UG1 LONGWALLS 101 TO 105 WATER MANAGEMENT PLAN

Version	Issue Date	Section Revised	Description	Review Team
1	September 2017	All	Approved	MCO
2	March 2019	Sections 1, 4, 13 and Figures	Amended 103 Layout	MCO
3	June 2020	All	Inclusion of LWs 104 and 105	MCO

Approved: S.J. Archinal Date: 11/06/2020

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1.0 INTRODUCTION

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

Moolarben Coal Operations Pty Ltd (MCO) is the operator of the Moolarben Coal Complex on behalf of the Moolarben Joint Venture (Moolarben Coal Mines Pty Ltd [MCM], Sojitz Moolarben Resources Pty Ltd and a consortium of Korean power companies). MCO and MCM are wholly owned subsidiaries of Yancoal Australia Limited.

The Moolarben Coal Complex comprises four approved open cut mining areas (OC1 to OC4), three approved underground mining areas (UG1, UG2 and UG4) and other mining related infrastructure (including coal processing and transport facilities) (Figure 2). Since the commencement of coal mining operations in 2010, mining activities have occurred within OC1, OC2, OC4 and UG1 (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).

Mining operations at the Moolarben Coal Complex are currently approved until 31 December 2038 and would continue to be carried out in accordance with Project Approval (05_0117) (Moolarben Coal Project Stage 1) as modified and Project Approval (08_0135) (Moolarben Coal Project Stage 2) as modified, granted under the NSW *Environmental Planning and Assessment Act, 1979* (EP&A Act).

1.1 PURPOSE AND SCOPE

This UG1 Longwalls 101 to 105 Water Management Plan (LW101-105 WMP) has been prepared to satisfy the requirements of Schedule 4, Condition 5(h) of Project Approval (08_0135) for the management of potential impacts to watercourses and aquifers due to secondary extraction of Longwalls 101 to 105.

The approved complex-wide Water Management Plan (WAMP) (as amended from time to time), developed in consultation with the Department of Planning Industry and Environment - Water, is implemented to manage surface water and groundwater related impacts across the Moolarben Coal Complex (including the Longwalls 101-105 Study Area). To avoid duplication of existing Environmental Management Plans, this LW101-105 WMP references components of the approved complex-wide WAMP.

This LW101-105 WMP has been prepared by MCO with input from suitably qualified experts (WRM Water & Environment [WRM] [surface water], HydroSimulations and SLR [groundwater], Mine Advice Pty Ltd and Mine Subsidence Engineering Consultants [MSEC]). The appointment of the team of suitably qualified and experienced persons (which includes representatives of MCO, WRM, SLR and MSEC) was endorsed by the Secretary of the DPIE.

In summary:

Purpose: This LW101-105 WMP outlines the management of potential environmental consequences on watercourses and aquifers resulting from the extraction of Longwalls 101-105.

Scope: This LW101-105 WMP covers watercourses and aquifers within the Longwalls 101-105 Study Area[1] (Figure 4).

Longwalls 101-105 form the UG1 Underground Mine at the Moolarben Coal Complex.

This amendment has been prepared to incorporate the final two longwall panels 104 and 105 of the UG1 mining area into the Extraction Plan. The only mine plan alteration from that approved under the Stage 2 Project Approval (08_0135) is the shortening of the commencing end of LW104 by 70m, which was conducted to facilitate the installation of a rear panel ventilation shaft and associated roadway.

1.2 STRUCTURE OF THE LONGWALLS 101-103 WATER MANAGEMENT PLAN

The remainder of the LW101-105 WMP is structured as follows:

Section 2 Describes the review and update of the LW101-105 WMP.

Section 3 Outlines the statutory requirements applicable to the LW101-105 WMP.

Section 4 Summarises the predicted subsidence impacts and environmental consequences resulting from the secondary extraction of Longwalls 101-105.

Section 5 Details the performance measures and indicators that will be used to assess environmental performance in relation to watercourses and aquifers.

Section 6 Describes the monitoring program.

Section 7 Describes the potential management measures that could be implemented to remediate any identified impacts to watercourses and aquifers.

1 Longwalls 101-105 and the area of land within the furthest extent of the 26.5 degree (°) angle of draw and 20 millimetre (mm) predicted subsidence contour.

Section 8	Provides a Contingency Plan to manage any unpredicted impacts and their consequences and describes the Trigger Action Response Plan (TARP) management tool.
Section 9	Describes the Annual Review requirements, audits, improvement of environmental performance and preparation for future Extraction Plans.
Section 10	Outlines the management and reporting of incidents.
Section 11	Outlines the management and reporting of complaints.
Section 12	Outlines the management and reporting of any non-compliance with statutory requirements.
Section 13	Lists the documents referred to in Sections 1 to 12 of this LW101-105 WMP.

