MOOLARBEN COAL COMPLEX

Extraction Plan Longwalls 104 to 105
Technical Report

Prepared for:

Moolarben Coal Operations
12 Ulan-Wollar Road, Ulan NSW 2850

SLR Ref: 665.10024-R02
Version No: -v2.0
March 2020

PREPARED BY

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
Level 1, The Central Building, UoW Innovation Campus
North Wollongong NSW 2500 Australia

T: +61 404 939 922
E: wollongong@slrconsulting.com   www.slrconsulting.com

BASIS OF REPORT

DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
665.10024-R02-v2.0	4 March 2020	Jackson Newton	Noel Merrick	Noel Merrick
665.10024-R02-v1.0	28 January 2020	Jackson Newton	Claire Stephenson	Claire Stephenson

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1 Introduction

The Moolarben Coal Complex (MCC) is an open cut and underground coal mining operation located approximately 40 kilometres (km) north of Mudgee in the Western Coalfields of New South Wales (NSW) (**Figure 1**).

Moolarben Coal Operations Pty Ltd (MCO) has approval under Project Approval (08_0135) for the extraction of Longwalls 101 - 105 as part of the Underground Mine 1 (UG1) of the Moolarben Coal Complex. MCO is preparing the Extraction Plan amendment to cover Longwalls 104 - 105, which will outline the proposed management, mitigation, monitoring and reporting of potential subsidence impacts and environmental consequences from the secondary extraction of Longwalls 104 - 105. Additional information on the MCC and UG1 is provided in the main text of the Extraction Plan.

This report responds to a request from MCO for a groundwater technical report for the Extraction Plan for UG1 Longwalls 104 - 105 of the Moolarben Coal Complex (**Figure 2**). The report will support the Water Management Plan component of the Longwalls 104 - 105 Extraction Plan and addresses relevant aspects of Project Approval (08_0135) Schedule 4 Condition 5 (h).

1.1 Scope of Work

This report pertains to Longwalls 104 – 105. It:

- provides a summary of outcomes of previous studies including hydrogeology, subsidence and potential groundwater impacts;
- outlines a monitoring program for monitoring the impacts of Longwalls 104 – 105 extraction;
- proposes trigger levels and management responses for the impacts of Longwalls 104 – 105 extraction;
- provides data analysis of key bores with respect to observed groundwater levels to date;
- confirms the location and saturated extent of the Tertiary palaeochannel definition in the vicinity of Longwalls 104 – 105 following analysis of additional investigation bores; and
- provides conclusions in regard to how the analysis in this report supports the findings of previous groundwater modelling assessments.

The scope of work includes review of the Approved Layout of Longwalls 104 – 105, as presented in the HydroSimulations (2017c) groundwater and shown in **Figure 3**. This Extraction Plan Layout for Longwalls 104 – 105 is largely in line with the Approved Layout but includes a reduction in the longwall lengths by approximately 70 m.

2 Background

Stage 1 at the MCC has been operating for several years, and at full development will comprise three open cut mines (OC1, OC2 and OC3), a longwall underground mine (UG4), and mining related infrastructure (including coal processing and transport facilities) (**Figure 2**).

Stage 2 at the Moolarben Coal Complex has commenced and at full development will comprise one open cut mine (OC4), two longwall underground mines (UG1 and UG2) and mining related infrastructure (**Figure 2**).

The UG1 underground mine is a component of the approved Moolarben Coal Complex (**Figure 2**). The UG1 Underground Mine commenced first workings in April 2016 and commenced secondary workings (longwall extraction) in October 2017 by longwall mining methods from the Ulan Seam within Mining Lease (ML) 1605, ML 1606, ML 1628, ML 1691 and ML 1715 (**Figure 3**).

The most recent assessment and approval for UG1 was the UG1 Optimisation Modification (Project Approval 08_0135 [Stage 2] Mod 2), which assessed the currently Approved Layout for UG1 (Longwalls 101 - 105) (**Figure 3**).

Several groundwater investigations, assessments and reviews have been undertaken since 2006 to assess the potential impacts of the approved MCC. Recent groundwater assessments undertaken for the approved Moolarben Coal Complex include:

- Moolarben Coal Complex Stage 2 PPR Groundwater Impact Assessment, November 2011 (RPS Aquaterra, 2011);
- Moolarben Coal Project Stage 1 Optimisation Modification Groundwater Assessment (AGE, 2013);
- Moolarben Coal Complex Stage 2 PPR Response to Submissions Additional Groundwater Impact Assessment (RPS Aquaterra, 2012);
- Moolarben Coal Complex Optimisation Modification Groundwater Modelling Assessment (HydroSimulations, 2015a); and
- Moolarben Coal Open Cut Optimisation Modification Groundwater Assessment (HydroSimulations, 2017c)

Project Approval 08_0135 Condition 5(h) of Schedule 4 includes the requirement that the UG1 Extraction Plan Water Management Plan includes a program to:

[1] confirm the location and saturated extent of the palaeochannel adjacent to the extents of underground 1 second workings, including drilling of additional investigation bores;

[2] validate, and if necessary revise, the groundwater model for the palaeochannel; and

[3] monitor and report on the groundwater impacts of underground 1 second workings on the palaeochannel; and a program to monitor and report on the predicted groundwater impacts on the paleochannel adjacent to underground 1 boundary.

These requirements were addressed during and subsequent to the preparation of the Extraction plan for longwall panels 101 to 103, and are discussed in relevant sections within this report. Groundwater monitoring and management at the Moolarben Coal Complex is conducted in accordance with the Water Management Plan, and the UG1 Longwalls 101 to 103 Water Management Plan.

2.1 Climate

Daily rainfall data is collected by MCO from the MCC Rainfall Station (ID WS3_M4). The closest Bureau of Meteorology (BoM) weather station is located at Wollar (Station 062032), approximately 16 km to the south-east of the Project. Data collected at Wollar from January 1901 until December 2019 was used for assessing the long-term rainfall trends in the vicinity of the Project. **Table 1** compares the long-term average monthly rainfall measured at Wollar against rainfall measured at Wollar and on Site over 2019. It shows how intense rain events in January and March caused the month to exceed average rainfall at both Wollar and at Site, with below average rainfall experienced in all other months of 2019.

Table 1 Monthly rainfall data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average monthly rainfall (mm)†	66.5	61.9	53.0	38.7	37.5	43.8	41.9	40.8	41.2	50.7	55.7	59.6	591.3
2019 Rainfall (mm) – Wollar	72.0	5.0	110.5	0.0	20.0	6.0	4.0	10.0	23.0	7.0	30.0	6.0	293.5
2019 Rainfall (mm) – Site Data	113.4	4.4	130.4	0.6	21.6	12.2	3.8	9.6	31.2	7.6	19.2	6.0	360.0

Note: † Based on averaged daily rainfall data (site measurement) February 2007 to present.
*Data up to 31st October

Rainfall trends for Wollar over the past century are indicated by analysis of the cumulative rainfall departure (CRD) (**Figure 4**). The CRD shows trends in rainfall relative to the long-term average and provides a historical record of relatively wet periods and droughts. A rising trend in slope in the CRD plot indicates periods of above average rainfall for the given sample period, whilst a declining slope indicates periods when rainfall is below the mean for that sample period. As shown in **Figure 4**, in general the project area has experienced below average rainfall since the end of 2016. As shown in **Figure 5**, which presents CRD and monthly rainfall from 2010 to 2020, the positive trends observed over 2019 relate to the above average rain events recorded during January and March. Across 2019 the CRD continued a declining trend owing to the below average rainfall received during the period.

2.2 Hydrogeological Regime

The Moolarben Coal Complex area is located in the Western Coalfields on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks of Triassic and Permian age, including coal measures. The dominant outcropping lithologies over the Moolarben Coal Complex are the Triassic Narrabeen Group (Wollar Sandstone) and the Permian Illawarra Coal Measures. The siltstones and sandstones of the Triassic Narrabeen Group form elevated, mesa-like incised plateaus associated with the Goulburn River National Park and the Munghorn Gap Nature Reserve.

2.2.1 Alluvial Aquifers

Quaternary alluvial deposits in the vicinity of the Moolarben Coal Complex are associated with Lagoon Creek, Goulburn River, Moolarben Creek and Wilpinjong Creek.

There is no 'highly productive' groundwater, as defined under the Aquifer Interference Policy (AIP) (NSW Government, 2012), mapped in the vicinity of the Moolarben Coal Complex. The nearest 'highly productive' groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

2.2.2 Tertiary Palaeochannel Deposits

Tertiary palaeochannel deposits have been recognised in the Goulburn River diversion (at Ulan) and in the Murragamba and Wilpinjong creek valleys, with a thickness of 40 m to 50 m. Palaeochannels are remnants of inactive river or stream channels that have been later filled in or buried by younger sediment. The infill sediments consist of poorly-sorted semi-consolidated quartzose sands and gravels in a clayey matrix.

A range of drilling and geophysical investigations has been conducted to better define the thickness and the extent of the palaeochannel to the north-east of UG1. HydroSimulations (2017b) determined that the modified UG1 mine layout for Longwalls 101 - 103 would not pass beneath any water-bearing palaeochannel sediments and identified further investigations to be undertaken for LW 104 and 105. Further investigations have been undertaken to further define the palaeochannel extent in the vicinity of LW104 - 105 and are presented in **Section 7**.

2.2.3 Porous Rock Groundwater Systems

The porous rock groundwater systems include the Narrabeen Group sandstones and the Illawarra Coal Measures, consisting of coal seams, conglomerate, mudstones and siltstones.

None of the identified groundwater systems are significant aquifers for groundwater abstraction. The most permeable units are the Ulan Seam and Marrangaroo Conglomerate, while the sandstones of the Narrabeen Group are of lower permeability and are elevated above the Moolarben Coal Complex. The Illawarra Coal Measures also include low permeability mudstones and siltstones.

Recharge to the groundwater systems would occur primarily from direct rainfall and runoff infiltration. The Permian and Triassic groundwater systems in the vicinity of the Moolarben Coal Complex are primarily recharged at outcrop and subcrop locations. Where the Triassic and/or Permian strata are overlain by alluvium, colluvium or highly weathered bedrock, additional recharge may occur from these unconsolidated surficial materials.

There are no high priority culturally significant sites listed in the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009. However, a spring known as The Drip is a groundwater dependent ecosystem (GDE) with local cultural significance. This water feature is likely to be fed from perched water in the Sandstone north of the Goulburn River and is not considered relevant to this Extraction Plan as it is located more than 6 km to the north of the UG1 mine and there is no likely mechanism for impact from the extraction of Longwalls 104 - 105.

2.3 Mining

The Moolarben Coal Complex includes four approved Open Cut pits and three approved underground mines. Current mining operations at the Moolarben Coal Complex are occurring in UG1, OC2 and OC4. Moolarben Underground 1 is located adjacent to OC1 (to the north-west), OC2 (to the west) and OC4 (to the south-east). Extraction of LW104 and 105 is expected to be undertaken from 2020 until 2022.

The Moolarben Coal Complex is located adjacent to the Ulan Mine to the north-west and Wilpinjong Mine to the east, both of which target the Ulan Seam of the Permian aged Illawarra Coal Measures. Groundwater assessments include these neighbouring operations.

2.4 Groundwater Use

Groundwater usage in the area is primarily composed of mine dewatering for the Moolarben Coal Complex and the neighbouring Ulan Mine Complex and Wilpinjong Coal Mine.

There is one privately owned bore (GW800279) in the vicinity of the Moolarben Coal Complex, located approximately 6 km to the north of UG1 Longwalls 104 – 105 (**Figure 8**). The bore is a relatively shallow bore (24 m) developed in Triassic strata and connected to the river alluvium. The predicted drawdown is less than the 2 m minimal impact considerations as specified under the AIP.

2.5 Subsidence

Potential subsidence impacts for the Approved Layout for the UG1 longwalls (Longwalls 101 - 105) were assessed by MSEC (2015), and subsequently approved (subject to conditions), as part of the approved UG1 Optimisation Modification.

MSEC (2020) reviewed the layout for Longwalls 104 - 105 for the Extraction Plan (referred to as the Extraction Plan Layout) and concluded:

"…the overall impact assessments for the natural and built features based on the Extraction Plan Layout are unchanged, or reduce compared to those based on the Approved Layout."

The comparison of the maximum predicted subsidence parameters resulting from the extraction of Longwalls 104 - 105, based on the Extraction Plan Layout, with those based on the Approved Layout is provided in **Table 2**. The values are the maxima anywhere above longwall layouts.

It can be seen that the maximum predicted total subsidence parameters based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 104 - 105. Whilst the specific values of the maximum tilt and curvatures are not shown, due to these representing the localised irregular movements rather than the macro (i.e. overall) movements, these parameters do not change (MSEC, 2020).

Table 2 Comparison of Maximum Predicted Conventional Subsidence Parameters based on the Approved Layout and the Extraction Plan Layout

Layout	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
Approved Layout (LW104-105)	2400	> 100	> 3	> 3
Extraction Plan Layout	2400	> 100	> 3	>3

Source: MSEC 2019

In regard to potential for subsidence-related surface cracking, MSEC (2020) states:

"The depths of cover over the underground mining areas vary from 47 m to 165 m. Where the depths of cover above Longwalls 104 to 105 are less than 100 m, surface cracking is expected to be typically in the order of 150 to 200 mm wide, but could be as large as 500 mm wide where the depths of cover are the shallowest. The surface crack widths are likely to be smaller where the depths of cover are greater, or where the surface cracks result from the travelling wave. Where the depths of cover above Longwalls 104 to 105 are 100 to 150 m, the surface crack widths are expected to be typically in the order of 100 to 150 mm wide."

The extent of potential cracking predicted by MSEC (2020) for the Extraction Plan Layout is consistent with the Approved Layout.

3 Potential Groundwater Impacts

HydroSimulations (2015a) presents potential impacts associated with the Approved Layout. The Extraction Plan Layout would result in the same, or lower, potential impacts in comparison to the Approved Layout (as assessed and approved for the UG1 Optimisation Modification), given:

- The Longwalls 104-105 lengths have been reduced from those that were simulated by approximately 70 m.
- MSEC (2020) predicts potential subsidence impacts for the Extraction Plan Layout would be the same or lower than those for the Approved Layout.
- Groundwater modelling revised to reflect updated palaeochannel extents identifies negligible change to predicted groundwater inflows.

Details on the numerical groundwater model design are included in **Section 3.1** and model results are discussed in **Section 3.1.4**. Additional to this a risk assessment was conducted for the Longwall 101 to 105 extraction plan as outlined in **Section 3.3**.

3.1 Groundwater Modelling

HydroSimulations (2017c) conducted the groundwater impact assessment for the now approved site operations (Approved Layout) as part of the Open Cut Optimisation Modification.

The HydroSimulations 2017 model was used as part of the groundwater impact assessment and captures operations at MCC open cut mining with approved MCC underground mining and approved mining at the Ulan and Wilpinjong coal mines. Therefore, the HydroSimulations (2017c) numerical groundwater model was utilised to understand the groundwater impacts associated with the Extraction Plan Layout.

Since the groundwater assessment by HydroSimulations (2017c), additional investigations have better defined the paleochannel extent, as summarised in **Section 7**. The groundwater model was updated to include the paleochannel features; however, no other changes to the model were made. Model updates resulting from the palaeochannel definition also satisfy Condition 2 outlined in **Section 7.1**. A brief summary of the design and construction of the groundwater model is included in **Sections 3.1.1** to **Section 3.1.4**; full details are included in HydroSimulations (2017c). Details on the updates to the model are included in **Section 3.1.4**.

3.1.1 Model Objectives

A regional scale model was developed to be capable of replicating groundwater trends and response to mining at MCC as well as nearby Ulan and Wilpinjong mines. The objectives of the modelling for this study include the ability of the model to:

- quantify groundwater interception (direct and indirect) as a result of mining at longwalls 104 and 105;
- predict groundwater level change (drawdown) as a result of mining at longwalls 104 and 105;
- predict any contribution to drawdown at private landholder bores as a result of mining at longwalls 104 and 105; and
- update the model to incorporate findings from paleochannel investigation and predict if this contributes any changes to predictions relevant to longwalls 104 and 105.

3.1.2 Model Code and Design

The HydroSimulations (2017c) model uses MODFLOW-USG Beta (Panday *et al.*, 2013) with the AlgoMesh v1.2 user interface (HydroAlgorithmics, 2017). The model extends approximately 55 km from west to east and approximately 60 km from north to south, covering an area of approximately 3,000 km^2 and comprises of 11 layers and a total of 848,753 cells. Further details on the groundwater model are summarised in HydroSimulations (2017c).

The groundwater model layers are listed below:

- Layer 1: Quaternary Alluvium / Tertiary Palaeochannel / Base of Weathering.
- Layer 2: Tertiary Palaeochannel / Base of Weathering (below alluvium) / Jurassic.
- Layer 3: Upper Triassic.
- Layer 4: Lower Triassic.
- Layer 5: Upper Permian.
- Layer 6: Middle Permian.
- Layer 7: Lower Permian.
- Layer 8: Ulan Seam (A1 to C lower).
- Layer 9: Ulan Seam (Working Section 2).
- Layer 10: Marrangaroo Formation.
- Layer 11: Basement.

3.1.3 Timing and Calibration

Transient model calibration was conducted from January 2005 to March 2017. Calibration achieved a satisfactory Scaled Root Mean Square (SRMS) performance measure of about 4.6%, and a mass balance error of less than 0.01%.

The prediction period was run from April 2017 to the end of 2038 to simulate extraction for the full duration of approved MCC open cut and underground mining and approved mining at the Ulan and Wilpinjong coal mines.

3.1.4 Model Updates and Scenarios

The conceptualisation of the groundwater regime was revised to include an updated palaeochannel zone in layers 1 and 2 as discussed in **Section 7.3**. The palaeochannel zone extends about 500 m north-west and south-west, as shown in **Figure 7**. The zone was assigned higher permeability of 3.0 m/day and 0.6 m/day horizontal and vertical hydraulic conductivity, respectively. The scaled RMS with model updates applied is 4.7 % compared to the previous 4.6 %, with a negligible water balance change of approximately 0.1 ML/day less storage gain during the calibration period.

Two models were run to allow identification of UG1-only impacts:

- Approved Run – All approved mining; and
- Null UG1 Run – All approved mining excluding UG1.

3.2 Groundwater Modelling Results

The numerical groundwater model was used to predict groundwater impacts associated with the Extraction Play Layout, and specifically the extraction of LW104 and LW105 in 2020 to 2022.

The predicted UG1-only mine inflow is about 3.1 ML/day (1131 ML/year) in 2020 and decreases to 2.3 ML/day (840 ML/year) in 2022 at the completion of LW105 mining.

The incremental drawdown due to UG1 mining has been calculated by subtracting the Approved Run water levels from the Null UG1 Run water levels. Predicted drawdowns in model Layer 1 for the alluvium/regolith and the Tertiary palaeochannel at the end of Longwall 105 mining are shown in **Figure 7.** Predicted 0.5 m drawdown contours are located on the northern edge of the LW 105 panel beside the previous palaeochannel outline and 2 m drawdown contours are located on the extended north-west palaeochannel area in **Figure 7**. Drawdowns greater than 2 m are predicted in Layer 1 regolith in the central section of LW103, and along the north-eastern end of LW105.

The revised groundwater model has been used to assess the effects of the updated palaeochannel, and review the sensitivity to possibly higher fracturing, on mine inflows to UG1, as well as palaeochannel alluvial takes. The findings are:

- Negligible changes to UG1 mine inflow.
- Negligible differences for the alluvial takes during UG1 mining.
- Negligible effect on any mine inflows if fracturing of the palaeochannel sediments is assumed.

In summary, and consistent with previously approved impacts:

- Negligible differences for the alluvial takes during UG1 mining.
- No private bores are likely to be affected by 2 m drawdown or more, with all located outside the 2 m drawdown area.
- No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry above UG1.
- With the exception of drawdown in the Permian overburden and Ulan Seam in the north-eastern extents of UG1, there would be no discernible change in drawdown resulting from UG1 extraction.
- The Ulan Seam has no productive water use other than for mining purposes.
- No change to beneficial use category is anticipated.

3.3 Risk Assessment

On 30 January 2020, a team consisting of MCO operational, technical and environmental staff and specialist consultants participated in a facilitated environmental risk assessment (ERA) workshop on the UG1 Longwalls 104 - 105 inclusive. The water issues identified by the risk assessment included impacts on groundwater level, quality and take.

The ERA indicated that risks relevant to groundwater for Longwalls 104-105 were as low as reasonably practicable (ALARP) or tolerable after the effective implementation of the identified controls.

