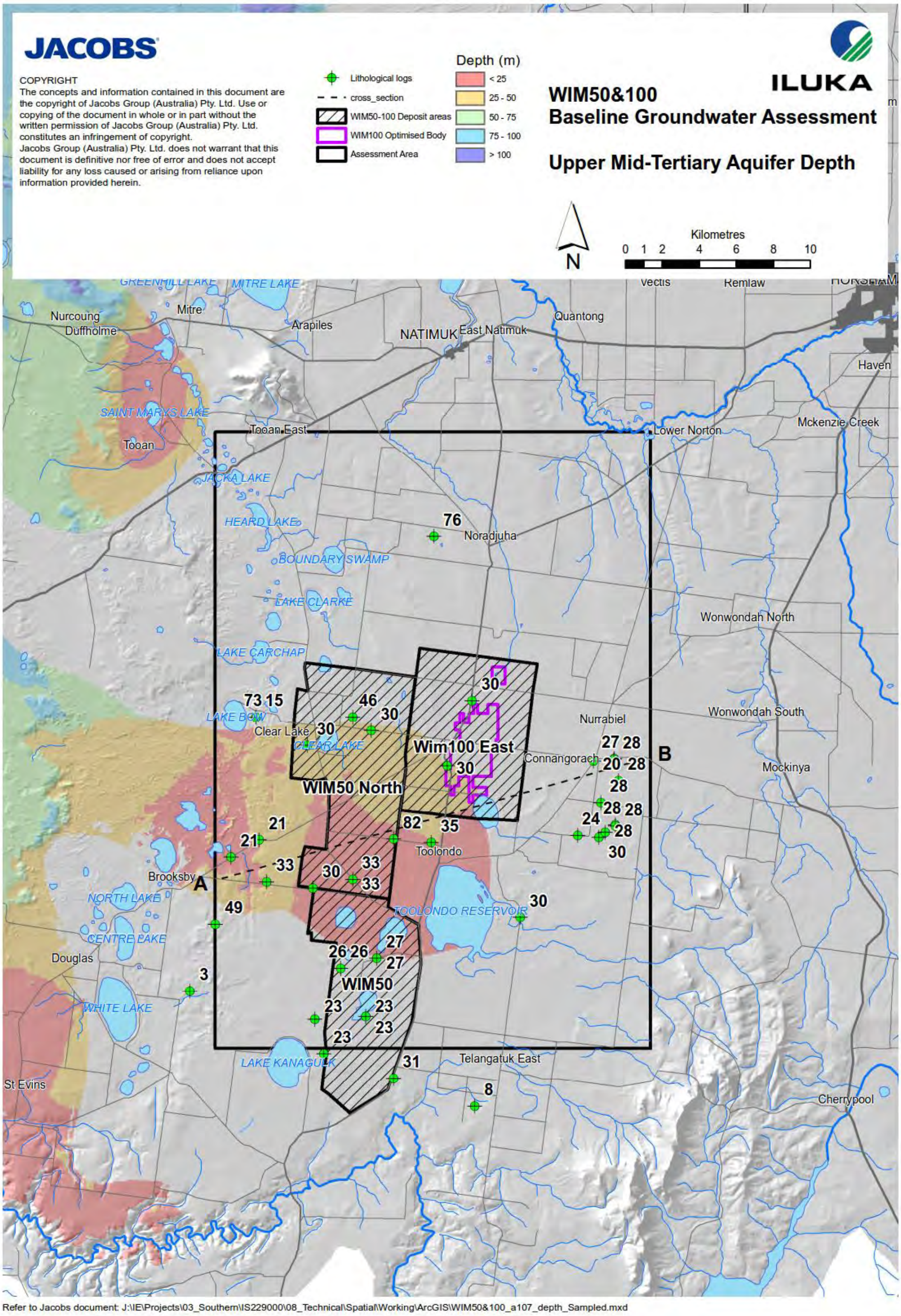

Figure 5-1 Cross section A to B, available lithological logs and extent/depth to Murray Group Limestone as defined by the VAF

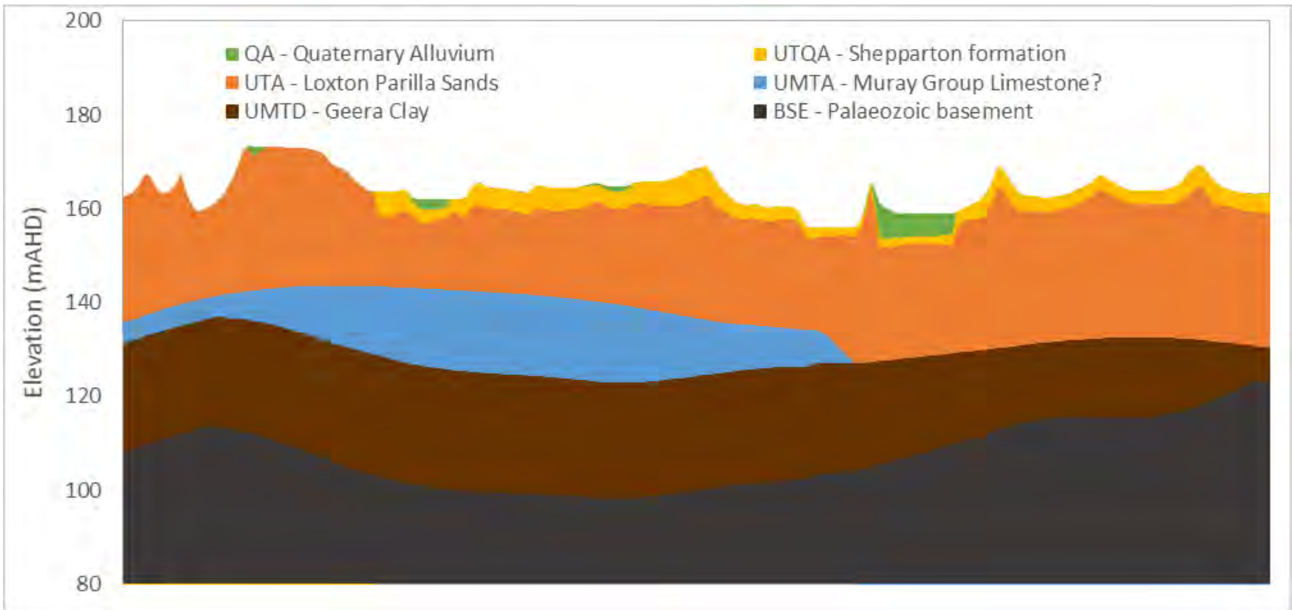

Figure 5-2 Hydrostratigraphic layers from Victoria Aquifer Framework for cross section A – B in Figure 5-1

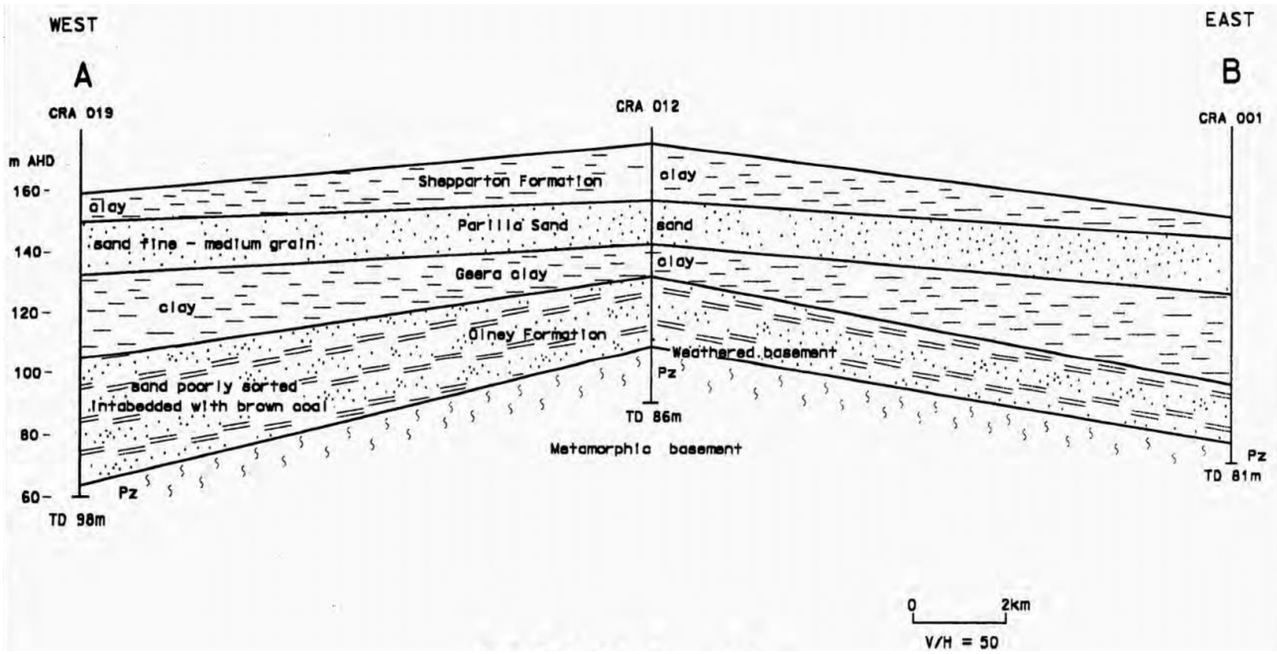

Figure 5-3 Hydrostratigraphic layers from Smart (2001c)

5.3 Aquifer characteristics

As indicated in Section 5.2, the LPS is considered the major aquifer unit in the assessment area. Previous modelling in the south west of the assessment area has classed all other units as aquitards, and assigned a horizontal hydraulic conductivity of 0.01 m/day, a specific storage of 1 x 10^{-5}, and a porosity of 0.05 for the Palaeozoic Bedrock, Upper Tertiary Aquitard and Upper Tertiary/Quaternary Aquifer (CDM Smith, 2014).

The hydraulic conductivity adopted for the LPS in the same study ranged from 0.05 to 17 m/day with a specific storage of 1 x 10^{-5} and a porosity of 0.03 to 0.2, with higher conductivities and porosities assigned closer to the

Glenelg River and Rockland Toolondo Channel (CDM Smith, 2014). The vertical hydraulic conductivities used were 10% of the horizontal hydraulic conductivities in this study.

This is consistent with hydraulic conductivities measured in the LPS in the southern Murray Basin by Rockwater, (1987) which ranged from 0.03 to 5.3 m/day, with an overall hydraulic conductivity of around 1 to 2 m/day (Smart, 1991). These values are also similar to the value of 0.37 m/day given by infiltration test work in the Parilla Sand as reported by Judkins (2001) and values of between 1 and 2 m/day for similar materials obtained by Wimmera Industrial Minerals at their WIM150 deposit.

5.4 Groundwater levels and flow

The water table between the Toolondo Reservoir and Douglas Depression occurs within the fine grained facies of the LPS (Smart, 2001a). Records from Smart (2001a) indicate that groundwater levels were >20 meters below ground surface closer to the Merrits Swamp, declining to around 7 meters below ground surface closer to the Douglas Depression. The hydraulic gradient was towards the depression, indicating groundwater flow in this direction.

Groundwater monitoring in the east of the assessment area by URS (2008) found groundwater levels to be around 10 to 12 meters below ground surface underneath the Connangorach Swamp, declining to >20 meters below ground surface approximately 5 km north of the swamp, at Jallumba-Mockinya Road. The results indicate groundwater recharge and mounding of the water table under the swamp, with groundwater flow occurring in a northerly direction from the swamp.

The Victorian water table mapping of the area indicates a northward trending regional groundwater flow direction from the outcropping Palaeozoic Basement in the south, towards the Wimmera River in the north, with some westward flow component towards the Douglas Depression (Figure 5-4). The mapping indicates groundwater levels of >170 m AHD in the south of the assessment area declining to <130 m AHD in the north of the assessment area. The groundwater levels measured by URS (2008) and inferred by water table mapping indicate that the HM zone in the LPS is saturated. The groundwater contours illustrated in Figure 5-4 are based on the Victorian water table mapping (DELWP, 2014) with minor alterations for monitoring data collected as part of this project (see Section 6).

Regular groundwater level monitoring over relatively long timescales has occurred in few places around the assessment area. Bores for which this data are available (VVG, 2018) have been illustrated in Figure 5-4, and monitoring data has been presented for a selection of these in Figure 5-5 and Figure 5-6.

In the west of the assessment area between Lake Bow and Clear Lake, groundwater levels have been measured in nested bores 112202 and 112203. The VAF indicates that these bores represent groundwater levels in the Geera Clay and LPS, respectively. This is consistent with lithological logs which indicate the presence of clay and sand within the respective screened sections.

The hydrographs for these bores indicate that between 1991 and 2000, groundwater levels in the LPS were above those in the Geera Clay, indicating a vertically downward hydraulic gradient (Figure 5-5). However, since 2000, groundwater levels in the sands have generally been below those in the clay, indicating a vertically upward hydraulic gradient. The groundwater levels in the LPS are consistent with long-term rainfall trends in the area, with a general decline in levels from the early 90s and a brief increase around 2010. The trends observed in Figure 5-5 may reflect the relative difference in the hydraulic conductivity of the two units. That is, because the LPS has a higher hydraulic conductivity than the Geera Clay, groundwater levels may respond more quickly to stimuli such groundwater recharge (during periods of increased rainfall) or periods when groundwater discharge and evaporation exceed rainfall.

Another nested site including bores 58449, 58450 and 58451 is located in the north east of the assessment area near Tyer Swamp (Figure 5-4). The VAF indicates that these bores are screened in the Renmark Formation, Geera Clay and LPS, respectively. Groundwater levels in the Geera Clay and Renmark Group (58449 and 58450) are higher than groundwater levels in the overlying LPS (58451), indicating an upward hydraulic gradient between the Geera Clay/Renmark Group and LPS in the area (Figure 5-6).