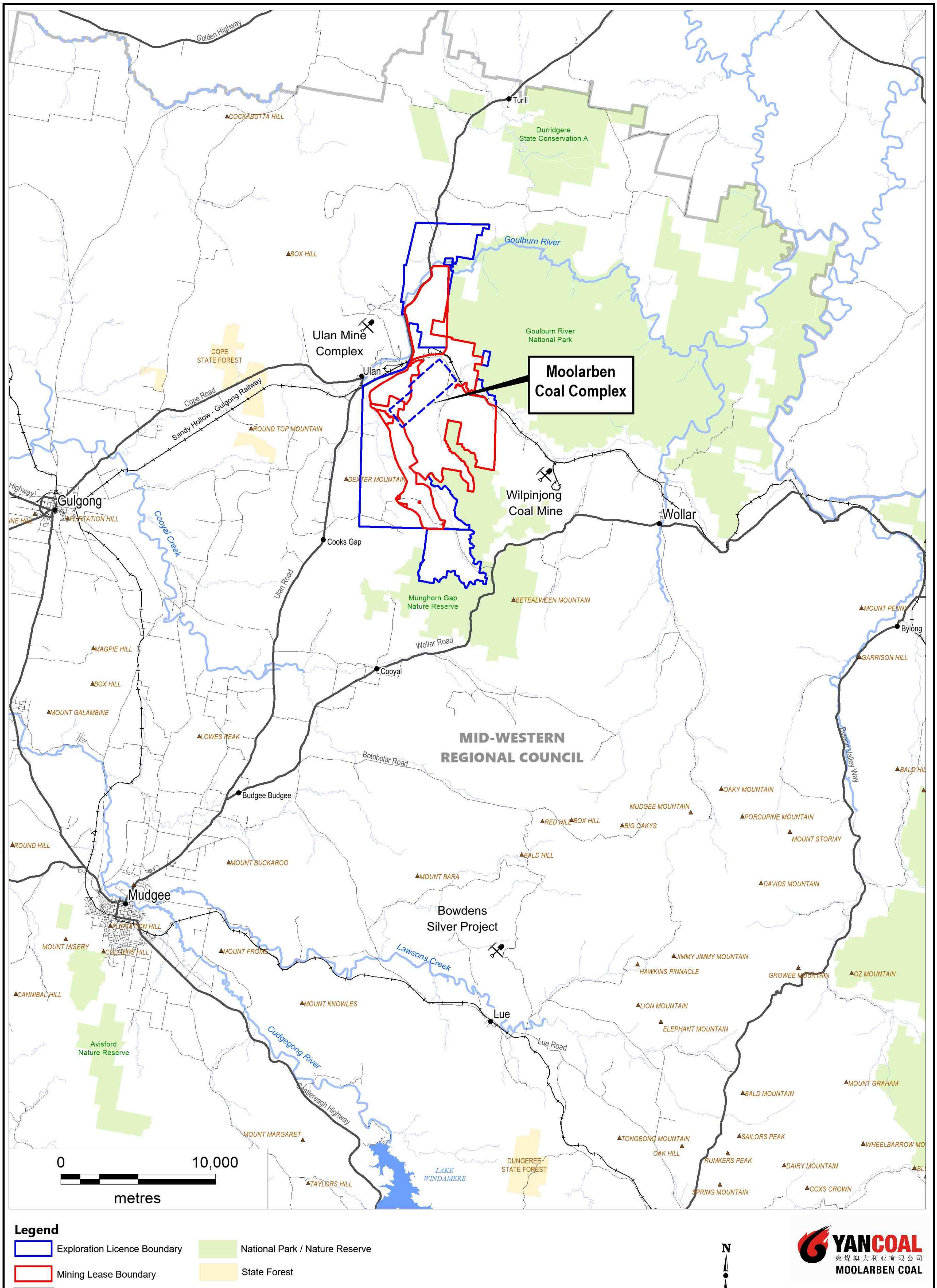


Figure 1
Regional Location

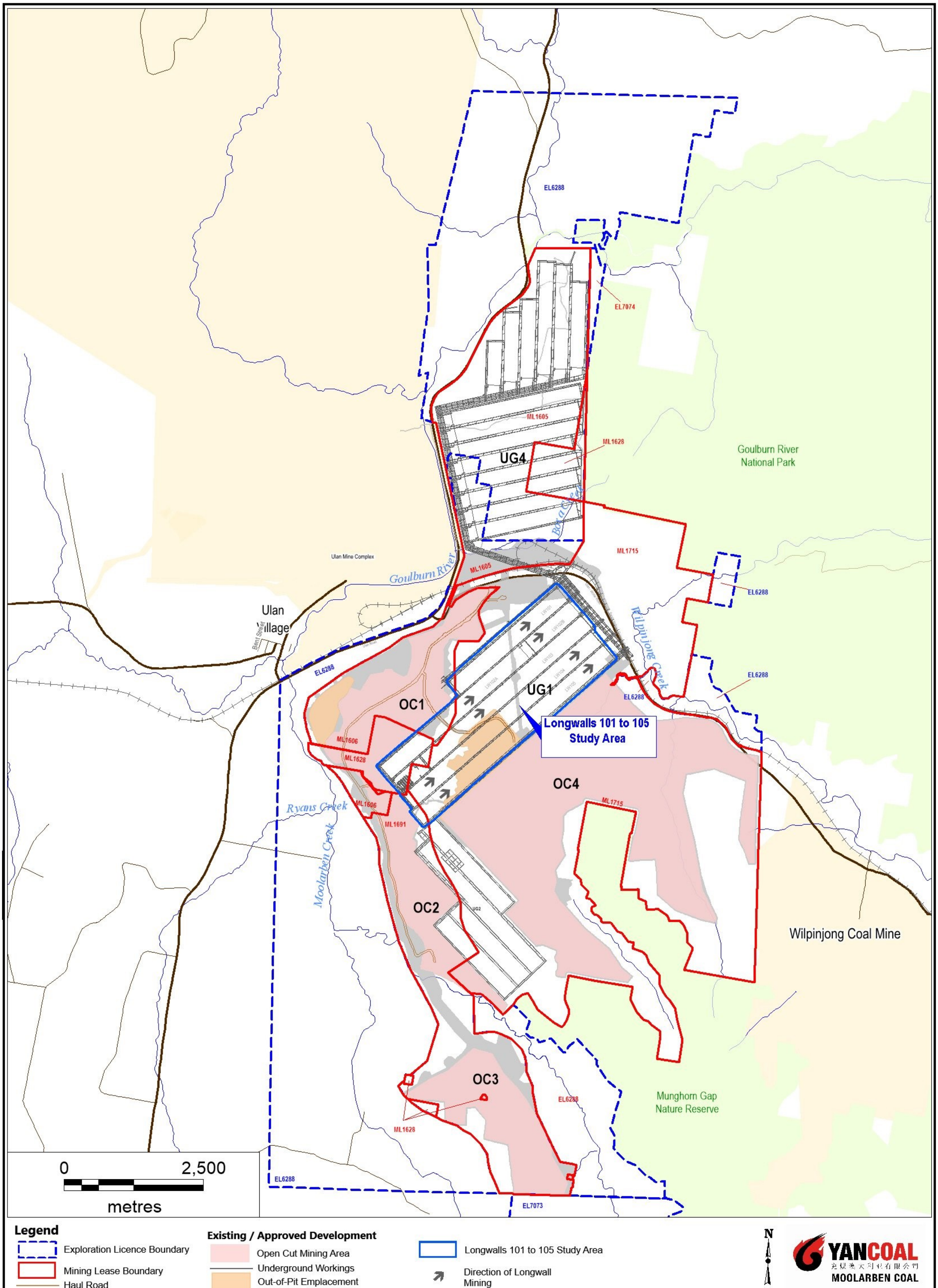


Figure 2
Moolarben Coal Complex Layout

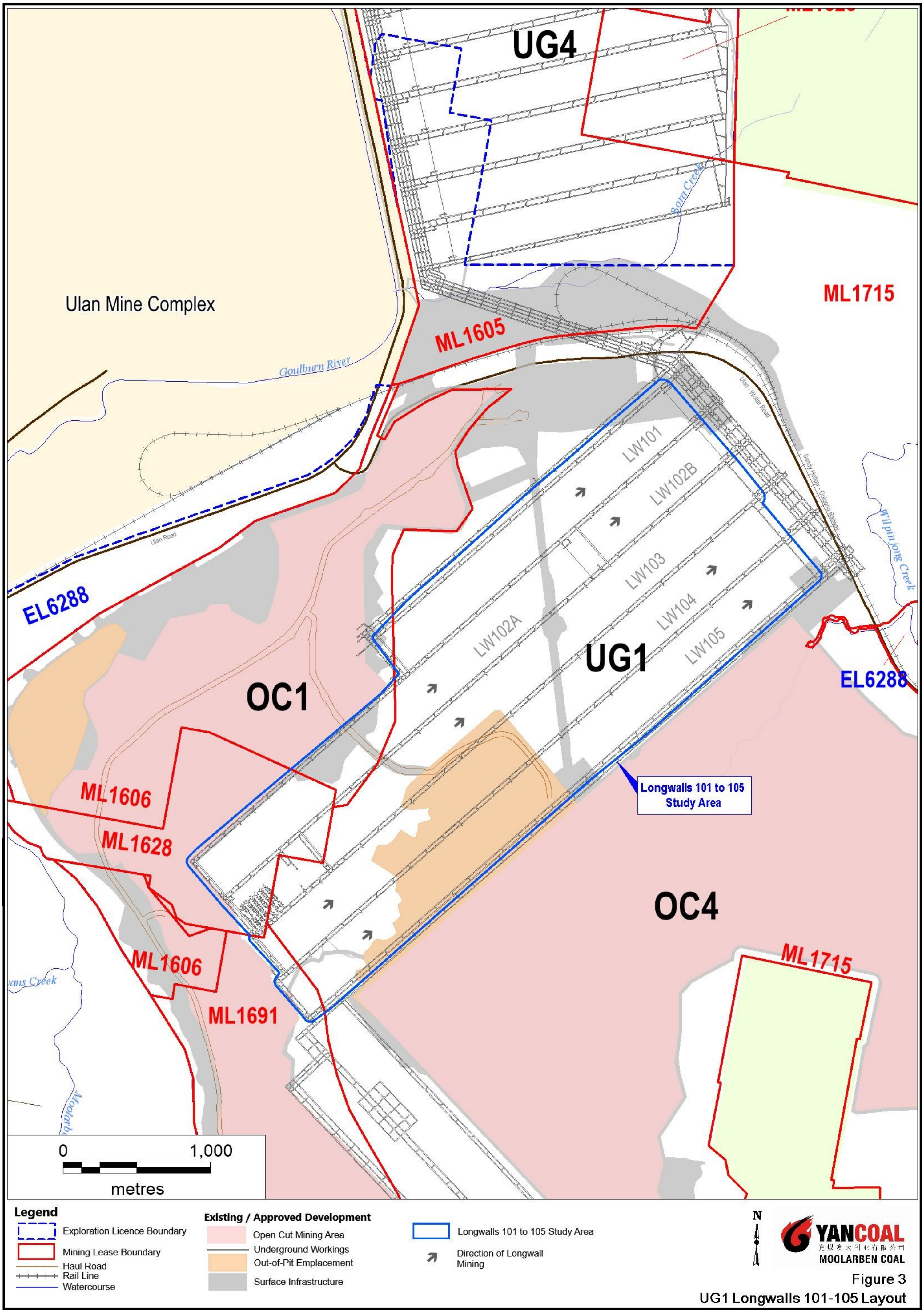


Figure 3
UG1 Longwalls 101-105 Layout

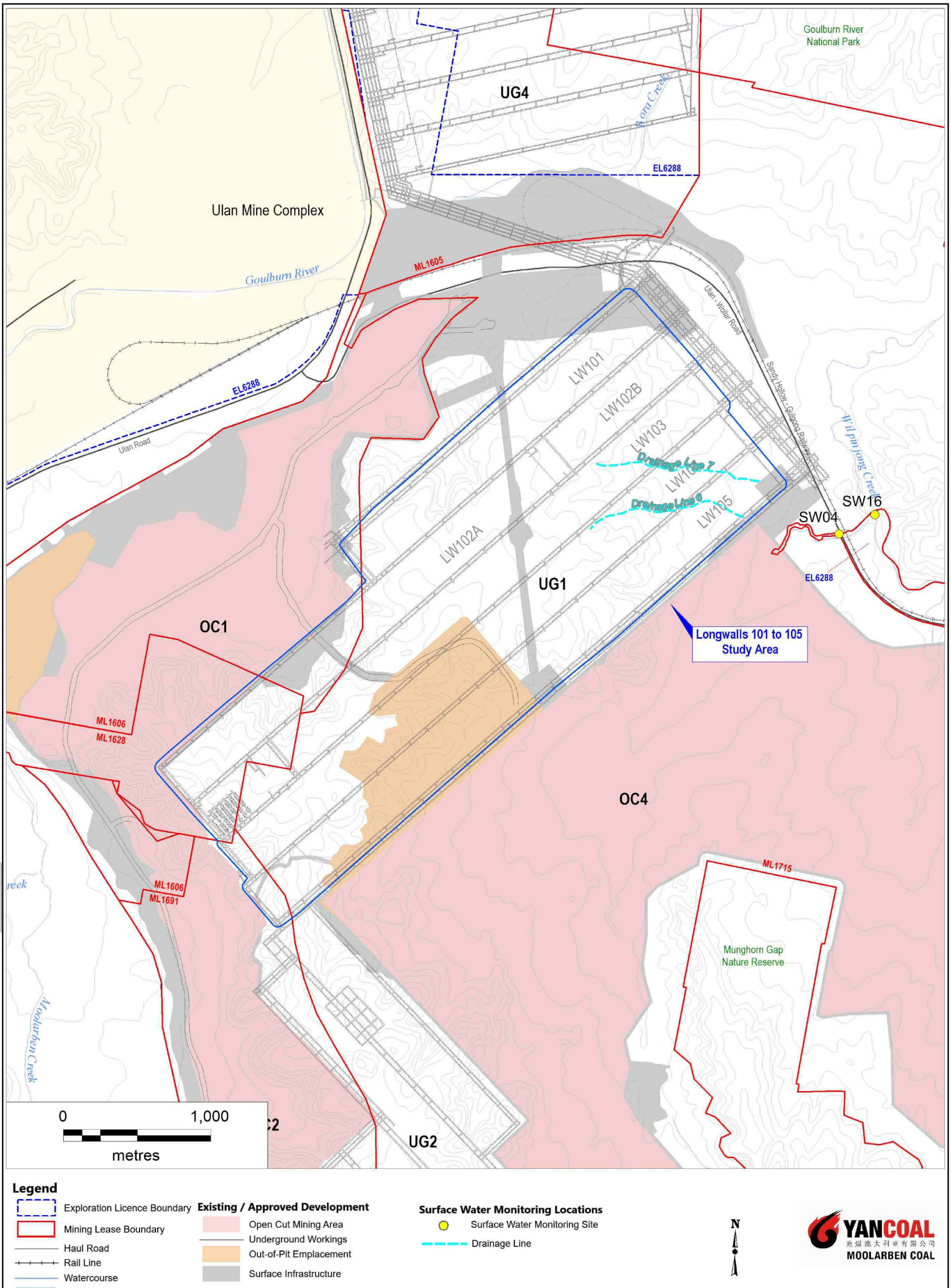


Figure 4
Drainage Lines and Surface Water Quality Monitoing Locations

2.0 WATER MANAGEMENT PLAN REVIEW AND UPDATE

In accordance with Condition 5, Schedule 6 of Project Approval (08_0135), this LW101-105 WMP will be reviewed
as followed:

> *5. Within 3 months of the submission of:*
> *(a) the submission of annual review under condition 4 above;*
> *(b) the submission of an incident report under condition 7 below;*
> *(c) the submission of an audit under condition 9 below; or*
> *(d) any modification to the conditions of this approval or MP 05_0117 (unless the conditions require otherwise),*
>
> *the Proponent shall review and, if necessary, revise the strategies, plans, and programs required under this approval to the satisfaction of the Secretary. Where this review leads to revisions in any such document, then within 4 weeks of the review the revised document must be submitted to the Secretary for approval.*

2.1 ACCESS TO INFORMATION

In accordance with Condition 11, Schedule 6 of Project Approval (08_0135), MCO will make the approved LW101-105 WMP publicly available on the MCO website.

3.0 STATUTORY REQUIREMENTS

MCO's statutory obligations are contained in:

- the conditions of the NSW Project Approval (05_0117) (as modified) and NSW Project Approval (08_0135) (as modified);
- the conditions of Commonwealth Approvals (EPBC 2007/3297, EPBC 2013/6926, EPBC 2008/4444, and EPBC 2017/7974);
- relevant licences and permits, including conditions attached to the Environment Protection Licence (EPL) No. 12932 and Mining Leases,
- water access licences (WALs) under the NSW *Water Management Act, 2000* and water licences under the NSW *Water Act, 1912*; and
- other relevant legislation.

Obligations relevant to this LW101-105 WMP are described below.

3.1 EP&A ACT APPROVAL

Condition 5(h), Schedule 4 of Project Approval (08_0135) requires the preparation of a Water Management Plan (i.e. this LW101-105 WMP) as a component of the Extraction Plan. In addition, Conditions 5(n), 5(p) and 6, Schedule 4 and Condition 3, Schedule 6 of Project Approval (08_0135) outline general management plan requirements that are applicable to the preparation of this LW101-105 WMP. Table 1 presents these requirements and indicates where they are addressed within this LW101-105 WMP.

Table 1: Water Management Plan Requirements

Project Approval (08_0135) Condition	LW101-105 WMP Section
Condition 5, Schedule 4	
5. The Proponent shall prepare and implement an Extraction Plan for all second workings on site to the satisfaction of the Secretary. Each extraction plan must:	
...	
(h) include a Water Management Plan, which has been prepared in consultation with EPA and DPI Water, which provides for the management of the potential impacts and/or environmental consequences of the proposed second workings on watercourses and aquifers, including:	This document
• *surface and groundwater impact assessment criteria, including trigger levels for investigating any potentially adverse impacts on water resources or water quality;*	Section 5
• *a program to monitor and report stream flows, assess any changes resulting from subsidence impacts and remediate and improve stream stability;*	Sections 6 and 8

Table 1 (Continued): Water Management Plan Requirements

Project Approval (08_0135) Condition	LW101-105 WMP Section
• *a program to monitor and report groundwater inflows to underground workings;*	Sections 6 and 8
• *a program to predict, manage and monitor impacts on groundwater bores on privately-owned land;*	Sections 6 and 8
• *a program to:*	Attachment 2
– *confirm the location and saturated extent of the palaeochannel adjacent to the extents of underground 1 second workings, including drilling of additional investigation bores;*	Sections 4 and 6
– *validate, and if necessary revise, the groundwater model for the palaeochannel; and*	Sections 4 and 7
– *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; and*	Sections 6 and 8
...	
(n) include a contingency plan that expressly provides for adaptive management where monitoring indicates that there has been an exceedance of any performance measure in Table 18 and 19, or where such exceedances seem likely;	Section 7
...	
(p) include a program to collect sufficient baseline data for future Extraction Plans.	Section 8.3
Condition 6, Schedule 4	
6. The Proponent shall ensure that the management plans required under conditions 5(g)-(l) above include:	
(a) an assessment of the potential environmental consequences of the Extraction Plan incorporating any relevant information that has been obtained since this approval; and	Sections 4 and 6.4
(b) a detailed description of the measures that would be implemented to remediate predicted impacts.	Section 7
Condition 3, Schedule 6	
3. The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include:	
(a) detailed baseline data	Sections 4.4.1 and 4.5.1
(b) a description of:	
• *the relevant statutory requirements (including any relevant approval, licence or lease conditions);*	Section 3
• *any relevant limits or performance measures/criteria;*	Section 5
• *the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures;*	Section 5
(c) a description of the measures that would be implemented to comply with the relevant statutory requirements, limits, or performance measures/criteria;	Sections 7
(d) a program to monitor and report on the:	Sections 6 and 8
• *impacts and environmental performance of the project;*	
• *effectiveness of any management measures (see c above);*	
(e) a contingency plan to manage any unpredicted impacts and their consequences;	Section 7
(f) a program to investigate and implement ways to improve the environmental performance of the project over time;	Sections 6 and 8

Table 1 (Continued): Water Management Plan Requirements

Project Approval (08_0135) Condition	LW101-105 WMP Section
(g) a protocol for managing and reporting any:	
• *incidents;*	Section 9
• *complaints;*	Section 10
• *non-compliances with statutory requirements; and*	Section 111
• *exceedences of the impact assessment criteria and/or performance criteria; and*	Section 7
(h) a protocol for periodic review of the plan.	Section 2

3.2 OTHER LEGISLATION

MCO will operate the Moolarben Coal Complex consistent with Project Approval (08_0135) and any other legislation that is applicable to an approved Part 3A Project under the EP&A Act.

The following Acts may be applicable to, but are not limited to, the conduct of the Moolarben Coal Complex:

- *Crown Lands Act, 1989;*
- *Fisheries Management Act, 1994;*
- *Heritage Act, 1977;*
- *Coal Mine Subsidence Compensation Act 2017*
- *Mining Act, 1992;*
- *National Parks and Wildlife Act, 1974;*
- *Biodiversity Conservation Act, 2016;*
- *Protection of the Environment Operations Act, 1997;*
- *Roads Act, 1993;*
- *Water Act, 1912;*
- *Water Management Act, 2000;*
- *Work Health and Safety Act, 2011*; and
- *Work Health and Safety (Mines and Petroleum Sites) Act, 2013.*

Relevant licences or approvals required under these Acts will be obtained as required.

3.3 WATER LICENCES HELD BY MCO

The water licences held by MCO are listed in Table 1a.

Groundwater use including incidental use or "take" of groundwater will be assessed for each water source affected by the Moolarben Coal Complex, and accounted for by way of the groundwater licences held by the Moolarben Coal Complex.

Table 1a: Relevant Water Licences Held by MCO

Licence Number	Description
WAL36340, 37583 and 19424	Wollar Creek Water Source – Hunter Unregulated and Alluvial Water Sources
WAL37582 and 41888	Upper Goulburn River Water Source – Hunter Unregulated and Alluvial Water Sources
WAL39799	Sydney Basin - North Coast Fractured and Porous Rock Groundwater Source

[1] In accordance with Condition 29, Schedule 3 and Condition 25, Schedule 3 of the NSW Project Approvals (05_0117 and 08_0135, respectively), MCO would obtain additional licences/allocations under the *Water Management Act, 2000* and *Water Act, 1912* as they are required for activities at the Moolarben Coal Complex.

4.0 PREDICTED SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES

4.1 LONGWALLS 101-105 EXTRACTION SCHEDULE

Longwalls 101-105, the 103 Plunge Panel and the area of land within the furthest extent of the 26.5° angle of draw and 20 mm predicted subsidence contour (i.e. the Longwalls 101-105 Study Area) are shown on Figures 3 and 4. Longwall extraction will occur from the west to the east. The longwall layout includes approximately 311 metre (m) panel widths (void) with 20 m pillars (solid).

The provisional extraction schedule for Longwalls 101-105 is provided in Table 2.

Table 2: Provisional Extraction Schedule

Longwall	Estimated Start Date	Estimated Duration	Estimated Completion Date
101	-	-	Complete
102 (A+B)	-	-	Complete
103	September 2019	9 months	June 2020
103 Plunge	-	-	Complete
104	July 2020	12 months	July 2021
105	July 2021	12 months	July 2022

Following approval of the UG1 Optimisation Modification in April 2016, MCO delineated a geological feature in Longwall 102 that prevented economic mining of this section, and has subsequently revised the longwall layout to incorporate a barrier pillar around this feature. The barrier pillar separating Longwalls 102A and 102B is approximately 140 m in length. In addition, following further detailed design, Longwalls 101-103 have been shortened by approximately 70 m to provide safe operational conveyor distance between the end of the longwalls and main headings.

A second geological intrusion has been located at the commencing end of LW103 preventing viable extraction by longwall mining methods in this area. As a consequence, the LW103 commencing position has been moved outbye of the influence of this structure, and a first workings plunge panel has been established to partially extract the remanent coal that would otherwise become sterilised.

LW104 commencing end has also been shortened by 70m to facilitate the installation of a rear panel ventilation shaft and associated roadway.

With the exception of these changes, the longwall geometry is the same as that for the approved UG1 Optimisation Modification, and MSEC (2017 and 2020) concludes that the overall impact assessments for the natural and built features are unchanged or reduced.

4.2 ENVIRONMENTAL RISK ASSESSMENT

Environmental Risk Assessments (ERA) have been conducted for the Longwall 101-105 Extraction Plan to provide appropriate consideration to risk assessment and risk management in accordance with the draft DPIE and DRE (2015) *Guidelines for the Preparation of Extraction Plans*. The suitably qualified and experienced experts endorsed by the Secretary of the DPIE for the preparation of the UG1 Longwalls 101-105 Extraction Plan participated in the ERAs.

The ERAs indicated that risks relevant to surface water and groundwater in the Longwalls 101-105 Study Area were in the "Low" or "Medium" category, and it was expected that the risks could be managed with implementation of the appropriate mitigation, management and/or control measures.

4.3 PREDICTED SUBSIDENCE IMPACTS

Subsidence impact predictions for the drainage lines in the Longwalls 101-105 Study Area were conducted in 2015 for the UG1 Optimisation Modification (the Approved Layout) and have been revised to reflect the latest longwall layout (the Extraction Plan Layout) (MSEC, 2017,2019 and 2020).

No rivers, creeks or watercourses are impacted by subsidence from Longwalls 101-105. The only drainage line predicted to be impacted by subsidence from Longwalls 101-105 are ephemeral drainage line DL6 and DL7.

MSEC (2020) compared the maximum predicted subsidence impacts on DL6 and DL7 due to the extraction of Longwalls 101-105 based on the Extraction Plan Layout, with the maximum predictions due to the extraction of Longwalls 101-105 based on the Approved Layout. This comparison is provided in Table 3.

Table 3: Comparison of Maximum Predicted Conventional Subsidence Parameters for Drainage Line 7 based on the Approved Layout and the Extraction Plan Layout

Layout	Subsidence[1] (mm)	Tilt[2] (mm/m)	Hogging Curvature[3] (km^{-1})	Sagging Curvature[3] (km^{-1})
Approved Layout (Longwalls 101-105)	2200	65	>3.0	>3.0
Extraction Plan Layout	2200	65	>3.0	>3.0

Source: MSEC (2020).

mm/m = millimetres per metre, km^{-1} = 1/kilometres.

1 Subsidence refers to vertical displacements of the ground.

2 Tilt is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those two points.

3 Curvature is the second derivative of subsidence, the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections.

The maximum predicted total subsidence parameters for DL6 and DL7 based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 105 (MSEC, 2020).

The maximum predicted total conventional subsidence, tilt and curvature for drainage line DL6 and DL7 resulting from the extraction of Longwalls 101 to 105, based on the Extraction Plan Layout, are provided in Table 4.

Table 4: Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for Drainage Line 6 and 7 Resulting from the Extraction of Longwalls 101 to 105

Location	Subsidence (mm)	Tilt (mm/m)	Hogging Curvature (km^{-1})	Sagging Curvature (km^{-1})
Drainage Line 6	2200	65	> 3.0	> 3.0
Drainage Line 7	2200	60	> 3.0	> 3.0

Source: after MSEC (2017)

4.4 SURFACE WATER

4.4.1 Baseline Data

The Moolarben Coal Complex is located in the Upper Goulburn River and Wollar Creek catchments (both sub-catchments to the larger Goulburn River and Hunter River catchments), which have catchment areas of approximately 2,455 square kilometres (km^2) and 532 km^2, respectively. Both catchments drain to the Goulburn River which flows in an easterly direction, eventually joining the Hunter River approximately 150 km downstream of the Moolarben Coal Complex.