4 Monitoring Program

4.1 Groundwater Monitoring

Groundwater monitoring at the MCC is currently undertaken in accordance with the complex-wide Groundwater Management Plan (GMP) (MCO, 2018). The objectives of the GMP are to establish baseline groundwater quality and water level data and to implement a program of data collection that can be utilised to assess potential impacts of mining activities on the groundwater resources of the area.

In February 2020 a revised version of the GMP was provided by MCO to the Department of Planning and Environment, which describes MCO's proposed improvements to the current GMP. The description of monitoring and management below is consistent with the revised GMP dated February 2020.

The groundwater monitoring network currently consists of monitoring sites distributed across all major hydrogeological units, comprising of standpipe (SP) sites and multi-level vibrating wire piezometer (VWP) sites. The standpipe piezometers can be used for monitoring water level either manually or with an automated datalogger, as well as for collection of water samples for groundwater quality monitoring purposes. The VWPs are grouted and therefore can only be used for monitoring groundwater pressures.

A sub-set of the monitoring network which is most relevant to UG1 Longwalls 104 - 105 is detailed in **Table 3**, with bore locations provided in **Figure 8**.

The assessment of riparian vegetation undertaken by Ecovision Consulting for the Stage 2 EA did not indicate any specific riparian plant communities that could be considered groundwater dependent ecosystems (GDEs) and therefore no specific groundwater monitoring for riparian vegetation communities is required.

4.2 Groundwater Inflows

Since commencement of UG1 first workings in April 2016, underground dewatering has been monitored by means of flowmeters on dewatering lines. Dewatering volume is a combination of groundwater inflows, supply and recirculation from adjacent open cuts.

Water supply to the underground workings is also monitored. Groundwater take determinations consider water balance reconciliations, groundwater model predictions, licensed extractions and recirculation to underground.

4.3 Groundwater Levels

Table 3 details the monitoring program for groundwater levels at monitoring bores relevant to UG1 Longwalls 104 - 105. The piezometers will be monitored manually on a monthly basis, or continuously by means of automatic dataloggers, as detailed in **Table 3**.

PZ130 within the UG1 Longwalls 104 - 105 area has VWPs that might be disrupted as mining progresses in these areas. The more elevated piezometers in PZ130 have more chance of survival. PZ170 is proposed to be decommissioned prior to mining LW105 to manage risks due to air ingress into the underground workings.

Table 3 Groundwater Bores Relevant to UG1 Longwalls 104-105

Bore	Type	Depth (m)	Screened Interval (mbgl)	Lithology Screened	Water Level Monitoring Frequency	Historical Water Level Range (mbgl)	Water Quality Monitoring Frequency	Date Established	Licence No.	Easting (GDA 94 Z55)	Northing (GDA 94 Z55)
PZ127*	VWP	152	43	Triassic	Datalog Reported monthly	Dry	N/A	23/11/2007	20BL173935	762799	6424948
			68	Permian overburden	Datalog Reported monthly	47.2 - 52.1	N/A				
PZ130*	VWP	111	38.5	Permian overburden	Datalog Reported monthly	37.7 - 40.4	N/A	29/11/2007	20BL173935	760940	6422438
			64	Permian overburden	Datalog Reported monthly	51.6 - 58.9	N/A				
			97	Ulan Seam	Datalog Reported monthly	79.3 - 88.2	N/A				
PZ186	VWP	118	13.5	Palaeochannel Alluvium	Datalog Reported monthly	TBC	N/A	28/01/2020	20BL173935	764788	6425865
			40	Upper Permian	Datalog Reported monthly	TBC	N/A				
			65	Middle Permian	Datalog Reported monthly	TBC	N/A				
			86	Lower Permian	Datalog Reported monthly	TBC	N/A				
			118	Ulan Seam	Datalog Reported monthly	TBC	N/A				
PZ188	SP	18.5	12 - 18	Palaeochannel	Datalog	7.29 - 8.40	6 months	14/05/2009	20BL173935	764478	6426084

Bore	Type	Depth (m)	Screened Interval (mbgl)	Lithology Screened	Water Level Monitoring Frequency	Historical Water Level Range (mbgl)	Water Quality Monitoring Frequency	Date Established	Licence No.	Easting (GDA 94 Z55)	Northing (GDA 94 Z55)
				Alluvium	Reported monthly						
PZ189	SP	65	59 - 95	Permian overburden	Datalog Reported monthly	10.41 - 14.90	6 months	20/05/2009	20BL173935	764503	6426089
PZ179	VWP	145	29	Triassic	Datalog Reported monthly	24.6 - 28.0	N/A	4/07/2008	20BL173935	764688	6426599
			33	Permian overburden	Datalog Reported monthly	25.8 - 32.7	N/A				
			145	Ulan seam	Datalog Reported monthly	28.9 - 71.4	N/A				
PZ170*	SP	31	26 - 29	Permian overburden	Datalog Reported monthly	14.68 - 16.56	6 months	17/03/2008	20BL173935	763591	6424306
PZ211		20	17-20	Tertiary paleochannel	Datalog Reported monthly	Dry	6-monthly	24/7/2017	20BL173935	763442	6426146
PZ213		22	20-22	Tertiary paleochannel	Datalog Reported monthly	TBC	6-monthly	25/7/2017	20BL173935	764341	6425229
PZ214		25	22-25	Tertiary paleochannel	Datalog Reported monthly	TBC	6-monthly	27/7/2017	20BL173935	764135	6425720

* To be lost/decommissioned by mining.

4.4 Groundwater Quality

Table 4 details the monitoring program for groundwater quality at monitoring bores relevant to UG1 Longwalls 104 - 105. Samples are taken six-monthly and sent for laboratory analysis of key parameters (**Table 4**).

Field measurements of EC and pH are recorded at the time of water quality sampling conducted for relevant bores. No change is required for the Longwalls 104 - 105 Extraction Plan.

Table 4 Groundwater Quality Monitoring Program

Class	Parameters
Physical parameters	EC, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), and pH
Major cations	Calcium, magnesium, sodium, potassium
Major anions	Carbonate, bicarbonate, chloride, and sulphate
Dissolved metals	Aluminium, arsenic, boron, cobalt, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc
Nutrients	Ammonia, nitrate, phosphorus, reactive phosphorous
Other	fluoride

4.5 Streamflow

Streamflow monitoring forms part of the surface water monitoring regime. Streamflow monitoring is undertaken in Wilpinjong creek. The streamflow data from this program will inform the monitoring of stream baseflows (i.e. net groundwater discharge to the stream system) throughout the life of the Moolarben Coal Complex. Streamflow monitoring is discussed further in the existing complex-wide Surface Water Management Plan.

4.6 Climate Monitoring

Climate monitoring data are collected from an automatic weather station on site.

The recorded rainfall data are used to differentiate between natural groundwater level variations caused by rainfall induced recharge, and abstraction induced variations due to mining or groundwater pumping[1]. For shallow unconfined aquifers there is a direct and often immediate relationship between rainfall and groundwater level. For deeper aquifers this relationship often holds but with a time-lagged and muted response.

[1] By calculation of rainfall residual mass (cumulative deviation from the mean), and observation of abstraction timing.

5 Trigger Levels and Management Response

MCO evaluates the environmental performance of the Moolarben Coal Complex against the predictions of impact made in Environmental Assessment documents and the performance measures described in the complex-wide GMP.

Periodic review of performance is undertaken by comparison of observed monitoring results against model predictions. The performance is assessed in terms of specific parameters by the application of trigger levels which are used to initiate a response action, as detailed in the following sections.

MCO has established trigger values to determine the need for investigation and possible response actions for potential impacts to groundwater levels and quality in the alluvial and Triassic groundwater systems.

The Permian strata are already extensively affected by past mining, are predicted to undergo significant further impact from ongoing mining at the Moolarben Coal Complex, the Ulan Mine Complex and the Wilpinjong Coal Mine, and contain groundwater of generally poor quality. Accordingly, trigger levels have not been set for the monitoring piezometers screened in the Permian.

5.1 Groundwater Quality Triggers

In accordance with the Groundwater Management Plan the ANZECC (2000) guidelines for Fresh and Marine Water Quality apply to the quality of both surface waters and groundwaters. These guidelines were developed to protect environmental values relating to above ground uses such as irrigation and stock use.

ANZECC (2000) recommends that wherever possible site specific data be used to define trigger values for physical and chemical factors which can adversely impact the environment, rather than using ANZECC guideline values.

Groundwater monitoring results indicate that baseline values of pH and EC in the vicinity of the Moolarben Coal Complex vary across a wide range and can be outside the ANZECC (2000) guideline values for ecosystem protection. Therefore, site specific trigger levels based on the baseline data have been developed for monitoring the impact of the Moolarben Coal Complex.

5.1.1 Salinity Triggers

Table 1 of the NSW Aquifer Interference Policy sets out the minimal impact considerations for aquifer interference activities for less productive groundwater sources, including (inter alia):

- Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.

The alluvial WSP that regulates the alluvial water sources does not designate beneficial uses for the alluvial aquifers in the vicinity of the Moolarben Coal Complex. The fractured and porous rock WSP does not designate beneficial uses for the groundwater (i.e. groundwater within the porous rock water groundwater system) in the vicinity of the Moolarben Coal Complex.

The following beneficial uses were recommended by the National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia for major (or significant) aquifers and have been adopted by the NOW in its Groundwater Quality Protection Policy (Department of Land and Water Conservation, 1998):

- ecosystem protection;
- recreation and aesthetics;
- raw water for drinking water supply; and
- agricultural water and industrial water.

The National Land and Water Resources Audit (Murray Darling Basin Commission, 2005) specified groundwater quality ranges for beneficial use categories based on salinity (**Table 5**). These salinity based categories generally align with the beneficial uses within the NSW Groundwater Quality Protection Policy.

Table 5 Groundwater Quality Categories: Electrical Conductivity

Beneficial Use	Quality Range	Description
Potable	Up to 800 µS/cm (500 mg/L TDS)*	Suitable for all drinking water and uses.
Marginal Potable	800-2,350 µS/cm (500-1,500 mg/L TDS)*	At the upper level this water is at the limit of potable water, but is suitable for watering of livestock, irrigation and other general uses.
Irrigation	2,350-7,800 µS/cm (1,500-5,000 mg/L TDS)*	At the upper level, this water requires shandying for use as irrigation water or to be suitable for selective irrigation and watering of livestock.
Saline	7,800-22,000 µS/cm (5,000-14,000 mg/L TDS)*	Generally unsuitable for most uses. It may be suitable for a diminishing range of salt-tolerant livestock up to about 6,500mg/L [~10,150 µS/cm] and some industrial uses.
Highly Saline	> 22,000 µS/cm (14,000 mg/L TDS)*	Suitable for coarse industrial processes up to about 20,000 mg/L [~31,000 µS/cm].

Note: * Approximate EC ranges derived from TDS ranges, with conversion Factor of 1.5625 applied.
Source: National Land and Water Resources Audit (Murray Darling Basin Commission, 2005)

Salinity investigation triggers have been developed based on the 95th percentile baseline salinity level recorded at each relevant bore location where sufficient data is available. Should a measured salinity level exceed the investigation trigger for two consecutive monitoring events the groundwater Trigger Action Response Plan described in the complex wide GMP will be initiated.

The bore in **Table 6** (a sub-set of those in the complex wide GMP) is considered to be relevant for investigating potential changes in groundwater quality due to longwall mining of Longwalls 104 -105. The recommended salinity trigger (from the revised GMP dated February 2020) is also presented in **Table 6**. It can be observed that trigger level is well below the beneficial use category threshold.

Table 6 Salinity and pH Trigger Levels

Bore	Depth (m)	Lithology Screened	Salinity Triggers			pH Trigger Level (5th to 95th percentile)*
			Historical lab EC (5th to 95th percentile) (µS/cm)*	EC Trigger Level (µS/cm)	Beneficial Use Category Based on Lab EC 95th Percentile	
PZ188	18.5	Palaeochannel Alluvium	198 – 394 (245)	394	Potable	4.7 – 6.9 (5.5)

Note: * NB. Historical values in brackets are median values

5.1.2 pH Triggers

pH triggers have been developed from the 5th and 95th percentile baseline pH levels recorded at bore locations considered relevant to Longwalls 104 – 105 and where sufficient data is available. Should a measured pH level exceed the trigger for two consecutive monitoring events, the groundwater Trigger Action Response Plan described in the complex wide GMP will be initiated. Recommended trigger values (from the revised GMP dated February 2020) are presented in **Table 6**.

5.2 Groundwater Level Triggers

Investigation triggers for measured groundwater levels have been reviewed taking into account minimal impact considerations in the AIP.

There is no 'highly productive' groundwater, as defined in the AIP, mapped in the vicinity of the Moolarben Coal Complex. The nearest 'highly productive' groundwater is a portion of the alluvial aquifer associated with Wilpinjong Creek downstream of the Wilpinjong Coal Mine.

The AIP describes the following minimal impact considerations for less productive groundwater sources:

- Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m 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.

A maximum of a 2m decline cumulatively at any water supply work.

There are no high priority GDEs or high priority culturally significant sites identified in the alluvial WSP or fractured and porous rock WSP in the vicinity of the Moolarben Coal Complex.

Groundwater level triggers have been developed to identify drawdown trends that could potentially lead to a private bore being impacted (i.e. experiencing great than 2 m drawdown). These water level triggers are based on baseline monitoring data to date and have been developed by a suitably qualified secretary-approved hydrogeologist. Trigger values are set at 50% of the minimum saturated bore depth of designated groundwater trigger monitoring bores to enable detection of any significant adverse mining related impacts to other groundwater users.

The Trigger Action Response Plan described in the complex wide GMP will be initiated following two consecutive monthly monitoring rounds outside the trigger levels to determine whether the cause of water level/pressure decline is a result of MCO's mining activity, including borefield pumping, and to recommend an appropriate response action, if required.

The bores in **Table 7** (which are a sub-set of those in the complex wide GMP) have been selected as representative bores for monitoring potential changes in groundwater levels due to underground mining in Longwalls 104 - 105.

Table 7 Trigger Groundwater Levels – Alluvium Bores

Piezometer Number	Base of Alluvium/Tertiary Palaeochannel (mAHD)	Interval/Level Monitored (mbgl)	Minimum Observed Groundwater Level/Pressure		Trigger Level (mAHD)
			(mbgl)	(mAHD)	
PZ188	403.6	12 – 18	10.0	413.7	409.4
PZ213	387.6	20 - 22	13.7	413.8	409.7
PZ214	397.0	22 - 25	16.8	413.9	409.8

6 Data Analysis

6.1 Key Palaeochannel Alluvium Bores

The key palaeochannel alluvium monitoring bores pertinent to Longwalls 104 - 105 are:

- PZ187 – 1.0 km from the takeoff line for Longwall 103 (replaced by PZ186 VWP);
- PZ188 – 0.8 km from the takeoff line for Longwall 103;
- PZ213 – above the takeoff line for longwall 105; and
- PZ214 – 0.5 km from the takeoff line for longwall 104.

Time-series graphs of groundwater level, EC and pH are provided in **Figure 13** - **Figure 16**, **Figure 25** - **Figure 28**, and **Figure 34** - **Figure 37**.

PZ187, PZ188, PZ213, and PZ214 have a similar groundwater level response which correlates well with the rainfall trend represented by the CRD on the figures, without any significant time lag. This suggests that the water levels are controlled by direct vertical infiltration of rainwater, with possible contributions from coincident streamflow.

The groundwater quality is, in general, fresh at all sites and is moderately acidic.

6.2 Key Permian Overburden Bores

The key Permian overburden monitoring bores pertinent to Longwalls 104-105 are:

- PZ170 – over longwall 105;
- PZ186 – 1.0 km from the takeoff line for Longwall 103 (converted to VWP);
- PZ189 – 0.8 km from the takeoff line for Longwall 103.

Time-series graphs of groundwater level, EC and pH are provided in **Figure 17** - **Figure 19**, **Figure 29** - **Figure 31**, and **Figure 38** - **Figure 40**.

PZ186 and PZ189 have similar groundwater level patterns. The responses correlate well with the rainfall trend with a time lag observed. Current water levels at PZ186 are about 30 m lower than the overlying palaeochannel alluvium bore (PZ187). The current water level at PZ189 is about 13 m lower than the overlying alluvium bore (PZ188). This suggests that the water levels are controlled by direct vertical infiltration of rain water through the alluvium. Bore PZ170 displays a similar declining trend to PZ186 and PZ189, with a lower response to the CRD observed. All bores for this unit are outside the predicted zone of drawdown for this unit with the exception of PZ170 which is expected to have a 0.8 m decline in water level.

The groundwater quality is fresh at bores PZ188 and PZ189 with a moderately acidic pH. Bore PZ170 displays saline water quality with a moderately acidic pH.

6.3 Key Ulan Seam Bores

The key Ulan Seam monitoring bores pertinent to Longwalls 104-105 are:

- PZ104 – about 2.7 km north-east of the takeoff line for Longwall 105;
- PZ191– about 1.7 km north-west of the takeoff line for Longwall 101.

Time-series graphs of groundwater level, EC and pH are provided in **Figure 20** - **Figure 21**, **Figure 32** - **Figure 33**, and **Figure 41** - **Figure 42**.

PZ104 and PZ191 both display declining water levels in response to drier than average conditions as observed in the CRD as well as effects from current mining consistent with approved impacts. As a result of LW104-105 mining, an additional 3.6 m of drawdown is predicted at bore PZ104, with no additional drawdown predicted for PZ191. The CRD response at PZ104 shows a time lag of approximately 11 months. These responses suggest that the water levels are predominantly controlled by vertical infiltration of rain water into the coal seam at outcrop/subcrop, with lateral migration of a pressure response through the seam.

In mid-2019, there was an abrupt decline in groundwater level by about 15m to ~349 mAHD observed at PZ191. This decline is consistent with predicted drawdown associated with approved operations. Groundwater levels have since recovered to approximately 357 mAHD and have remained stable since December 2019.

The groundwater quality at bore PZ104 is saline with a strongly alkaline pH. Groundwater quality at bore PZ191 is brackish to marginal with recent pH measurements fluctuating between strongly acidic and neutral pH in line with water level fluctuations.

6.4 Key VWP Bores

The key multi-level VWP monitoring bores pertinent to Longwalls 104-105 are:

- PZ127 – over the pillar between Longwalls 102 and 103;
- PZ130 – over the pillar between Longwalls 104 and 105;
- PZ179 – 1.3 km from the takeoff line for Longwall 102.

Time-series graphs of groundwater level are provided in **Figure 22** - **Figure 24.**

At each site there is a fairly consistent vertical gradient indicative of downwards groundwater movement.

At PZ127, only the Ulan Seam VWP (141 m) shows any correlation with rainfall trend, and it appears considerably lagged in time. PZ130 shows no correlation with rainfall trends as observed in the CRD. In addition, the head in the Ulan Seam (97 m) (about 450 mAHD) appears anomalously high. Both PZ130 and PZ127 are in the vicinity of basalt intrusions.

PZ179 Triassic (29 m) and Permian overburden (33 m) VWPs show some relation to the CRD with the exception of a recent rising trend. The Ulan Seam VWP (145 m) show a gradual declining water level likely in response to mining at UG1 and drier than average conditions observed in the CRD.

As a result of LW104-105 mining, the following is predicted:

- 28 m additional drawdown at PZ127 in the Permian overburden.
- Approximately 11 m additional drawdown at PZ130 in the Permian overburden and no additional drawdown in the Ulan Seam.
- Approximately 3 m additional drawdown at PZ179 in the Permian overburden and ~7 m additional drawdown in the Ulan Seam.

7 Tertiary Palaeochannel Definition

7.1 Objective

Further investigation into the extent and saturation status of the Tertiary Palaeochannel has been undertaken in consideration of UG1 LW104 and LW105 to:

[1] confirm the location and saturated extent of the palaeochannel adjacent to the extents of underground 1 second workings, including drilling of additional investigation bores;

[2] validate, and if necessary revise, the groundwater model for the palaeochannel; and

[3] monitor and report on the groundwater impacts of underground 1 second workings on the palaeochannel; and a program to monitor and report on the predicted groundwater impacts on the paleochannel adjacent to underground 1 boundary.

7.2 Investigations

In relation to item [1] in **Section 7.1** [Objectives], numerous investigations into the location and saturated extent of the Tertiary palaeochannel have been undertaken including additional drilling and geophysical investigations. The following presents an overview of investigations conducted in 2019 by HydroSimulations and SLR including:

- Description of data reviewed to define the extent of palaeochannel as shown in the HydroSimulations (2015a) report for the UG1 Modification.
- Additional investigation works undertaken since the UG1 LW101-103 Extraction Plan that have been incorporated into the palaeochannel definition work.