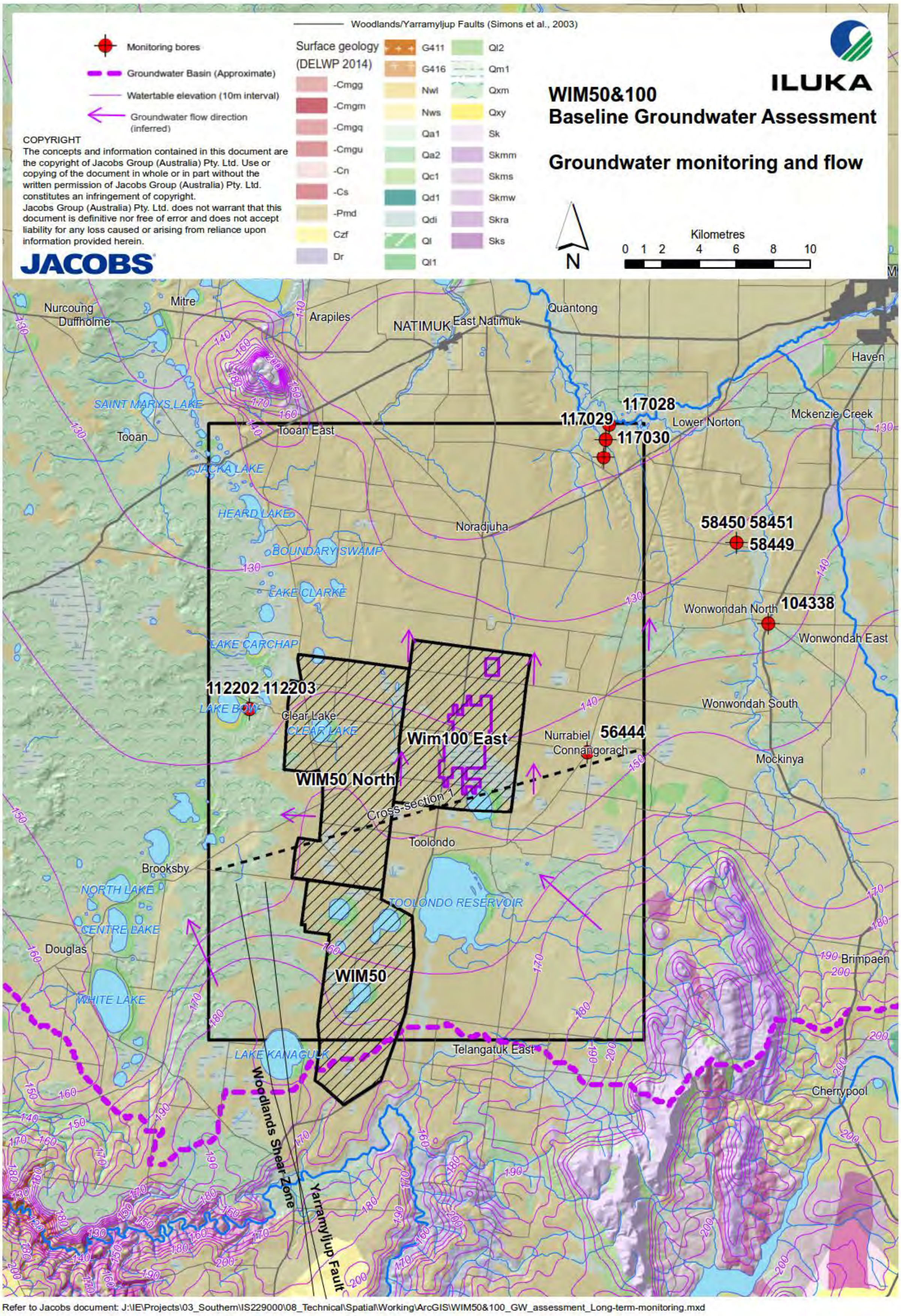

Figure 5-4 Regional groundwater levels at the WIM100 East assessment area

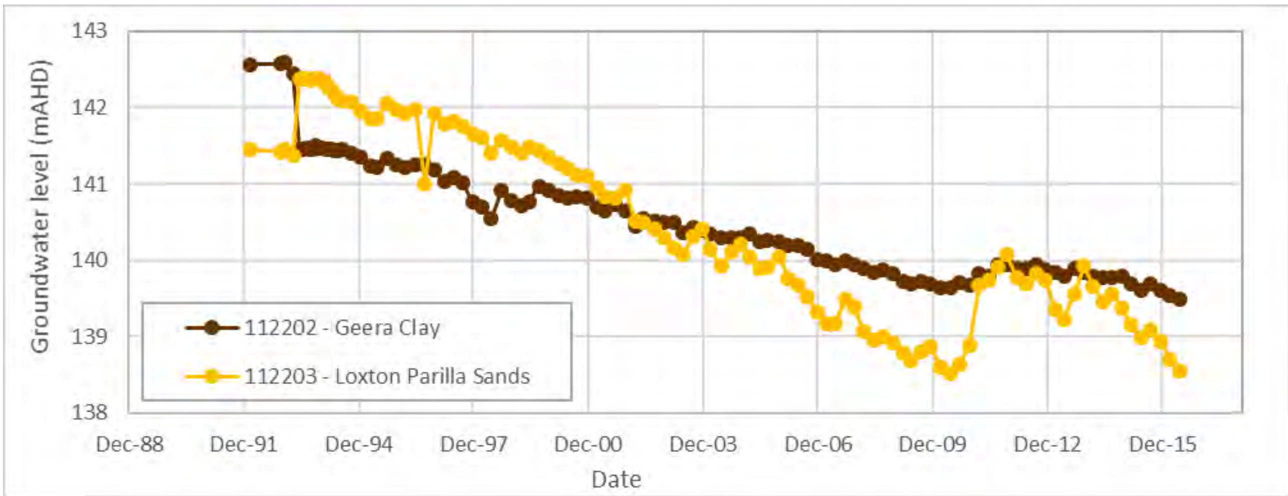

Figure 5-5 Groundwater hydrographs in bore 112202 and 112203

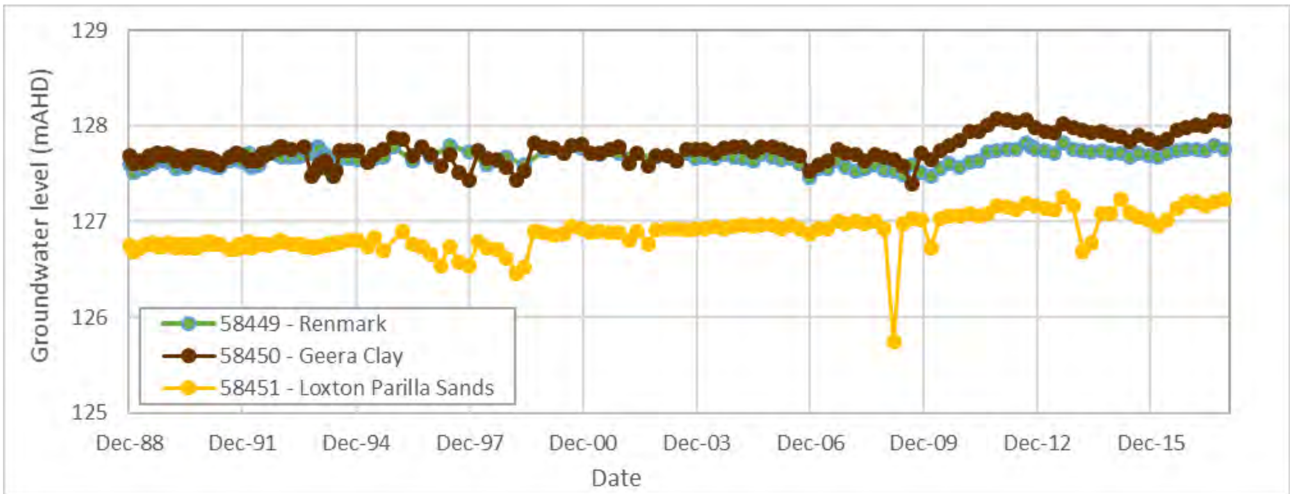

Figure 5-6 Groundwater hydrographs in bores 58449, 58450 and 58451

5.5 Groundwater quality

This section considers the broad salinity of groundwater throughout the assessment area. Further comment based on monitoring conducted by Iluka is presented in Section 6.

Groundwater salinity mapping (DELWP, 2014) of the water table (locally the LPS) indicates salinities of between 7,000 and 13,000 mg/L in the south west of the assessment area, between the Toolondo Reservoir and the Douglas Depression. The mapping also indicates lower salinities in the north of the assessment area, ranging between 3,500 and 7,000 mg/L between Jallumba and Noradjuha.

This is broadly consistent with salinity monitoring by URS (2008) which found salinities ranging between 2,000 and 5,000 mg/L in the LPS to the north of the Connangorach Swamp, in the east of the assessment area. The exception to this was an observation bore immediately down hydraulic gradient of the swamp which was significantly fresher, presumably as a result of proximal groundwater recharge. The study also found the bores drilled below the LPS (presumably in the Upper Tertiary Aquitard) were higher in salinity, with electrical conductivities (EC) greater than 15,000 µS/cm (equivalent to ~10,000 mg/L).

These data indicate that regional groundwater within the assessment area will generally need to be protected with respect to the beneficial uses as outlined in segment C of the Groundwaters of Victoria SEPP (EPA, 1997). This includes:

- Maintenance of ecosystems
- Stock watering
- Industrial water use
- Primary contact recreation
- Buildings and structures

5.6 Groundwater dependant ecosystems

Mapping of groundwater dependent ecosystems (GDEs) indicates that many of the lakes and swamps in the north west of the assessment area have a moderate to high potential to be groundwater dependant, including Lake Clear, Lake Carchap, Lake Clarke, Boundary Swamp and Heard Lake (BOM, 2018). The terrestrial vegetation surrounding these lakes and swamps, as well as that fringing the Natimuk Channel, Darragan Creek and Sandy Creek to the north of the assessment area, are also likely to be groundwater dependant (Appendix A).

Previous groundwater modelling in the area is consistent with the above described mapping, and indicates that the lakes in the Douglas Depression extending from White Lake to Lake Mobla represent potential groundwater discharge zones (CDM Smith, 2014).

McAuley (1992) found that seepage was occurring in the Rocklands-Toolondo Channel to the south of the Toolondo Reservoir, resulting in groundwater mounding under the channel. Groundwater monitoring at bore 112211 located ~1 km east of the channel near Toolondo Reservoir is consistent with this, and indicates groundwater levels from 13 to 15 m below ground level. Further, GDE mapping does not classify vegetation along the channel as being groundwater dependant (Appendix A). This further indicates that the Rocklands-Toolondo Channel is a losing system and not a groundwater receptor near the Tolondo Reservoir. Whilst some seepage is recognised, the volumes from the channel are not significant in a regional context and do not fundamentally alter the regional groundwater flow patterns.

The Glenelg River to the south of the WIM50 deposit has been highlighted as an area with a high potential to host groundwater dependant ecosystems. Analysis has shown that there are significant periods of zero flow for gauging stations at Fulham Bridge on the Glenelg River, approximately 1.5 km to the south of the WIM50 deposit, indicating that groundwater flow contributions in these reaches are ephemeral (Alluvium, 2013). However, a prominent feature of the upper Glenelg River is the occurrence of deep (2–8 m) saline pools, which are indicative of strong saline groundwater intrusion (Glenelg Hopkins CMA, 2016).

URS (2007) have illustrated that groundwater feeds into the Glenelg River from the Edgewood Groundwater Management Area which lies to the rivers south. It is further speculated that groundwater flow and discharge to the Glenelg River is, at least in part, facilitated by fracture flow associated with areas of major faults that intersect the river, including the Yarramyljup Fault and Woodlands Shear Zone. While these faults also extend north from the Glenelg River into the region between White Lake and the Toolondo Reservoir (Figure 5-4), water table mapping indicates that groundwater flow in this area is to the north and west. Accordingly, there is no current evidence in the available groundwater monitoring or mapping data to suggest that preferential flow along these fault lines is occurring in the area to the north of Lake Kanagulk. The possibility of such preferential flow should be remain a consideration for future assessments, even though it is regarded as unlikely.

Regardless, it remains plausible that flows south of Lake Kanagulk toward the Glenelg River may be enhanced by structural features such as the Yarramyljup Fault and Woodlands Shear Zone. Further, it is recognised that there is an absence of active groundwater monitoring in this area. Given this, it is recommended that prior to undertaking any works that may affect groundwater levels in this area, the understanding of groundwater flow be refined and if necessary, additional groundwater monitoring be undertaken to either confirm or refute the potential for concentrated, or preferential flow in the vicinity of fault lines.

In addition to the aquatic and terrestrial GDE's discussed above and illustrated in Appendix A, stygofauna represent subterranean GDE's which have the potential to be affected by mining activities. The identification of stygofauna throughout aquifers in Victoria has not been assessed with the same level of detail as aquatic and terrestrial GDE's. As such, the likelihood of stygofauna occurrence has been considered separately in addition to this report (see Jacobs 2018).

5.7 Summary

The above conceptualisation of the assessment area has been summarised in Figure 5-7. It illustrates the direction of the prevailing groundwater flow directions in an east-west orientation, with localised groundwater recharge via surface water bodies and swamps where water may pool intermittently. It further illustrates that groundwater flow towards the Douglas Depression is only likely to occur in the west of the assessment area, with the remainder directed to the north and east. The extent of the UMTA inferred by the VAF has also been illustrated, however, the nature of the unit remains somewhat unresolved as there is limited drilling to this depth in the region. As the UMTA is used for irrigation throughout the western Murray Basin where the Murray Group Limestone predominates, the occurrence and nature of the UMTA in the assessment area requires further evaluation.

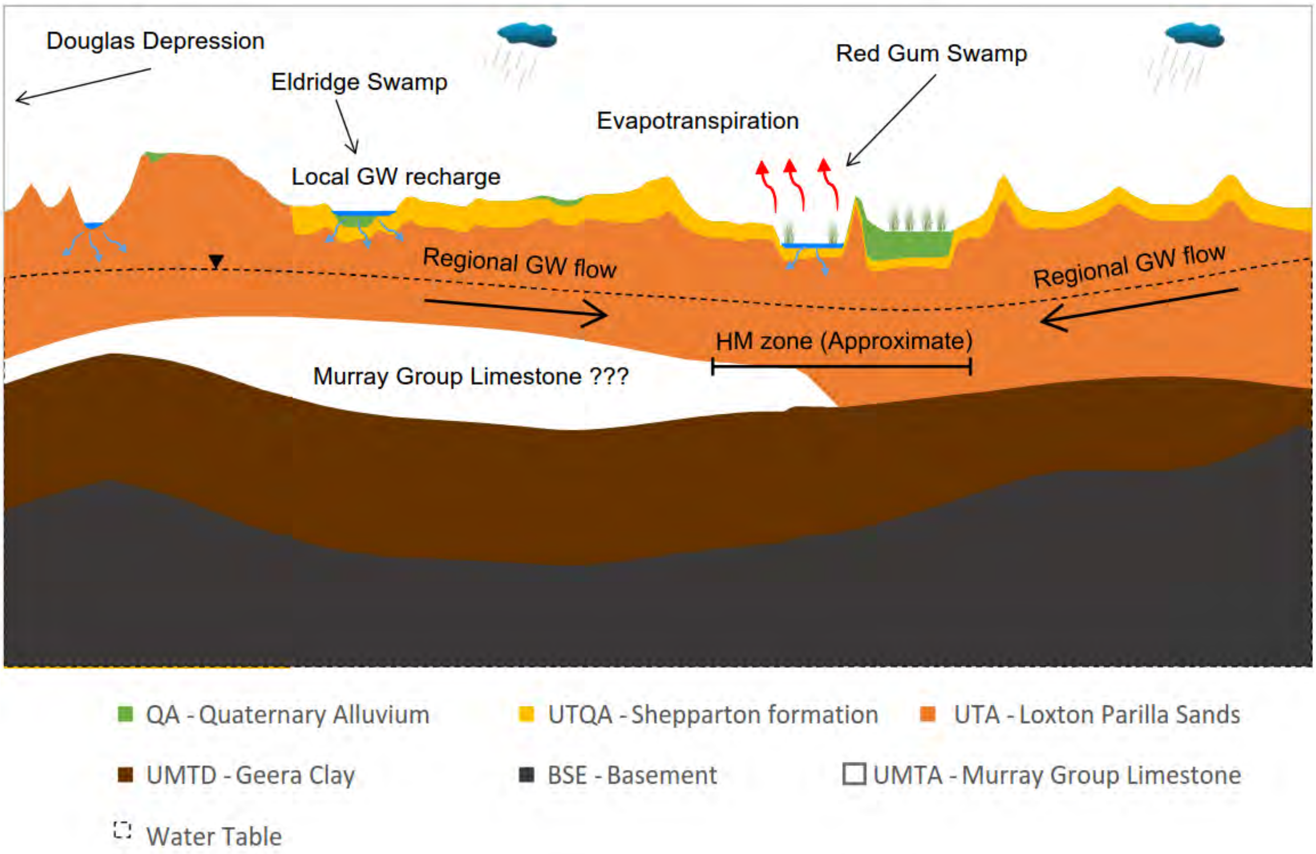

Figure 5-7 Hydrogeological conceptualisation of the assessment area

6. Groundwater monitoring

6.1 Location and details

A total of 35 groundwater monitoring bores were considered was part of the groundwater monitoring program executed for this project. Of the 35 monitoring bores considered, Iluka's groundwater monitoring contractor has indicated that:

- 18 were not found
- 5 were dry
- 3 were blocked or obstructed

As such, a total of 9 bores were found to be operational and thus sampled as part of this monitoring program. A full list of each bore considered as part of the monitoring program, its construction details and location is detailed in Appendix B.