Moolarben Creek is a tributary of the Upper Goulburn River sub-catchment and flows along the western boundary of the Moolarben Coal Complex. Wilpinjong Creek is a tributary of Wollar Creek sub-catchment and flows along the east and north-east of the Moolarben Coal Complex into Wollar Creek, before joining the Goulburn River approximately 26 km downstream of the Moolarben Coal Complex.

Four minor drainage lines were identified by MSEC (2015) within the UG1 Study Area (i.e. associated with Longwalls 101-105) as part of the Subsidence Assessment for the *UG1 Optimisation Modification Environmental Assessment* (UG1 Optimisation Modification). All drainage lines identified in the vicinity of the Longwalls 101-105 Study Area are ephemeral as water only flows during, and for short periods after, each rain event (MSEC, 2015).

Of the drainage lines identified within the UG1 Study Area, only a section of drainage lines DL6 and DL7 are impacted by Longwalls 101 to 105 (Figure 4). DL6 and DL7 are tributaries of Murragamba Creek, which flows into Wilpinjong Creek.

DL4 and DL5 are located within the approved out-of-pit emplacement and no longer exist.

4.4.2 Summary of Subsidence Impacts to Drainage Lines

MSEC (2017 and 2020) concluded the maximum predicted total subsidence parameters for the drainage lines based on the Approved Layout are the same as those for the Extraction Plan Layout for Longwalls 101 to 105. Therefore, the potential impacts on the drainage lines are the same as those assessed based on the Approval Layout. In summary (MSEC, 2017 and 2020):

- The drainage lines within the Study Area are top of catchment ephemeral drainage features as water only flows during and for short periods after each rain event. Small residual ponded areas may occur for short periods of time immediately after major rain events along the shorter flatter grade sections of the drainage lines. Additional ponding may occur along the drainage lines resulting from the extraction of Longwalls 101 to 105.
- Sections of beds downstream of the additional ponding areas, may erode during subsequent rain events, especially during times of high flow. It is expected that, over time, the gradients along the drainage lines would approach grades similar to those that existed before mining. The extent of additional ponding along the drainage lines would, therefore, be expected to decrease with time.
- Fracturing and dilation of the bedrock would occur as a result of the extraction of these longwalls.
- In times of heavy rainfall, the majority of the surface water runoff would be expected to flow over the surface cracking in the beds and only a small proportion of the flow would be diverted into the fractured and dilated strata below. In times of low flow, however, a larger proportion of the surface water flow could be diverted into the strata below the beds and this could affect the quality and quantity of this water flowing through the cracked strata beds. Nevertheless, during high flow or low flow times, this small quantity is expected to have little impact on the overall quality of water flowing out of the drainage lines.

WRM (2017 and 2020) considered the potential impacts to drainage lines DL6 and DL7 as a result of the extraction of Longwalls 101-105 and concluded that, consistent with predicted impacts for the Approved Layout:

- The predicted changes in grade are expected to increase the risk of erosion over a reach length of about 100 m immediately downstream of the chain pillar.
- The predicted changes in grade are expected to increase the risk of ponding over a reach length of about 100 m immediately upstream of the chain pillar.

- It is expected that over time, the gradients along the drainage lines would approach grades similar to those which existed before mining. The extent of additional ponding along the drainage lines would therefore be expected to decrease with time.
- It is also expected that, with time, the fracturing in the bedrock would be filled with alluvial and colluvial materials during subsequent flow events, reducing the diversion of surface water flows into subsurface flows.
- It may be necessary, however, that some remediation of the beds of the drainage line would be required, such as infilling of surface cracks with materials comprising a high clay content, or by locally regrading and re-compacting the surface.

4.5 GROUNDWATER

4.5.1 Baseline Data

Previous groundwater assessments have extensively detailed the hydrogeological regime and groundwater quality within and surrounding the Moolarben Coal Complex. Previous assessments include:

- *Moolarben Coal Project – Groundwater Assessment* (Peter Dundon and Associates Pty Ltd, 2006);
- *Moolarben Stage 2 Groundwater Assessment* (Aquaterra Consulting Pty Ltd, 2008);
- *Moolarben Complex Stage 2 – Preferred Project Report – Groundwater Impact Assessment* (RPS Aquaterra, 2011);
- *Moolarben Coal Complex Stage 1 Optimisation Modification Groundwater Assessment* (Australasian Groundwater & Environmental Consultants Pty Ltd, 2013);
- *Moolarben Coal Complex UG1 Optimisation Modification – Environmental Assessment – Groundwater Assessment* (Dundon Consulting Pty Limited, 2015);
- *Moolarben Coal Complex UG1 Optimisation Modification Groundwater Modelling Assessment* (HydroSimulations, 2015); and
- *Moolarben Coal Open Cut Optimisation Groundwater Assessment (Hydrosimulations, 2017)*;

4.5.2 Hydrogeological Regime

The Moolarben Coal Complex area is located in the Western Coalfield on the north-western edge of the Sydney-Gunnedah Basin, which contains sedimentary rocks, including coal measures, of Permian and Triassic age. 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.

4.5.3 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 *NSW Aquifer Interference Policy*, 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.

4.5.4 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 maximum 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 have been conducted to better define the thickness and the extent of the palaeochannel to the north-east of UG1. These investigations have determined that the extent of saturated palaeochannel is outside the LW101 to 103 footprint and extends over portions of the LW104-105 footprint (attachment 2).

An extensive description of the location and saturated extent of the palaeochannel is provided by SLR (2020) which includes analysis of additional investigation bores drilled after the UG1 Optimisation Modification Environmental Assessment to confirm the location and saturated extent of the palaeochannel adjacent to the extents of Longwalls 101 to 105 in fulfilment of Condition 5(h), Schedule 4 of Project Approval 08_0135.

4.5.5 Porous Rock Groundwater Systems

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

4.5.6 Groundwater Use

None of the identified groundwater systems is a significant aquifer. 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 outcrops and subcrops. 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 there is no credible mechanism for impact from the extraction of Longwalls 101-105.

4.5.7 Private Bores

No private bores are predicted to experience greater than minimal impact (i.e. drawdown greater than 2 m, as defined in the *NSW Aquifer Interference Policy*) due to the Moolarben Coal Complex.

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 101 – 105. 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.

4.5.8 Predicted Impacts

Potential groundwater impacts due to the extraction of Longwalls 101-105 were assessed in 2015 as part of the UG1 Optimisation Modification (the Approved Layout). These predicted impacts have been reviewed by HydroSimulations (2017) and SLR (2020) for the updated palaeochannel extent and Extraction Plan 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 lengths of Longwalls 101-103 have been reduced from those that were simulated by approximately 70 m.
- MSEC (2017and 20) 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 inflow and alluvial takes.

In summary, the approved potential groundwater impacts of the Moolarben Coal Complex are predicted to remain consistent for the minor changes in the layout of Longwalls 101 to 105 and updated tertiary palaeochannel extent for the Extraction Plan.

Key outcomes of previous groundwater assessments for the approved Moolarben Coal Complex are (HydroSimulations, 2017and SLR, 2020):

- Groundwater modelling revised to reflect updated palaeochannel extents identifies negligible change to predicted groundwater inflows and alluvial takes.
- No private bores are likely to be affected by 2 m drawdown or more due to the Moolarben Coal Complex, including UG1.
- No drawdown is anticipated in the Upper Triassic (or Lower Triassic) as these sediments are inherently dry in the vicinity of UG1.
- Drawdown in the permian coal measures; however, as the permian coal measures has no productive water use other than for mining purposes, no change to beneficial use category is anticipated.

5.0 PERFORMANCE MEASURES, PERFORMANCE INDICATORS AND INVESTIGATION TRIGGER LEVELS

5.1 SUBSIDENCE IMPACT PERFORMANCE MEASURES

This LW101-105 WMP has been developed to manage the potential environmental consequences of the secondary extraction of Longwalls 101-105 on drainage lines and aquifers in accordance with Condition 5(h), Schedule 4 of Project Approval (08_0135).

In accordance with Condition 1, Schedule 4 of Project Approval (08_0135), MCO must ensure that there is no exceedance of the subsidence impact performance measures listed in Table 18 of Condition 1, Schedule 4 and Table 19 of Condition 3, Schedule 4 of Project Approval (08_0135).

The subsidence impact performance measure relevant to water resources in the Longwalls 101-105 Study Area is listed in Table 5.

Table 5: Water Subsidence Impact Performance Measure

Feature	Subsidence Impact Performance Measure
Drainage Lines (DL1 – DL7)	No greater subsidence impacts or environmental consequences than predicted in the EA.

Source: Table 18 of Condition 1, Schedule 4 of Project Approval (08_0135).

Notes:

- MCO is required to define more detailed performance indicators (including impact assessment criteria) for each of these performance measures in the various management plans that are required under this approval.
- Measurement and/or monitoring of compliance with performance measures and performance indicators is to be undertaken using generally accepted methods that are appropriate to the environment and circumstances in which the feature or characteristic is located. These methods are to be fully described in the relevant management plans. In the event of a dispute over the appropriateness of proposed methods, the Secretary of the DPIE will be the final arbiter.

The performance measure *'No greater subsidence impacts or environmental consequences than predicted in the EA'* for Drainage Lines (DL1-DL7) reflects the predictions by MSEC (2015), which are summarised in Section 4.4.2.

WRM (2017 and 2020) has developed objectives and performance indicators to assess whether potential subsidence impacts on surface drainage are not greater than those predicted. Table 6 details the objectives and performance indicators for DL6 and DL7.

Table 6: Surface Water Subsidence Management Objectives and Performance Indicators

Objective	Performance Indicator
Drainage Lines	
No significant increase in active erosion in DL6 and DL7.	• Change in visible erosion. • Development of, or change in, headcut erosion along DL6 and DL7.
No change in stream character for DL6 and DL7 beyond approved.	• Change in character, such as increased erosion or change in vegetation along drainage line. • Extensive duration of water ponding.
No measurable change in downstream water quality.	• Downstream water quality (consistent with approved complex-wide Surface Water Management Plan [SWMP]).
Minimise change in surface flow when cracks appear (as is predicted to occur)	• Appearance of unsealed surface cracking across the bed of DL6 and DL7.

5.2 SURFACE WATER QUALITY TRIGGER INVESTIGATION LEVELS

The complex-wide SWMP includes water quality investigation trigger levels. As DL6 and DL7 are (minor drainage line) tributaries of Murragamba Creek (which flows into Wilpinjong Creek), the water quality investigation trigger levels established for Wilpinjong Creek at monitoring site SW16 (Figure 4 and Table 7) (based on analysis of surface water quality monitoring data) are relevant to this LW101-105 WMP, to confirm subsidence impacts from Longwalls 101-105 do not result in adverse water quality impacts to the downstream environment.

Table 7: Surface Water Quality Trigger Investigation Levels

Waterway	Monitoring Site	pH		EC (µs/cm)		Turbidbity (NTU)	
		20th/80th %ile Trigger Values	ANZECC Guideline	80th %ile Trigger Value	ANZECC Guideline	80th %ile Trigger Value	ANZECC Guideline
Wilpinjong Creek	SW16	6.5 – 7.4	6.5 – 8.0	714	350	64	25

Note: The shaded cells indicate the adopted water quality trigger level.

%ile = percentile, EC = electrical conductivity, µS/cm = microSiemens per centimetre and NTU = Nephelometric Turbidity Units.

5.3 GROUNDWATER TRIGGER INVESTIGATION LEVELS

There are no subsidence performance measures relevant to groundwater. Notwithstanding, a summary of groundwater levels and quality investigation triggers relevant to Longwalls 101-105 is provided below. Triggers are consistent with the complex-wide Groundwater Management Plan.

Salinity and pH Triggers

Salinity and pH investigation trigger levels are defined in Table 8 and are a sub-set of those in the complex-wide Groundwater Management Plan [GWMP] considered by SLR (2020) to be those relevant for investigating potential changes in groundwater quality due to longwall mining in Longwalls 101- 105. 105.

Salinity triggers have been developed based on the 95th percentile baseline salinity level recorded at relevant bore locations. Should a measured salinity level exceed the trigger for two consecutive monitoring events, and the measured salinity is in a lower beneficial use category than the trigger level, then the groundwater investigation protocol described in the complex-wide GWMP will be initiated.

pH triggers have been developed from the 5th and 95th percentile baseline pH levels recorded at each bore location considered relevant to Longwalls 101-105. Should a measured pH level exceed the trigger for two consecutive monitoring events, then the groundwater investigation protocol described in the complex-wide GWMP will be initiated.

Table 8: Salinity and pH Trigger levels

Bore	Depth (m)	Lithology Screened	Salinity Triggers			pH Trigger Level (5th to 95th percentile)[1]
			Historical lab EC (5th to 95th percentile) (µS/cm)[1]	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)

1 Historical values in brackets are median values.

Groundwater Level Triggers

Triggers for measured groundwater levels have been developed based on the minimal impact considerations in the *NSW Aquifer Interference Policy*.

There is no ‘highly productive’ groundwater, as defined under the *NSW Aquifer Interference Policy*, 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.

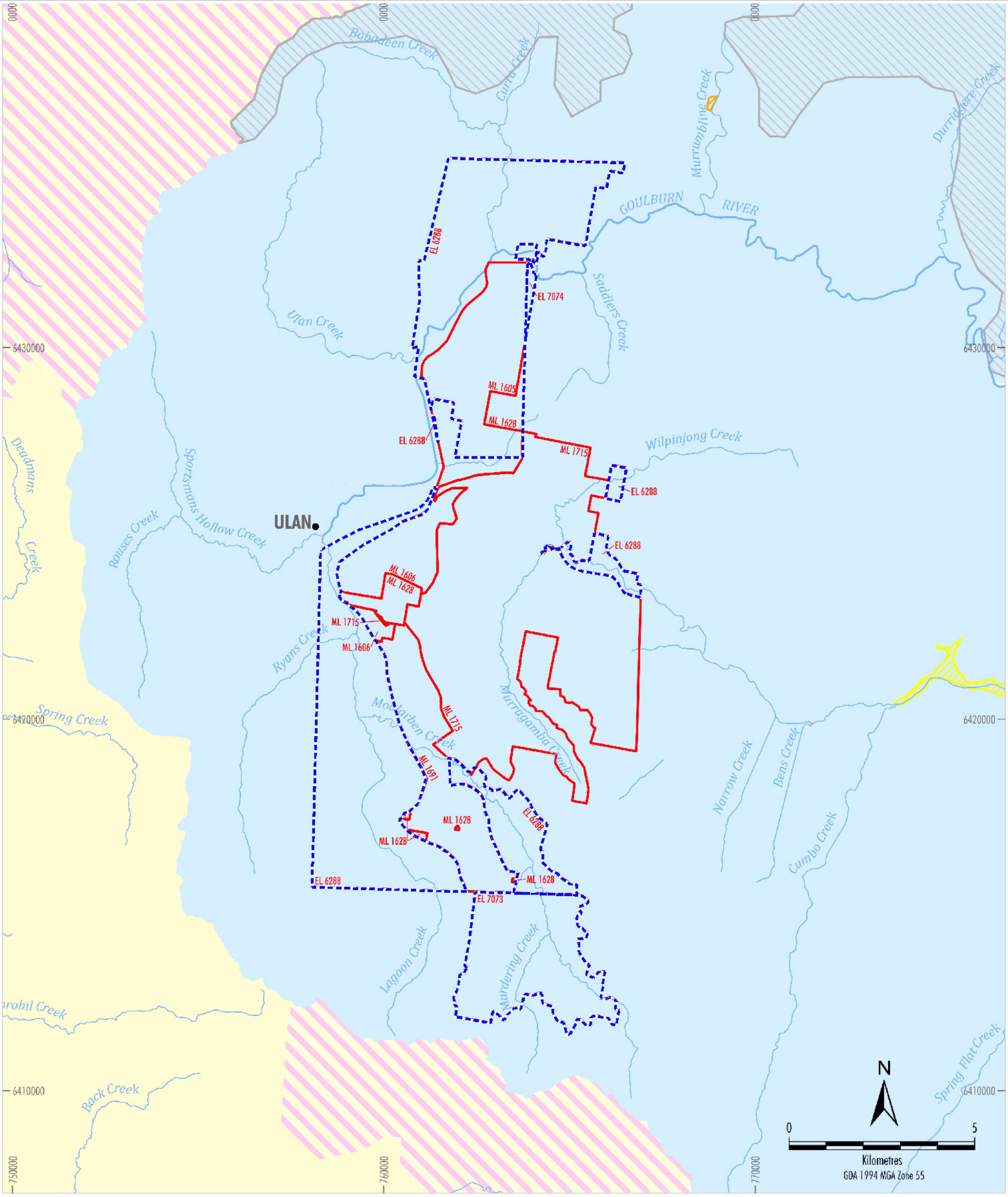
The *NSW Aquifer Interference Policy* describes the following minimal impact considerations for less productive groundwater sources:

> *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 groundwater dependent ecosystems or high priority culturally significant sites identified in the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* or *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* in the vicinity of the Moolarben Coal Complex (Figure 5).