The preparation of UG1 LW101 to 103 Extraction Plan included a review of the saturated extent of the palaeochannel (Hydrosimulations, 2017b; HS2017/08) based on the available drilling, resistivity traverses and a transient electromagnetics (TEM) survey by Groundwater Imaging Pty Ltd (2014). Report HS2017/03 concluded that the "UG1 mine layout for Longwalls 101-103 would not pass beneath any water bearing palaeochannel sediments" and that "*the edge of the palaeochannel near the LW104-105 takeoff lines has not been completely resolved*". Recommendations were made for further drilling and geophysics to assist in resolution of the palaeochannel extent and installation of additional monitoring bores north-east of LW105 .

In accordance with these recommendations, PZ213 was installed north-east of LW105 and three additional holes were drilled: MCR503, MCR504 and MCR505. Following review of the additional holes, additional drilling was recommended.

Field investigation in 2019 was conducted by Groundwater Exploration Services (GES) Pty Ltd in association with MCO personnel[2]. This included a passive seismic survey along five transects using the Moho Tromino tool. This tool responds to natural shear waves and claims to be responsive to the thickness of lower-velocity material (e.g. alluvium and weathered rock) above higher-velocity hard rock (e.g. Permian coal measures). The initial images (**Figure 9**) show a zone of high normalised amplitudes 10-20 m thick down to 70 m maximum depth; drilling, however, revealed sands typically down to about 30 m depth.

[2] Based on information provided in email communications from GES from March to June 2019.

Ten additional holes were drilled at locations shown in **Figure 10** and downhole geophysics was run with natural gamma and density sondes in four holes (MCR826, MCR827, MCR829 and MCR830). Each hole maintains a water table at 14.6 ± 5.2 m below ground level (mbgl). The water level elevations are all similar at 413.9 ± 0.9 mAHD, as shown in **Figure 11 [a]**. Water salinities, however, vary substantially from a minimum of 280 µS/cm near the Longwall 105 take-off, to a maximum of about 3,800 µS/cm at the most southerly bore (**Figure 11 [b]**). The median salinity of about 1,500 µS/cm indicates that the water in the palaeochannel is more saline to the south of the previously interpreted boundary in the vicinity of LW104 and LW105. This finding is consistent with previous findings of elevated conductivities in the electrical resistivity and TEM surveys. The only low salinity value (at MCR826, near the take-off) is similar to the values at PZ214 (183 µS/cm) and PZ213 (420 µS/cm) in the main channel beneath the SE Mains (**Figure 11 [b]**).

Aquifer testing was conducted at three of the investigation holes (MCR853, MCR855, and MCR867) and two monitoring bores (PZ213 and PZ214). All tests were pumping tests using low-flow submersible pumps with rates from 2.5 to 6 litres/minute. Drawdown responses were analysed with Aqtesolv software assuming a leaky-confined conceptual model and the screen interval as the effective aquifer thickness. Within the main channel beneath the SE Mains, the interpreted horizontal hydraulic conductivity ranges between about 1 and 4 m/day. South of the Longwall 105 take-off, the interpreted horizontal hydraulic conductivity has a similar range (1-3 m/day) except for site MCR867 (0.1 m/day) which is likely to be close to the palaeochannel boundary.

An extensometer over Longwall 102 gave displacement patterns that suggest a height of fracturing between 61 m and 67 m (sensor depths 85 m and 79 m) (**Figure 12**). The Ditton fracture zone height is 65 m or 85 m for an assumed spanning beam thickness of 40 m or 20 m, respectively. The 95th percentile (A95) is 103 m for 20 m spanning beam thickness (**Figure 12**). As the groundwater model has conservatively applied the A95 height for 20 m spanning beam thickness, the vertical extent of fracturing is overestimated at this location.

7.3 Summary of Findings – Palaeochannel Definition

With reference to Item [1], the location and saturated extent of the palaeochannel adjacent to the extents of underground 1 second workings has been defined.

The field investigations of 2019 suggest that the saturated Tertiary palaeochannel extends southwards to a position where the base of Tertiary material reaches about 413 mAHD, beyond which the Tertiary/Permian interface rises in elevation. As the average water level was found to be about 414 mAHD, it is unlikely that saturated alluvium would be present to the south and west of the 413 mAHD Tertiary/Permian interface contour.

Towards the edge of the palaeochannel, the sediments are likely to be dominated by colluvium derived from Triassic sandstone and would have progressively lower permeability as the edge is approached. The investigations have shown the deterioration in water quality (as EC) southwards from the approved Longwall 105 take-off line. Higher permeability coupled with higher salinity, as observed at MCR855, could indicate pockets of isolated Tertiary alluvium or stagnant conditions as indicated by the low hydraulic gradients measured in the investigations of 2019.

It is concluded that the additional investigations in 2019 have now defined the location and saturated extent of the palaeochannel adjacent to UG1.

With reference to Item [2], the groundwater model was updated to reflect the revised palaeochannel extent and permeabilities. The hydraulic conductivities have been increased conservatively in the model to the highest value found in the three aquifer tests in the palaeochannel area.

No revision has been made of the estimated fracture heights. The extensometer results over Longwall 102 suggest that the Ditton heights are overestimated, and consequent quantification of palaeochannel alluvial takes is thereby conservative.

With reference to Item [3], the revised groundwater model has been used to assess the effects of the extended palaeochannel, and possibly higher fracturing, on mine inflows to UG1and alluvial takes. The findings are:

- Negligible changes to UG1 mine inflow.
- Negligible differences for the alluvial takes during UG1 mining.
- Negligible effect on any mine inflows for assumed fracturing of the palaeochannel sediments.

Monitoring of “predicted groundwater impacts on the palaeochannel adjacent to underground 1 boundary” will be satisfied by continued monitoring at PZ213 and PZ214.

8 Conclusion

The key findings of this Longwalls 104 - 105 Extraction Plan groundwater technical report review are:

- Additional investigations in 2019 have now defined the location and extent of the paleochannel adjacent to UG1.
- The additional bores and groundwater modelling found that Longwalls 104 – 105 will pass below water-bearing palaeochannel sediments with a maximum drawdown of up to 2 m predicted.
- The groundwater model was revised to reflect the revised palaeochannel extents, and higher permeabilities to the central core of the channel.
- The revised groundwater model found:
    - Negligible changes to UG1 mine inflow.
    - Negligible differences for the alluvial takes during UG1 mining.
    - Negligible effect on any mine inflows for assumed subsidence induced fracturing of the palaeochannel sediments.
    - No private bores are likely to be affected by 2 m drawdown or more. No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry. With the exception of drawdown at the level of the Permian and Ulan Seam in the north-eastern extents of UG1, there would be no discernible change in drawdown resulting from UG1 extraction.
- The Ulan Seam has no productive water use other than for mining purposes. No change to beneficial use category is anticipated.
- Monitoring bores from the existing monitoring network located in close proximity to Longwalls 104 – 105 are suitable to monitor groundwater levels and quality and confirm potential impacts are consistent with those previously assessed and approved.
- Groundwater level and quality trigger levels established for these bores (as per the GMP dated February 2020) with investigation protocols to be implemented should triggers be exceeded (as identified by monitoring) are suitable for the UG1 Longwalls 104 – 105 Extraction Plan.

This review, based on currently available records, indicates no material groundwater impacts from mining of Longwalls 104 - 105 beyond what was assessed and approved in the Moolarben Coal Complex UG1 Optimisation Modification Groundwater Modelling Assessment (HydroSimulations, 2015a) are expected.

9 References

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APPENDIX A

Figures

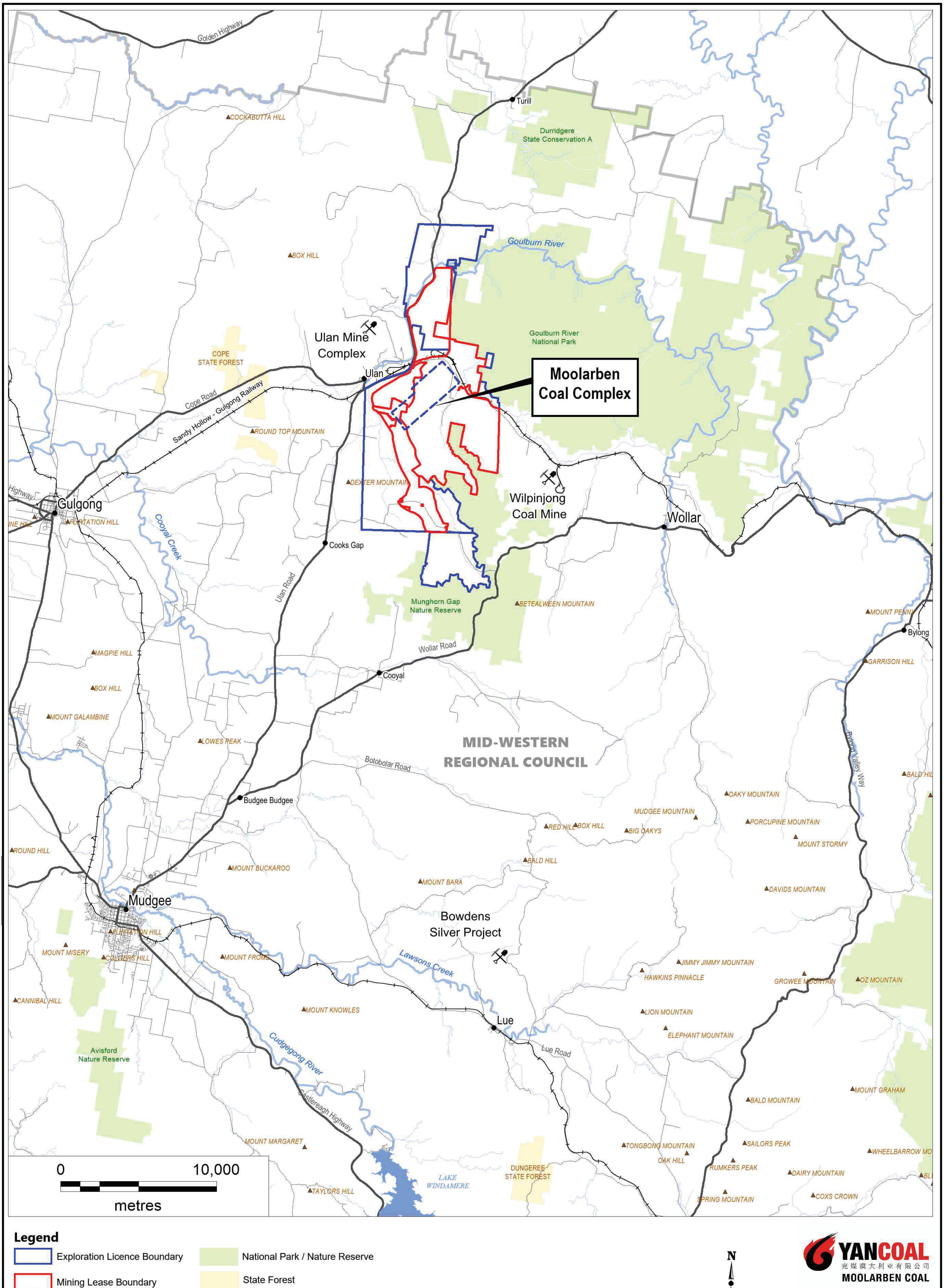


Figure 1
Regional Location

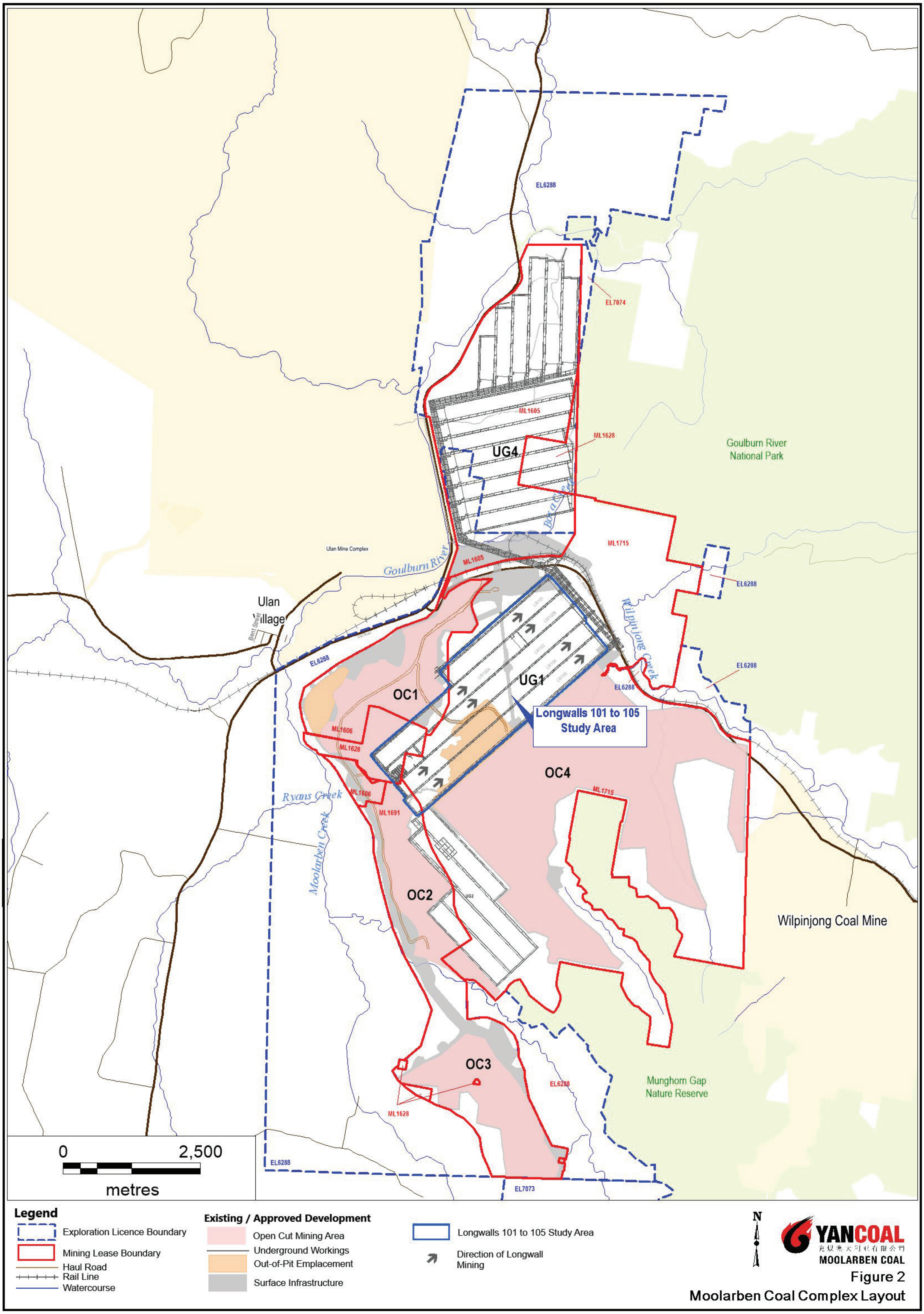
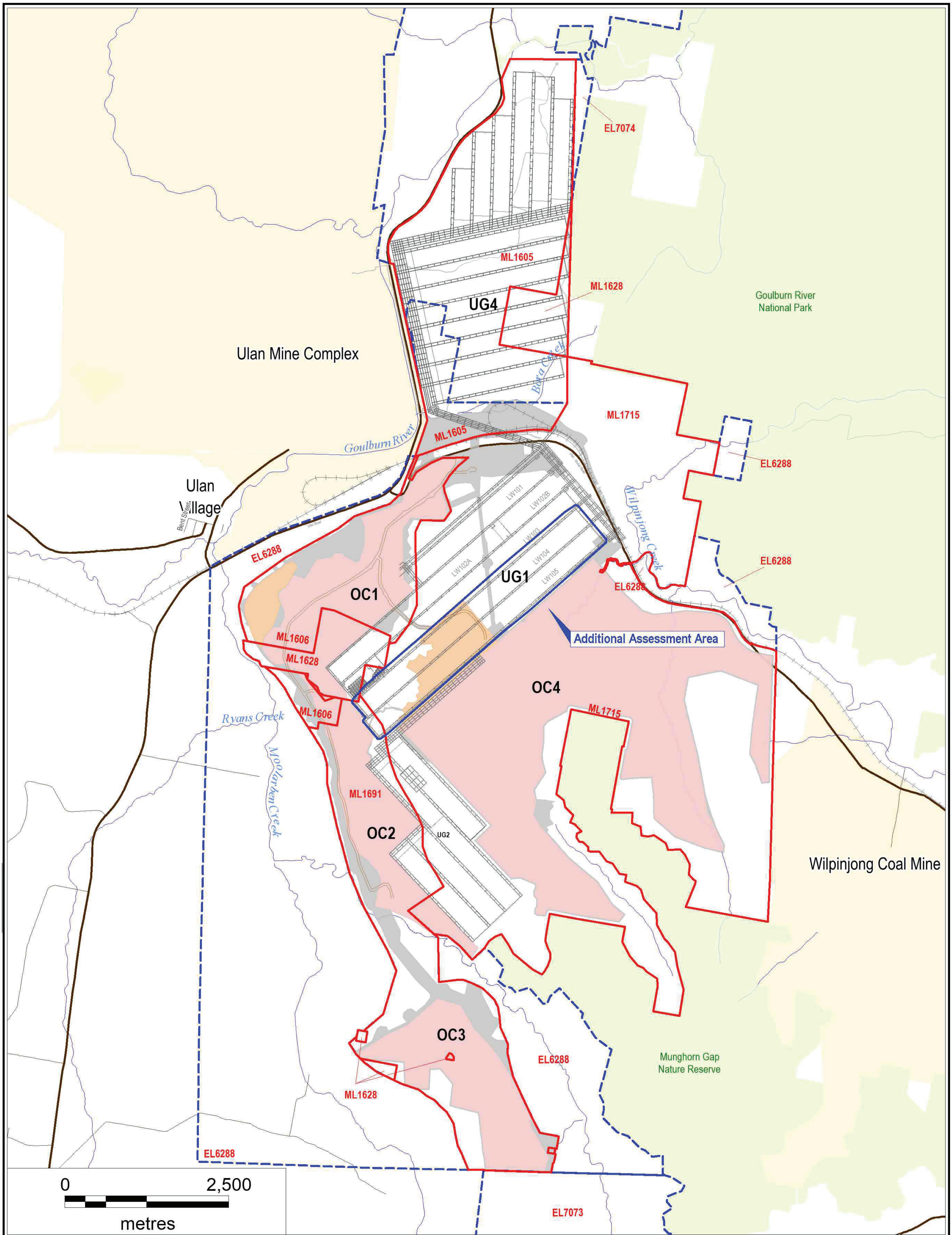


Figure 2

Moolarben Coal Complex Layout



LEGEND

- Mining Lease Boundary
- Exploration Licence Boundary
- Underground Workings
- Open Cut Mining Area
- Out of Pit Emplacement Area
- Surface Infrastructure
- Additional Assessment Area
- Roads
- Rail Line
- Watercourse

N

YANCOAL
MOOLARBEN COAL

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Additional Assessment Area

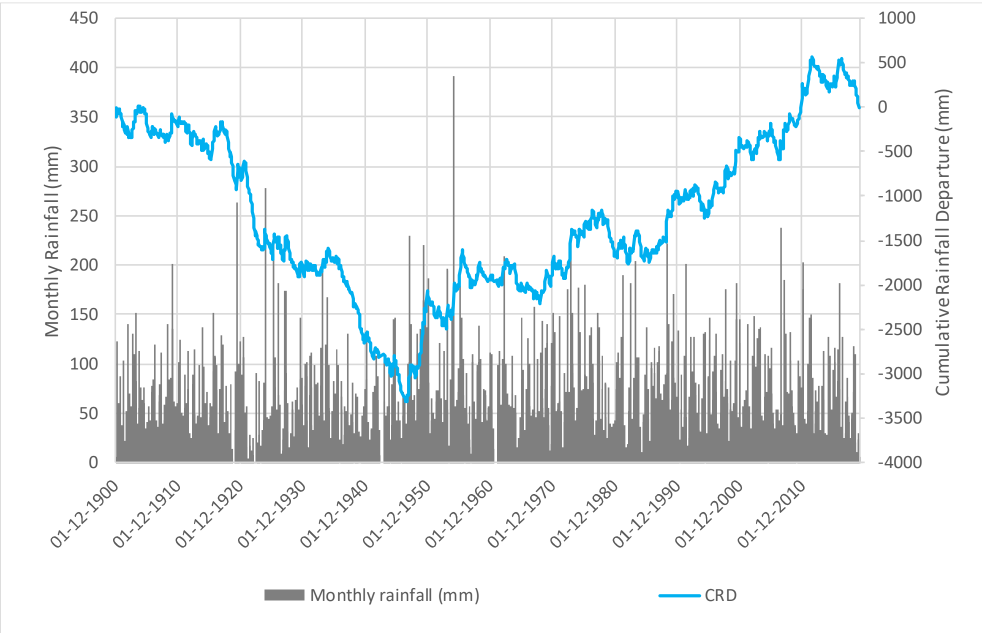

Figure 4 Monthly Rainfall and Cumulative Rainfall Departure (Wollar Station 062032) – All Data