The location and status of each of these bores has been illustrated in Figure 6-1. It is noted that at the time of the sampling program, bores 58449, 58450 and 58451 were considered to be too far to the north-west of the WIM50-100 deposit areas to be of relevance to the baseline assessment. As such, these have not been considered further.

Three of the sampled bores were screened below the LPS (>30 m) and in the Geera Clay, while the remainder were typically screened between 10 and 20 m depth in the LPS.

The depths and unit in which each monitoring bore was screened has been illustrated in Figure 6-2 below, with the screened interval indicated by bold text and borders. The location of these bores has been illustrated in Figure 6-1 below.

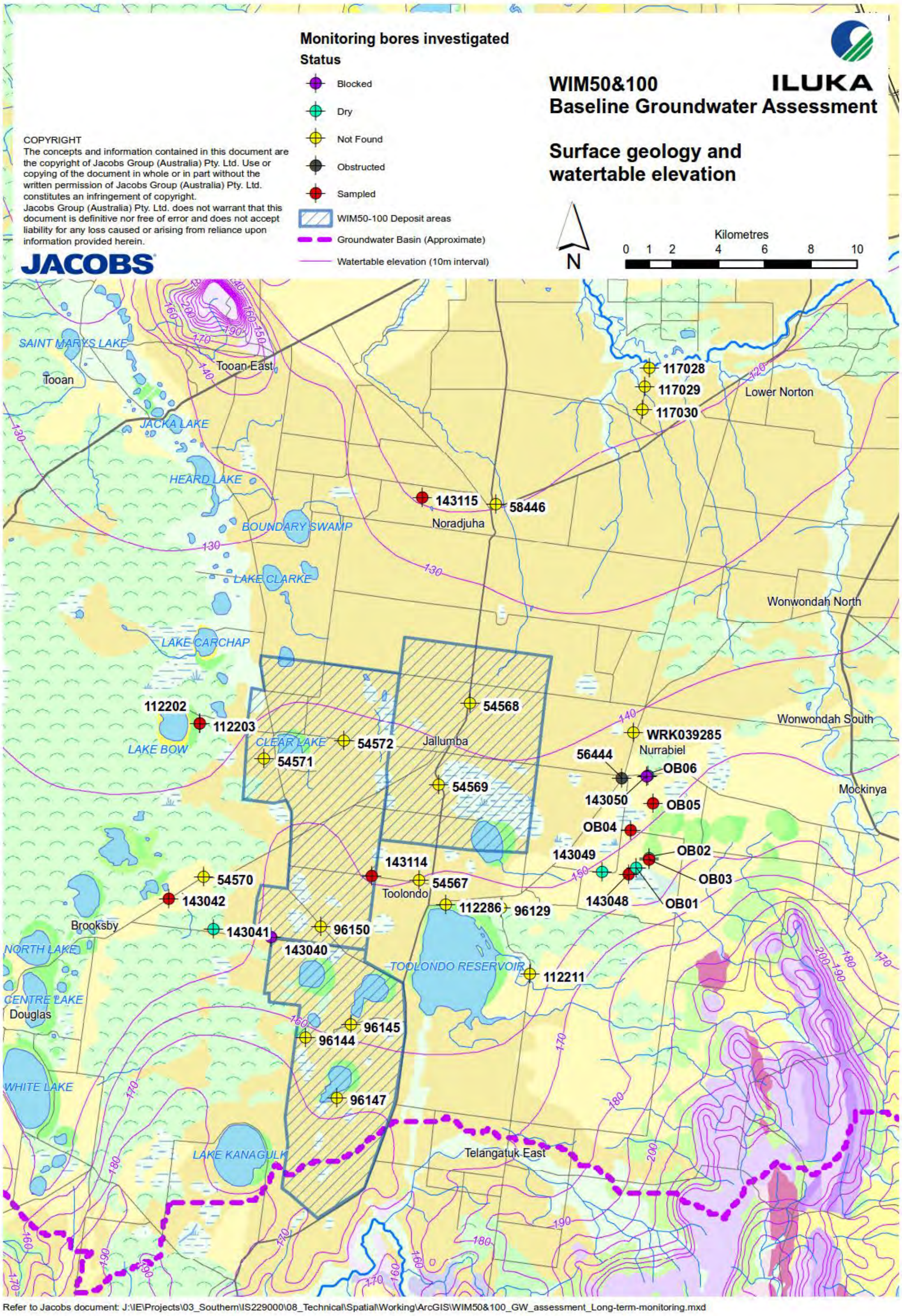

Figure 6-1 Location of monitoring bores visited during investigations

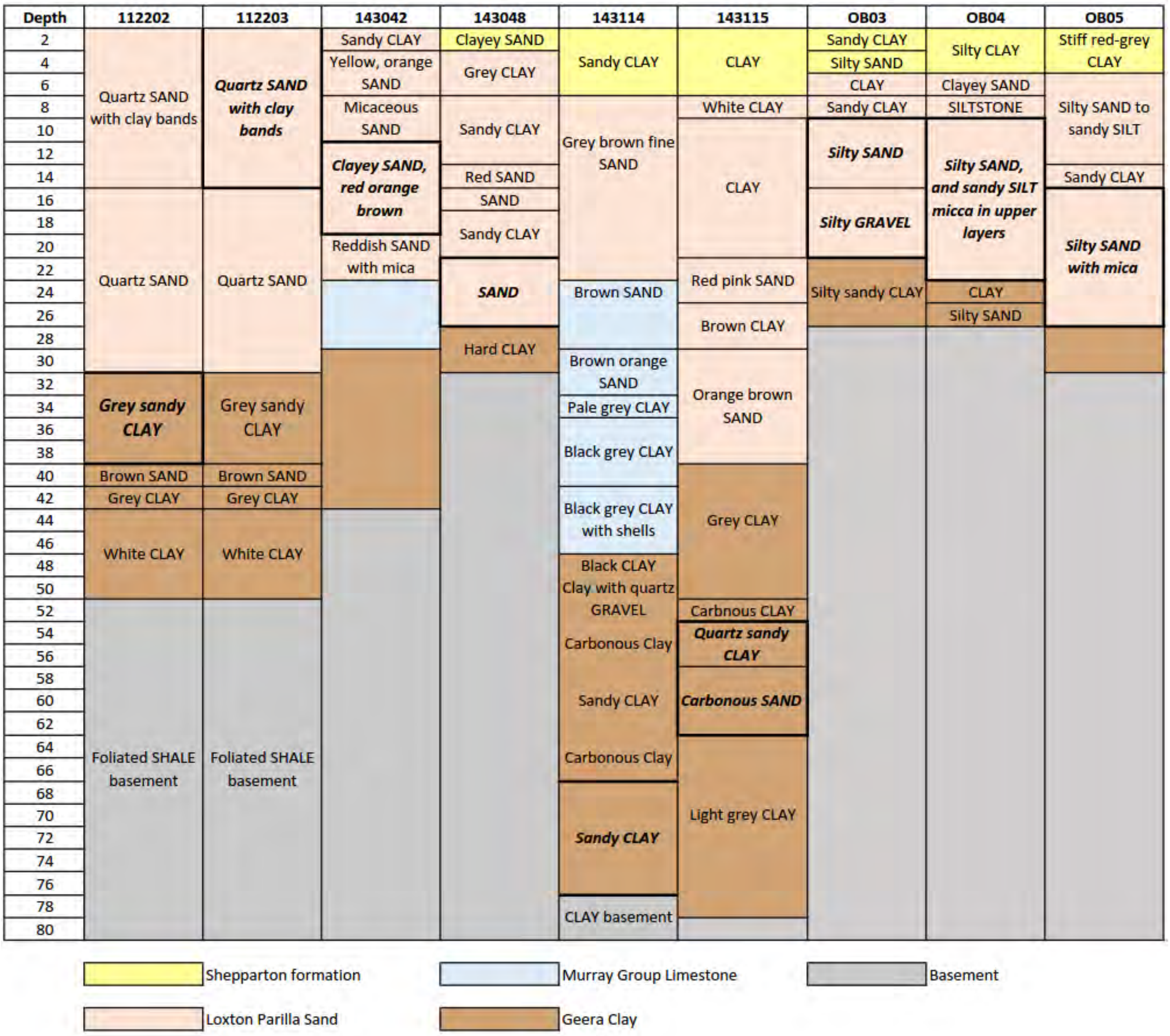

Figure 6-2 Depth and stratigraphy in which monitoring bores have been screened

6.2 Echo mine site groundwater monitoring and analysis

6.2.1 Groundwater levels and EC

Historical groundwater monitoring data has been collected at the Echo mine site at bores OB03, OB04, OB05 and 143048, all screened in the LPS. The historical monitoring of groundwater levels and EC in these bores has been illustrated in Figure 6-3 below. The figure shows that there has generally been little water table fluctuation over the last decade (<0.5 m) in all bores except 143048. This bore is near Connangorach Swamp, and fluctuations probably reflect local groundwater recharge. As with historical monitoring in section 5.4, seasonal water table fluctuations are not apparent further from the swamp, and are likely indicative of evapotranspiration typically exceeding rainfall in the area, and the reduced likelihood of groundwater recharge away from surface water bodies.

EC monitoring at these bores indicates an increase in salinity from around 1,000 to 2,000 µS/cm at 143048 and OB03, to around 4,000 µS/cm at OB04, to over 10,000 µS/cm at OB05 (Figure 6-3). The lower salinities at 143048 and OB03 are consistent with the recharge of fresh water occurring at the nearby Connangorach Swamp. The increase in salinity at OB04 and OB05 could be related to both evaporation or mixing between the relatively fresh recharge water and regionally saline groundwater. As groundwater levels are typically >10 m below the ground level in the area, the trend is probably not related to the evaporation of groundwater along its flow path, and more likely to reflect mixing between fresh recharge and regional groundwater. It is noted the EC of water sampled from OB05 is variable prior to 2011. A review of sampling notes at these times indicates that the collection of sufficient water to monitor was difficult. As such, the variability in the EC may be related to sampling difficulties.

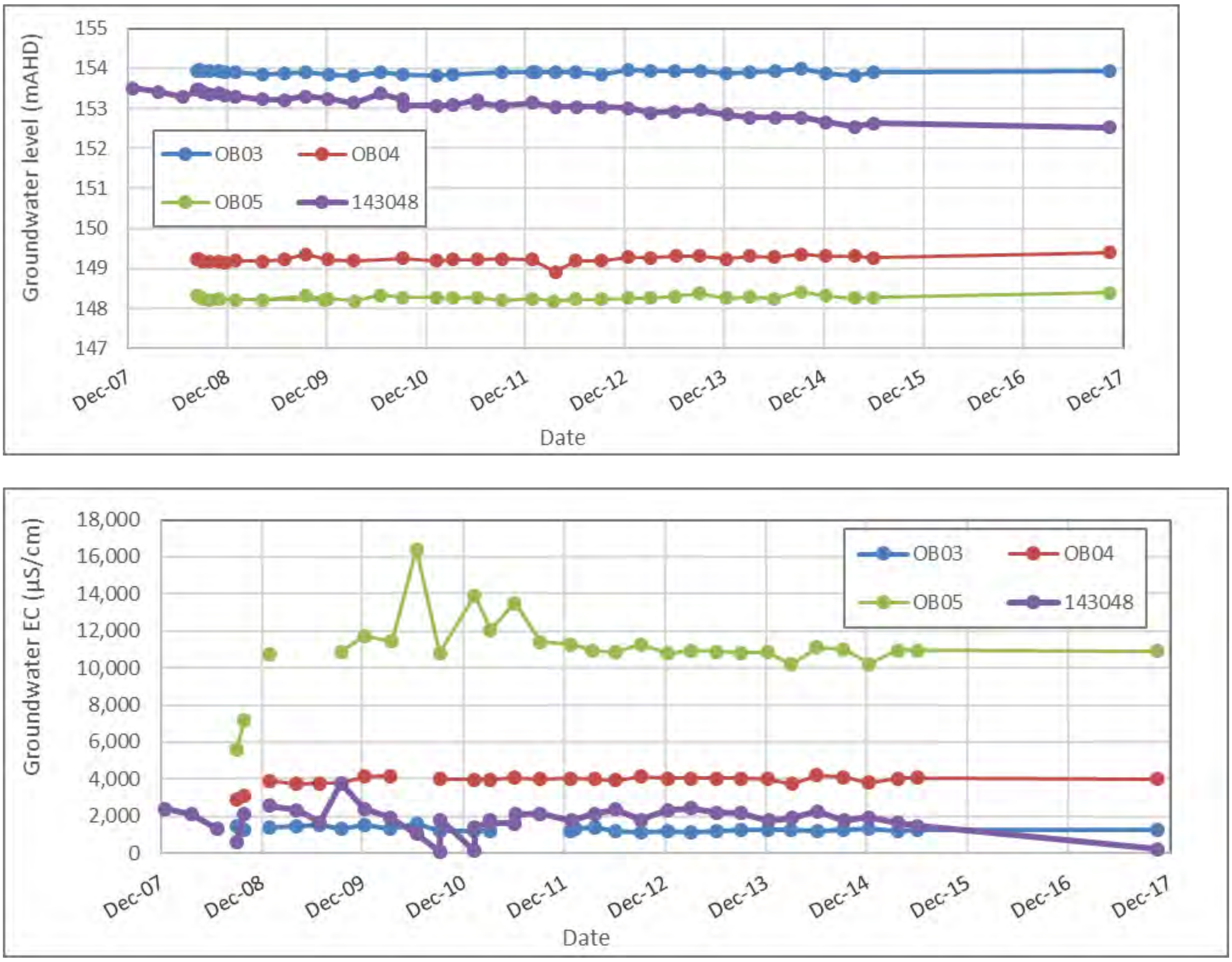

Figure 6-3 Historical groundwater level and EC monitoring at Echo mine site

6.2.2 Major ions

The concentration of major ions in groundwater sampled from the Echo site have been illustrated in box and whisker plots in Appendix C. These illustrate the distribution of major ion concentrations measured in each bore over a ~10 year period, and form the preliminary baseline hydrogeochemical conditions for this study area.

As with EC, the greatest variability in major ion concentrations occurs at OB5, and is probably related to difficulties in sampling that bore on a number of occasions, which may have resulted in samples that are less representative. Bores 143048 and OB03 yield the next greatest number of outliers, potentially as a results of sporadic nearby recharge through surface water features.

The concentration of almost all major ions is consistent with salinity trends, with typically higher concentrations of major ions in OB05, followed by OB04 and then OB03 and 143048. The exception to this is K, which is less variable across the monitoring bores. This suggests that the concentration of K in recent recharge may be relatively similar to that of regional (older) groundwater.

6.2.3 Ion ratios

Along with evaluating the concentration of major ions in groundwater, it is also often useful to evaluate how the ratio of some ions, relative to others, vary at different salinities and between locations. In doing this, it is possible to infer some of the major processes occurring within different aquifers. This assessment has been conducted using historical Echo site groundwater data (Appendix C) with respect to:

- Cl/SO_4 – to identify where SO_4 is present in higher amounts, such as from gypsum or other sources
- Na/Ca – to identify where Ca may be present in higher amounts
- Na/Mg – to identify were Mg may be present in higher amounts

It is expected that these trends may not be representative of those at the WIM100 East deposit, but at least present baseline information for the south east of the assessment area. Bore 143048 had the highest Cl/SO_4 ratios, although the most variable, followed by OB03, OB04 and finally OB05. This suggests higher proportion of sulfate relative to chloride in regional groundwater in comparison to recharging water, perhaps related to gypsum or dolomite dissolution.