The groundwater investigation protocol detailed in the approved complex-wide GWMP would be initiated in cases where groundwater monitoring identifies the potential for a greater than 2 m reduction in the groundwater level at a private bore, determined against groundwater level hydrograph trends.

Groundwater level triggers have been developed for alluvium monitoring bores 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.



LEGEND

Exploration Licence Boundary

Mining Lease Boundary

Water Sharing Plan for the NSW Murray Darling Basin Fractured Rock Groundwater Sources 2011

Lachlan Fold Belt MDB Groundwater Source

Water Sharing Plan for the NSW Murray Darling Basin Porous Rock Groundwater Sources 2011

Sydney Basin MDB Groundwater source

Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016

Sydney Basin - North Coast Groundwater Source

Oxley Basin Coast Groundwater Source

Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009

Unnamed Alluvial in Wollar Creek Water Source

Unnamed Alluvial in Goulburn River Water Source

YANCOAL
MOOLARBEN COAL

Figure 5
Relevant Mapped Groundwater Sources

Table 9: Trigger Groundwater Levels – Alluvium Bores

Piezometer Number	Base of Alluvium/Tertiary Palaeochannel (m AHD)	Interval/Level Monitored (mbgl)	Minimum Observed Groundwater Level/Pressure		Trigger Level (m AHD)
			(mbgl)	(m AHD)	
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

m AHD = metres Australian Height Datum, mbgl = metres below ground level.

The above trigger levels are intended to trigger an investigation to determine whether the cause of the water level/pressure decline is caused by MCO's mining activity, excluding borefield pumping, and to recommend an appropriate response action. Prior to initiating a response action, an exceedance of a trigger level would need to occur for at least two successive monthly monitoring rounds, to eliminate possible anomalous readings.

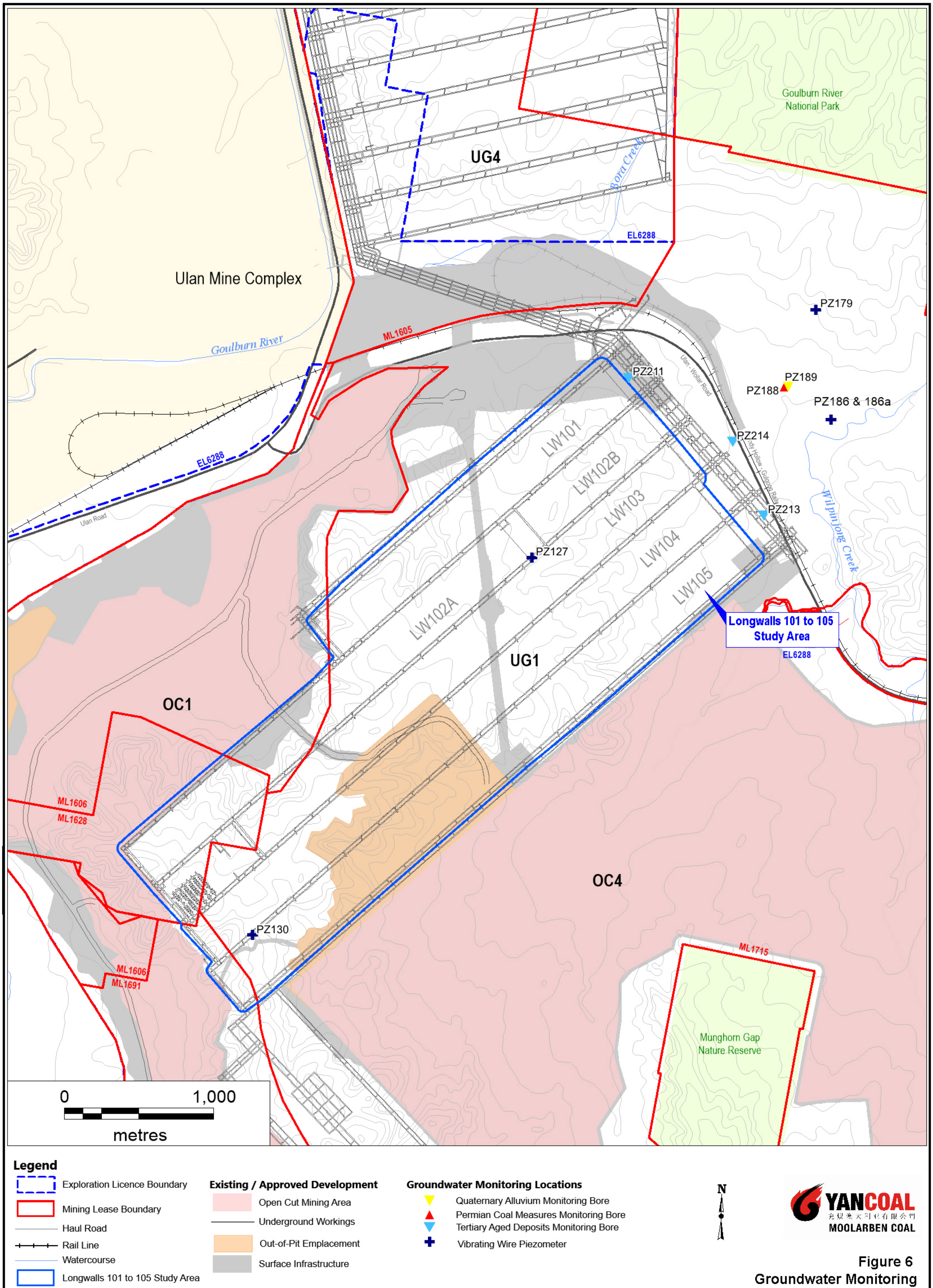


Figure 6
Groundwater Monitoring and Investigation Locations

6.0 MONITORING

6.1 POTENTIAL SUBSIDENCE IMPACTS

A monitoring program has commenced to monitor the impact of the secondary extraction of Longwalls 101-105on DL6 and DL7. The key components of the monitoring program are summarised in Table 10.

Table 10: Water Monitoring Program Overview

Monitoring Component	Parameter	Timing/Frequency	Responsibility
Pre-mining			
Visual inspection and photographic record of drainage line DL6 & DL7	Baseline photographic record. Walk the length of drainage line DL6 & DL7 over Longwall 103 to 105 and note any areas of active erosion, sediment deposition, water ponding or streambed cracking.	Prior to undermining of drainage line.	Environmental and Community Manager
During Mining			
Visual inspection and photographic record of drainage line DK6 and DL7	Walk the length of drainage line DL6 & DL7 over Longwall 103 to 105 and note areas of active erosion, sediment deposition, water ponding or streambed cracking. Compare results against the baseline photographic record.	Within 3 months of undermining drainage line	Environmental and Community Manager
Post Mining			
Visual inspection and photographic record of drainage line DL6 and DL7	Walk the length of drainage line DL6 and DL7 over Longwall 103 to 105 and note any areas of active erosion, sediment deposition, water ponding or streambed cracking. Compare results against the baseline photographic record.	Ongoing inspections every 6 months for 1 year after undermining the drainage line	Environmental and Community Manager

Subsidence parameters will be measured in accordance with the Longwalls 101 to 105 Subsidence Monitoring Program.

6.2 SURFACE WATER FLOW AND QUALITY

Surface water monitoring for receiving watercourses is undertaken for flow, water quality, stream health and channel stability as described in the approved complex-wide SWMP.

Water quality sampling of receiving streams will continue to be undertaken in accordance with the approved complex-wide SWMP. Appropriate water quality monitoring at location downstream of DL6 and DL7 on on Murragamba Creek (SW04) and Wilpinjong Creek (SW16) are shown on Figure 4.

Monitoring parameters are detailed within the SWMP. These are replicated in Table 11 below.

Table 11: Complex Wide SWMP - Table 19 Extract - Monitoring Program

Site	Frequency	Parameters	Site Justification
SW04	Monthly (if flowing)	Flow – Observation pH, EC, TSS, TDS, temperature, turbidity	Downstream of OC4 on Murragamba Creek
	Six monthly (in addition to above)	Al, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Li, Ba, Sr, DO, Total P and Total N	
	After rainfall event (>30mm in 24 hours)	Flow – Observation pH, EC, TSS, TDS, Zn, Fe, turbidity	
SW16	Monthly (if flowing)	Flow – Observation pH, EC, TSS, TDS, temperature, turbidity	Downstream of the confluence of Murragamba Creek on Wilpinjong Creek
	Six monthly (in addition to above)	Al, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Li, Ba, Sr, DO, Total P and Total N	
	After rainfall event (>30mm in 24 hours)	Flow – Observation pH, EC, TSS, TDS, Zn, Fe, turbidity	

6.3 GROUNDWATER

Groundwater monitoring is undertaken for groundwater extraction, groundwater levels, groundwater quality and leachate/seepage losses from water and water storages as described in section 6.0 of the complex-wide GWMP. Groundwater monitoring bores considered by SLR (2020) to be relevant to Longwalls 101-105 are provided in Table 12. The locations of these groundwater monitoring bores are shown on Figure 6.

Groundwater Inflows

Groundwater inflows are determined by monitoring of dewatering (with flow meters), less metered supply inflows, estimated water stored underground, water loss in workings, and calculated recirculation from adjacent Open Cut workings. Groundwater take will be partitioned into the various water sharing plan sources using the relative proportions predicted in the groundwater model. Partitioning may be adjusted based on monitoring data, water geochemistry or expert input.

6.4 SUBSIDENCE – ENVIRONMENTAL CONSEQUENCES

MCO will compare the results of the subsidence impact monitoring against the water performance measure and indicators (Section 5.1). In the event that any observed subsidence impact exceeds a performance indicator, additional monitoring and assessment will be undertaken (Section 7). In the event that any observed subsidence impacts exceed the performance measure, MCO will assess the consequences of the exceedance in accordance with the measures described in Section78.

Table 12: Groundwater Bores Relevant to Longwalls 101-105

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 (m)	Northing (m)
PZ127 *	VWP	152	43	Triassic	Datalog - Reported monthly	Dry	N/A	23/11/2007	20BL173935	762799	6424948
	VWP		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
	VWP		64	Permian overburden	Datalog - Reported monthly	51.6 - 58.9	N/A				
PZ186	VWP	126	40	Upper Permian	Datalog - Reported monthly	TBC	N/A	28/1/2020	20BL173935	764788	6425865
	VWP		65	Middle Permian	Datalog - Reported monthly	TBC	N/A				
	VWP		86	Lower Permian	Datalog - Reported monthly	TBC	N/A				
	VWP		118	Ulan Seam	Datalog - Reported monthly	TBC	N/A				
PZ186 a	VWP	18	–13.5	Palaeochannel Alluvium	Datalog - Reported monthly	TBC	N/A	28/1/2020	20BL173935	764788	6425865
PZ188	SP	18.5	12 - 18	Palaeochannel Alluvium	Datalog - Reported monthly	7.29 - 8.40	6 months	14/05/2009	20BL173935	764478	6426084
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
	VWP		33	Permian overburden	Datalog - Reported monthly	25.8 - 32.7	N/A				

	VWP		145	Ulan seam	Datalog - Reported monthly	28.9 - 71.4	N/A				
PZ211	SP	20	17-20	Palaeochannel Alluvium	Manual monthly	dry	6-months	24/07/2017	20BL173935	763442	6426146
PZ213	SP	22	20-22	Palaeochannel Alluvium	Manual monthly	12.4 – 14.9	6-months	25/07/2017	20BL173935	764341	6425229
PZ214	SP	25	22-25	Palaeochannel Alluvium	Manual monthly	15.1 – 17.9	6-months	27/07/2017	20BL173935	764135	6425720

VWP = Vibrating Wire Piezometer, SP = Standpipe Piezometer, N/A = not applicable, * to be monitored until impacted by mining, TBC = To be completed (i.e. following installation).

7.0 MANAGEMENT AND CONTINGENCY MEASURES

Water management at the Moolarben Coal Complex is currently undertaken in accordance with the approved complex-wide WAMP and associated subplans (Site Water Balance, SWMP and GWMP). Sections 4.0 and 8.0 of the approved complex-wide SWMP provide details of the management system and management measures for surface water, respectively. Section 8.0 of the approved complex-wide GWMP describes management measures for groundwater systems.

In addition to the management systems and measures detailed in the approved complex-wide SWMP and GWMP, WRM (2017; 2020) and HydroSimulations (2017) have recommended measures which are specific to Longwalls 101-105 that will be implemented, where appropriate.

7.1 SURFACE WATER

Potential management measures to mitigate/remediate environmental consequences are provided in Table 13. The implementation of these management measures will be considered with regard to the specific circumstances of the subsidence impact (e.g. the location, nature and extent of the impact) and the assessment of environmental consequences. The implementation of management measures will be related to the scale of impact and the ability to, and value in, undertaking mitigation measures on a case by case basis.

The requirement and methodology for any subsidence remediation techniques will be determined in consideration of:

- Potential impacts of the unmitigated impact, including potential risks to public safety and the potential for self-healing or long-term degradation.
- Potential impacts of the remediation technique, including site accessibility.

Details of trigger events, investigations required, notifications to be undertaken, management and contingency actions for surface water are provided in Table 14.

Table 13: Potential Surface Water Management and Contingency Measures

Potential Management and Contingency Measures	
Measure	**Description**
Drainage Line 6 & 7	
Erosion Management	• Obtain specialist advice on appropriate remediation works.
Remediation of vegetation impacted by erosion and ponding	• Obtain specialist advice on likely cause of vegetation change and remediation strategy.
Water ponding management	• Obtain survey of ponded area to identify ponding depth and extent. • Investigate potential drainage works to restore existing drainage characteristics.
Downstream water quality management	• Manage in accordance with Surface Water Trigger Action Response Plan in section 8.0 of the approved complex-wide SWMP.

7.2 GROUNDWATER

An investigation will be initiated where the groundwater monitoring identifies results outside the trigger levels (or ranges) described in Section 5.3. Details of trigger events, investigations required, notifications to be undertaken, management and contingency actions for different aspects of the water management system are provided in Table 14.

Review of Groundwater Model

Consistent with the commitments within Project Approval 08_0135, a groundwater modelling review and model recalibration (where required) will be conducted 2 years (and 5 yearly thereafter) after commencing Stage 2 coal extraction.

Water Take

Groundwater extraction (take) is determined as described in Section 6.0 of the complex-wide GWMP and is reported in the Annual Review (Section 8.1). If water take exceeds the Available Water, an investigation will be undertaken and relevant non-compliances reported in accordance with Section 11. Available water for each licence will vary from year to year as a result of Available Water Determinations, water trading and carry-over provisions. Where mining related activities have resulted in water take in excess of Available Water, MCO will investigate reasonable and feasible contingency and remedial measures."