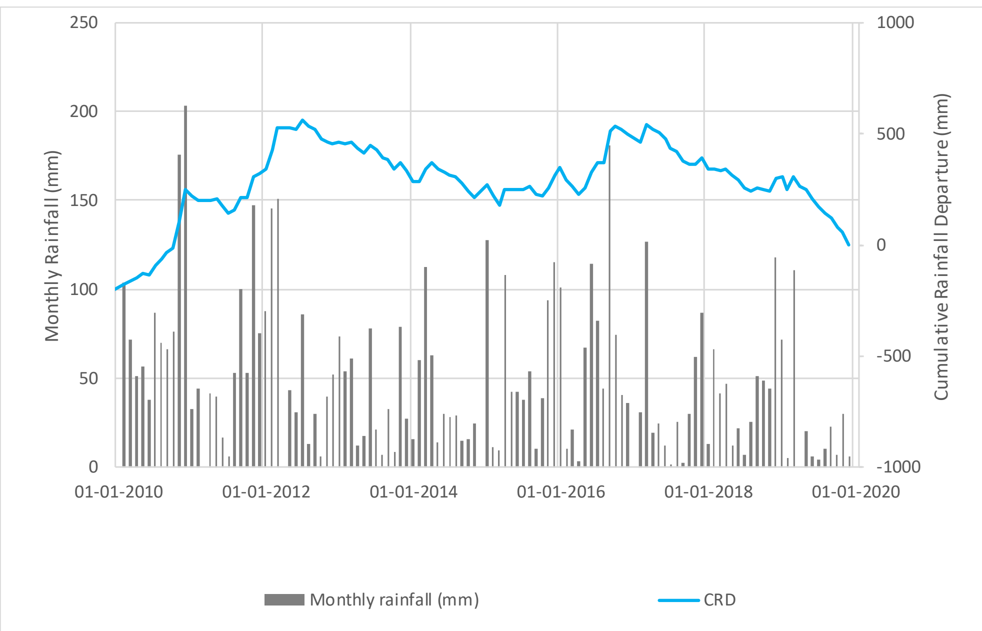

Figure 5 Monthly Rainfall and Cumulative Rainfall Departure (Wollar Station 062032) – 2010 to 2020

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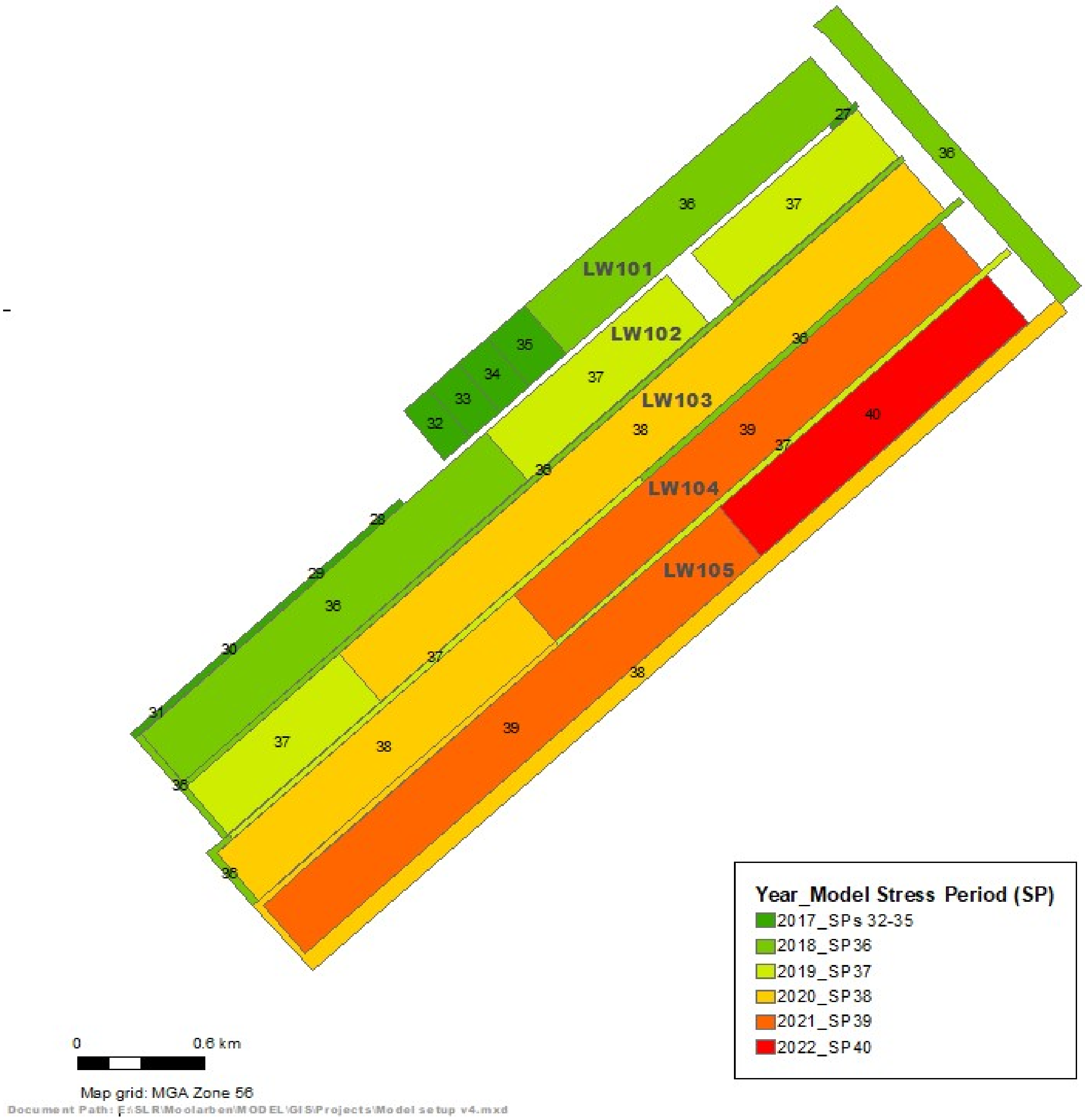

Figure 6 UG1 Mine Plan and Model Stress Period

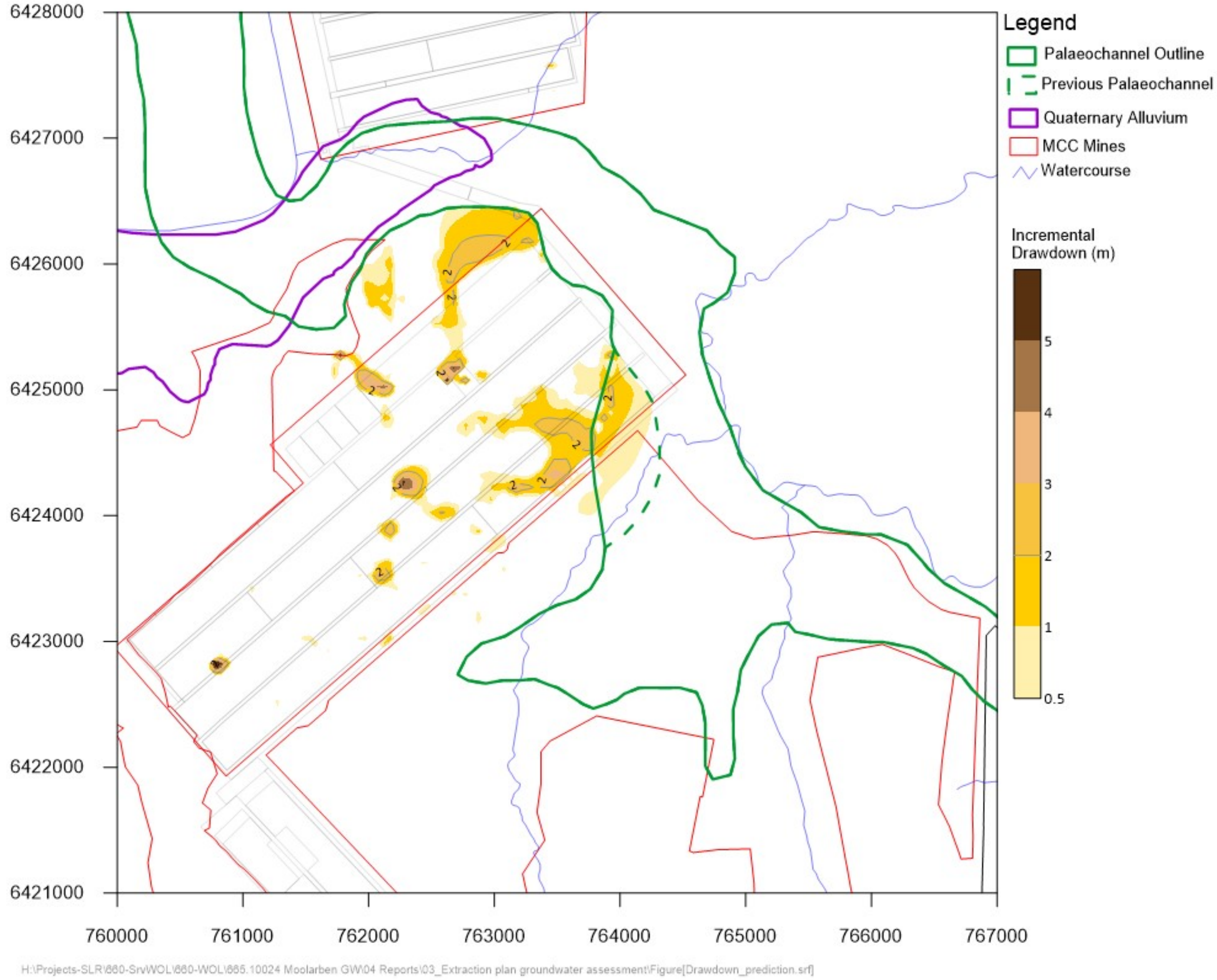

Figure 7 Predicted Drawdown at End of Longwall 105 Mining – Layer 1

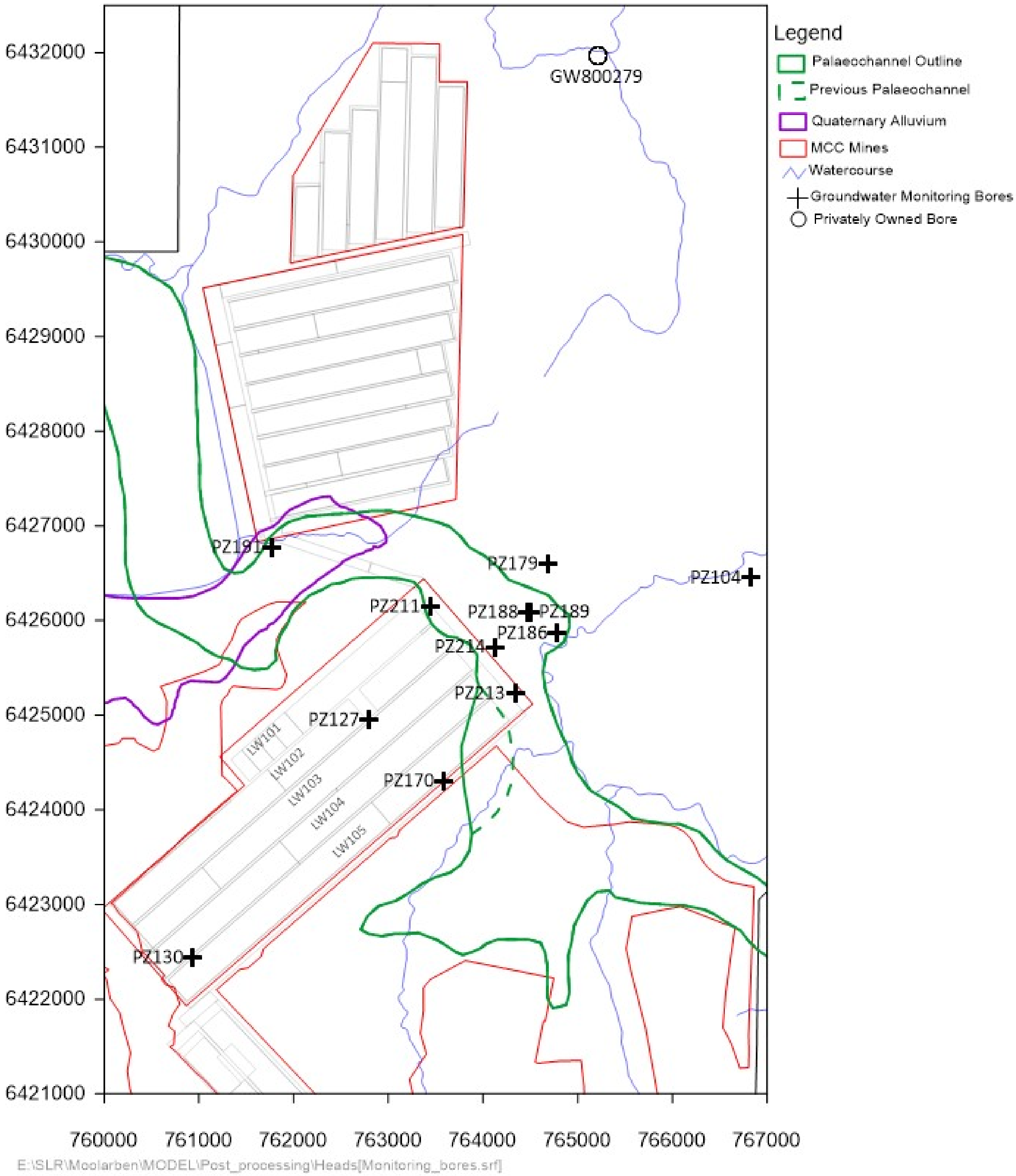

Figure 8 Groundwater Monitoring Bores Most Relevant to UG1 Longwalls 104-105

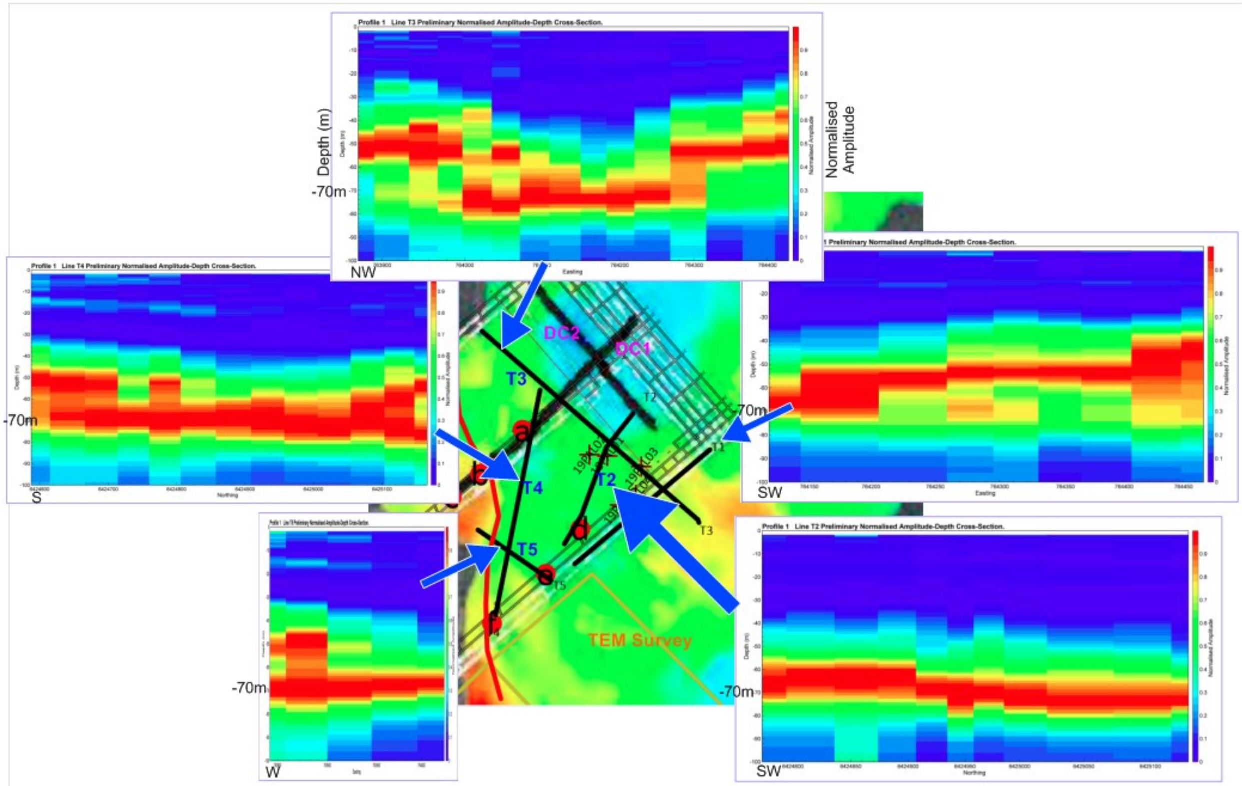

Figure 9 Location of Seismic Traverses T1 to T5 with Initial Indications of Geometry at the Hard Rock Interface