Ratios of Na to Ca were also higher and more variable in 143048 and OBO3 compared to OB04 and OB05, suggesting that Na/Ca of recently recharged water is lower than more regional water. This could be related to Ca inputs via dolomite or carbonate weathering, or Na sorption on clays.

There was no systematic trend observed in the ratio of Na to Mg between monitoring bores.

The above trends identified suggest that gypsum and/or dolomite dissolution with cation exchange may be affecting the major ion chemistry of groundwater around the Echo mine site in the east of the assessment area.

6.3 November 2017 groundwater monitoring and analysis

In November 2017, groundwater samples were collected from the 9 bores outlined in section 6.1 for the analysis of general water quality, major ions and radionuclides. As sampling and analysis of groundwater throughout the assessment area has yet to be undertaken at regular spatial and temporal intervals, it is difficult to consider the evolution of groundwater chemistry over time and along flow paths. As such, this assessment primarily considers chemical variation with respect to salinity and the hydrogeological units monitored. The assessment of temporal trends would be better facilitated by monitoring over time, and consideration of spatial trends would be better facilitated via the installation of bores at regular intervals along groundwater flow paths. This is discussed further in Section 7.

The variation of major ion ratios with respect to salinity has been illustrated in Appendix D. The figures in this section and Appendix D illustrate trends in groundwater chemistry categorised by unit (i.e. the LPS and Geera Clay) for the 2017 sampling program. Historical data from the Echo mine site which also monitors the LPS have been included in greyed out circles for historical reference.

6.3.1 Salinity

The relationship between electrical conductivity and total dissolved solids is illustrated in Figure 6-4 below. This has been illustrated for the November sampling period and for the long-term monitoring at the Echo site. The data indicates a relationship of 0.65 dissolved solids for every EC unit measured during the November 2017 sampling period, and a relationship of 0.59 dissolved solids for every EC unit measured over time at the Echo site. The correlation coefficient was 0.99 for the November sampling, indicating a good fit for the data.

The discrepancy between the two trend lines may be related to the variability in salinity, with a lower TDS:EC associated with the lower salinities recorded at the Echo site. Alternatively, it may be that the discrepancy simply reflects the larger data set at the Echo site, and that additional monitoring throughout the assessment area may yield a trend more consistent with that at the Echo site. The observed trend between TDS and EC trend is consistent in groundwater sampled from both the LPS and the Geera Clay.

Similar trends were observed between Cl and total dissolved solids, with a ratio of around a 2:1 TDS:Cl (Figure 6-5). This is consistent with the conservative nature of Cl in groundwater. As such, Cl has been used as a basis for subsequent salinity and major ion trend analysis.

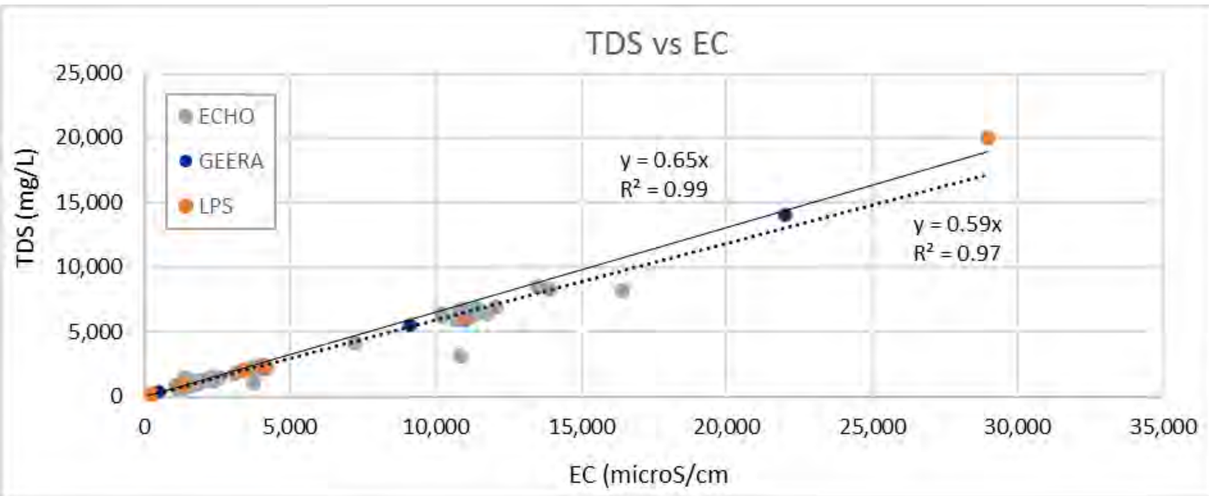

Figure 6-4 TDS vs EC in groundwater within assessment area

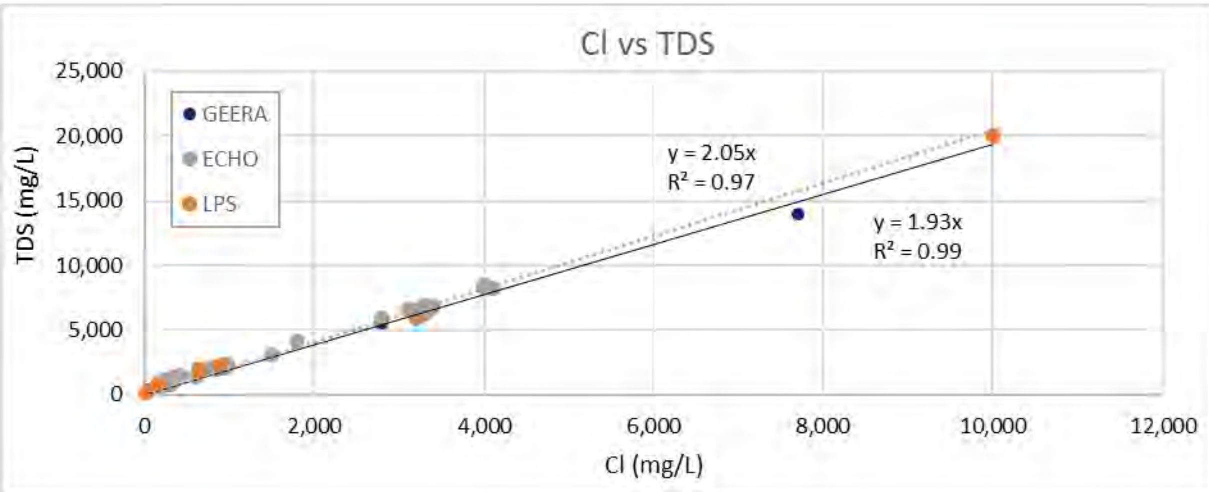

Figure 6-5 TDS vs Cl in groundwater from assessment area

6.3.2 Ion ratios

There does not appear to be a clear relationship between the ratio of SO_4 relative to Cl with increasing salinity throughout the assessment area, suggesting that gypsum dissolution is not a major process with respect to salinity (Appendix D). However, there is greater variability in the SO_4:Cl ratio at lower salinities, suggesting greater variability in sulfate relative to chloride in recharging waters.

The concentration of all major cations, relative to Cl, decline with increasing salinity (Appendix D). This may be related to a combination of various factors including:

- Recharge water being influenced by water-rock (soil) interaction
- The recharge of inland rainfall that is relatively depleted with respect to Cl
- The sorption of cations onto clays at higher concentrations and the relatively conservative nature of Cl

- o Mixing between recharge and regional groundwater

Concentrations of Na relative to Ca increase with salinity. However, the ratio of Na relative to Cl only falls to ~0.86 at higher salinities, which is commensurate with rainfall in the area (Cartwright and Weaver, 2005). This suggests that saline waters are most likely to be dominated by the evapo-concentration of rainfall, while ionic ratios in fresher waters are more susceptible to the effects of water-rock (soil) interaction.

It is noted that ionic ratios and salinity do not exhibit clear trends with depth or the stratigraphic unit in which monitoring bores have been screened. Rather, trends appear to reflect regional hydrogeological processes. This includes the recharge of relatively fresh water near surface water features and water rock (soil) interaction, flow down hydraulic gradient, and subsequent mixing with saline regional groundwater.

6.3.3 Radioactivity

The radioactivity of groundwater in the assessment area (Ra^{226}, Ra^{228} and U^{238}) has been illustrated in Figure 6-6 with respect to salinity. The figure illustrates a positive correlation between salinity and radioactivity, irrespective of the hydrostratigraphic unit that has been monitored. This suggests that the concentration of radionuclides in groundwater from the assessment area may be more closely related to the total concentration of dissolved solids in groundwater, as opposed to the specific depth or unit which has been monitored. This further implies that the radioactivity has co-evolved with the regional groundwater rather than being injected or added through other processes.

While this may be the case, the line of regression in Figure 6-6 does not fit all data perfectly. It is possible that some of the observed is discrepancy is derived from the level of recovery associated Ra^{226}, Ra^{228} and U^{238} analysis (illustrated as error bars in Figure 6-6). In any case, the correlation observed is only based on one sampling event, and further analysis is necessary to evaluate this trend fully.

Elevated (measureable) concentrations of radioactivity were found in bores 112202, 143042 and OB05 (and OBO4 with respect to U and U238 only). The spatial distribution of these is illustrated in Figure 6-7 with respect to Ra^{228}. It illustrates the absence of discernible spatial trends throughout the assessment area with respect to radionuclides, and the need for greater spatial density in the sampling program.

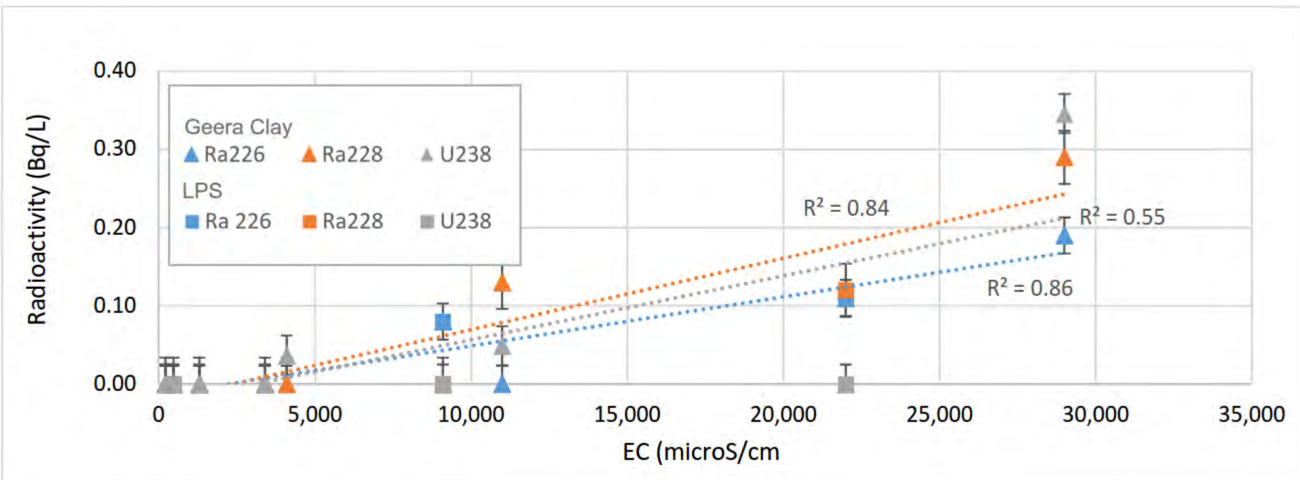

Figure 6-6 Ra^{226}, Ra^{228} and U^{238} vs EC in groundwater sampled during November 2017

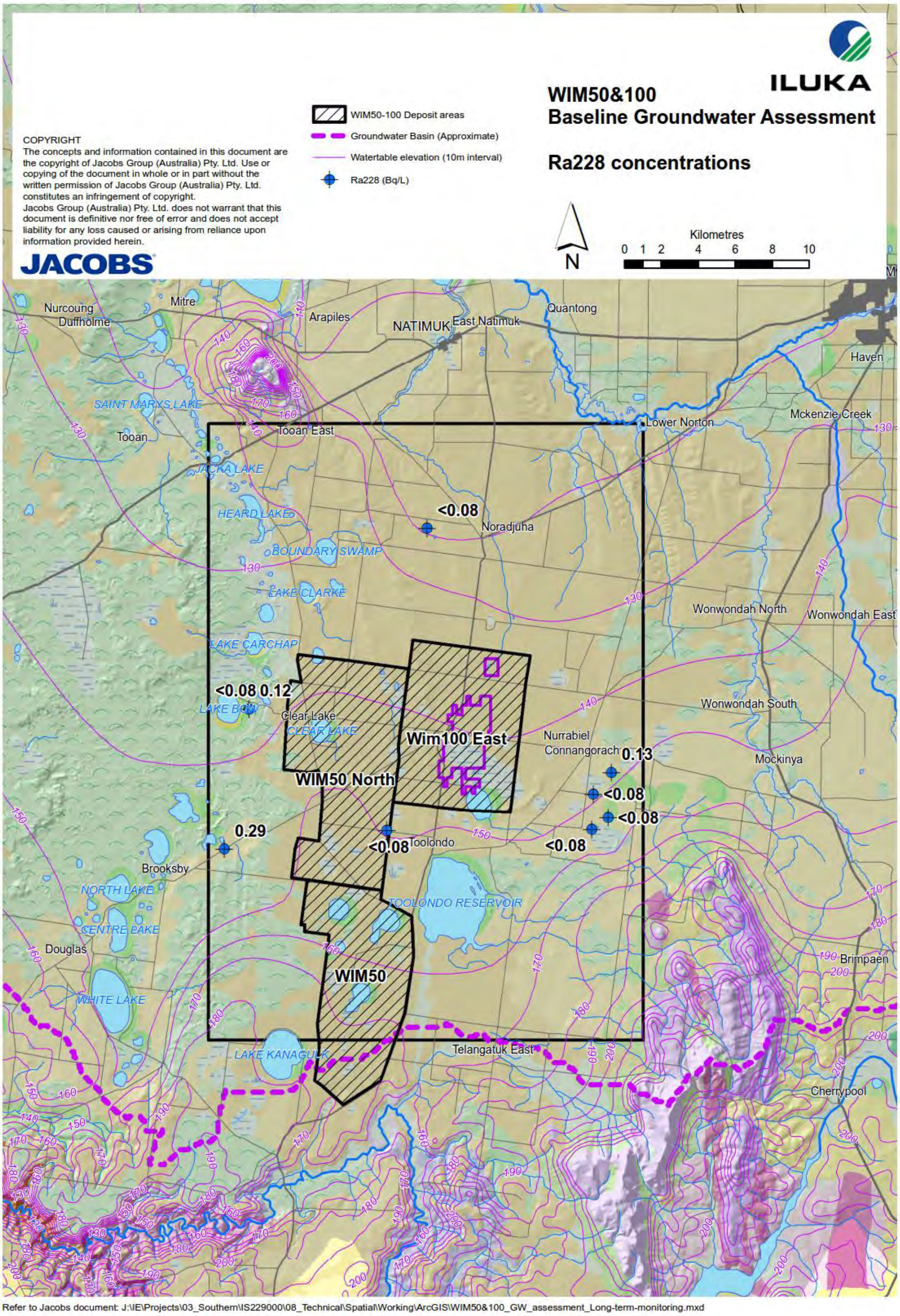

Figure 6-7 Location of Ra^{228} concentrations

6.4 Summary

Historical groundwater monitoring data collected at the Echo mine site indicates minimal seasonal fluctuations in groundwater levels. Long-term trends in groundwater levels suggest recharge to the water table aquifer (the LPS) via leakage through surface water bodies. Variations in groundwater chemistry are consistent with these observations, with greater variations in salinity and the concentration of major ions in bores closer to surface water features.