Table 14: Trigger Action Response Plan

Performance Criteria	Trigger	Action	Response
Surface Water			
No significant adverse mining related effects to downstream water quality (when compared to baseline and/or ANZECC limits).	Two consecutive monthly surface water quality monitoring results exceed (or below in event of a trigger of the lower pH limit) investigation triggers (**Table 7**) at trigger monitoring location (**Table 7**).	1. Check and validate data. 2. Notify ECM or delegate. 3. Undertake investigation to confirm if investigation trigger exceedance is mining-related: a. If necessary, engage a suitably qualified person. b. Review water quality relative to upstream quality, if water quality upstream of operations is greater than trigger location, cease investigation. c. Confirm if discharge has occurred in the previous 2 months prior to trigger. d. Consider other relevant recent conditions, including climate, flow, water releases, land-use activities. e. Consider other relevant monitoring data, e.g. for releases and stream health. f. If investigation confirms trigger exceedance is not mining-related, record data and cease investigation. 4. If trigger exceedance is mining related, confirm if mining-related activities have caused, or have the potential to cause, material environmental harm (i.e. exceedance of performance criteria). a. If so, notify DPIE and other relevant agencies immediately. b. If not, notify DPIE and other relevant agencies as soon as practicable. 5. Notify DPIE and other relevant agencies if performance measures are exceeded as soon as practicable. 6. Complete Preliminary investigation report and provide to DPIE and relevant agencies within 7 days of identifying the incident.	Where mining-related activities have resulted in trigger exceedances, implement contingency and remedial measures based on investigation. Measures may include: • Review and if necessary, revise Monitoring Program. • Review and revise this document if necessary and re-submit to DPIE. • Investigate potential management measures in Table 13. • Investigate other reasonable and feasible remedial measures.

Performance Criteria	Trigger	Action	Response
Groundwater Quality			
No greater than minimal impact for water users or high priority GDEs (as defined in the AIP for less productive groundwater) due to mining-related activities (i.e no change in beneficial use category).	Two consecutive groundwater quality monitoring results exceed (or below in the event of a lower pH trigger limit) investigation triggers at monitoring location.	1. Check and validate data. 2. Notify ECM or delegate. 3. Undertake investigation to confirm if investigation trigger exceedance is mining-related: a. If necessary, engage a suitably qualified person. b. Consider relevant recent conditions, including climate and land-use activities. c. Consider relevant monitoring data, e.g. other monitoring bores. d. If investigation confirms trigger exceedance is not mining-related, record data and cease investigation. 4. If trigger exceedance is mining-related, confirm if mining-related activities have caused, or have the potential to cause, material environmental harm (i.e. exceedance of performance criteria). a. If so, notify DPIE and other relevant agencies immediately. b. If not, notify DPIE and other relevant agencies as soon as practicable. 5. Notify DPIE and other relevant agencies if performance measures are exceeded as soon as practicable. 6. Complete Preliminary investigation report and provide to DPIE and relevant agencies within 7 days of identifying the incident.	Where mining-related impacts have resulted in trigger exceedances, implement contingency and remedial measures based on investigation. Measures may include: • Review and if necessary, revise Monitoring Program. • Review and revise this document if necessary and re-submit to DPIE. • Investigate reasonable and feasible remedial measures. • Review and repair/replace water management infrastructure if required.

Performance Criteria	Trigger	Action	Response
Groundwater Level			
No greater than minimal impacts to water users or high priority GDEs (as defined in the AIP for less productive groundwater) due to mining impacts.	Two consecutive groundwater level monitoring results exceed investigation trigger at monitoring locations.	1. Check and validate data. 2. Notify ECM or delegate. 3. Undertake investigation to confirm if investigation trigger exceedance is mining-related: a. If necessary, engage a suitably qualified person. b. Consider relevant recent conditions, including climate and land-use activities. c. Consider relevant monitoring data, e.g. other monitoring bores. d. If investigation confirms trigger exceedance is not mining-related, record data and cease investigation. 4. If trigger exceedance is mining-related, confirm if mining-related activities have caused, or have the potential to cause, material environmental harm (i.e. exceedance of performance criteria). a. If so, notify DPIE and other relevant agencies immediately. b. If not, notify DPIE and other relevant agencies as soon as practicable. 5. Notify DPIE and other relevant agencies if performance measures are exceeded as soon as practicable. 6. Complete Preliminary investigation report and provide to DPIE and relevant agencies within 7 days of identifying the incident.	Where mining-related impacts have resulted in trigger exceedances, implement contingency and remedial measures based on investigation. Measures may include: • Review and if necessary, revise Monitoring Program. • Review and revise this document if necessary and re-submit to DPIE. • Implement reasonable and feasible remedial measures. • Provide compensatory groundwater supply or other water supply. • Review and repair/replace water management infrastructure if required. • In the event of dispute, implement the Resolution process outlined in Section 5.5 of the Environmental Management Strategy.

ECM = Environment & Community Manager, DPIE = Department of Planning and Environment, EPA = Environment Protection Authority

8.0 REVIEW AND IMPROVEMENT OF ENVIRONMENTAL PERFORMANCE

8.1 ANNUAL REVIEW

In accordance with Condition 4, Schedule 6 of Project Approval (08_0135), MCO will conduct an annual review of operations conducted at the Moolarben Coal Complex (including the performance of this LW101-105 WMP) prior to 31 March for the preceding calendar year.

The Annual Review will:

- describe the works carried out in the previous calendar year, and the development proposed to be carried out over the current calendar year;
- include a comprehensive review of the monitoring results and complaints records of the Moolarben Coal Complex over the previous calendar year, including a comparison of these results against the:
  - relevant statutory requirements, limits or performance measures/criteria;
  - monitoring results of previous years; and
  - relevant predictions in the EA;
- identify any non-compliance over the last year, and describe what actions were (or are being) taken to ensure compliance;
- identify any trends in the monitoring data over the life of the Moolarben Coal Complex;
- identify any discrepancies between the predicted and actual impacts of the Moolarben Coal Complex, and analyse the potential cause of any significant discrepancies; and
- describe what measures will be implemented over the next year to improve the environmental performance of the Moolarben Coal Complex.

In accordance with Condition 11, Schedule 6 of Project Approval (08_0135), the Annual Review will be made available on the MCO website.

As described in Section 2, this LW101-105 WMP will be reviewed within three months of the submission of an Annual Review, and, if necessary, revised to ensure the plan is updated on a regular basis and to incorporate any recommended measures to improve environmental performance.

8.2 AUDITS

In accordance with Condition 9, Schedule 6 of Project Approval (08_0135), an independent environmental audit was conducted by the end of December 2015 and 2018, and will be undertaken every three years thereafter. A copy of the independent environmental audit report will be submitted to the Secretary of the DPIE and made publicly available on the MCO website.

The independent environmental audit will be conducted by a suitably qualified, experienced and independent team of experts whose appointment has been endorsed by the Secretary of the DPIE.

The independent environmental audit will assess the environmental performance of the Moolarben Coal Complex and assess whether it is complying with the requirements of Project Approval (08_0135), and any other relevant approvals, and recommend measures or actions to improve the environmental performance of the Moolarben Coal Complex.

As described in Section 2, this LW101-105 WMP will be reviewed within three months of the submission of an independent environmental audit, and, if necessary, revised to ensure the plan is updated on a regular basis and to incorporate any practicable recommended measures to improve environmental performance.

8.3 FUTURE EXTRACTION PLANS

In accordance with Condition 5(p), Schedule 4 of Project Approval (08_0135), MCO will collect baseline data for future Extraction Plans (e.g. for the next underground mining domain).

Consideration of environmental performance and management measures, in accordance with the review(s) conducted as part of this LW101-105 WMP, will inform the appropriate type and frequency of monitoring and management/mitigation for future Extraction Plans.

9.0 INCIDENTS

An incident is defined in Project Approval (08_0135) as a set of circumstances that:

- causes or threatens to cause material harm to the environment; and/or
- breaches or exceeds the limits or performance measures/criteria in Project Approval (08_0135).

The reporting of incidents will be conducted in accordance with Condition 7, Schedule 6 of Project Approval (08_0135).

MCO will notify the Secretary of DPIE and any other relevant agencies of any incident associated with the UG1 Underground Mine which causes or threatens to cause material harm to the environment immediately after MCO confirms that an incident has occurred. For any other incident associated with the UG1, MCO will notify the Secretary and any other relevant agencies as soon as practicable after becoming aware of the incident. Within seven days of the date of the incident, MCO will provide the Secretary of the DPIE and any relevant agencies with a detailed report on the incident. The report will:

- describe the date, time and nature of the exceedance/incident;
- identify the cause (or likely cause) of the exceedance/incident;
- describe what action has been taken to date; and
- describe the proposed measures to address the exceedance/incident.

10.0 COMPLAINTS

MCO maintains a Community Complaints Line (Phone Number: 1800 556 484) that is dedicated to the receipt of community complaints. The Community Complaints Line is publicly advertised and operates 24 hours per day, seven days a week, to receive any complaints from neighbouring residents or other stakeholders.

MCO has developed a Community Complaints Procedure which details the process to be followed when receiving, responding to and recording community complaints. The Community Complaints Procedure is supported by a Complaints Database.

The Community Complaints Procedure is a component of the MCO Environmental Management Strategy which requires the recording of relevant information including:

- the nature of the complaint;
- method of the complaint;
- relevant monitoring results and meteorological data at the time of the complaint;
- site investigation outcomes;
- any necessary site activity and activity changes;
- any necessary actions assigned; and
- communication of the investigation outcome(s) to the complainant.

In accordance with Condition 11, Schedule 6 of Project Approval (08_0135), the complaints register will be updated monthly and made available on the MCO website.

11.0 NON COMPLIANCE WITH STATUTORY REQUIREMENTS

A protocol for the managing and reporting of non-compliances with statutory requirements has been developed as a component of MCO's Environmental Management Strategy and is described below.

Compliance with all approvals, plans and procedures will be the responsibility of all personnel (staff and contractors) employed on or in association with the Moolarben Coal Complex.

The Environmental and Community Manager (or delegate) will undertake regular inspections, internal audits and initiate directions identifying any remediation/rectification work required.

As described in Section 9, MCO will notify the Secretary of the DPIE, and any other relevant agencies, of any incident associated with MCO as soon as practicable after MCO becomes aware of the incident. Within seven days of the date of the incident, MCO will provide the Secretary of the DPIE, and any relevant agencies, with a detailed report on the incident.

A report of MCO's compliance with all conditions of Project Approval (08_0135), MLs and relevant licenses will be included in each Annual Review. The Annual Review will be made publicly available on the MCO website.

As described in Section 8.2, an independent environmental audit was conducted by the end of December 2015, and will be undertaken every three years thereafter. A copy of the independent environmental audit report will be submitted to the Secretary of the DPIE and made publicly available on the MCO website.

12.0 REFERENCES

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ATTACHMENT 1

UG1 LONGWALLS 101 TO 105 WATER MANAGEMENT PLAN
SUBSIDENCE IMPACT REGISTER

UG1 Longwalls 101 to 105 Water Management Plan – Subsidence Impact Register

Impact Register Number	Impacted Water Feature	Impact Description	Does Impact Exceed the Land Performance Measure/Indicators? (Yes/No)	Were Management Measures Implemented? (Yes/No)	Were Management Measures Effective? (Yes/No)

ATTACHMENT 2

GROUNDWATER TECHNICAL REPORT

Document	Version	Issue	Effective	Review	Author	Approved
MCO_UG1_LW101-105_WMP	3	Jun 20	Jun 20	May 21	MCO	S. Archinal

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
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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Moolarben Coal Operations (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

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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APPENDICES