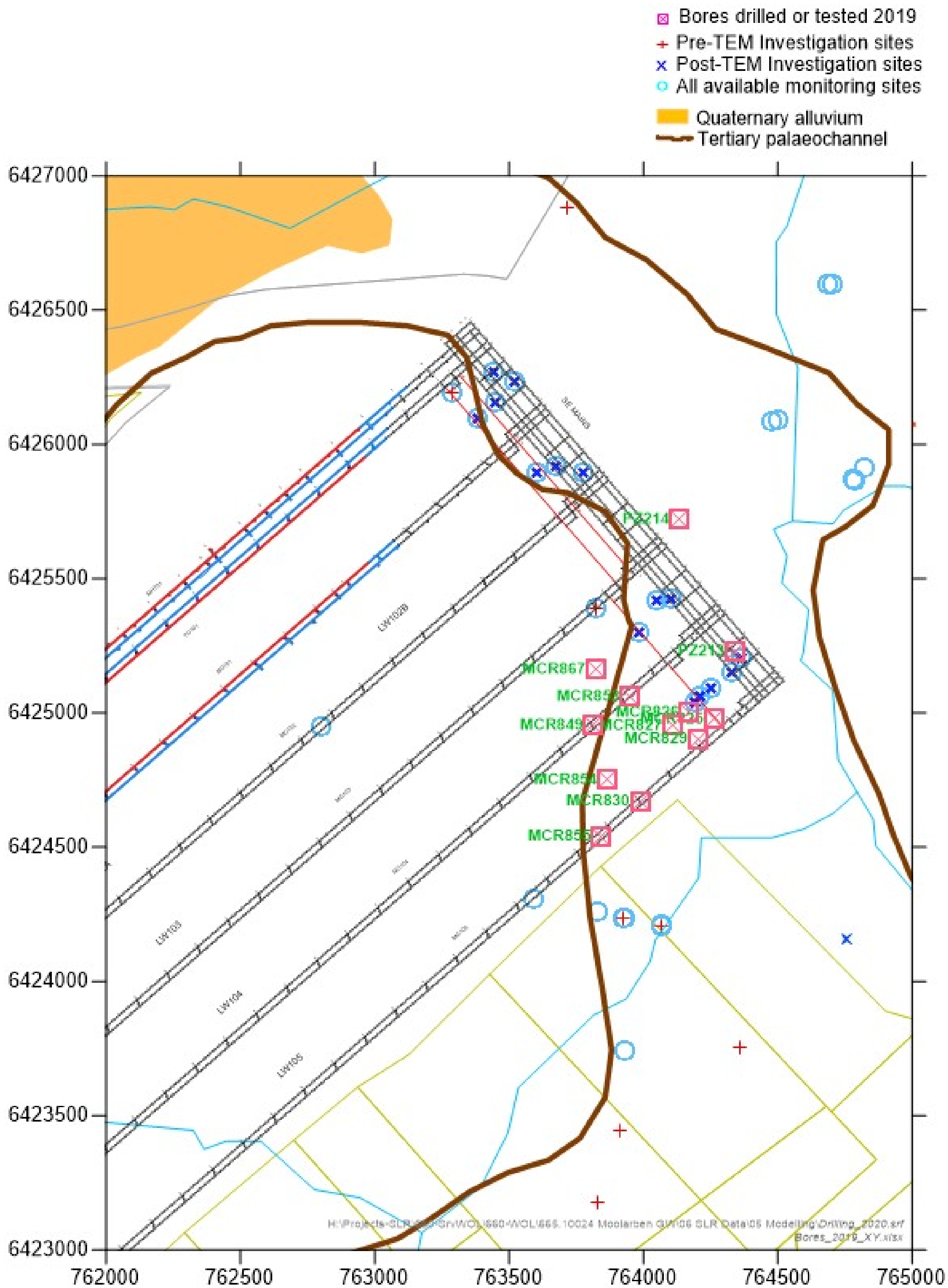

Figure 10 Locations of Bored Drilled or Tested in 2019

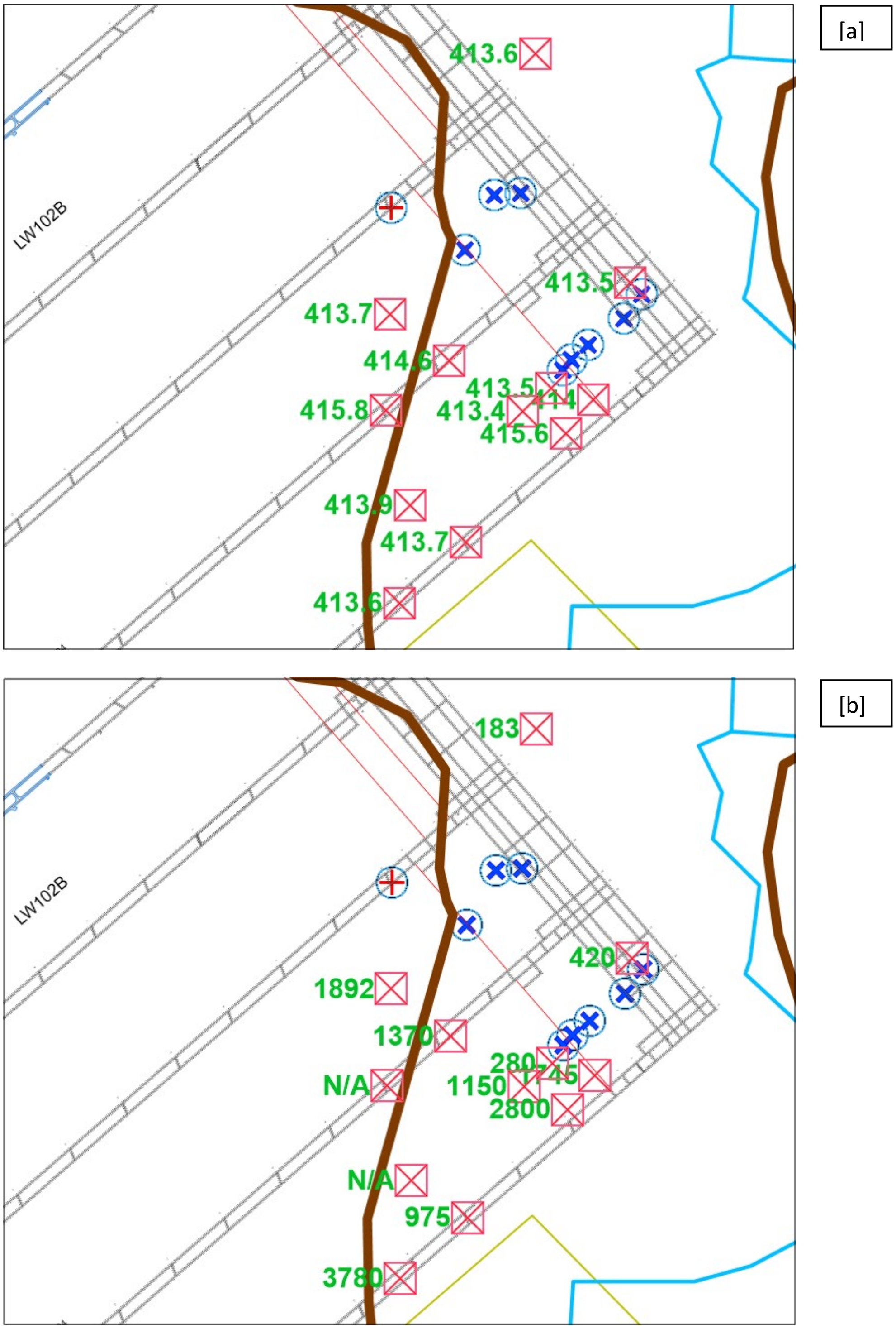

Figure 11 [a] Water Level (mAHD); [b] Electrical Conductivity EC (µS/cm)

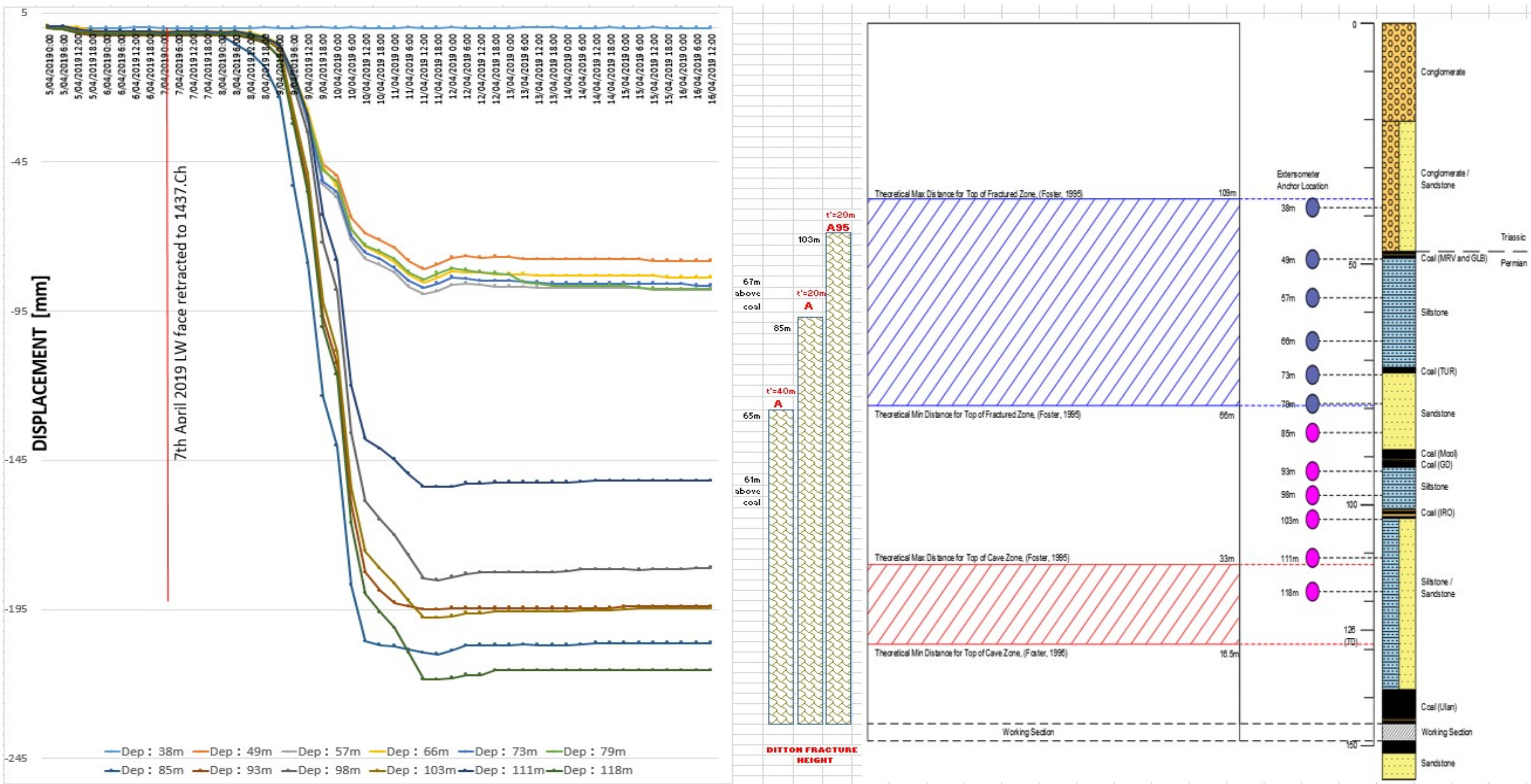

Figure 12 Extensometer 3.3 Displacement Curves Compared with Fracture Height Estimates

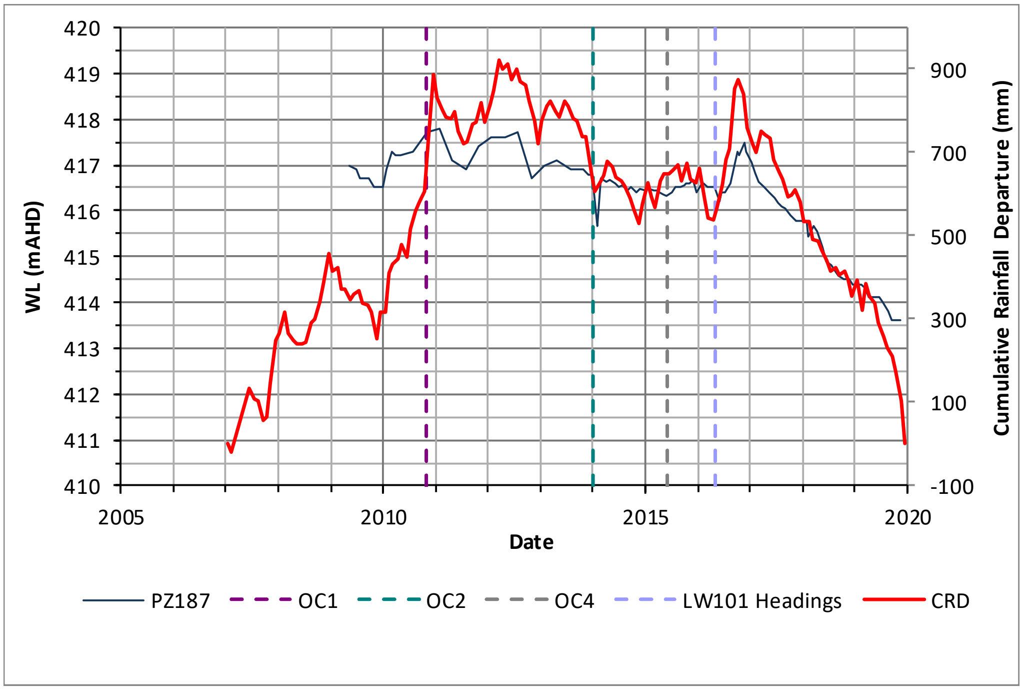

Figure 13 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ187

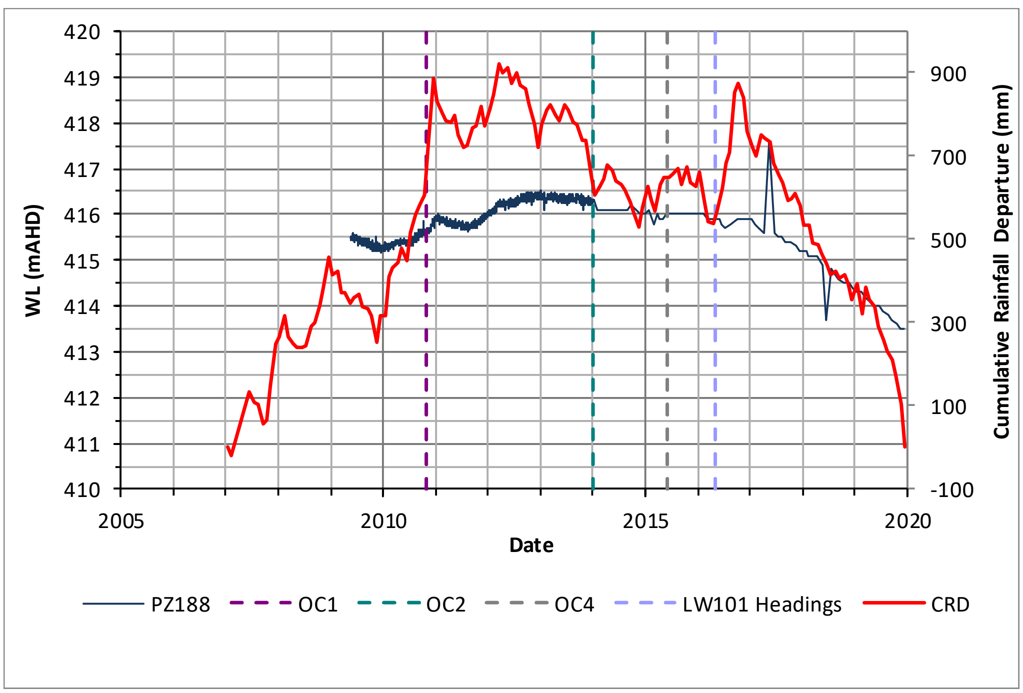

Figure 14 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ188

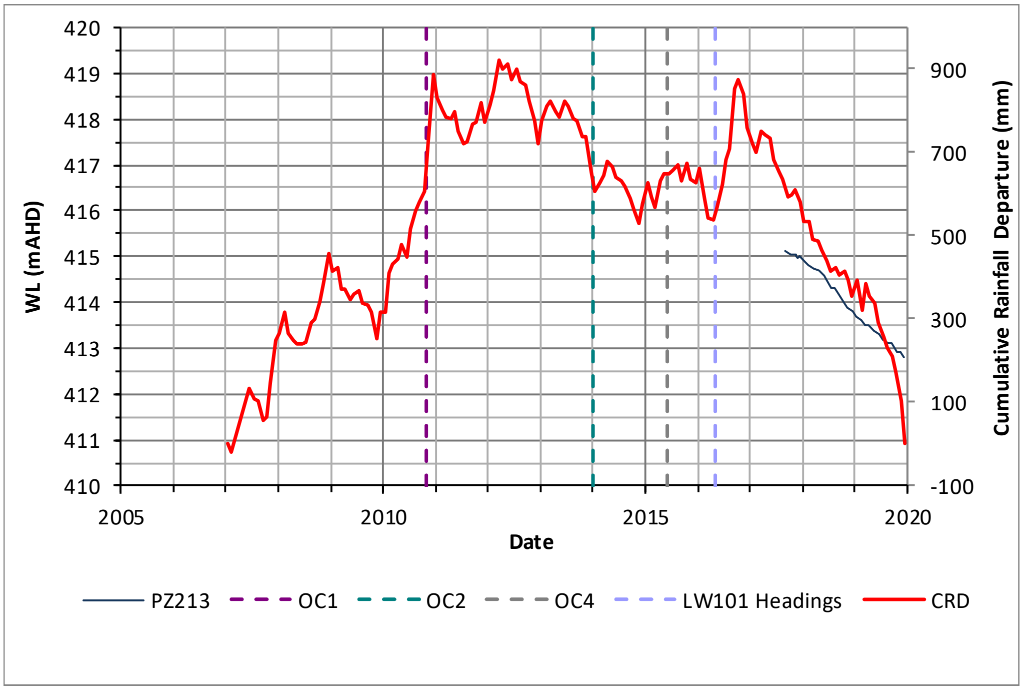

Figure 15 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ213

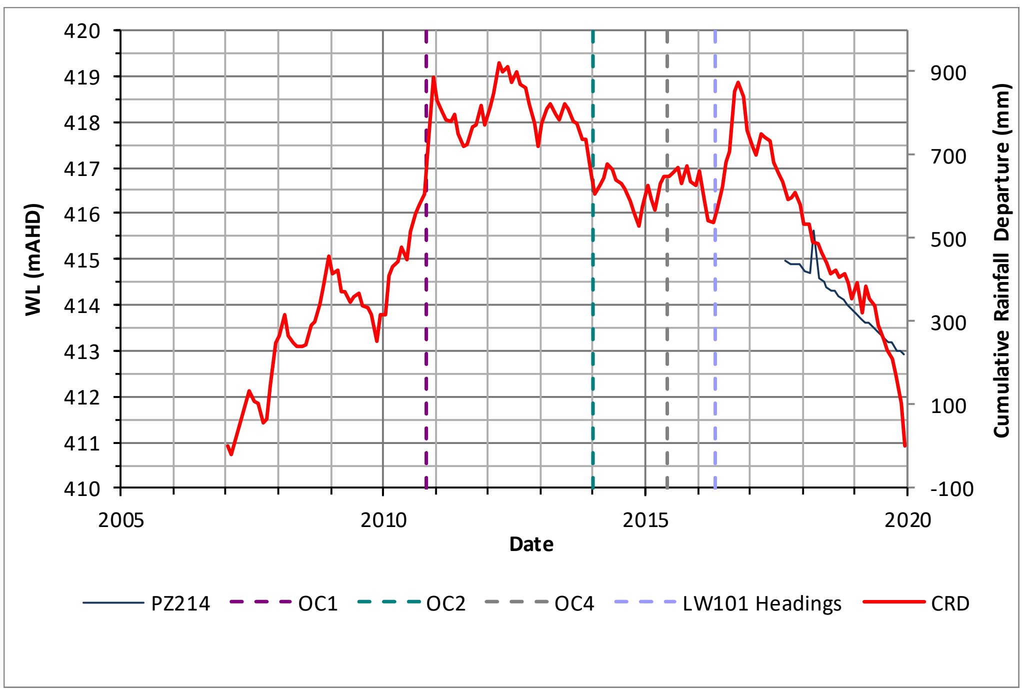

Figure 16 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ214

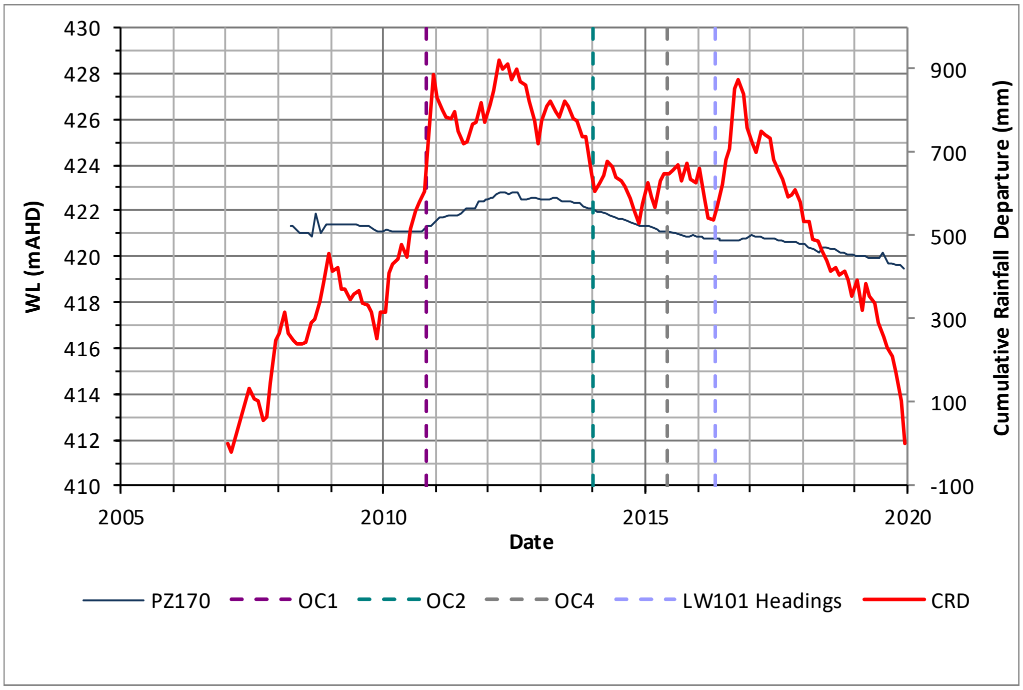

Figure 17 Groundwater Level Hydrograph for Permian Overburden Monitoring Bore PZ170