As well as being more variable, groundwater near such surface water features is fresher, and generally contains a higher proportion of dissolved cations relative to regional groundwater. This is likely to reflect a combination of water rock (soil) interaction and variabilities in the chemistry of rainfall.

At higher concentrations, groundwater chemistry reflects less influence of water-rock (soil) interaction and is more similar to evapo-concentrated rainfall, as evidenced by reductions in cation:chloride ratios to that more typical of rainfall in the area.

The radioactivity of Ra^{226}, Ra^{228} and U^{238} yield positive correlations with salinity, irrespective of the depth and geological formation being monitored, suggesting that the concentration of radioactive nuclides in groundwater from the assessment area may be more closely related to the total concentration of dissolved solids in groundwater.

7. Conclusions and recommendations

7.1 Conclusions

In order to inform this groundwater assessment, groundwater samples were collected from 9 monitoring bores throughout the assessment area and analysed for major ions, salinity and radionuclides. This was combined with data from online databases and historical groundwater monitoring for over a decade at 4 bores in the east of the assessment area, near the Echo mine site. The assessment has been limited by an absence of sampling and analysis at regular spatial and temporal intervals, however the following conclusions have been drawn:

1. Groundwater levels indicate a prevailing groundwater flow in the Loxton Parilla Sands (containing the ore body) to the north, with some flow west to the Douglas Depression, and local groundwater recharge via surface water features. Existing groundwater mapping suggests that groundwater flow towards the Glenelg River only occurs in the area south of Lake Kanagulk and Telangatuk East, however this has not been confirmed by groundwater monitoring in this study and may warrant further assessment.

2. Regionally, groundwater salinity ranges between 3,500 and 13,000 mg/L and as such, will typically need to be protected with respect to segment C of the Groundwaters of Victoria SEPP (EPA, 1997).

3. Groundwater is significantly fresher (less saline) than the typical regional salinity in areas surrounding surface water features (such as the Connangorach Swamp), indicating preferential recent recharge to the Loxton Parilla Sands via such features.

4. Fresher waters in the assessment area have more variable, and generally higher, cation:chloride ratios, likely resulting from the variability of ions in rainfall and in water-rock (soil) interaction near the surface.

5. Regional groundwater is more saline and has lower and less variable cation:chloride ratios than the fresh areas. These observations are consistent with groundwater salinization resulting from evaporation.

6. As fresh groundwater flows down hydraulic gradient, it mixes with more saline regional groundwater resulting in a decline in cation:chloride ratios.

7. A positive correlation is observed between the radioactivity of groundwater (Ra^{226}, Ra^{228} and U^{238}) and salinity, irrespective of the depth and geological formation being monitored. This suggests that the concentration of radionuclides in groundwater in the assessment area may be more closely related to the total concentration of dissolved solids in groundwater than the formation or depth being monitored.

8. While this would suggest that radioactivity may evolve with salts in solution and not sourced from later processes (such as leaching or mixing), the correlation is not an exact fit, is based on a limited data set, and would require ongoing monitoring to confirm.

9. The Victorian Aquifer Framework identifies the Murray Group Limestone or equivalent units in the area. However, bore logs in the vicinity of the ore body do not show a distinct limestone unit. Thus the degree of connection between the units in the vicinity of the ore and the regional limestone resource is not resolved. Given the use of the Murray Group Limestone for irrigation in the western Murray Basin, this requires further evaluation.

7.2 Recommendations

Based on the above conclusions, we recommend that future groundwater monitoring in the assessment area include:

- Continued sampling and analysis of groundwater from the existing network at a minimum of a quarterly frequency to allow assessment of background temporal variability in monitoring bores. This could be increased or decreased, however, it should allow the collection and analysis of at least 8 sample events prior to resource development in the area. The analytical suite is recommended to include:

- General water quality parameters (pH, EC, TDS, ORP, DO, Temperature)
- Speciated alkalinity and major ions (Na, K, Ca, Mg, Cl, F, Br, SO_4)
- Nutrients (P, PO_4, NO_2, NO_3, NH_4)
- Metals (Al (speciated), Sb, As, Ba, Be, B, Cd, Cr, Co, Cu, Fe (speciated), Pb, Mn, Mo, Ni, Se, Ag, Sr, Tl, Th, Sn, Ti, U, V, Zn, Hg)
- Radionuclides (Ra^{226}, Ra^{228}, U^{238}, U)

- If mining developments have the potential to affect groundwater levels in the south of the assessment area (i.e. around Lake Kanagulk and Telangatuk East), groundwater levels and flow in the area should be reviewed and if necessary, additional bores installed to assess the potential impact on flows towards the Glenelg River (to be designed once the scope of possible impacts is clearer).
- The construction of two bores to a depth of ~60 m in the west of the assessment area (where the Upper Mid Tertiary Aquifer has been identified in the VAF) to confirm the presence/absence of the Murray Group Limestone, and revision of the cross sections presented in section 5.7.
- If identified, this should be screened and nested with shallow (~30 m deep) bores in the overlying Loxton-Parilla Sands to establish hydraulic gradients and chemistry trends.
- The installation of two to four bores in the Loxton-Parilla Sands proximal (within 2 km) of the anticipated development area to allow:
  - more accurate characterisation of spatial trends near the proposed development site
  - confirmation of observed regional groundwater level trends near the proposed development site
  - confirmation of observed chemical trends near the proposed development site

An example of suitable locations for the installation of these monitoring bores has been illustrated in Figure 7-1 below.

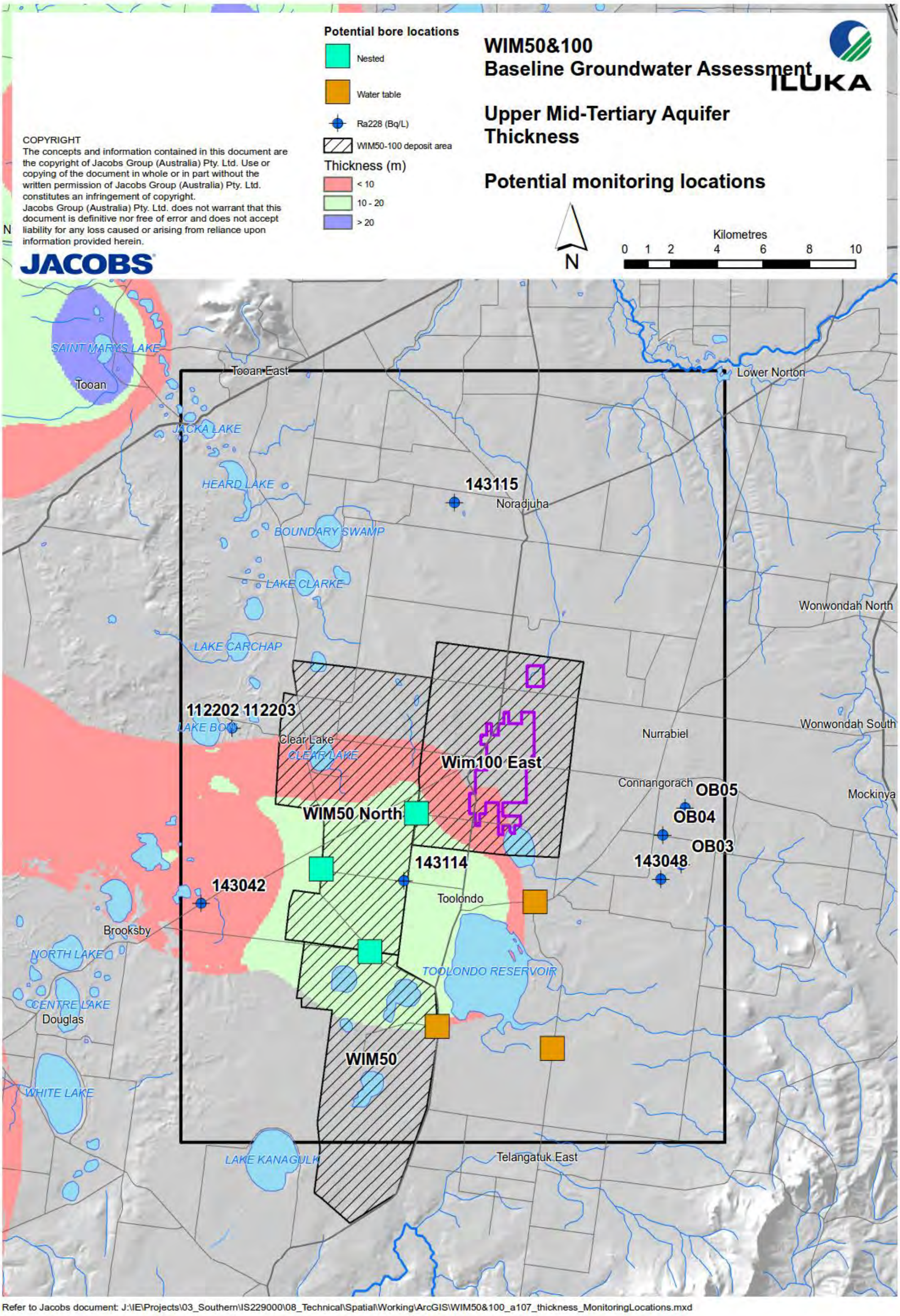

Figure 7-1 Proposed location of monitoring bores to augment existing monitoring network

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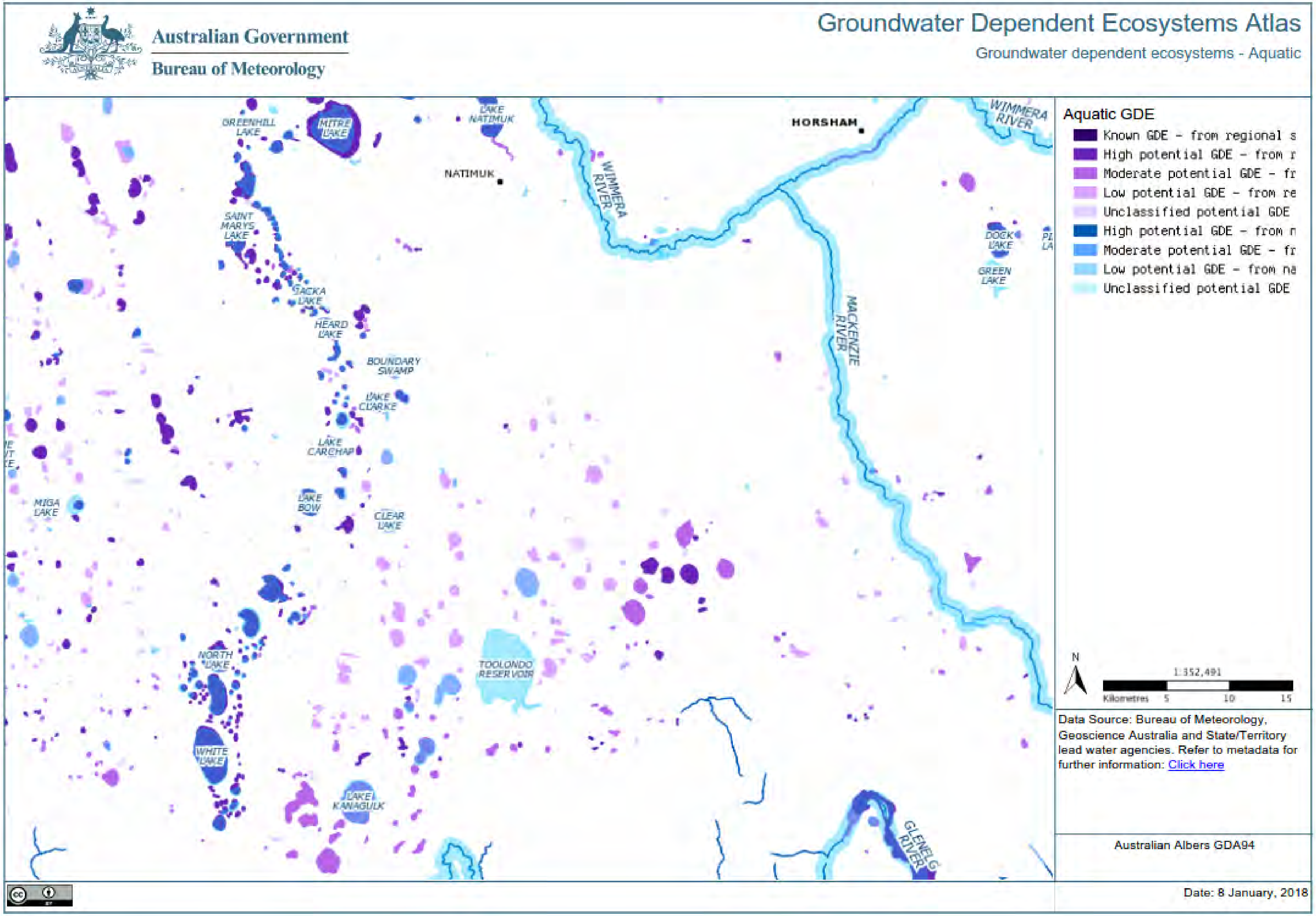
Appendix A. Maps