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

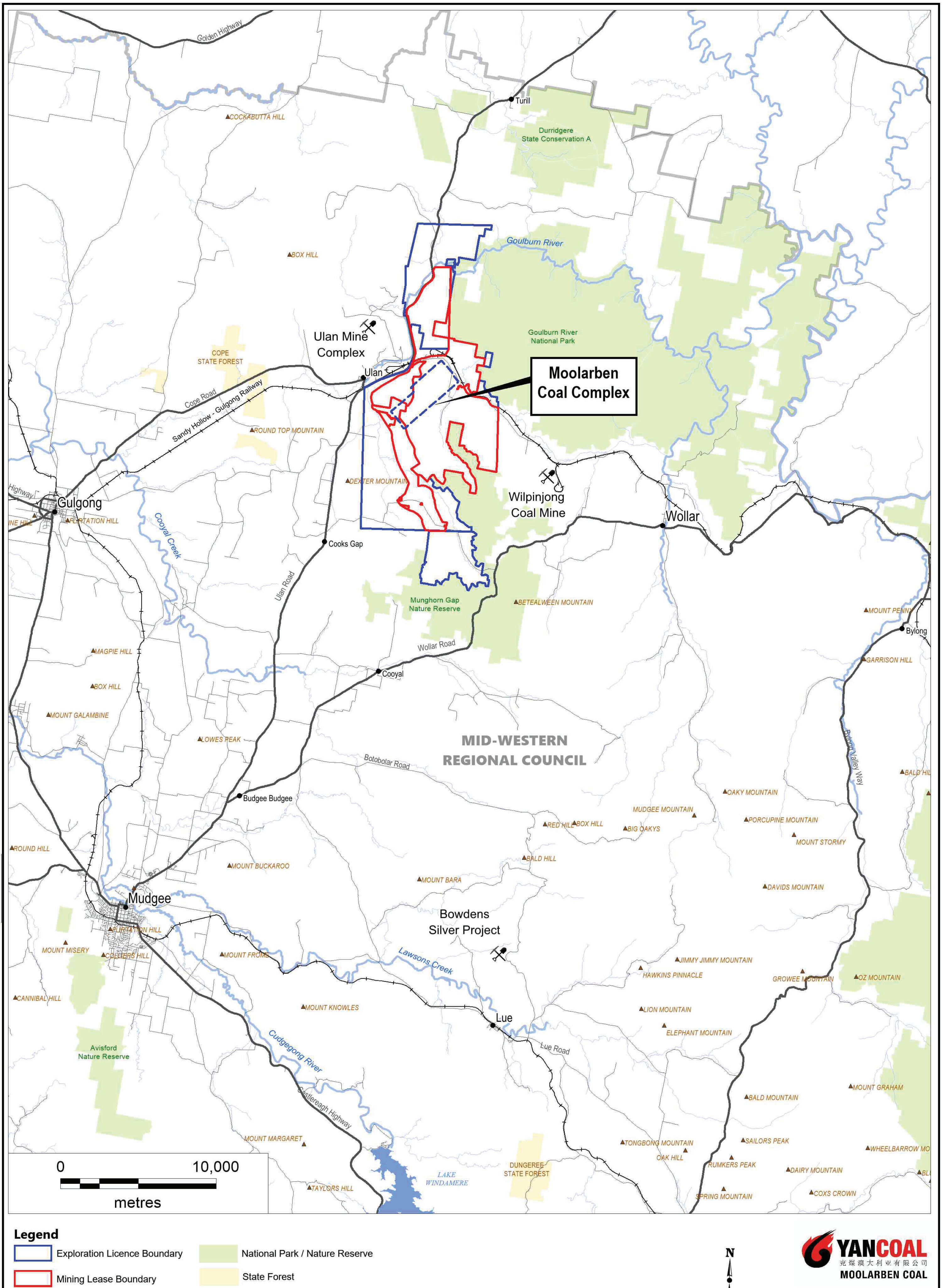


Figure 1
Regional Location

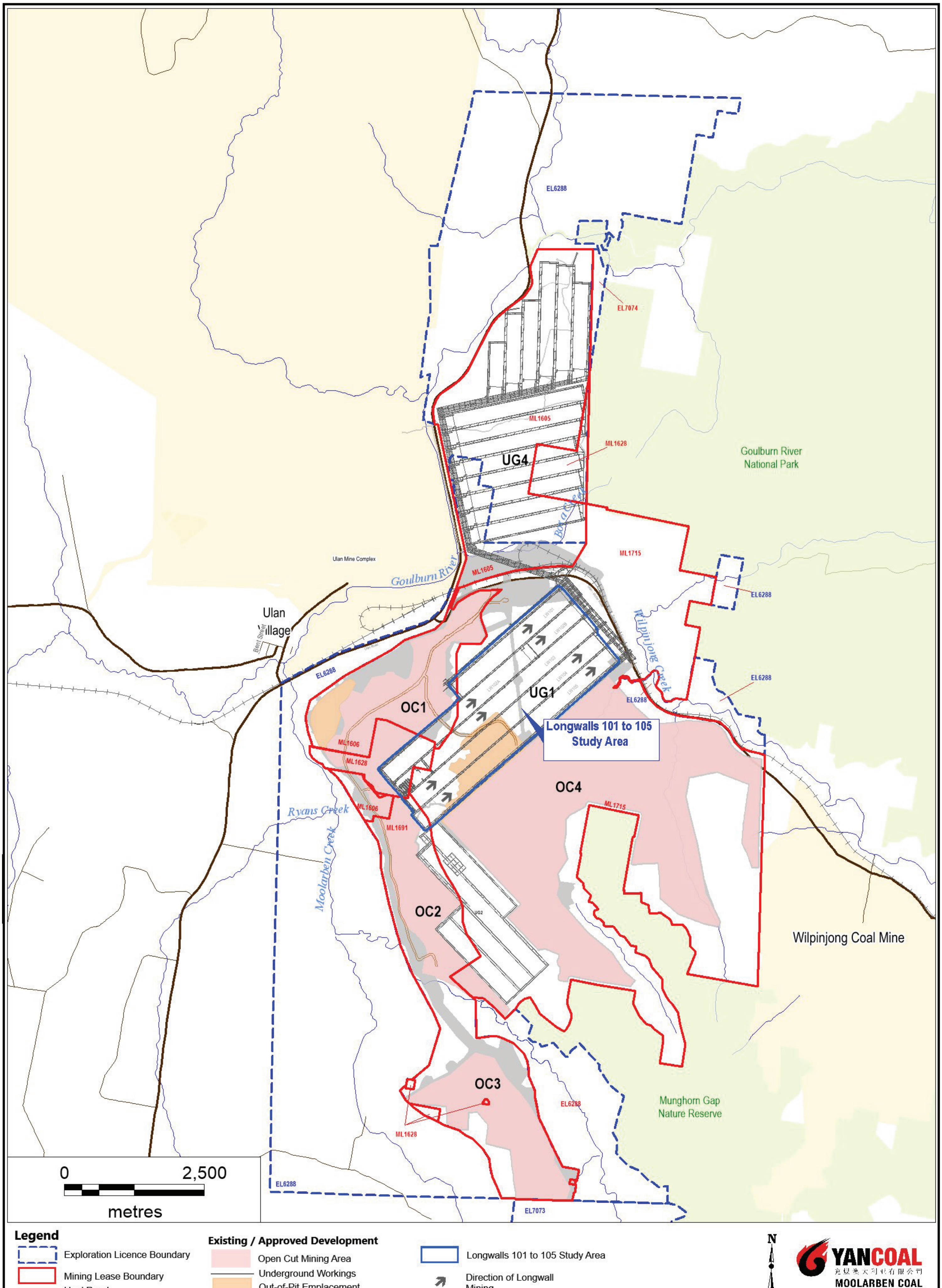
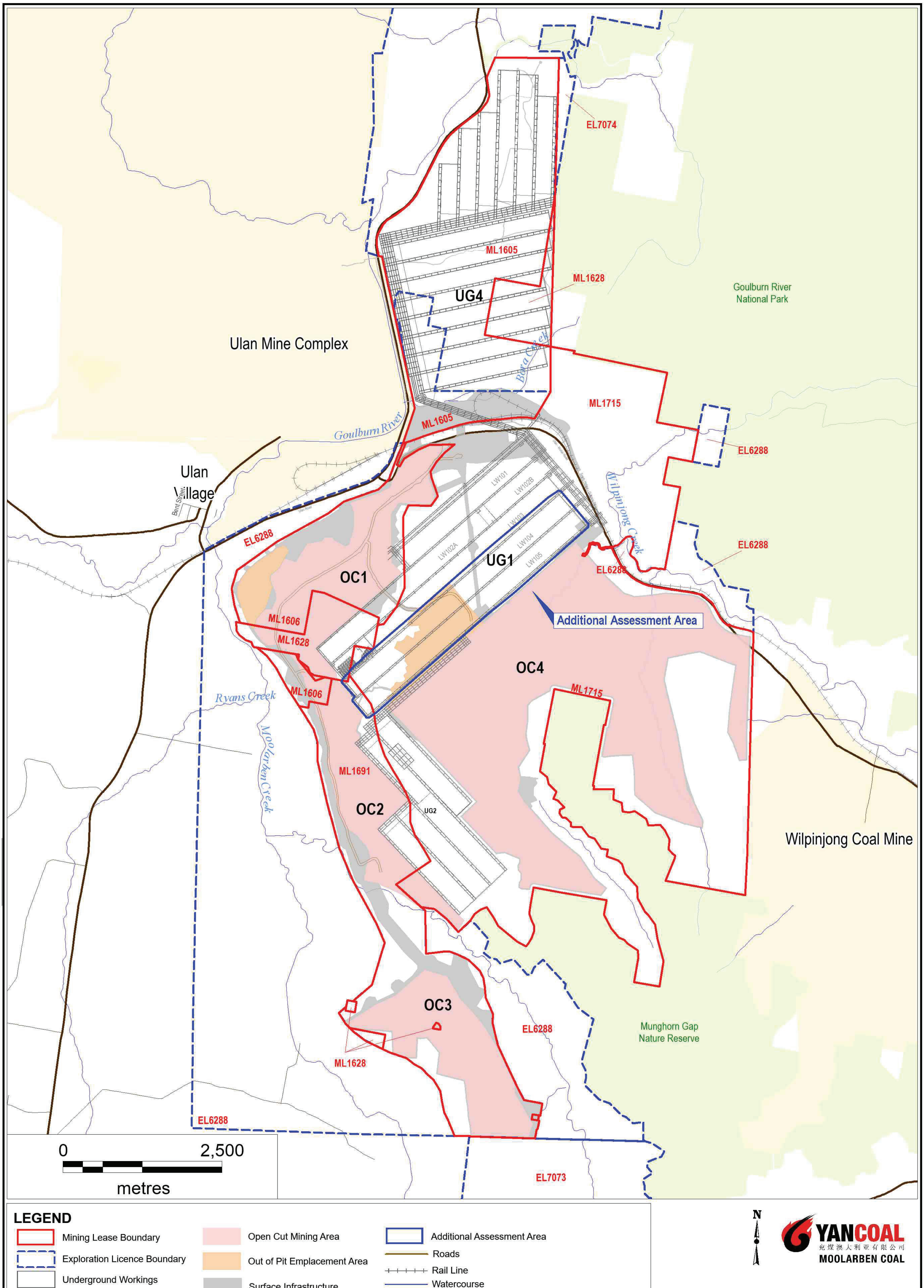


Figure 2
Moolarben Coal Complex Layout



Additional Assessment Area

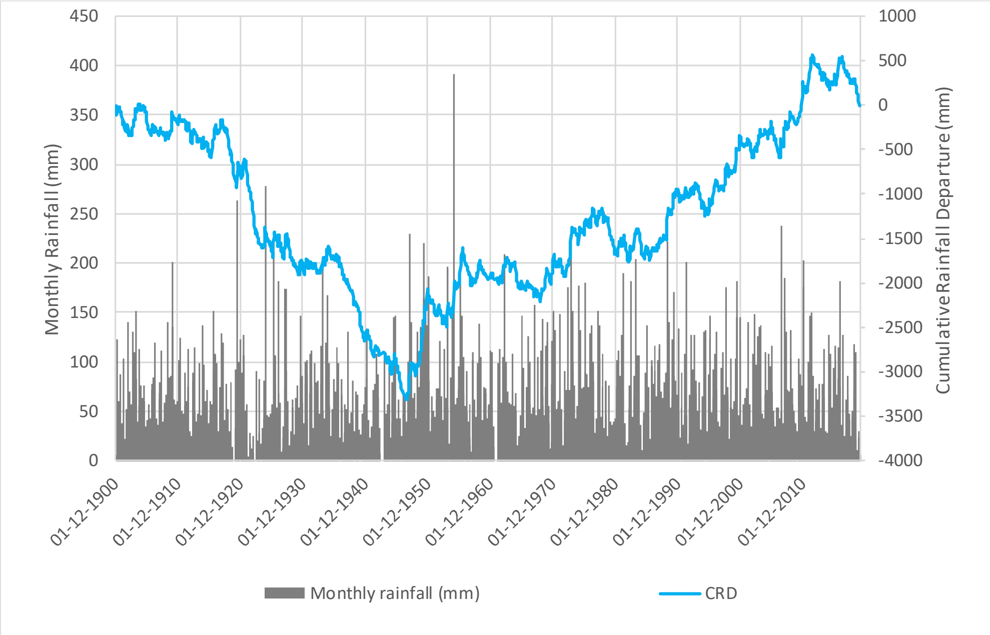


Figure 4 Monthly Rainfall and Cumulative Rainfall Departure (Wollar Station 062032) – All Data

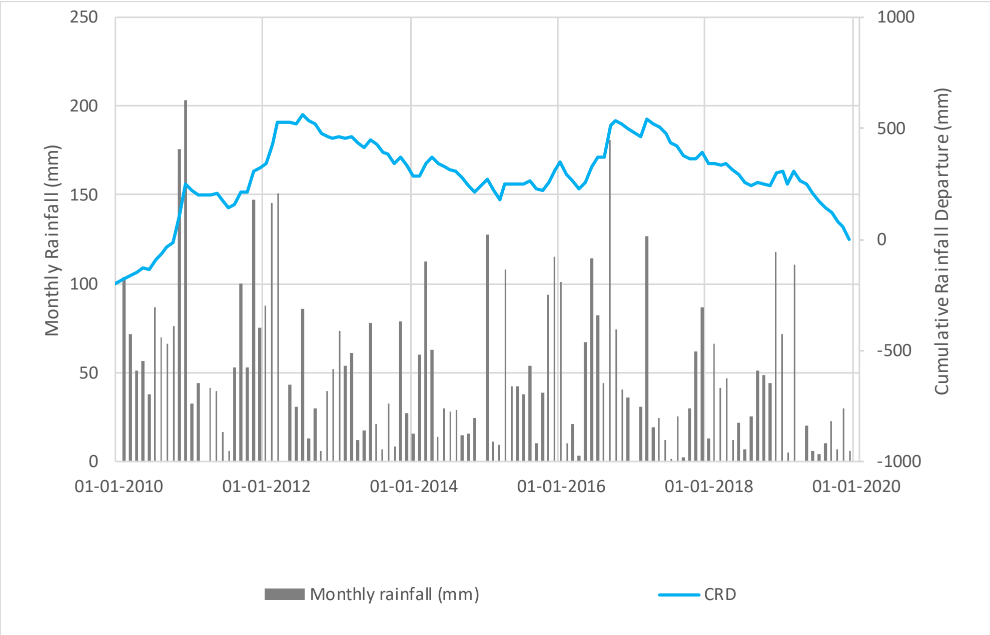


Figure 5 Monthly Rainfall and Cumulative Rainfall Departure (Wollar Station 062032) – 2010 to 2020

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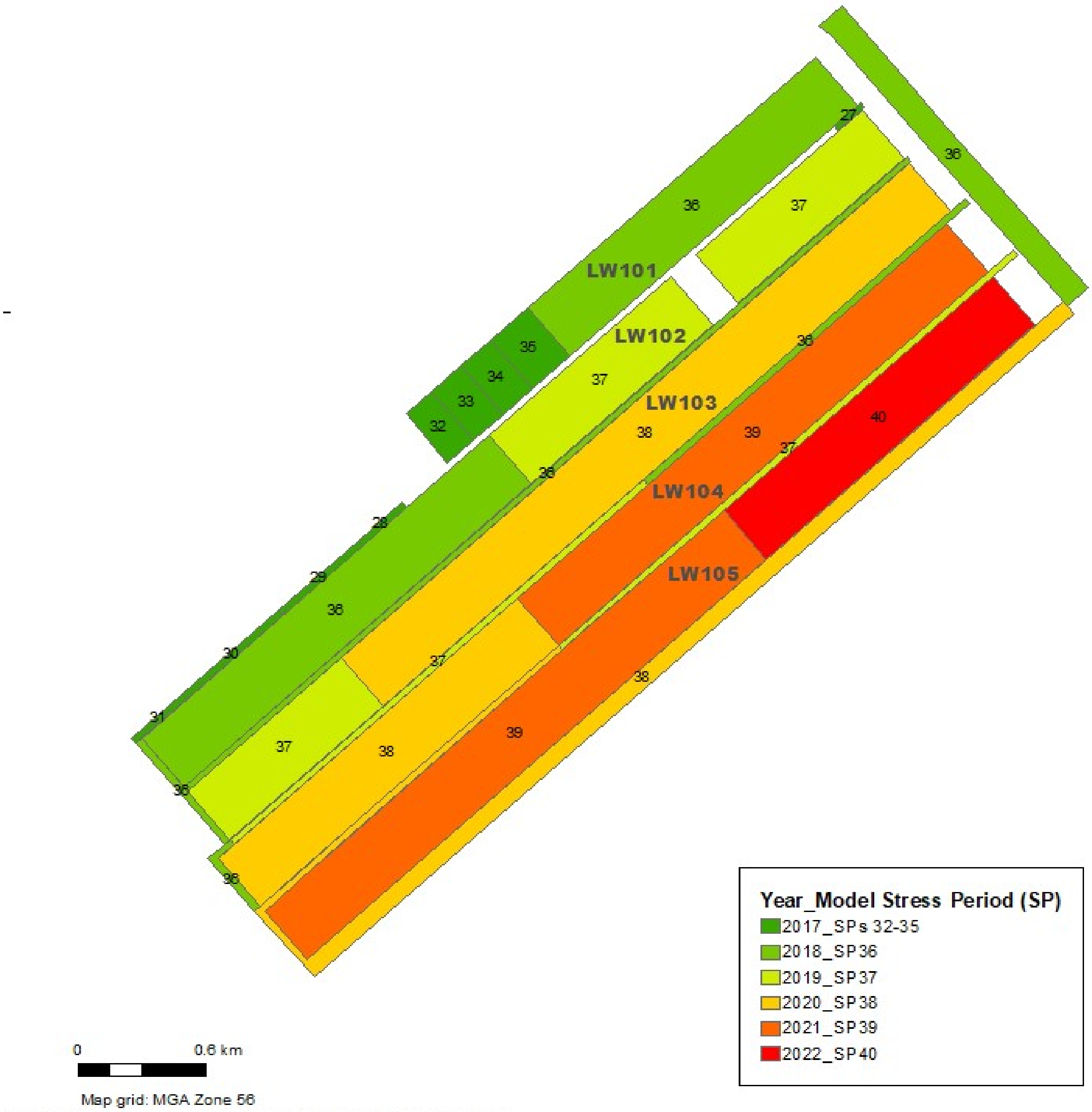