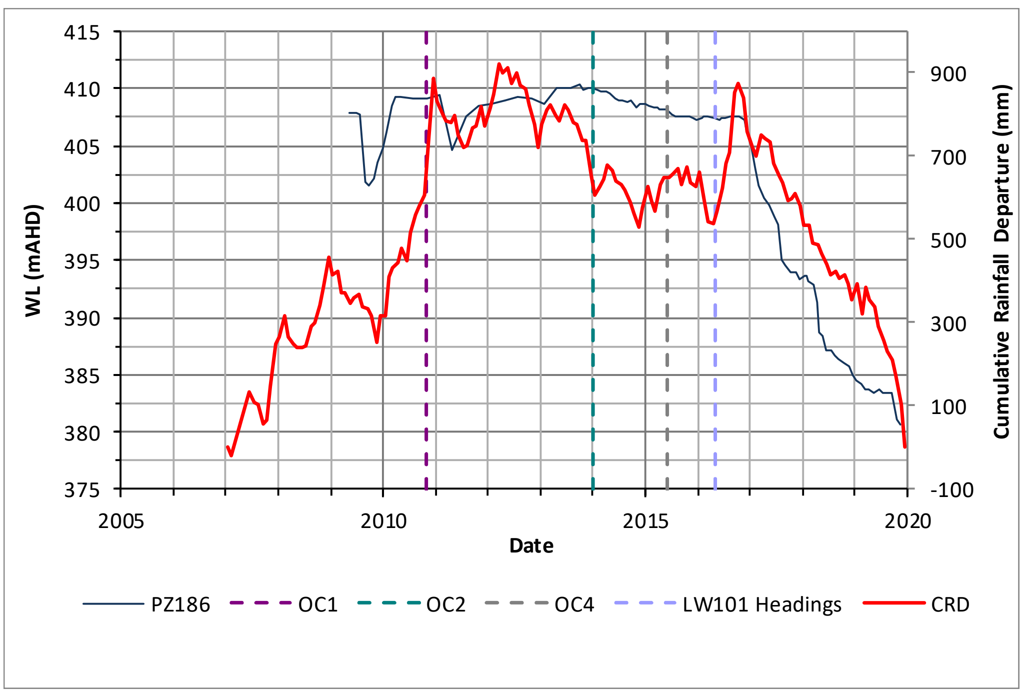

Figure 18 Groundwater Level Hydrograph for Permian Overburden Monitoring Bore PZ186

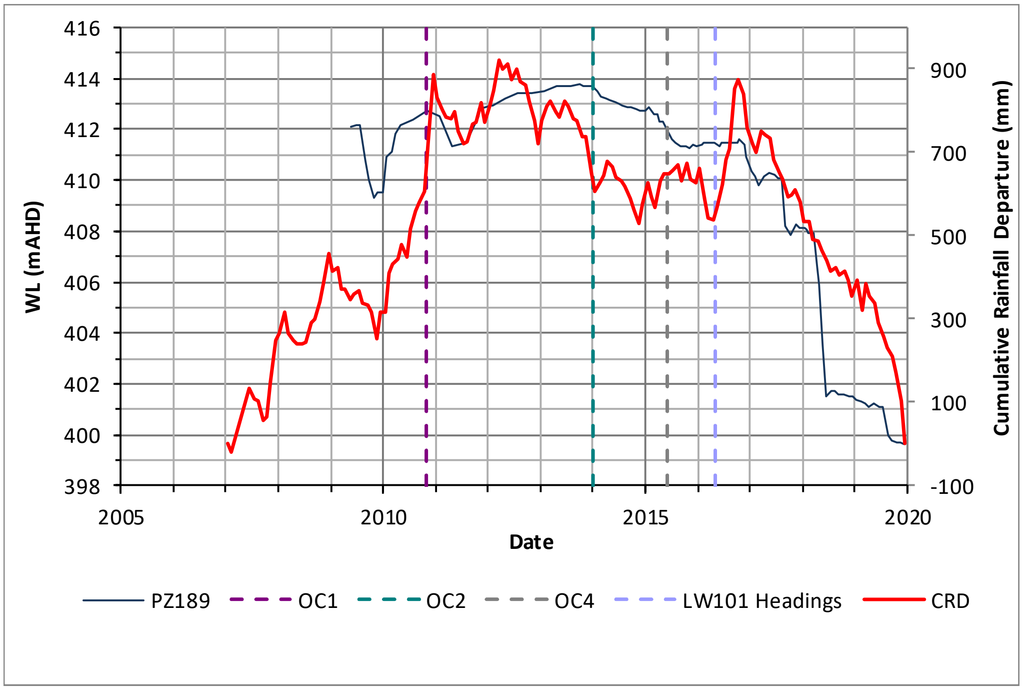

Figure 19 Groundwater Level Hydrograph for Permian Overburden Monitoring Bore PZ189