Australian Government
Bureau of Meteorology
Groundwater Dependent Ecosystems Atlas
Groundwater dependent ecosystems - Aquatic
Aquatic GDE
Known GDE - from regional s
High potential GDE - from r
Moderate potential GDE - fr
Low potential GDE - from re
Unclassified potential GDE
High potential GDE - from n
Moderate potential GDE - fr
Low potential GDE - from na
Unclassified potential GDE
HORSHAM
NATIMUK
WIMMERA RIVER
MACKENZIE RIVER
GLENELG RIVER
GREENHILL LAKE
MITRE LAKE
LAKE NATIMUK
SAINT MARYS LAKE
JACKA LAKE
HEARD LAKE
BOUNDARY SWAMP
LAKE CLARKE
LAKE CARCHAP
LAKE BOW
CLEAR LAKE
MIGA LAKE
NORTH LAKE
WHITE LAKE
LAKE KANAGULK
TOOLONDO RESERVOIR
DOCK LAKE
GREEN LAKE
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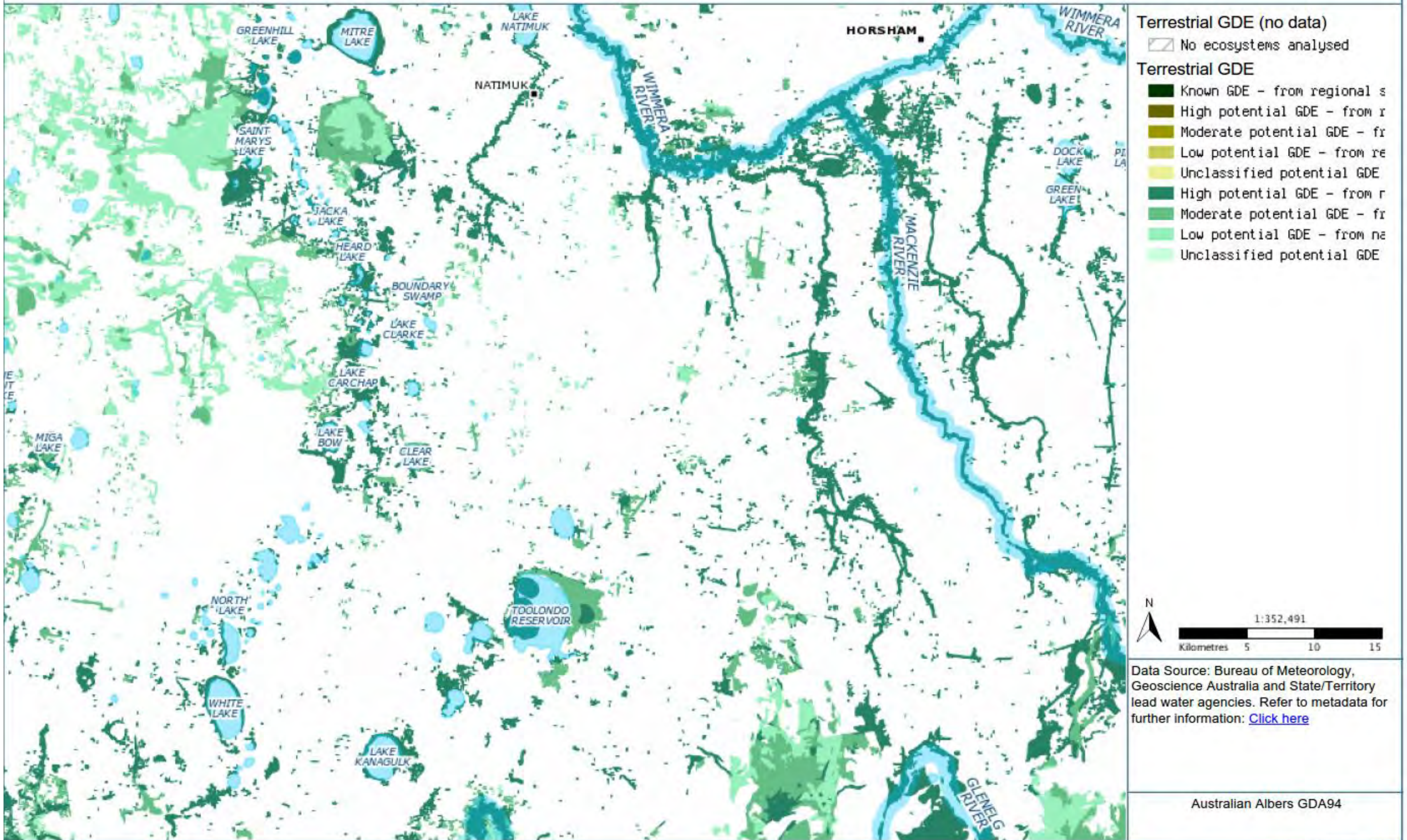
Date: 8 January, 2018

Australian Government
Bureau of Meteorology

Groundwater Dependent Ecosystems Atlas

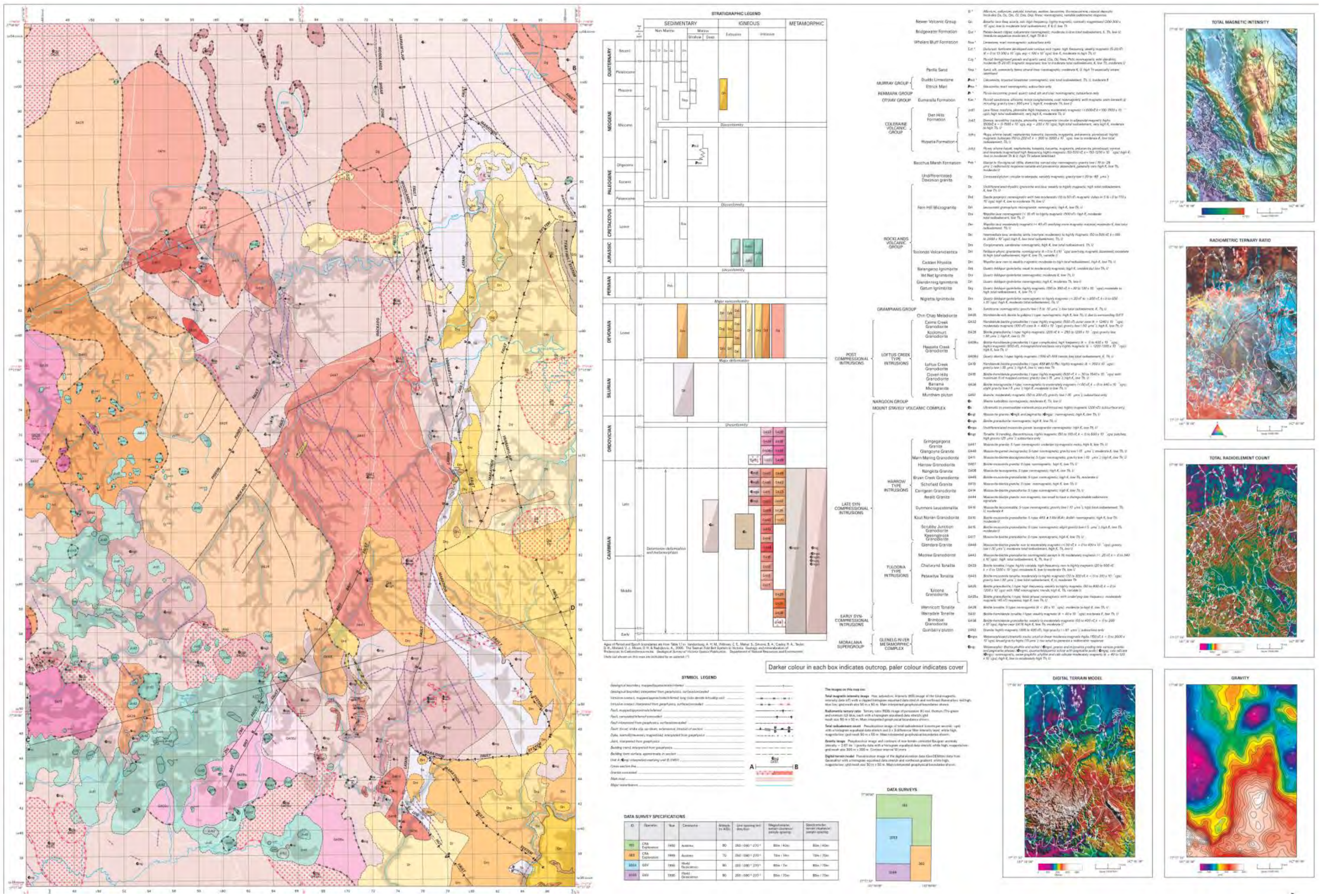
Groundwater dependent ecosystems - Terrestrial



Data Source: Bureau of Meteorology, Geoscience Australia and State/Territory lead water agencies. Refer to metadata for further information: Click here

Australian Albers GDA94

Date: 8 January, 2018


STRATIGRAPHIC LEGEND
Darker colour in each box indicates outcrop, paler colour indicates cover
SYMBOL LEGEND
DATA SURVEY SPECIFICATIONS
DATA SURVEYS
TOTAL MAGNETIC INTENSITY
RADIOMETRIC TERNARY RATIO
TOTAL RADIOELEMENT COUNT
DIGITAL TERRAIN MODEL
GRAVITY

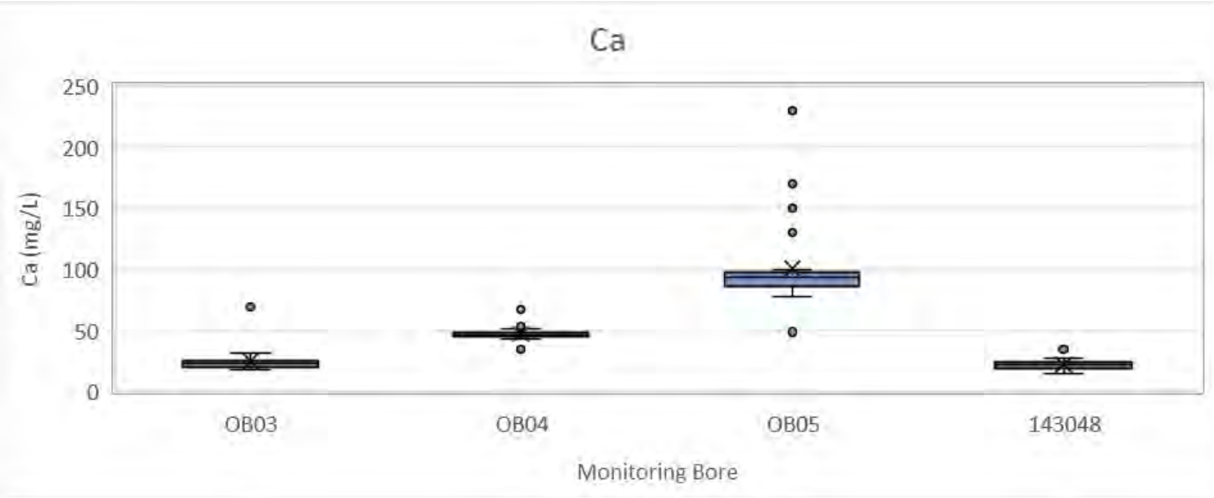
Appendix B. Monitoring bore status

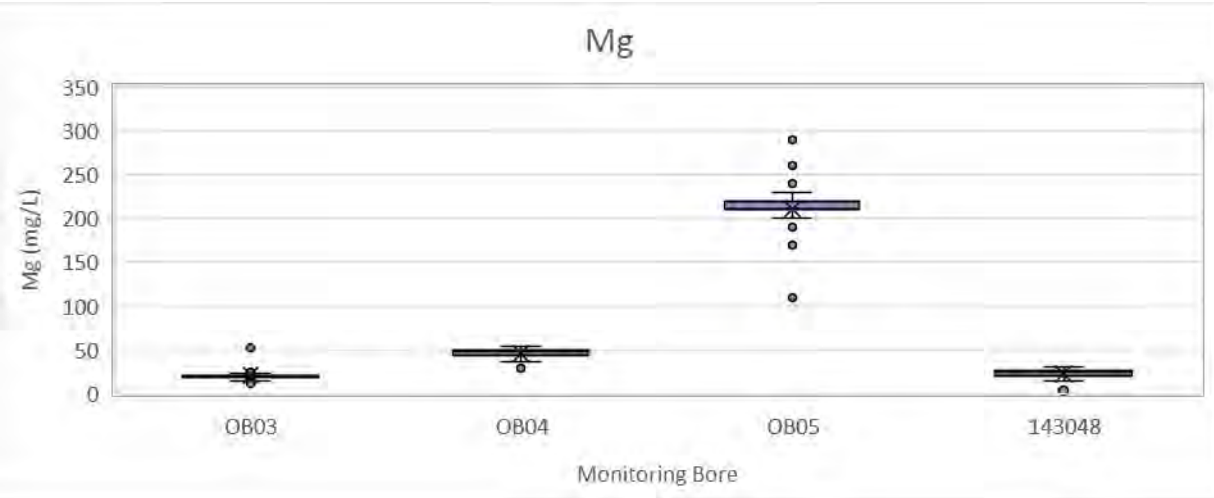
ID	Easting	Northing	Depth	Screen		Status	Lithology
				Top	Bottom		
54567	582871.2	5906726.8	35	-	-	Not found	Y
54568	585071.2	5914376.8	30	22.9	24.9	Not found	Y
54569	583721.2	5910876.8	30	26	28	Not found	Y
54570	573571.2	5906876.8	21	17.7	19.7	Not found	Y
54571	576171.2	5911976.8	30	27	29	Not found	Y
54572	579621.2	5912776.8	30	18.5	20.5	Not found	Y
56444	591625.6	5911134.3	20	17	19	Obstructed	Y
58446	586191.2	5922982.9	91.44	37.18	45.72	Not found	N
96129	586418.2	5905545.8	77.11	18.28	48.76	Not found	N
96144	577971.2	5899926.8	25.9	19.55	21.05	Not found	Y
96145	579921.2	5900476.8	27	17.29	18.29	Not found	Y
96147	579321.2	5897326.8	23	18.02	19.02	Not found	Y
96150	578621.2	5904726.8	33	19.5	21.5	Not found	Y
112202	573396.9	5913502.6	73.3	36	39	Sampled	Y
112203	573394.2	5913503.2	15	10	13	Sampled	Y
112211	587671.2	5902676.8	30	22.4	24.4	Not found	Y
112286	584021.2	5905676.8	9			Not found	N
117028	592821.3	5928876.9	8.8	6.8	8.8	Not found	N
117029	592621.3	5928076.9	10.6	8.6	10.6	Not found	N
117030	592521.3	5927076.9	15.8	13.8	15.8	Not found	N
143040	576480.2	5904272.8	30	18.5	23	Blocked	Y
143041	573979.2	5904605.8	33	22.4	27	Dry	Y
143042	572051.2	5905936.8	21	9	14	Sampled	Y
143048	591925.3	5906990.8	30	24.6	29.6	Sampled	Y
143049	590779.3	5907110.8	24	17.6	22.6	Dry	Y
143050	592754.3	5911251.8	27	17.2	22.2	Dry	Y
143114	580831.2	5906926.8	82	71	76	Sampled	Y
143115	583017.2	5923266.9	76	57	62	Sampled	Y
OB01	592260.815	5907273.083	28.25	24.6	28.25	Dry	Y
OB02	592813.839	5907678.873	28.25	24.6	28.25	Dry	Y
OB03	592808.852	5907621.726	28.25	24.6	28.25	Sampled	Y
OB04	592016.268	5908890.694	28.25	24.6	28.25	Sampled	Y
OB05	592987.208	5910065.179	28.25	24.6	28.25	Sampled	Y
OB06	592713.064	5911221.202	28.25	24.6	28.25	Blocked	Y
WRK039285	592138.3	5913132.8	63.39	28.95	29.56	Not found	N
8002269	571211	5902300	49	-	-	Not pursued	Y
8003428	578640	5913500	46	-	-	Not pursued	Y
94969	585221.2	5892476.8	8	-	-	Not pursued	Y
96137	569836.2	5898701.8	3	-	-	Not pursued	Y
96144	577971.2	5899926.8	26	-	-	Not pursued	Y

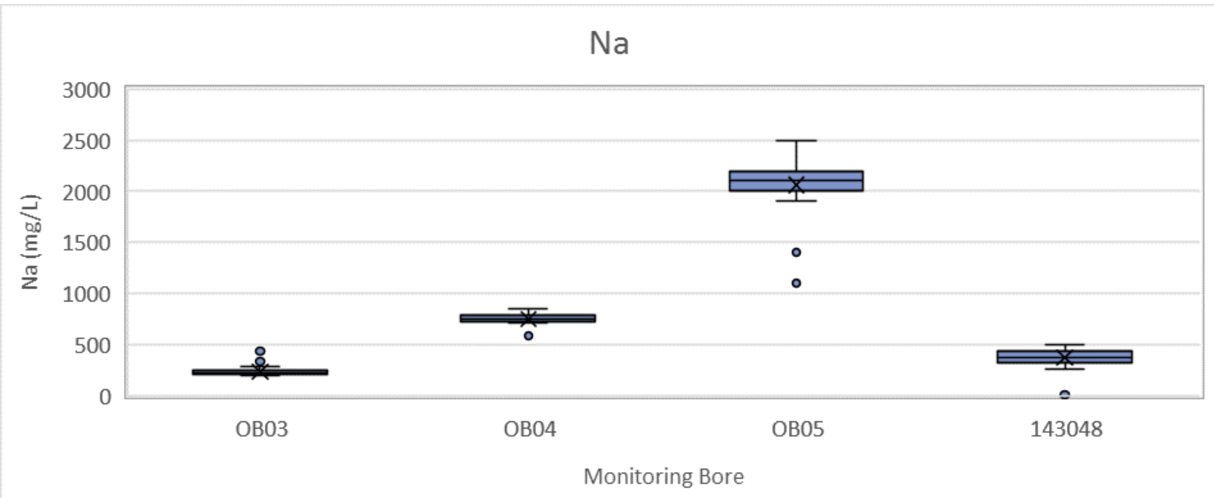
ID	Easting	Northing	Depth	Screen		Status	Lithology
				Top	Bottom		
96145	579921.2	5900476.8	27	-	-	Not pursued	Y
96146	576571.2	5897176.8	23	-	-	Not pursued	Y
96147	579321.2	5897326.8	23	-	-	Not pursued	Y
96148	577071.2	5895326.8	23	-	-	Not pursued	Y
96149	580821.2	5893976.8	31	-	-	Not pursued	Y
96150	578621.2	5904726.8	33	-	-	Not pursued	Y