Figure 6 UG1 Mine Plan and Model Stress Period

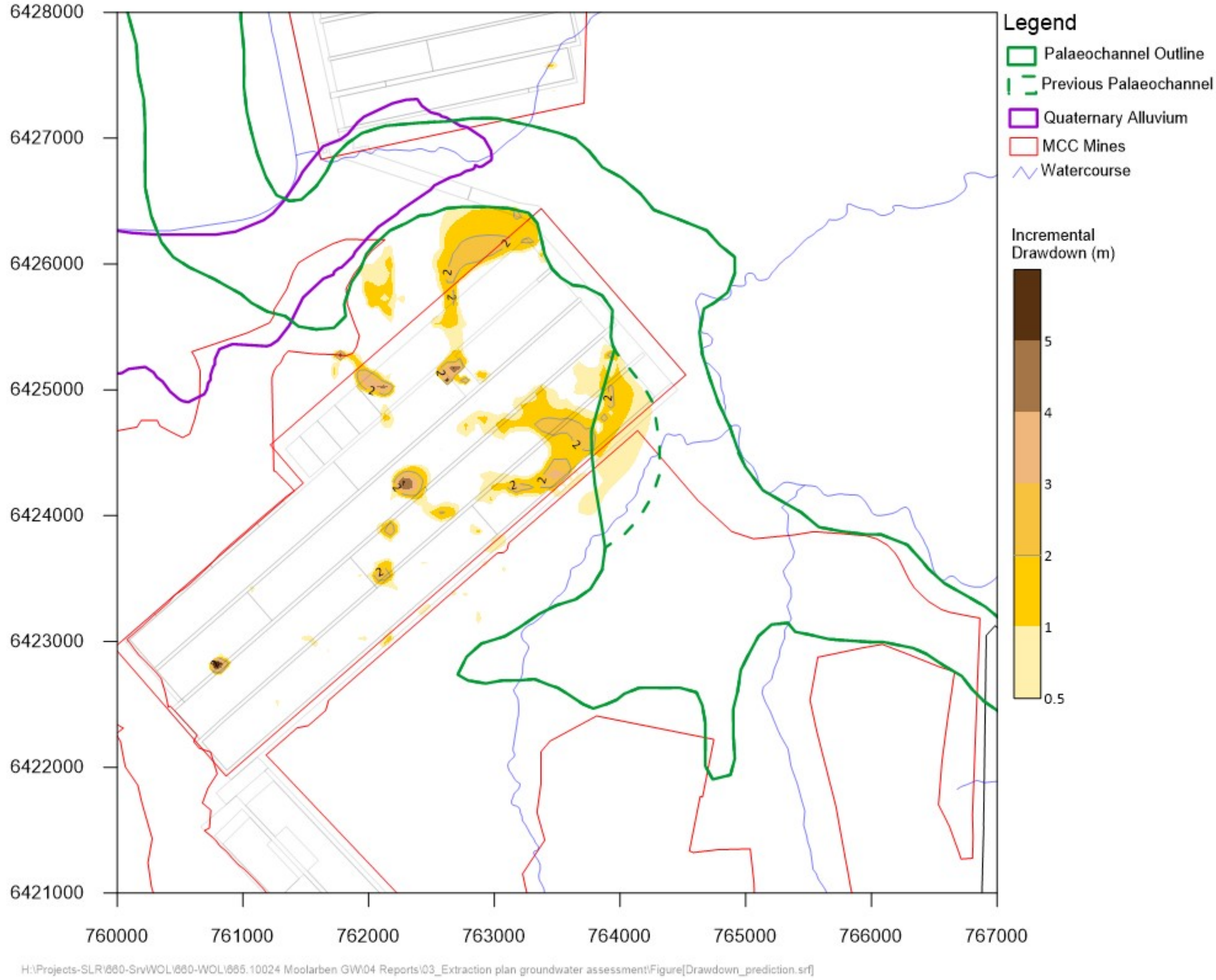

Figure 7 Predicted Drawdown at End of Longwall 105 Mining – Layer 1

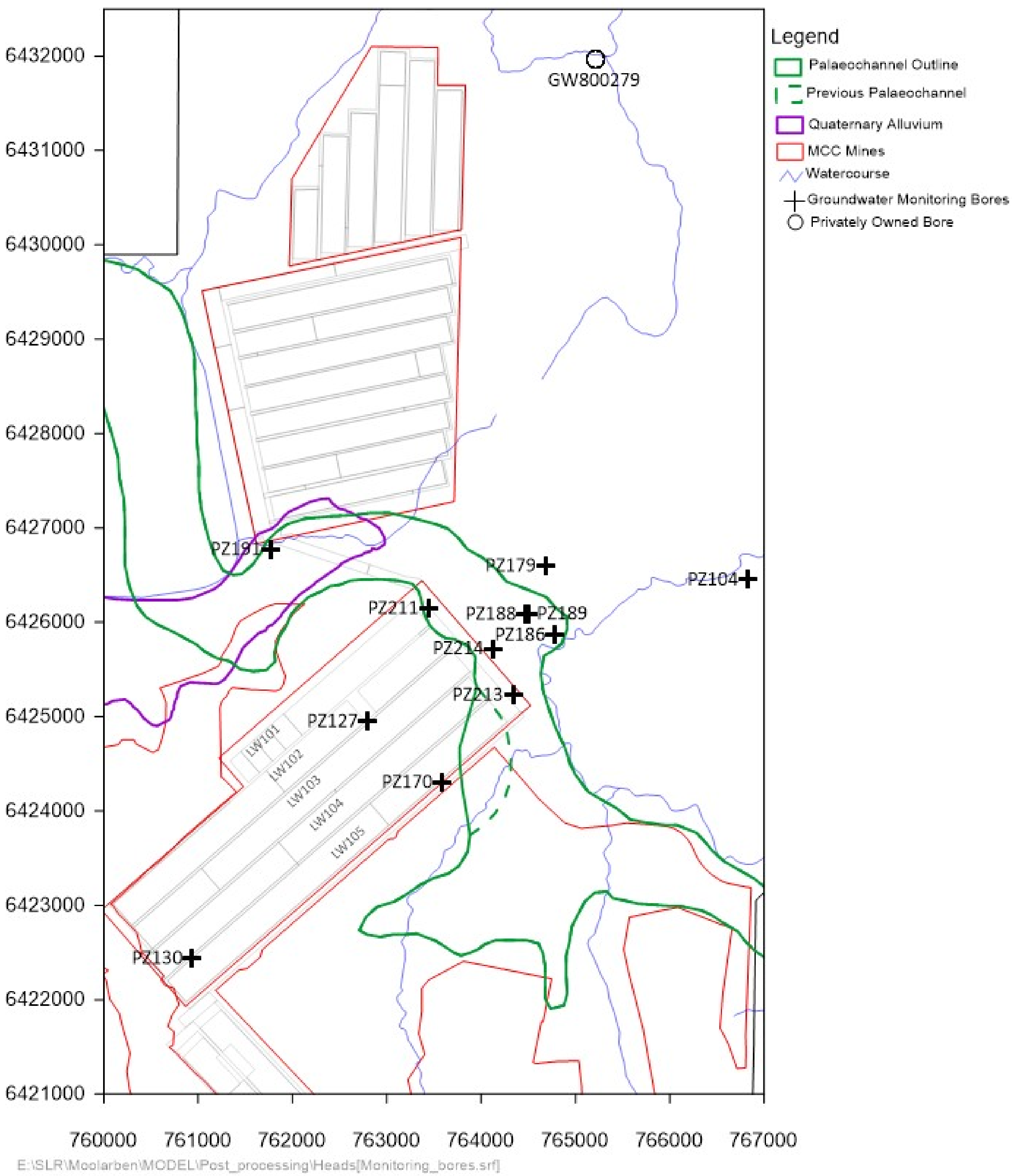

Figure 8 Groundwater Monitoring Bores Most Relevant to UG1 Longwalls 104-105

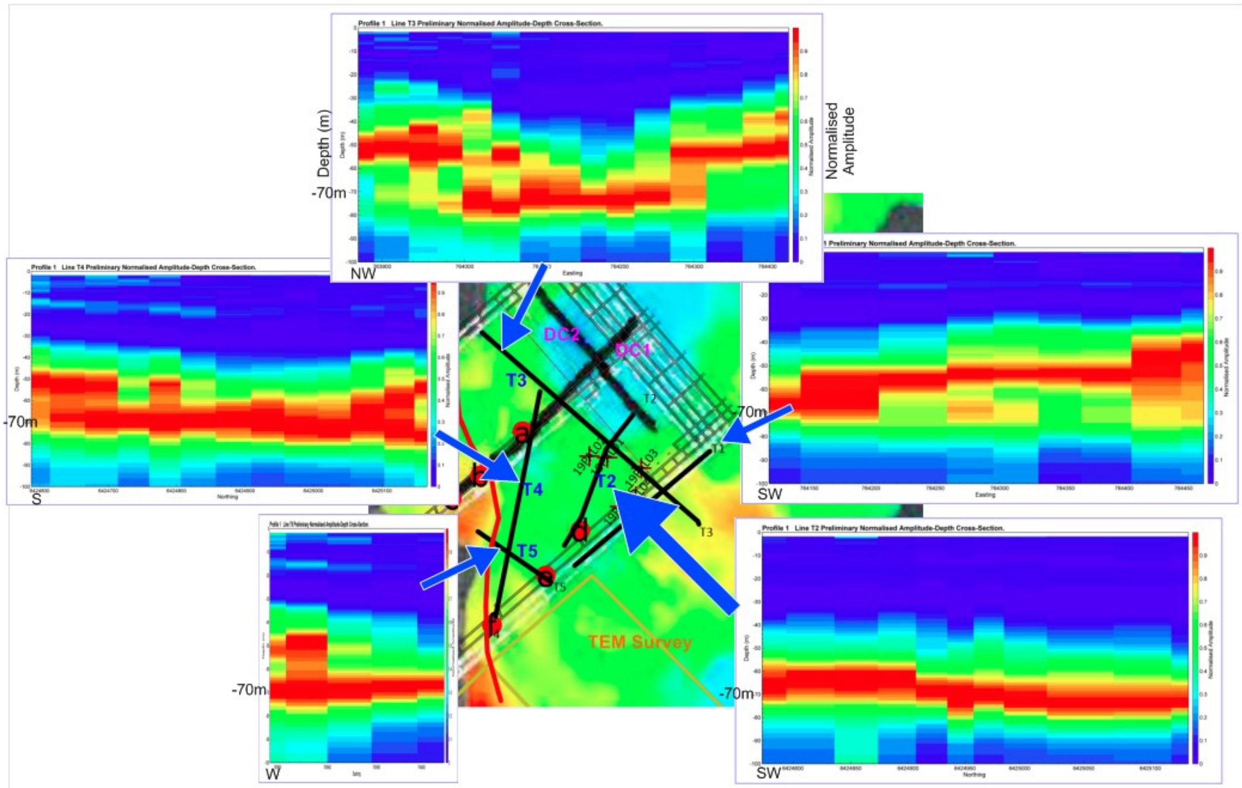

Figure 9 Location of Seismic Traverses T1 to T5 with Initial Indications of Geometry at the Hard Rock Interface

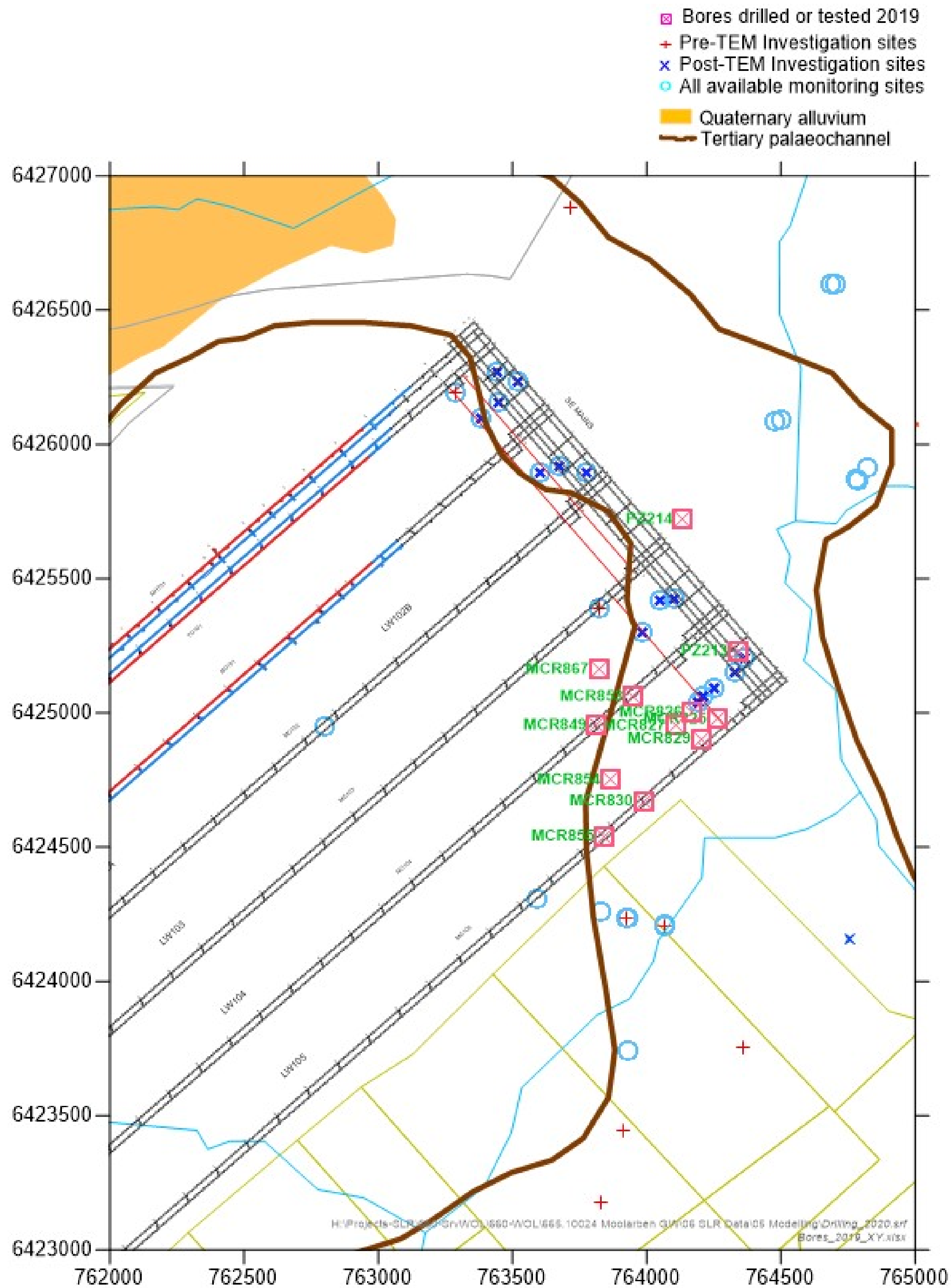

Figure 10 Locations of Bored Drilled or Tested in 2019

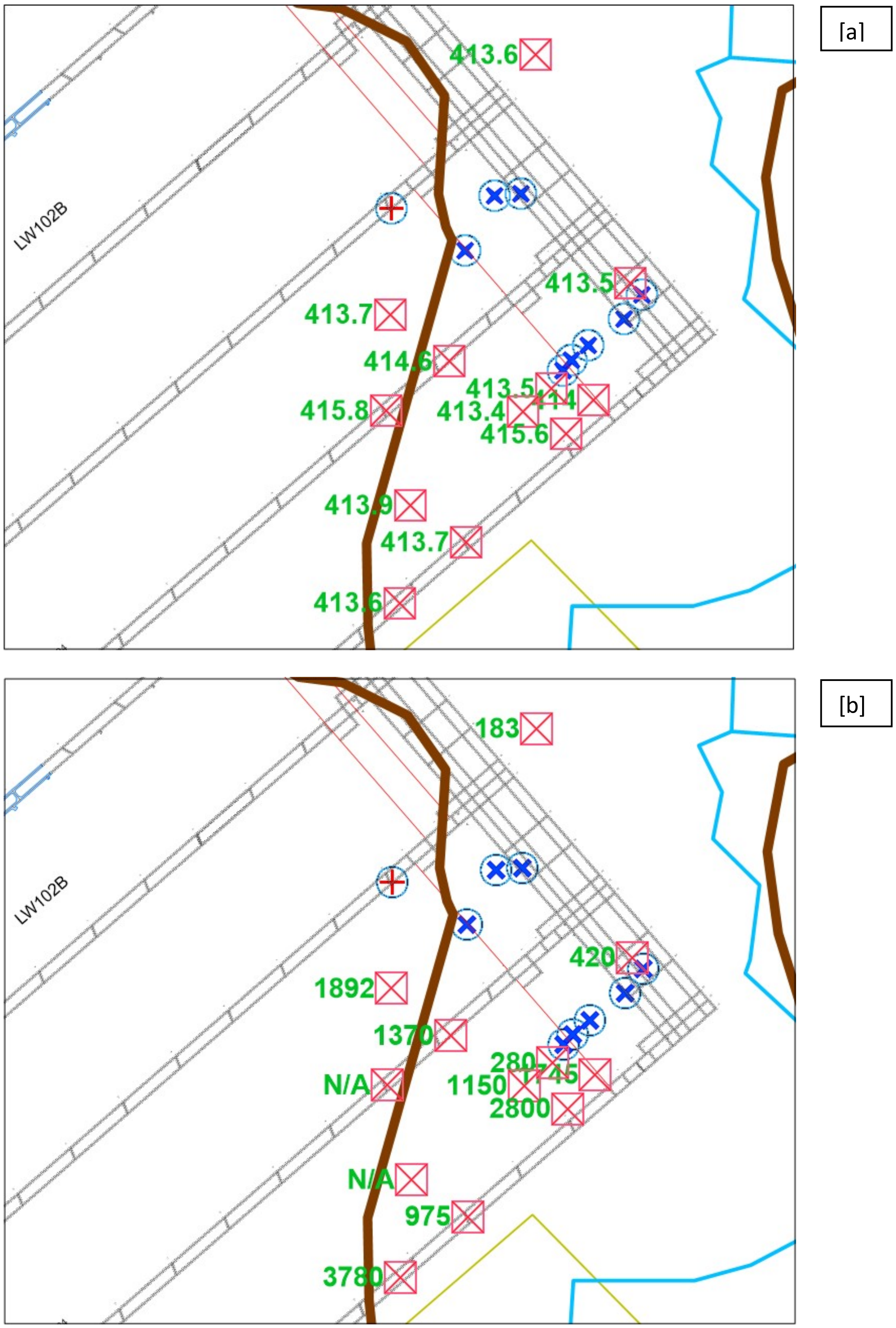

Figure 11 [a] Water Level (mAHD); [b] Electrical Conductivity EC (µS/cm)