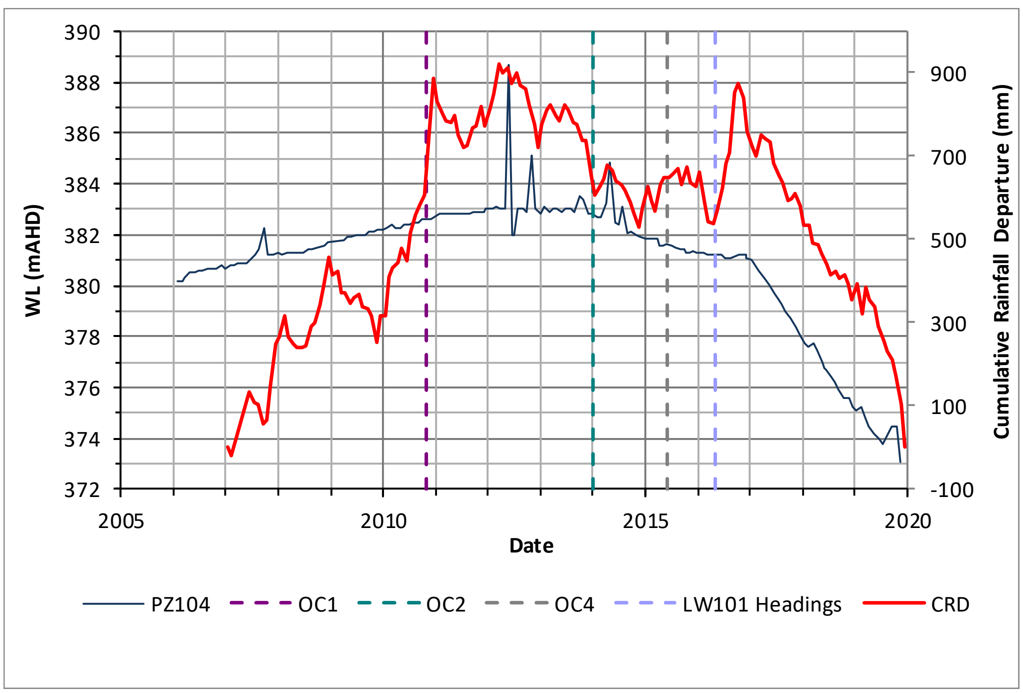

Figure 20 Groundwater Level Hydrograph for Ulan Seam Monitoring Bore PZ104

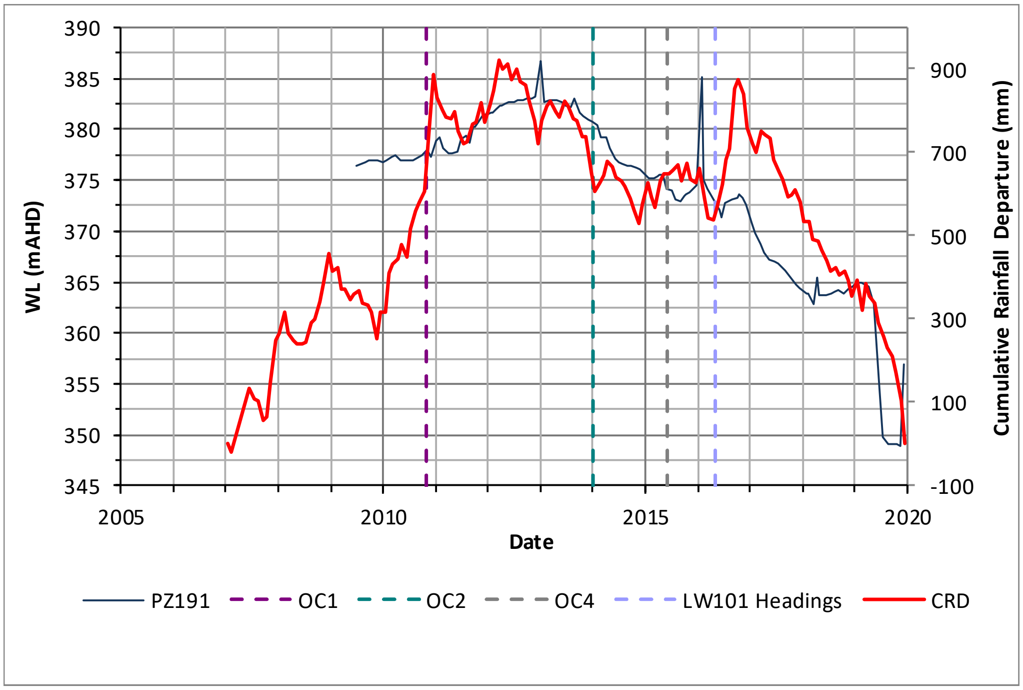

Figure 21 Groundwater Level Hydrograph for Ulan Seam Monitoring Bore PZ191

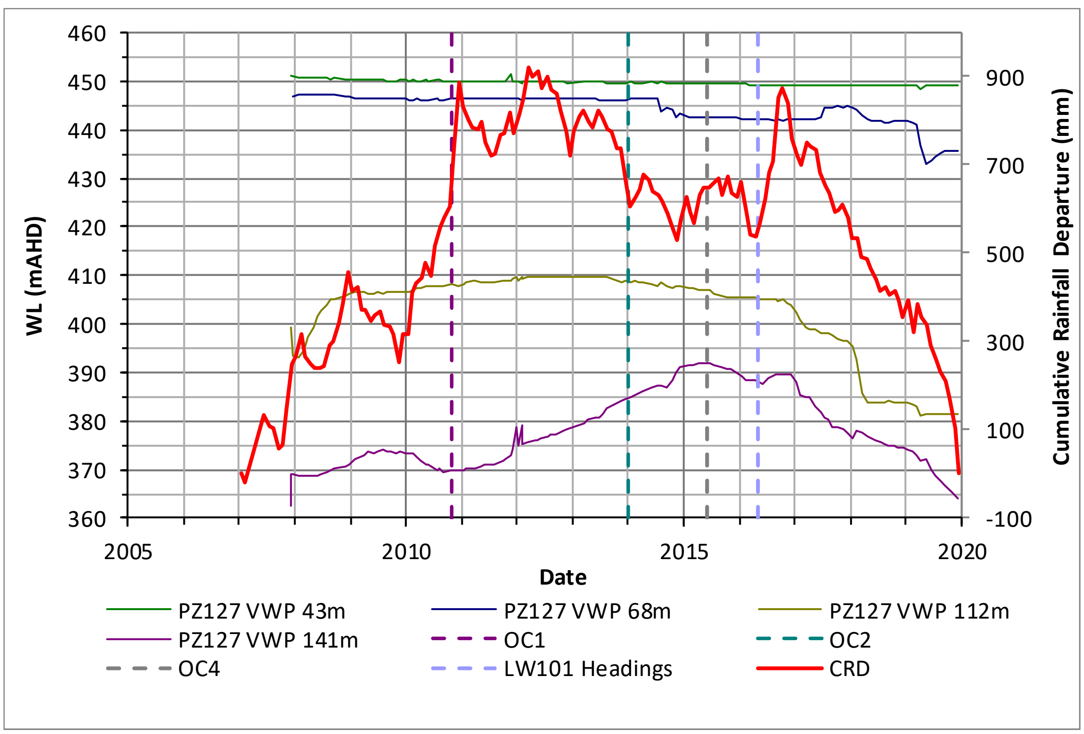

Figure 22 Groundwater Level Hydrograph for VWP Bore PZ127

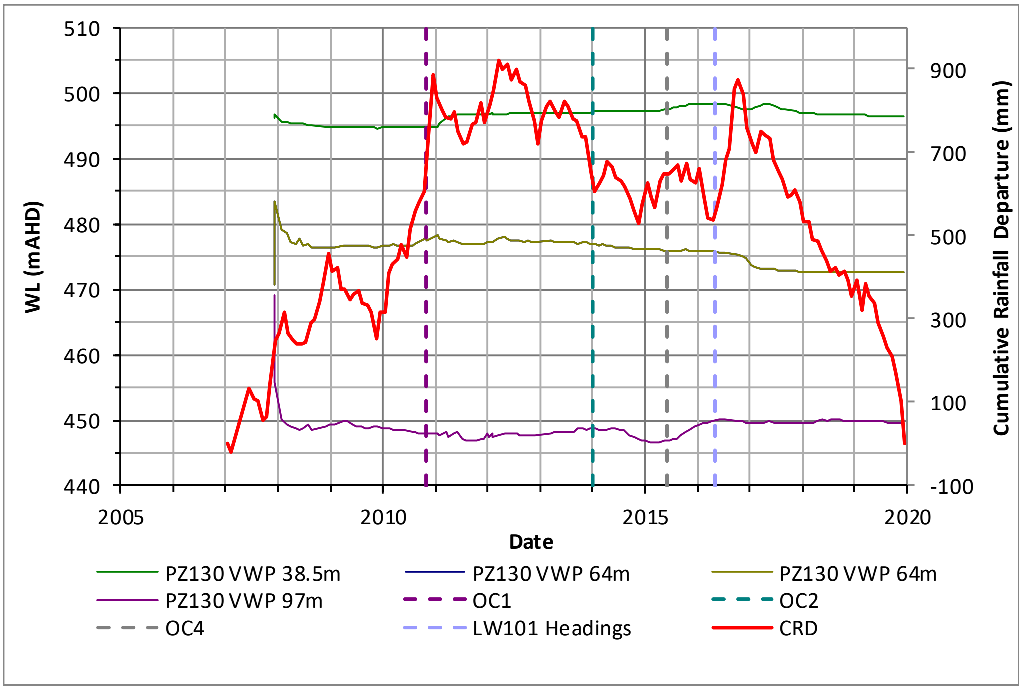

Figure 23 Groundwater Level Hydrograph for VWP Bore PZ130

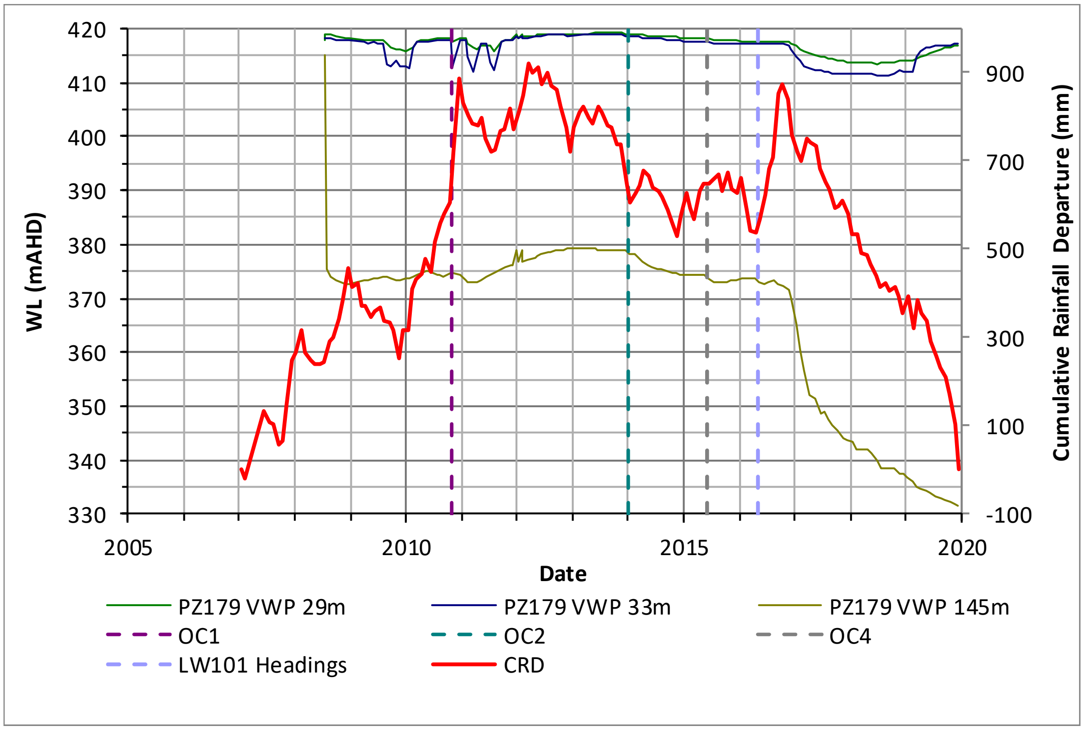

Figure 24 Groundwater Level Hydrograph for VWP Bore PZ179

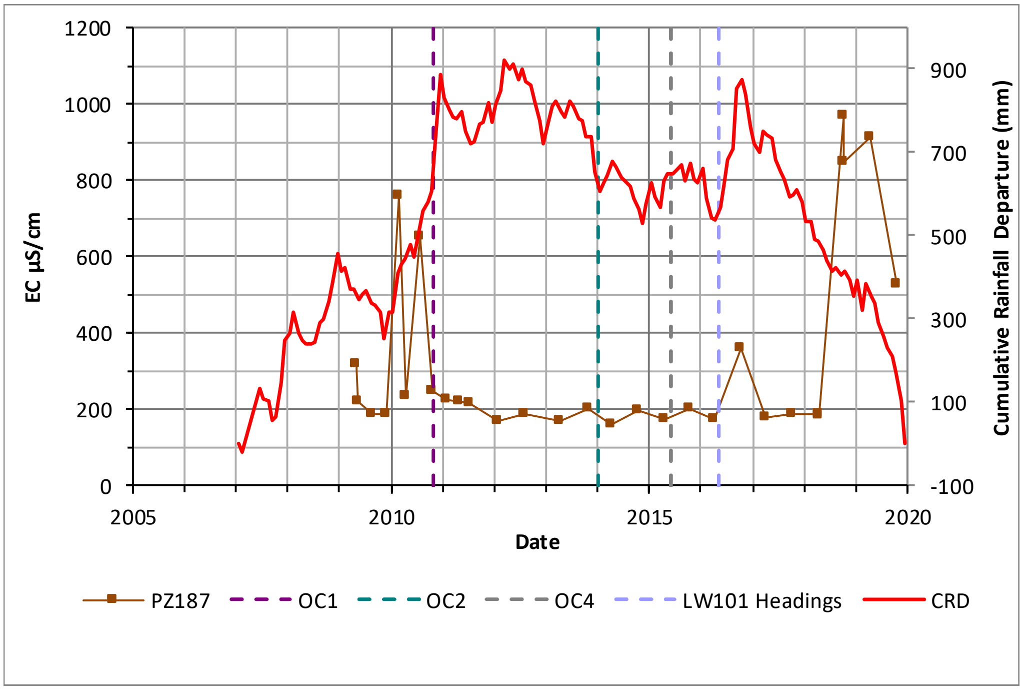

Figure 25 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ187

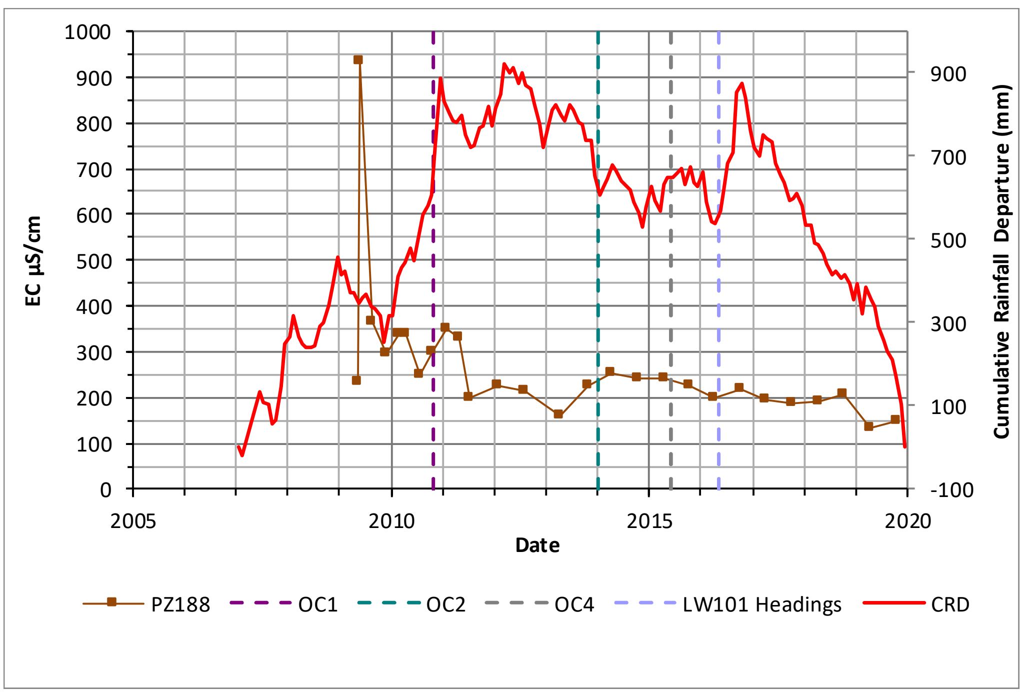

Figure 26 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ188

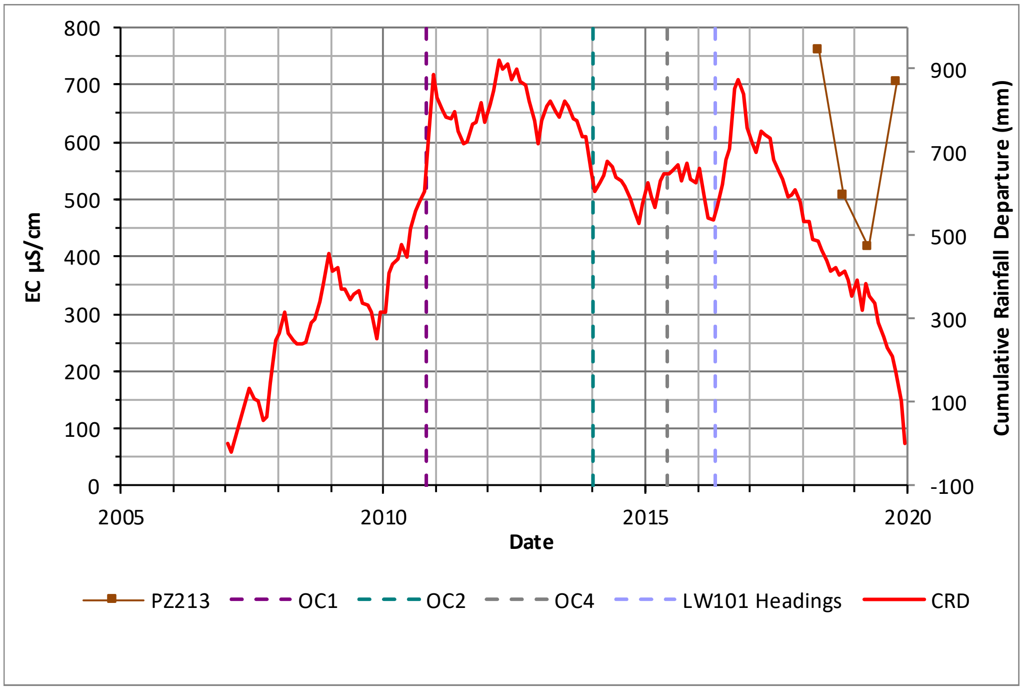

Figure 27 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ213

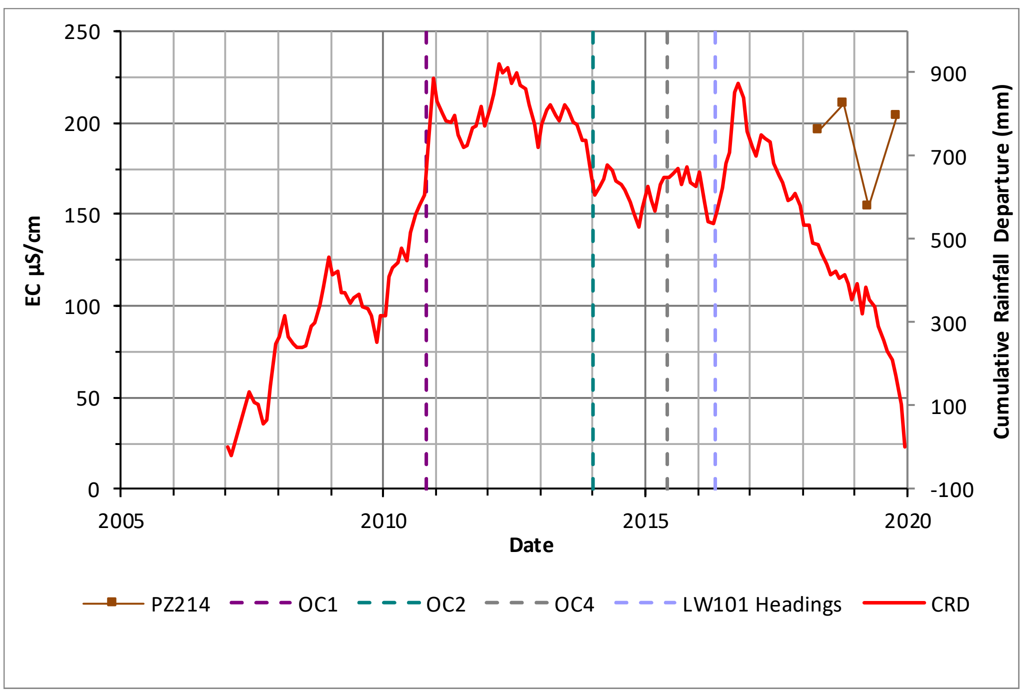

Figure 28 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ214

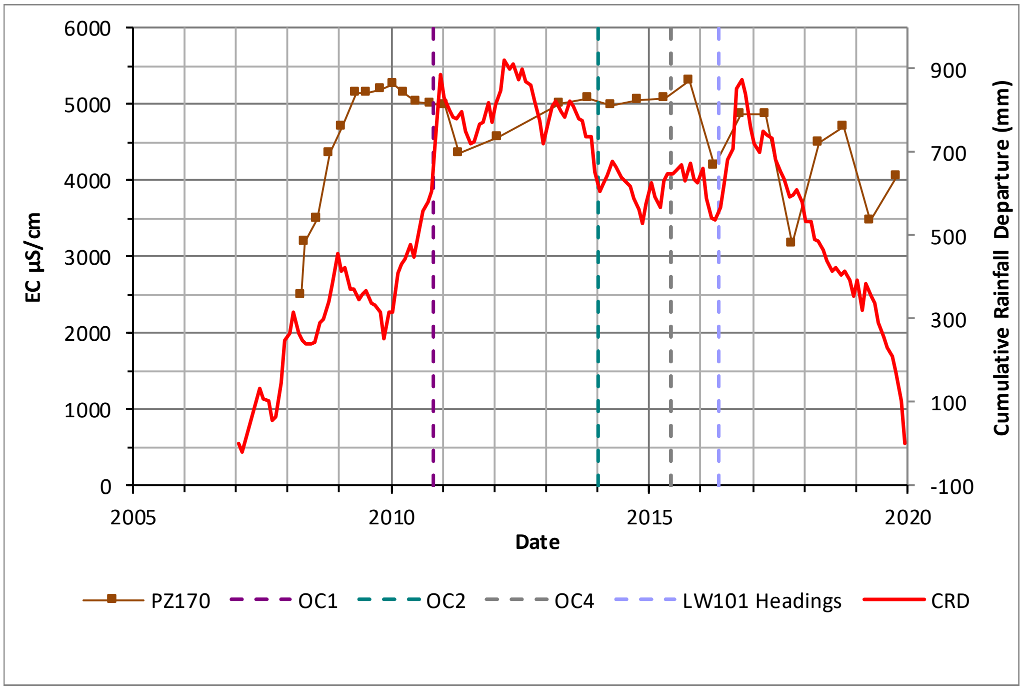

Figure 29 Groundwater Quality: Electrical Conductivity – Permian Overburden Monitoring Bore PZ170

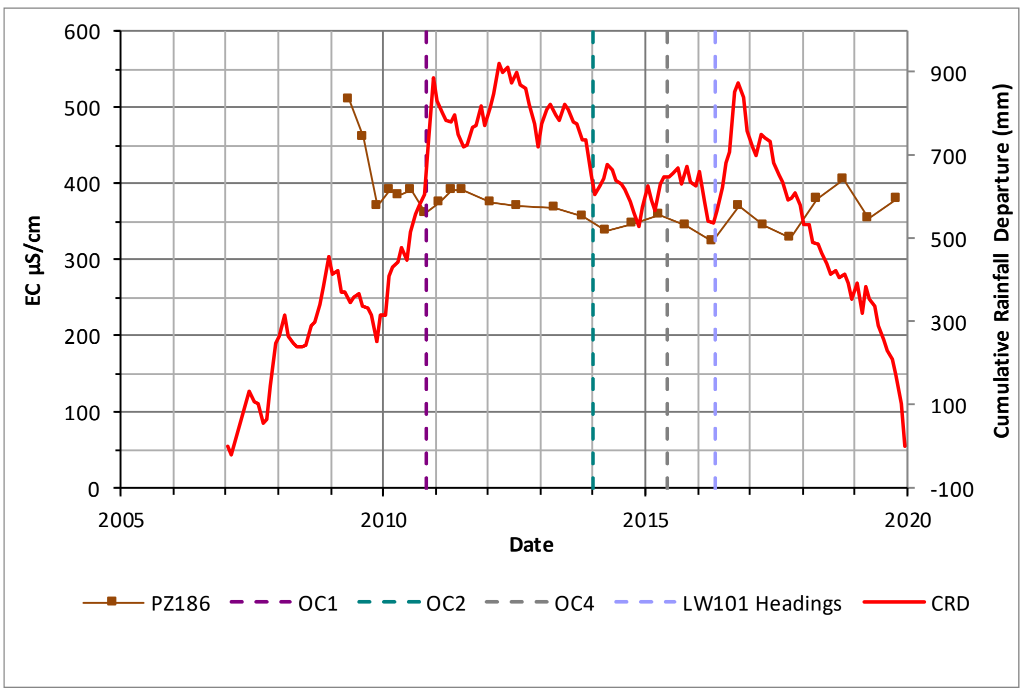

Figure 30 Groundwater Quality: Electrical Conductivity – Permian Overburden Monitoring Bore PZ186

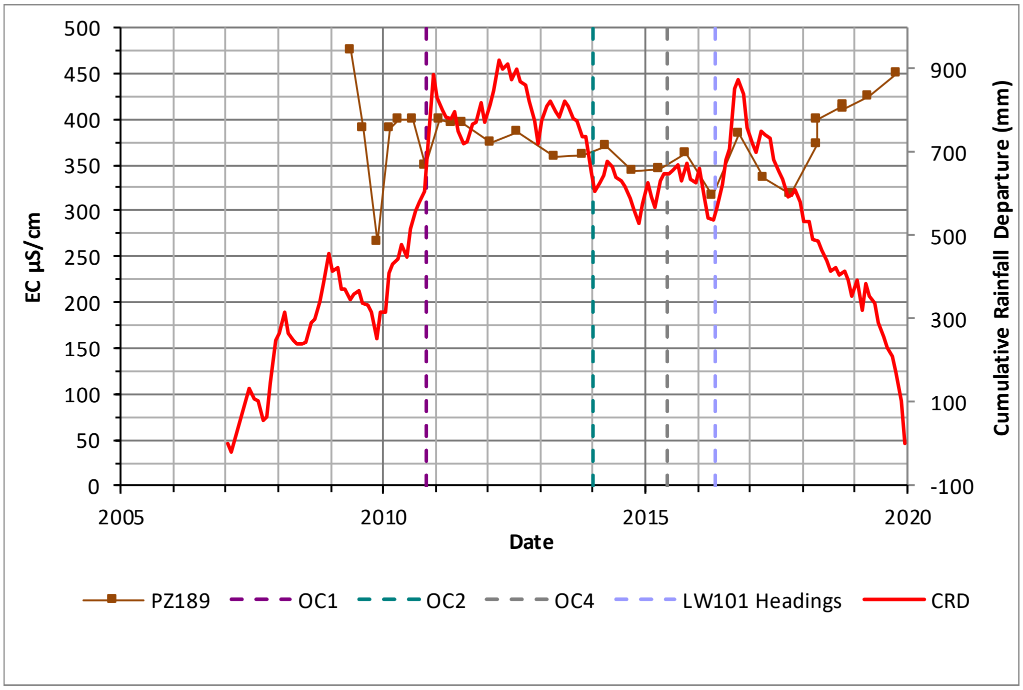

Figure 31 Groundwater Quality: Electrical Conductivity – Permian Overburden Monitoring Bore PZ189

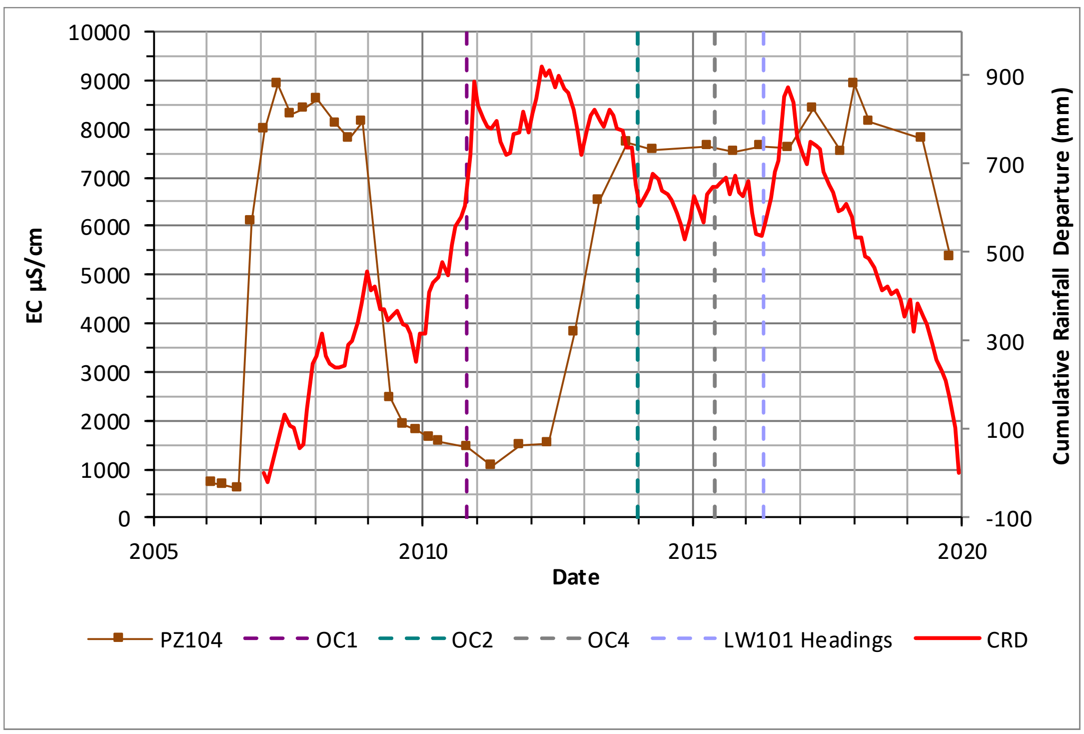

Figure 32 Groundwater Quality: Electrical Conductivity – Ulan Seam Monitoring Bore PZ104

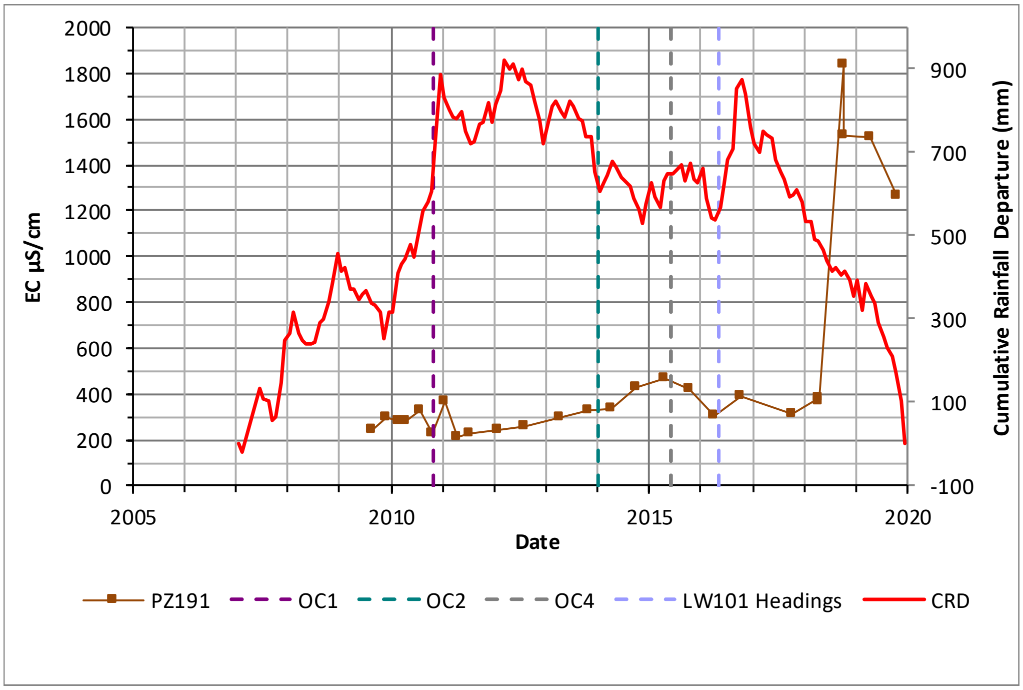

Figure 33 Groundwater Quality: Electrical Conductivity – Ulan Seam Monitoring Bore PZ191