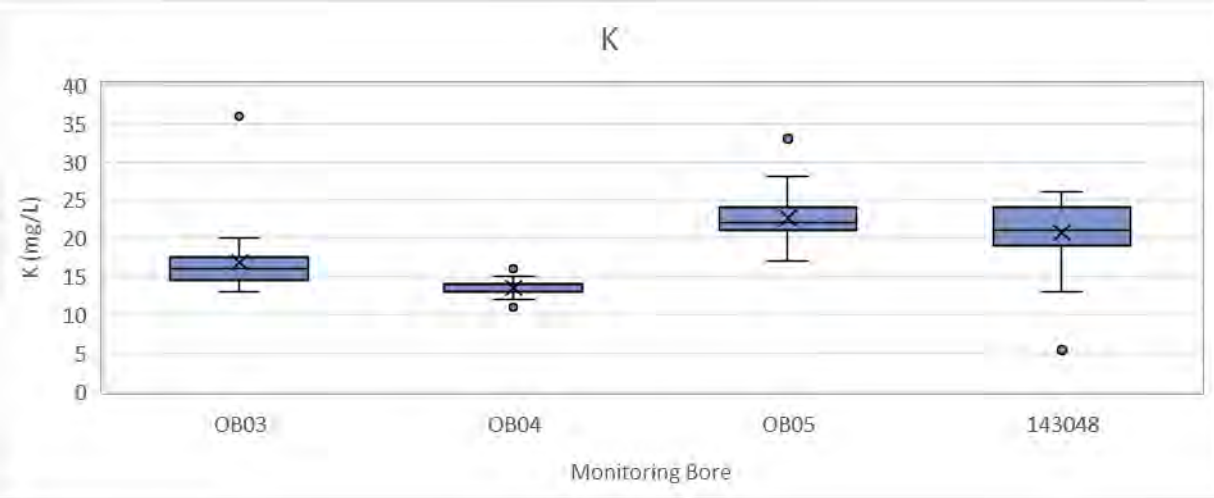
Appendix C. Groundwater chemistry - variability analysis

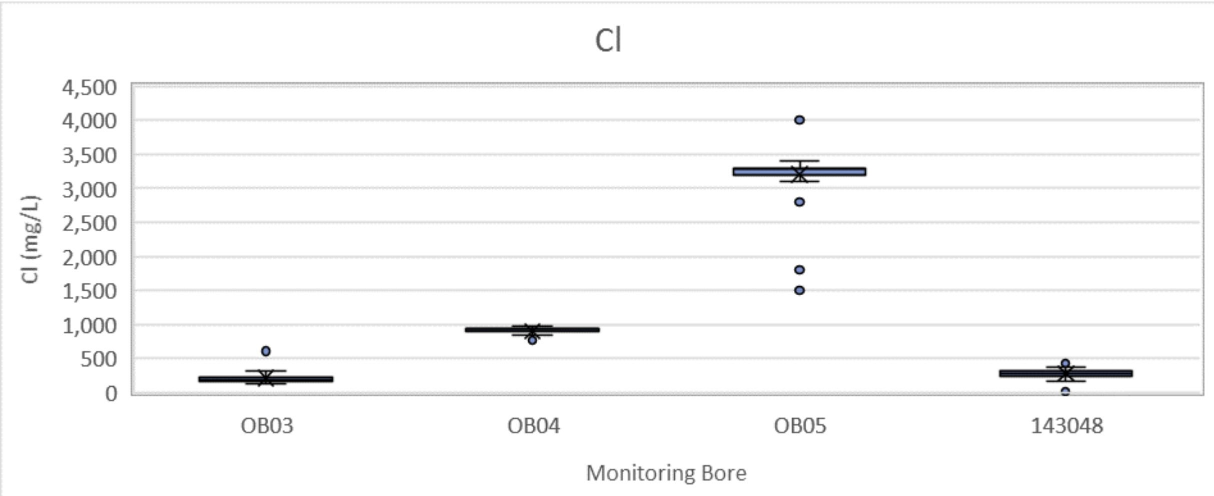
The below box and whisker plots demonstrate the distribution of data with respect to major ions in groundwater from bores at the ECHO site. The median is represented by the **line** in the box and the average by the **X**. The individual data points outside the whiskers indicate **outliers**.

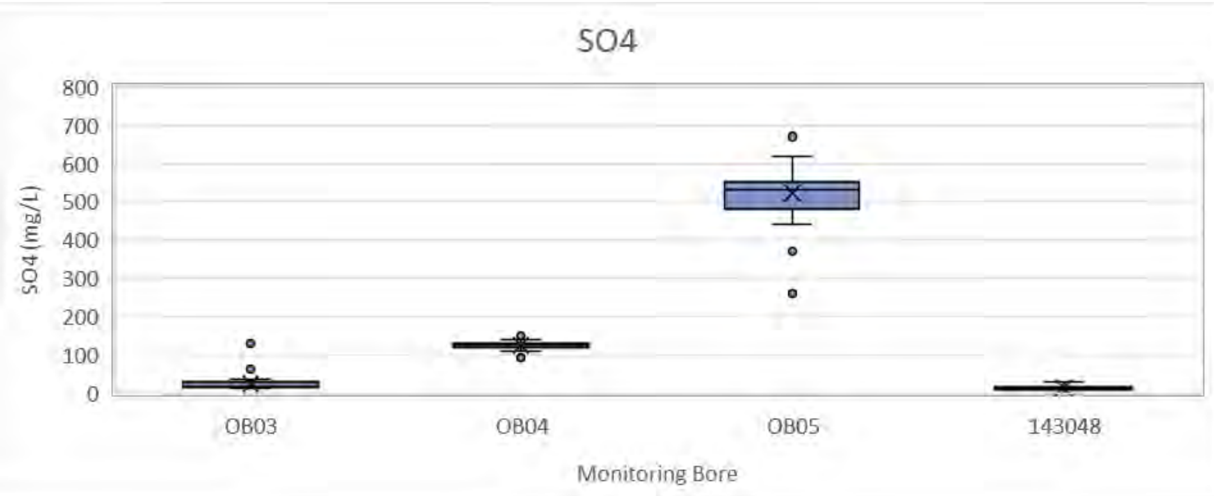


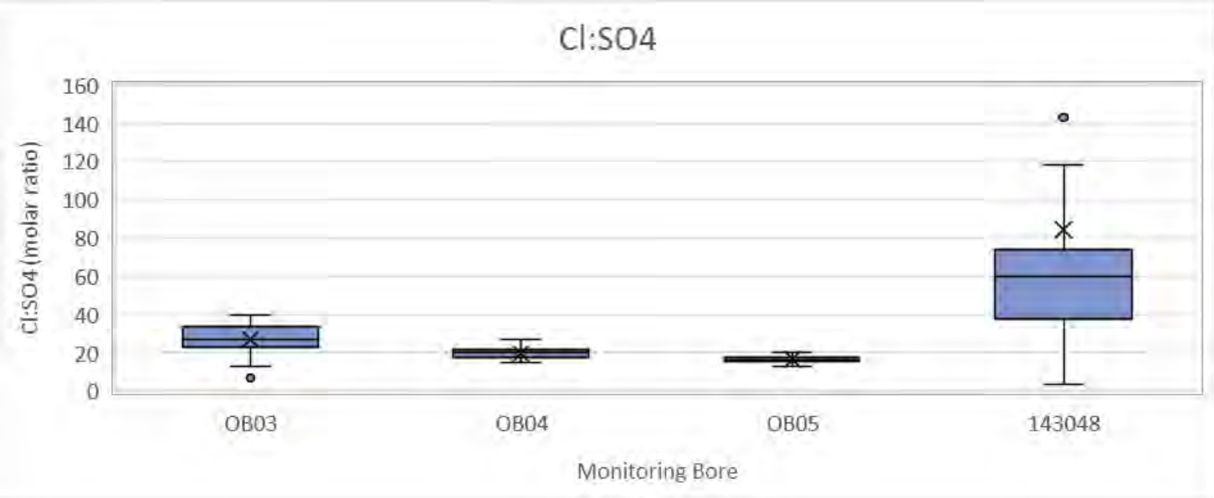


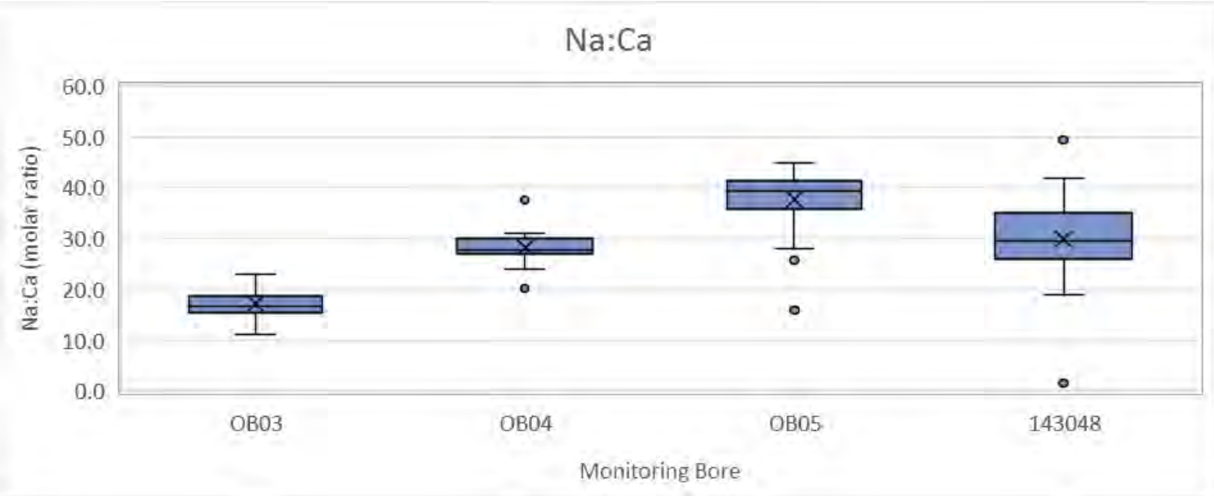


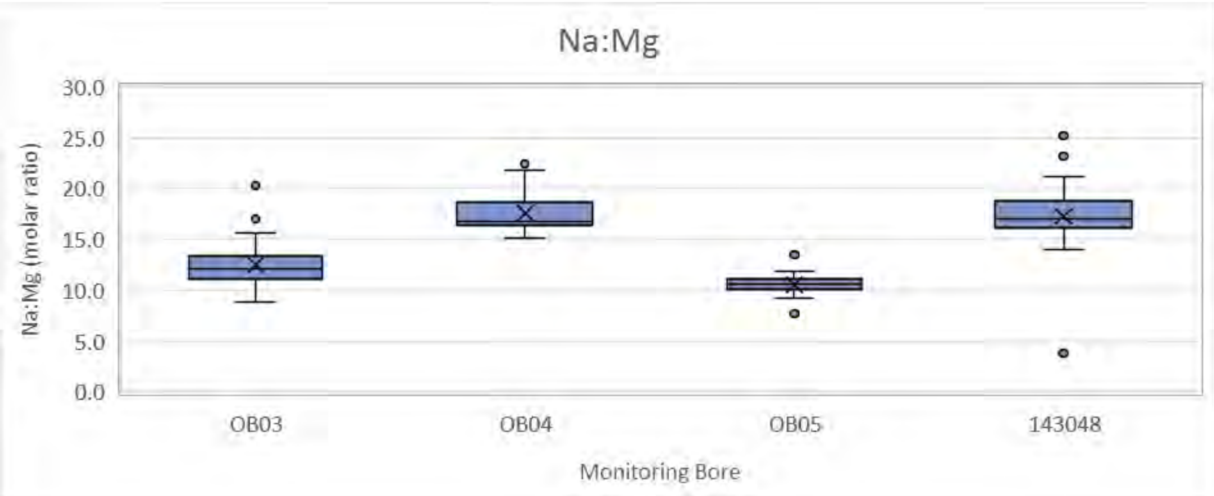

K
K (mg/L)
0
5
10
15
20
25
30
35
40
OB03
OB04
OB05
143048
Monitoring Bore


Cl
Cl (mg/L)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
OB03
OB04
OB05
143048
Monitoring Bore

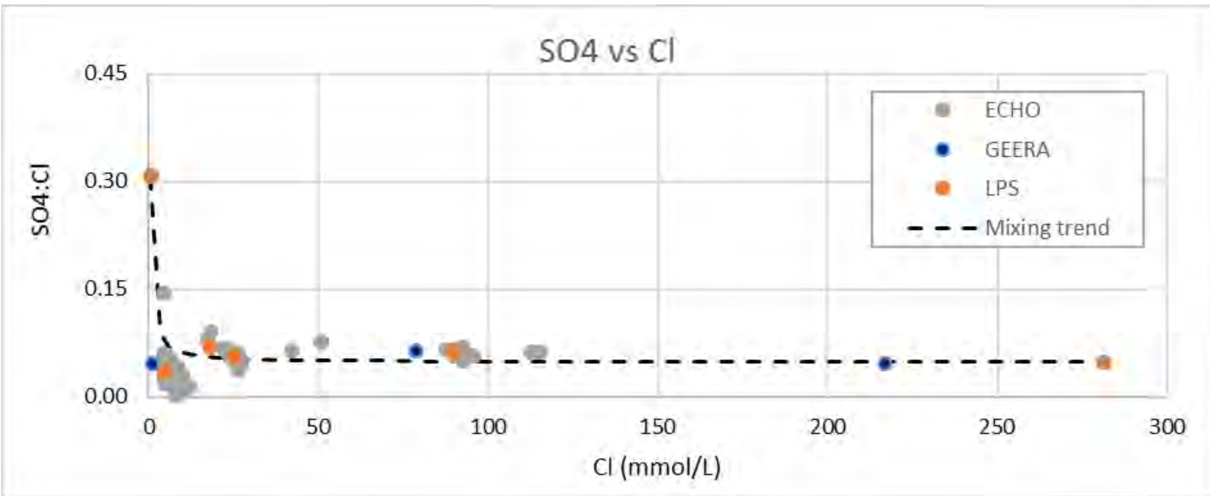

SO4
SO4 (mg/L)
0
100
200
300
400
500
600
700
800
OB03
OB04
OB05
143048
Monitoring Bore

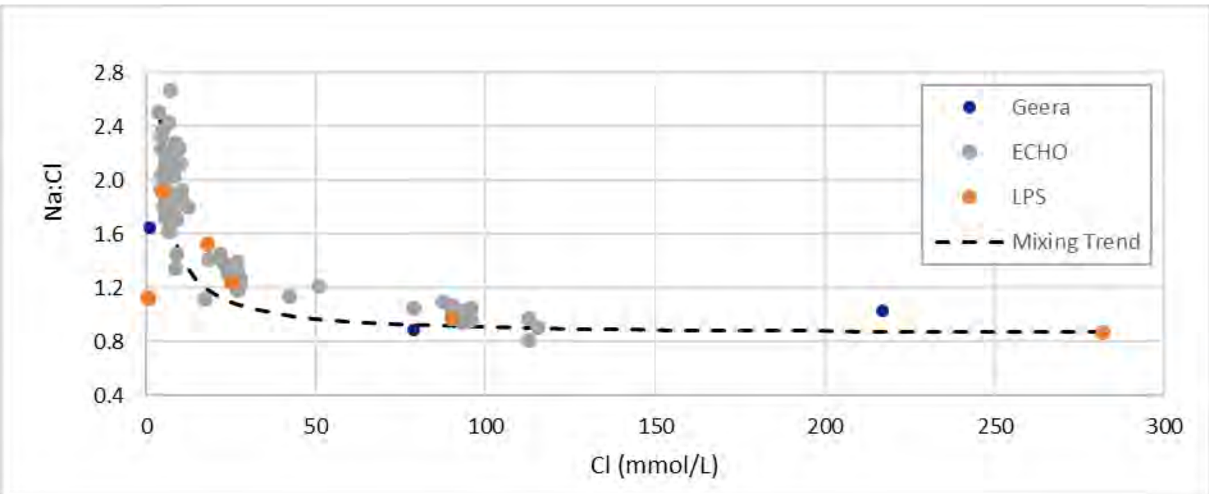

Cl:SO4
Cl:SO4 (molar ratio)
0
20
40
60
80
100
120
140
160
OB03
OB04
OB05
143048
Monitoring Bore

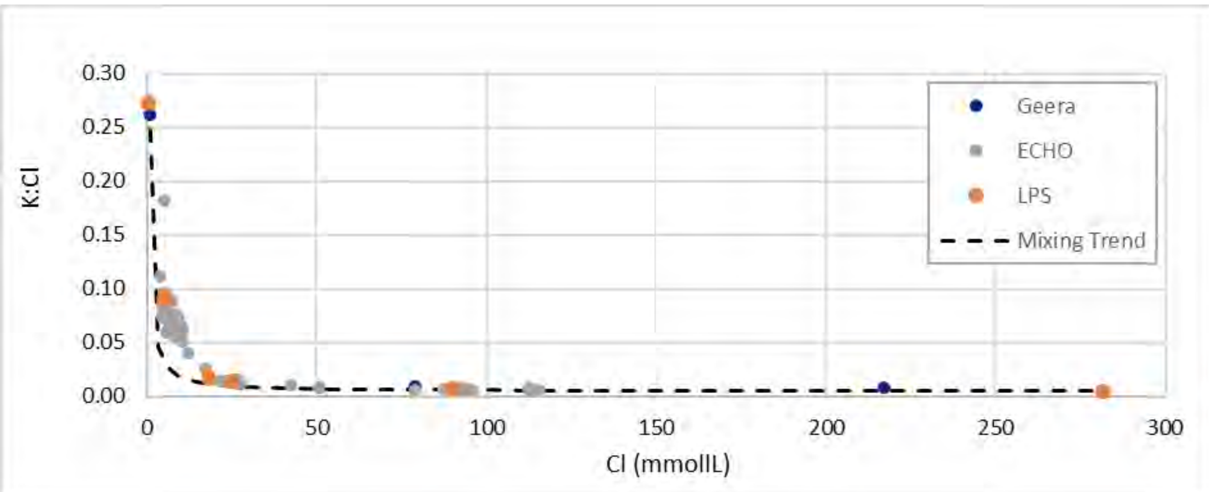

Na:Ca
Na:Ca (molar ratio)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
OB03
OB04
OB05
143048
Monitoring Bore

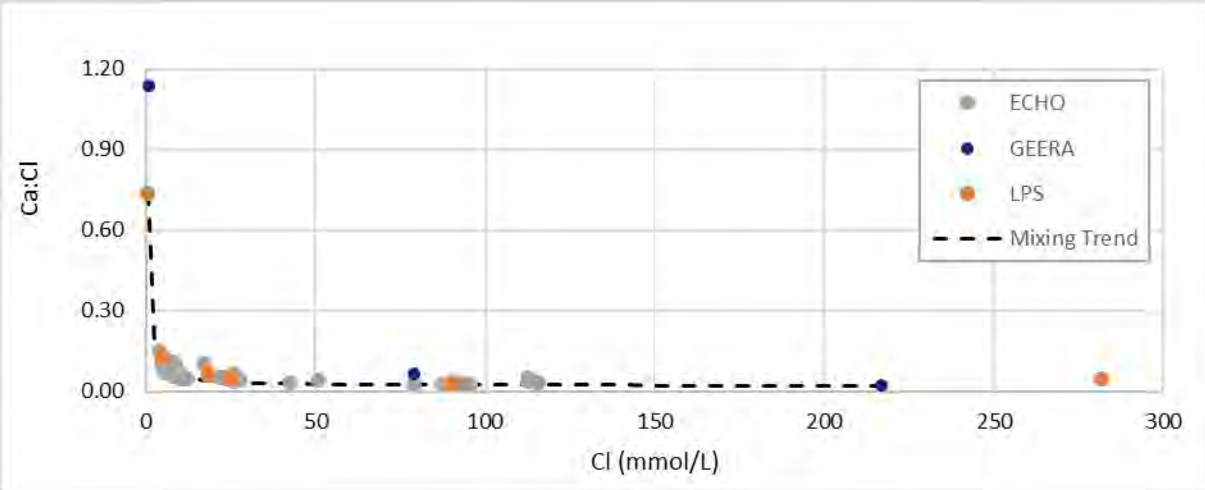

Na:Mg
Na:Mg (molar ratio)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
OB03
OB04
OB05
143048
Monitoring Bore

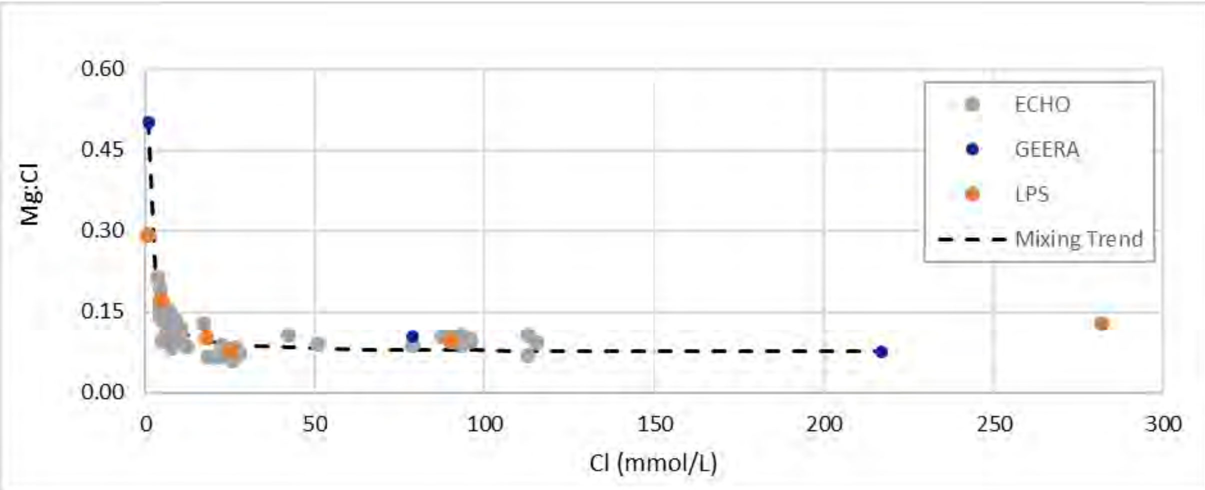
Appendix D. Groundwater chemistry – salinity analysis

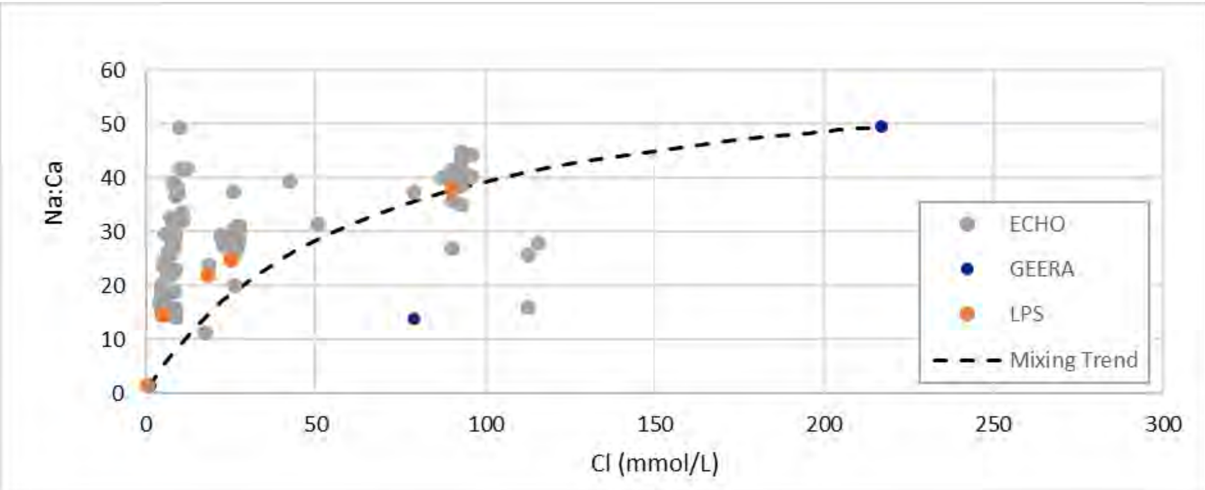







1.20
0.90
0.60
0.30
0.00
Ca:Cl
0
50
100
150
200
250
300
Cl (mmol/L)
ECHO
GEERA
LPS
Mixing Trend


0.60
0.45
0.30
0.15
0.00
Mg:Cl
0
50
100
150
200
250
300
Cl (mmol/L)
ECHO
GEERA
LPS
Mixing Trend


60
50
40
30
20
10
0
Na:Ca
0
50
100
150
200
250
300
Cl (mmol/L)
ECHO
GEERA
LPS
Mixing Trend

Appendix E. Summary Data and laboratory reports

Table 8-1 Summary of laboratory data

ID		112202	112203	143042	143048	143114	143115	OB03	OB04	OB05
Date		11/05/17	11/05/17	14/11/17	13/11/17	14/11/17	15/11/17	13/11/17	13/11/17	13/11/17
Unit		Geera	LPS	LPS	LPS	Geera	Geera	LPS	LPS	LPS
SWL	mAHD	148.46	148.41	153.1	170.63	165.65	142.84	167.735	169.768	171.391
Screen	Top m	36	10	9	24.6	71	57	14.8	18	18
	Bot m	39	13	14	29.6	76	62	20.8	24	24
Ra226	Bq/L	0.11	<0.05	0.19	<0.05	<0.05	0.08	<0.05	<0.05	<0.05
Ra228	Bq/L	0.12	<0.08	0.29	<0.08	<0.08	<0.08	<0.08	<0.08	0.13
U	mg/L	<0.002	<0.002	0.028	<0.002	<0.002	<0.002	<0.002	0.003	0.004
U238	Bq/L	<0.025	<0.025	0.346	<0.025	<0.025	<0.025	<0.025	0.037	0.049
EC	uS/cm	22000	3400	29000	220	470	9100	1300	4100	11000
pH	units	7.2	7.4	6.7	6.8	7.1	7.4	7.1	7.3	7.3
TDS	mg/L	14000	2000	20000	180	330	5500	820	2300	5900
Alk	mg/L CaCO3	310	690	990	56	180	260	350	590	610
HCO3		310	690	990	56	180	260	350	590	610
CO3		0	0	0	0	0	0	0	0	0
OH		0	0	0	0	0	0	0	0	0
SO4	mg/L	970	120	1300	15	<8	480	16	130	560
Cl	mg/L	7700	640	10000	18	32	2800	170	890	3200
F	mg/L	0.42	0.86	0.56	<0.1	0.19	0.28	0.52	0.54	0.46
NH3	mg/L N	0.46	<0.01	0.94	3.6	1.6	0.18	<0.01	<0.01	0.04
NO3	mg/L N	<0.01	2.1	<0.01	<0.01	<0.01	<0.01	0.1	0.01	0.12
NO2	mg/L N	<0.001	0.007	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	<0.001
PO4	mg/L P	<0.004	<0.004	0.008	<0.004	0.034	0.009	<0.004	0.021	0.008
P	mg/L P	0.064	0.012	0.036	0.97	0.2	0.11	0.07	0.048	0.22
An	meq/L	240	35	340	1.9	4.4	95	12	40	110
Cat	meq/L	270	34	340	2	4.8	97	12	38	110
Ca	mg/L	180	50	500	15	41	200	25	50	93
Mg	mg/L	400	45	870	3.6	11	200	20	48	210
Na	mg/L	5100	630	5600	13	34	1600	210	710	2000
K	mg/L	68	12	53	5.4	9.2	27	17	14	23
Al	mg/L	0.26	0.12	3.5	1.1	2.9	1.7	0.32	1.9	10
Sb	mg/L	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	0.002	0.004
As	mg/L	0.001	0.008	0.014	0.009	0.011	0.009	0.012	0.036	0.13
Ba	mg/L	0.026	0.038	0.12	0.011	0.025	0.058	0.047	0.056	0.08
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	mg/L	0.39	1.1	0.78	0.05	0.12	0.46	0.53	0.71	0.69
Cd	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0008
Cr	mg/L	<0.001	<0.001	0.012	0.006	0.003	0.001	<0.001	0.012	0.063
Co	mg/L	<0.001	<0.001	0.004	0.004	0.001	<0.001	<0.001	<0.001	0.007
Cu	mg/L	<0.001	0.002	0.001	0.022	0.001	0.001	<0.001	0.003	0.023
Fe	mg/L	0.16	0.81	2.2	2.9	4.6	1.2	0.61	1.7	16
Pb	mg/L	<0.001	<0.001	0.002	0.052	0.002	0.001	<0.001	0.003	0.38
Mn	mg/L	0.023	0.31	0.068	0.06	0.13	0.075	0.08	0.022	0.11
Mo	mg/L	0.001	0.002	<0.001	0.002	<0.001	<0.001	0.001	0.003	0.003
Ni	mg/L	<0.001	<0.001	0.002	0.008	0.002	0.001	<0.001	0.006	0.017
Se	mg/L	0.003	<0.001	0.009	<0.001	0.001	<0.001	<0.001	0.001	0.01
Ag	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

ID		112202	112203	143042	143048	143114	143115	OB03	OB04	OB05
Date		11/05/17	11/05/17	14/11/17	13/11/17	14/11/17	15/11/17	13/11/17	13/11/17	13/11/17
Sr	mg/L	0.52	3.1	11	0.071	0.33	2.6	0.24	0.59	1.6
Tl	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Th	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.012
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006
Ti	mg/L	0.009	<0.001	0.14	0.023	0.11	0.086	0.011	0.057	0.28
U	mg/L	0.003	<0.001	0.032	<0.001	<0.001	<0.001	<0.001	0.003	0.008
V	mg/L	0.005	<0.001	0.051	0.006	0.013	0.005	0.005	0.037	0.25
Zn	mg/L	0.001	0.005	0.007	0.9	0.008	0.14	0.008	0.033	0.078
Hg	mg/L	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EC	uS/cm	22200	3290	29900	224	454	8880	1241	4000	10920
pH	units'	7.26	7.26	6.63	6.61	7.01	7.36	6.99	7.14	7.15
T	°C	19.1	19.3	17	24	20.6	21.3	18.6	24.8	18.7
DO	mg/L	0.1	55	0.2	1.4	0.1	0.1	1.6	2.8	5.4
Redox	mV	10	0.3		30		-2	208	273	315
Turb	NTU			-17		50				