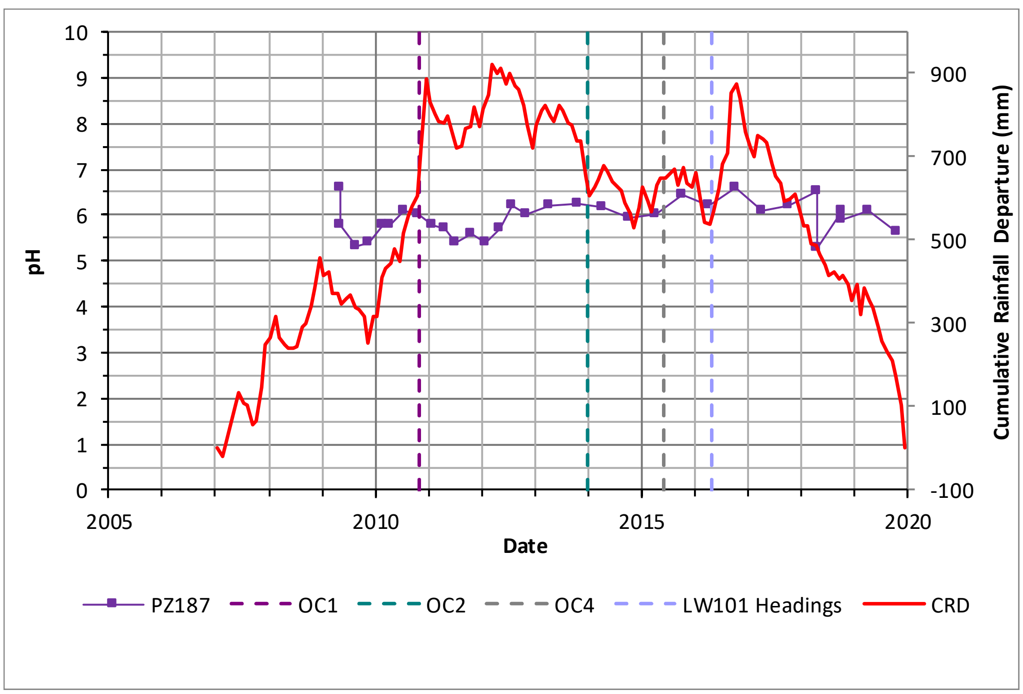

Figure 34 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ187

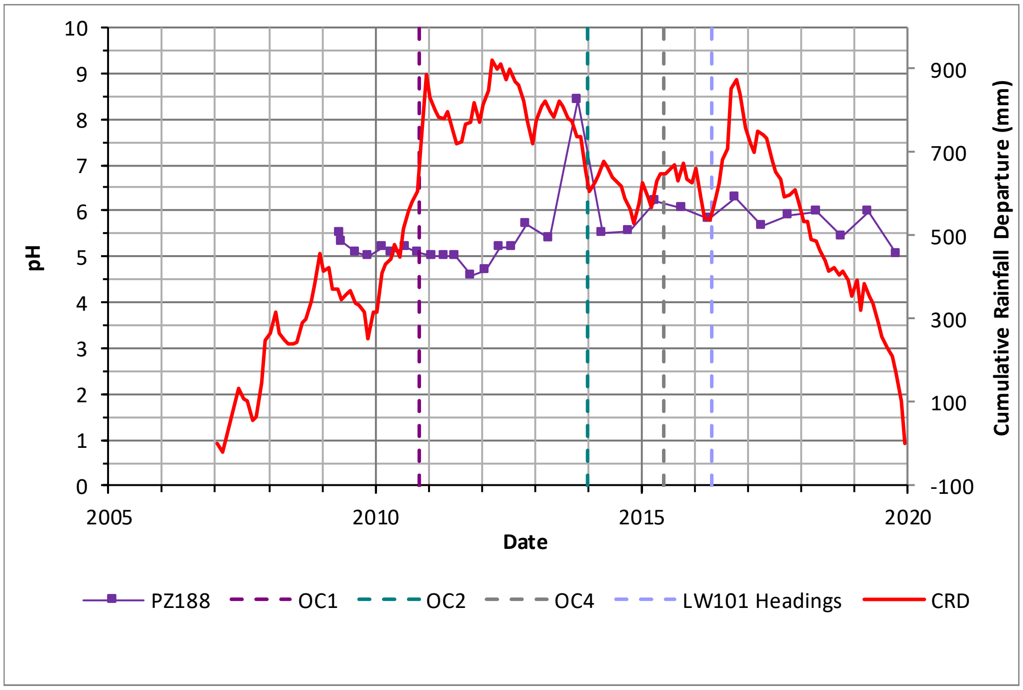

Figure 35 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ188

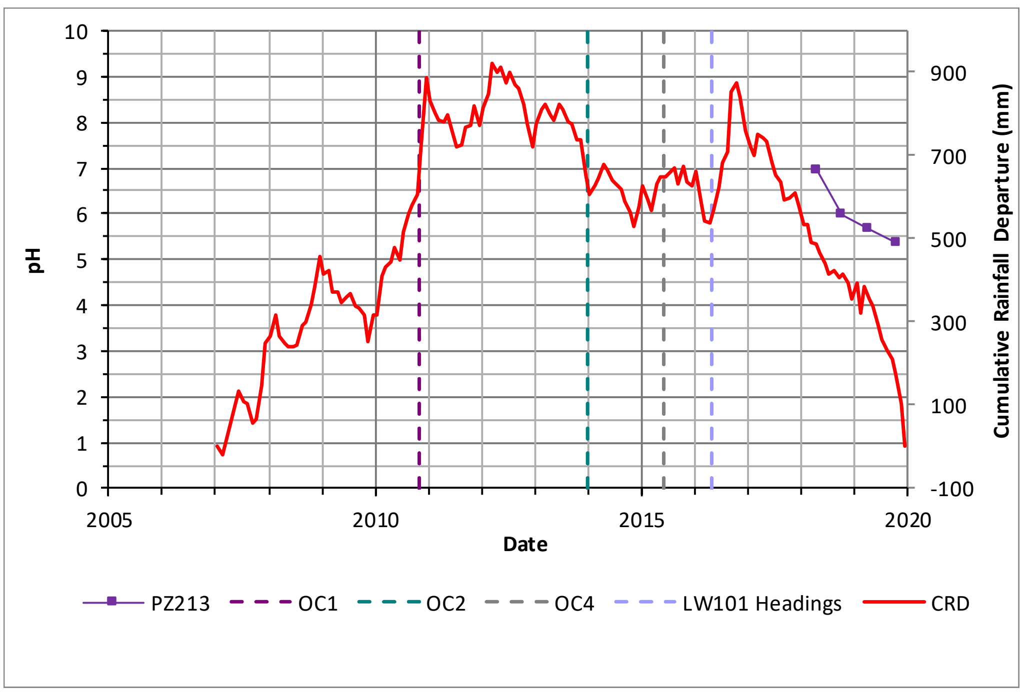

Figure 36 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ213

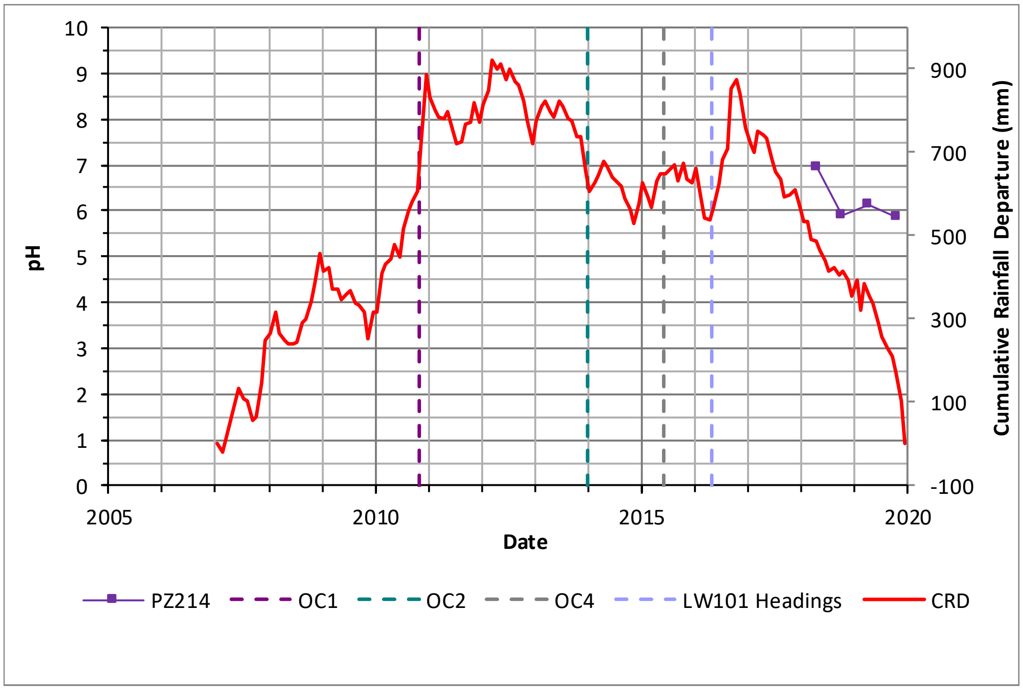

Figure 37 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ214

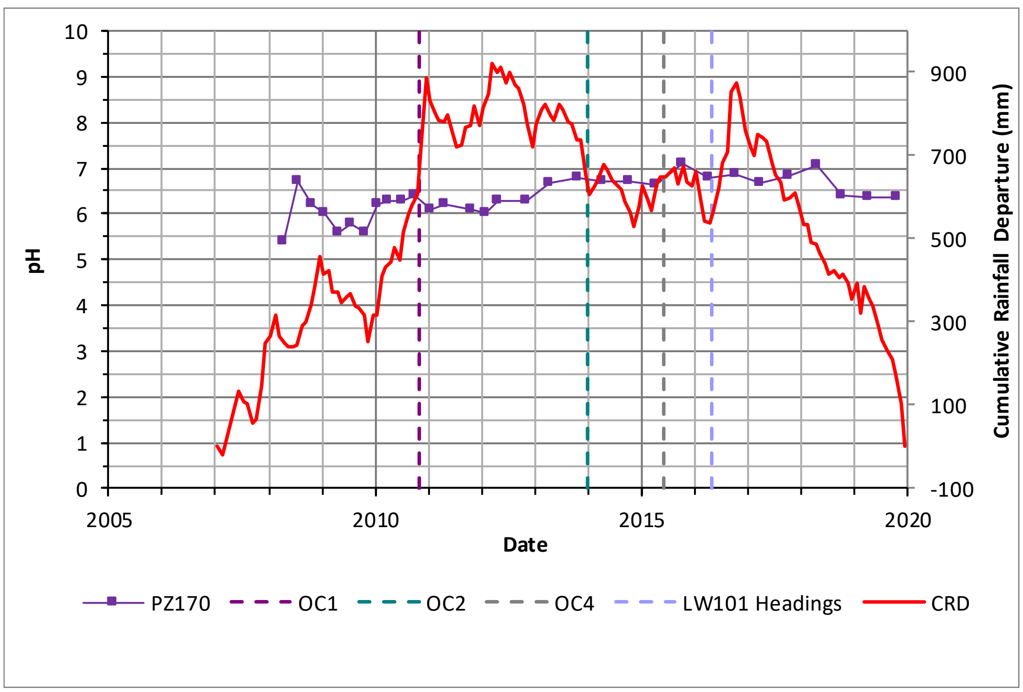

Figure 38 Groundwater Quality: pH – Permian Overburden Monitoring Bore PZ170

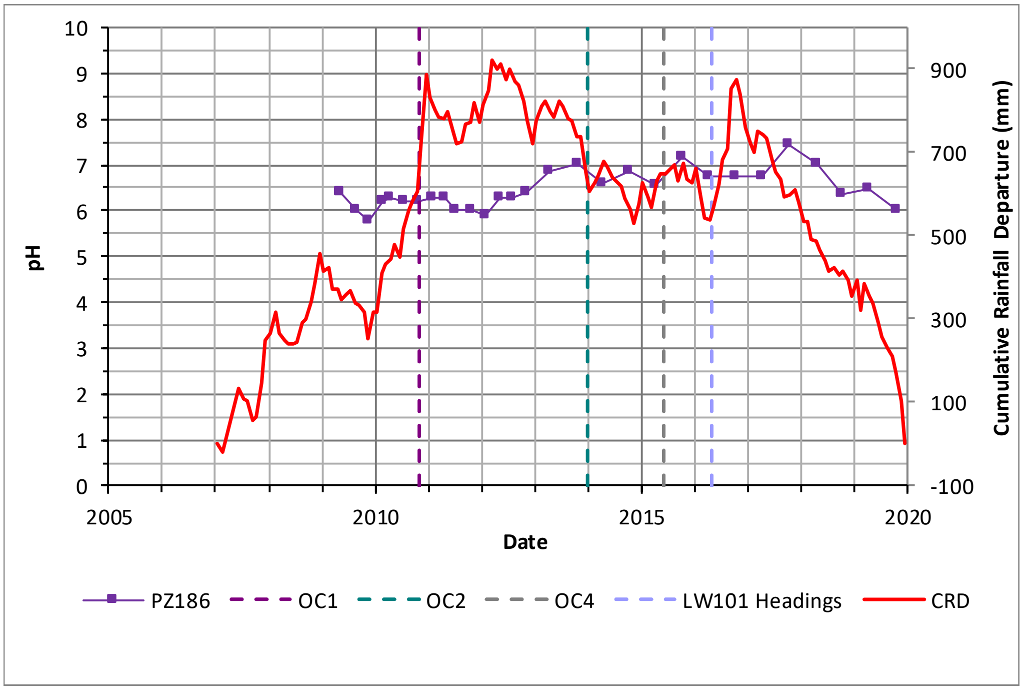

Figure 39 Groundwater Quality: pH – Permian Overburden Monitoring Bore PZ186

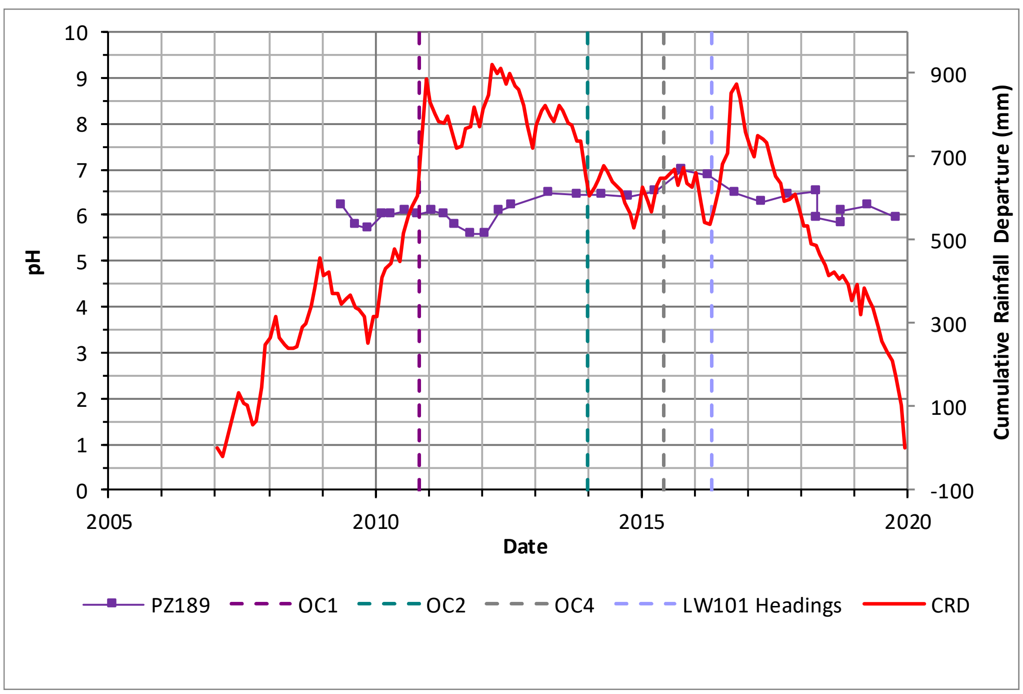

Figure 40 Groundwater Quality: pH – Permian Overburden Monitoring Bore PZ189

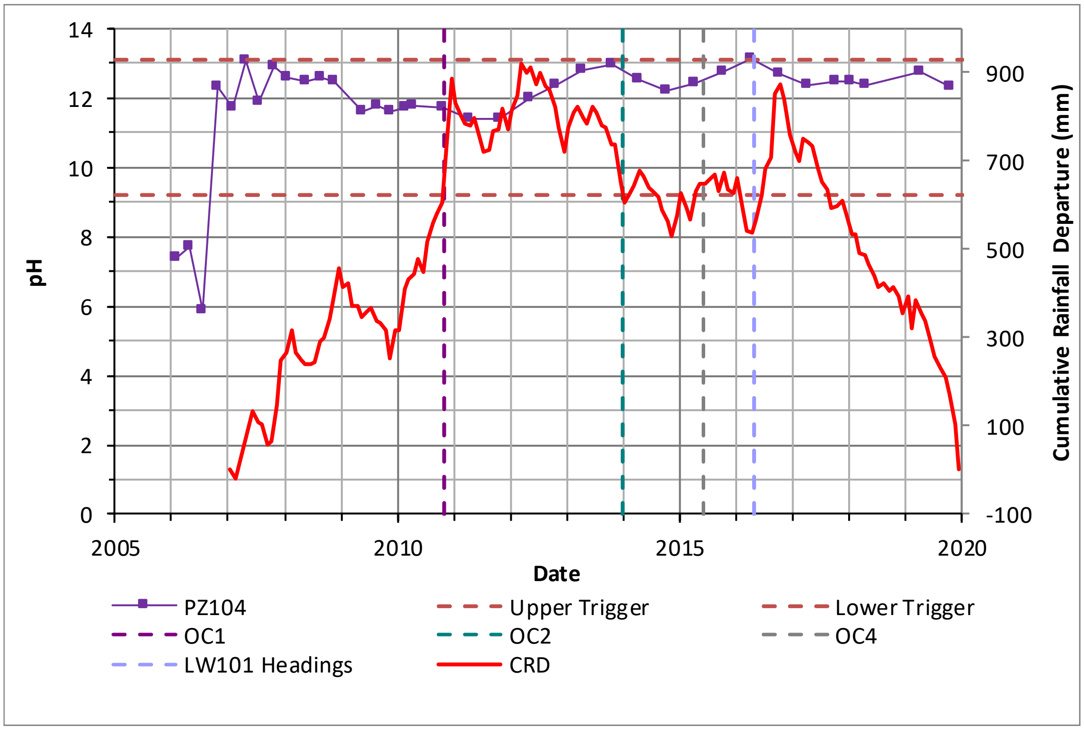

Figure 41 Groundwater Quality: pH – Permian Ulan Seam Monitoring Bore PZ104

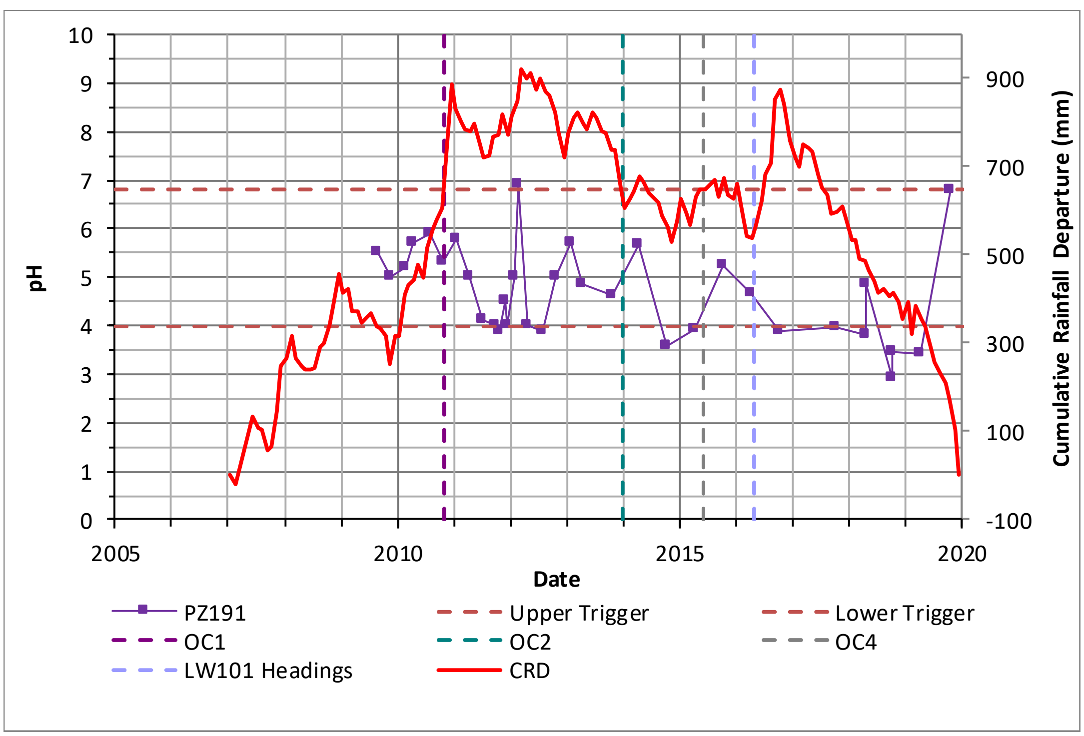

Figure 42 Groundwater Quality: pH – Permian Ulan Seam Monitoring Bore PZ191

ASIA PACIFIC OFFICES

BRISBANE
Level 2, 15 Astor Terrace
Spring Hill QLD 4000
Australia
T: +61 7 3858 4800
F: +61 7 3858 4801

CANBERRA
GPO 410
Canberra ACT 2600
Australia
T: +61 2 6287 0800
F: +61 2 9427 8200

DARWIN
Unit 5, 21 Parap Road
Parap NT 0820
Australia
T: +61 8 8998 0100
F: +61 8 9370 0101

GOLD COAST
Level 2, 194 Varsity Parade
Varsity Lakes QLD 4227
Australia
M: +61 438 763 516

MACKAY
21 River Street
Mackay QLD 4740
Australia
T: +61 7 3181 3300

MELBOURNE
Suite 2, 2 Domville Avenue
Hawthorn VIC 3122
Australia
T: +61 3 9249 9400
F: +61 3 9249 9499

NEWCASTLE
10 Kings Road
New Lambton NSW 2305
Australia
T: +61 2 4037 3200
F: +61 2 4037 3201

PERTH
Ground Floor, 503 Murray Street
Perth WA 6000
Australia
T: +61 8 9422 5900
F: +61 8 9422 5901

SYDNEY
2 Lincoln Street
Lane Cove NSW 2066
Australia
T: +61 2 9427 8100
F: +61 2 9427 8200

TOWNSVILLE
Level 1, 514 Sturt Street
Townsville QLD 4810
Australia
T: +61 7 4722 8000
F: +61 7 4722 8001

TOWNSVILLE SOUTH
12 Cannan Street
Townsville South QLD 4810
Australia
T: +61 7 4772 6500

WOLLONGONG
Level 1, The Central Building
UoW Innovation Campus
North Wollongong NSW 2500
Australia
T: +61 404 939 922

AUCKLAND
68 Beach Road
Auckland 1010
New Zealand
T: +64 27 441 7849

NELSON
6/A Cambridge Street
Richmond, Nelson 7020
New Zealand
T: +64 274 898 628