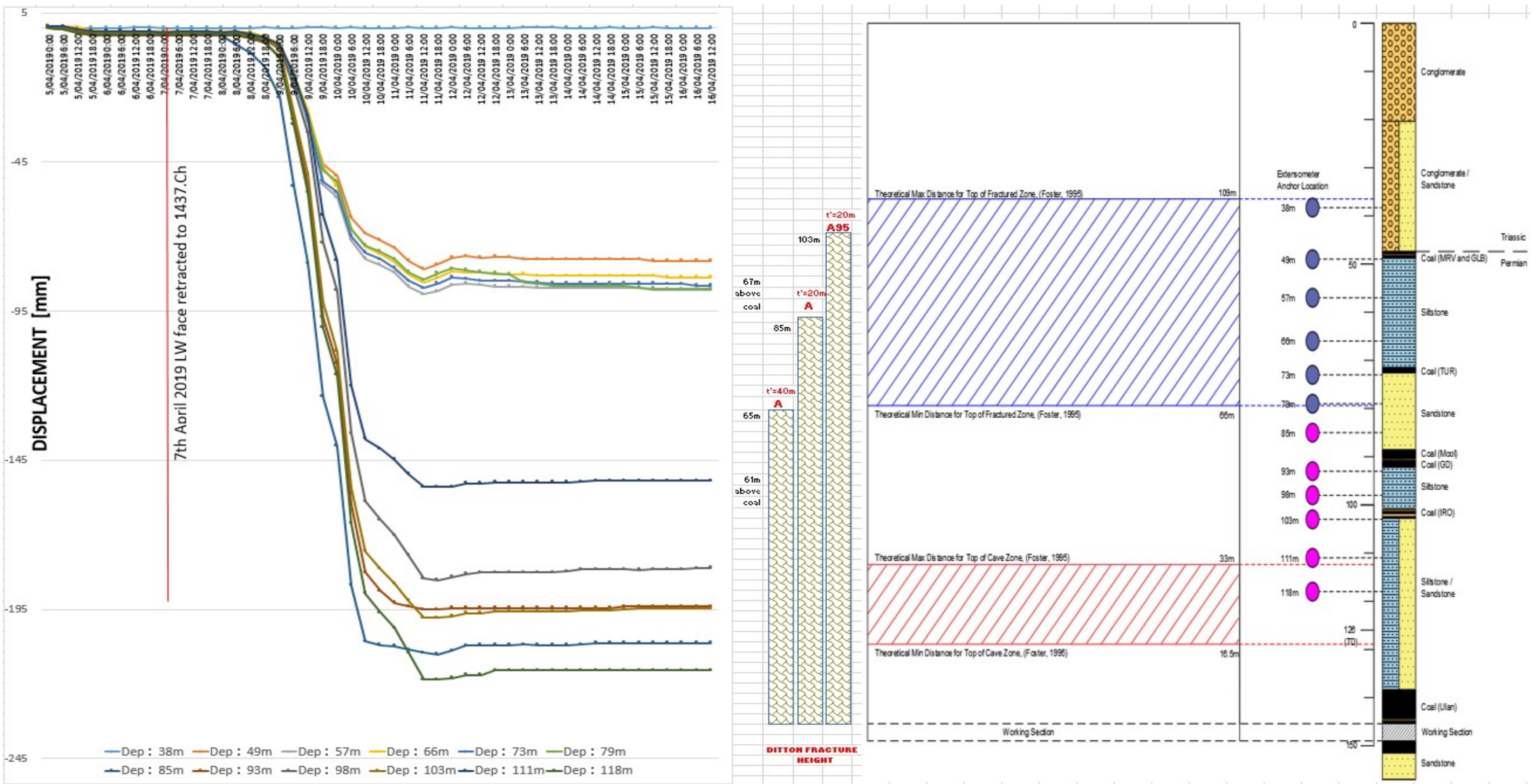

Figure 12 Extensometer 3.3 Displacement Curves Compared with Fracture Height Estimates

SLR

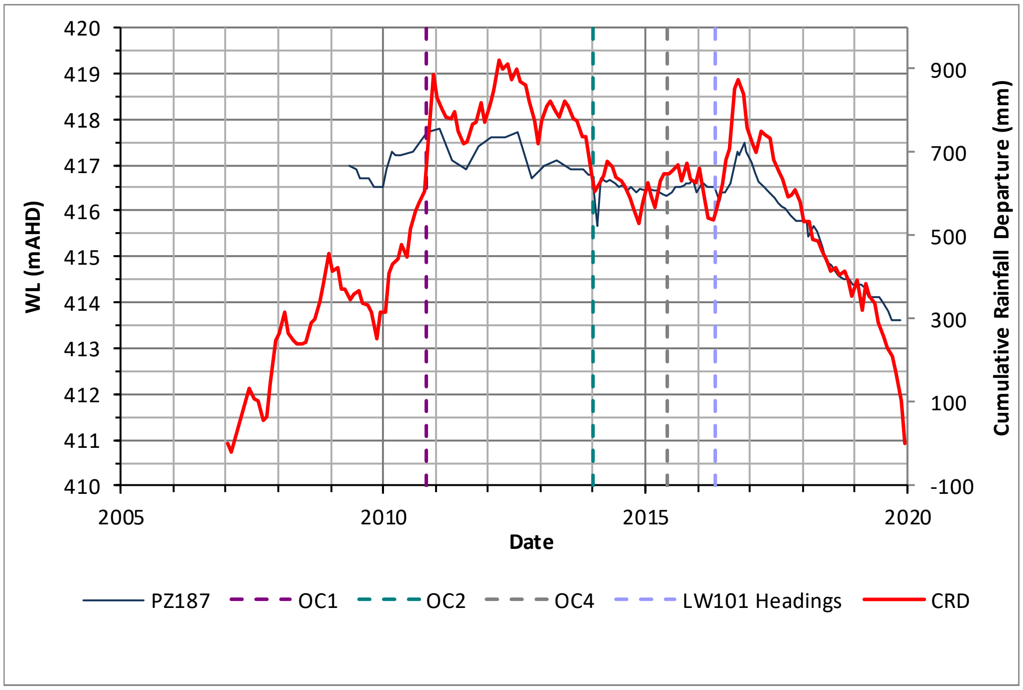

Figure 13 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ187

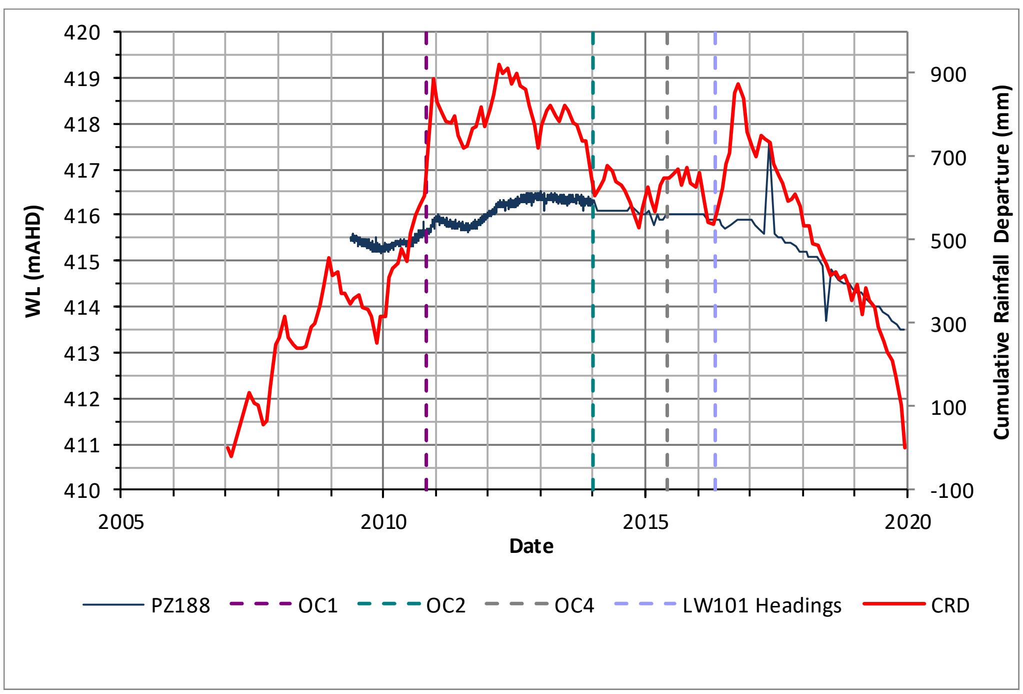

Figure 14 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ188

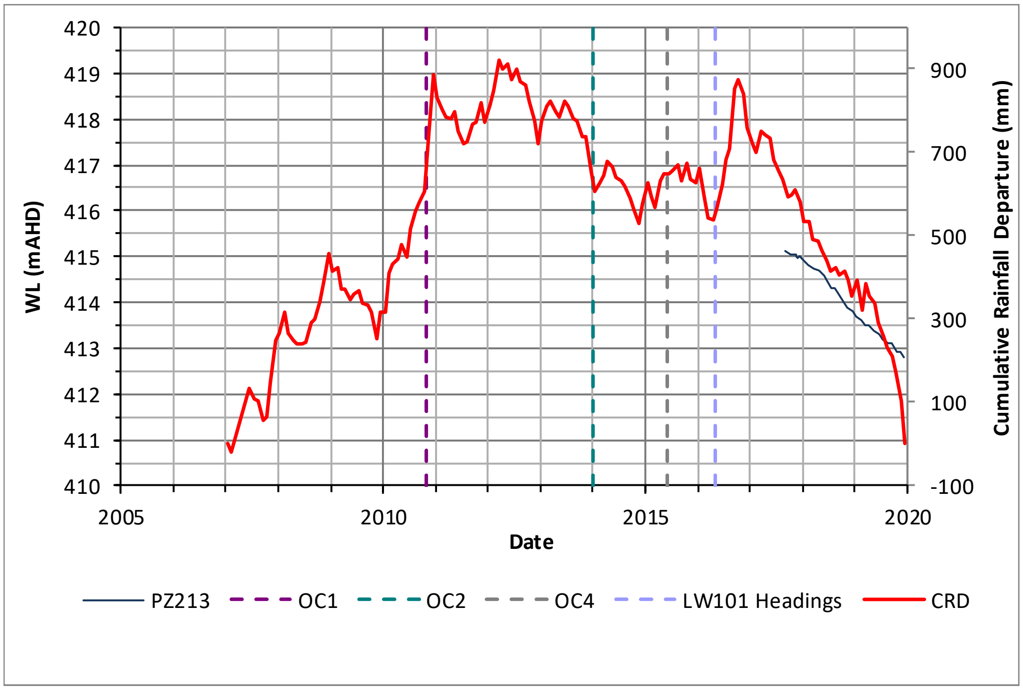

Figure 15 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ213

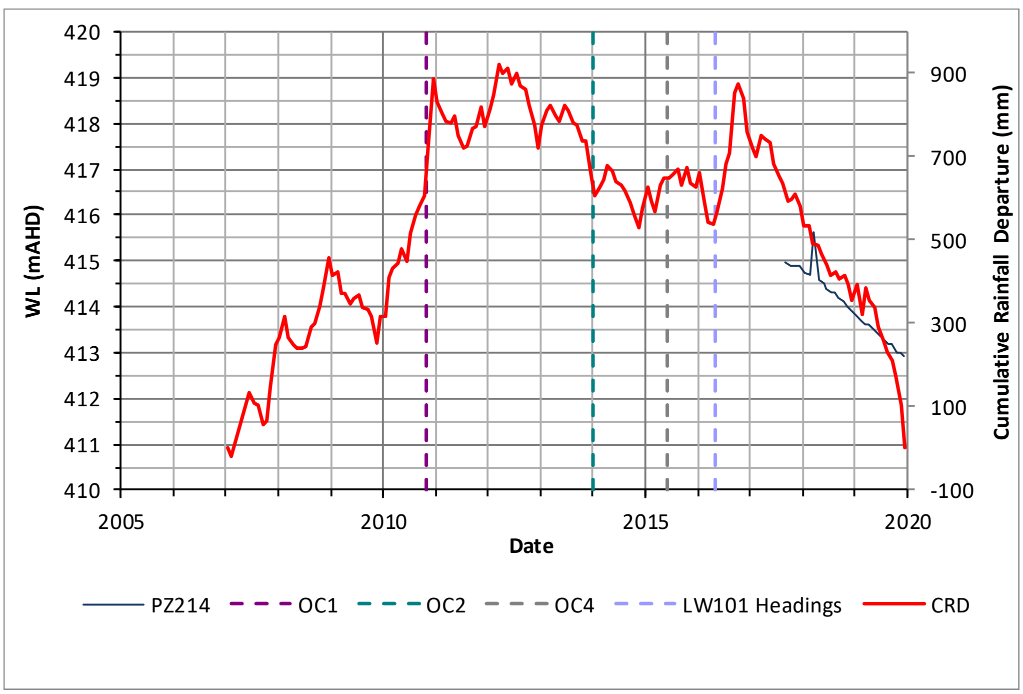

Figure 16 Groundwater Level Hydrograph for Palaeochannel Alluvium Monitoring Bore PZ214

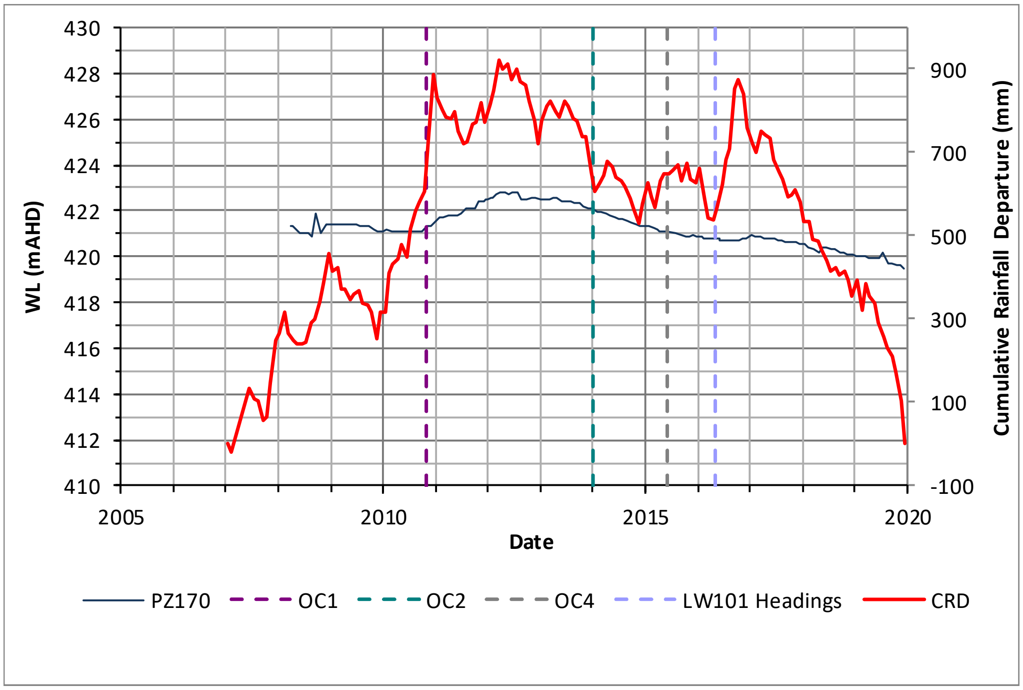

Figure 17 Groundwater Level Hydrograph for Permian Overburden Monitoring Bore PZ170

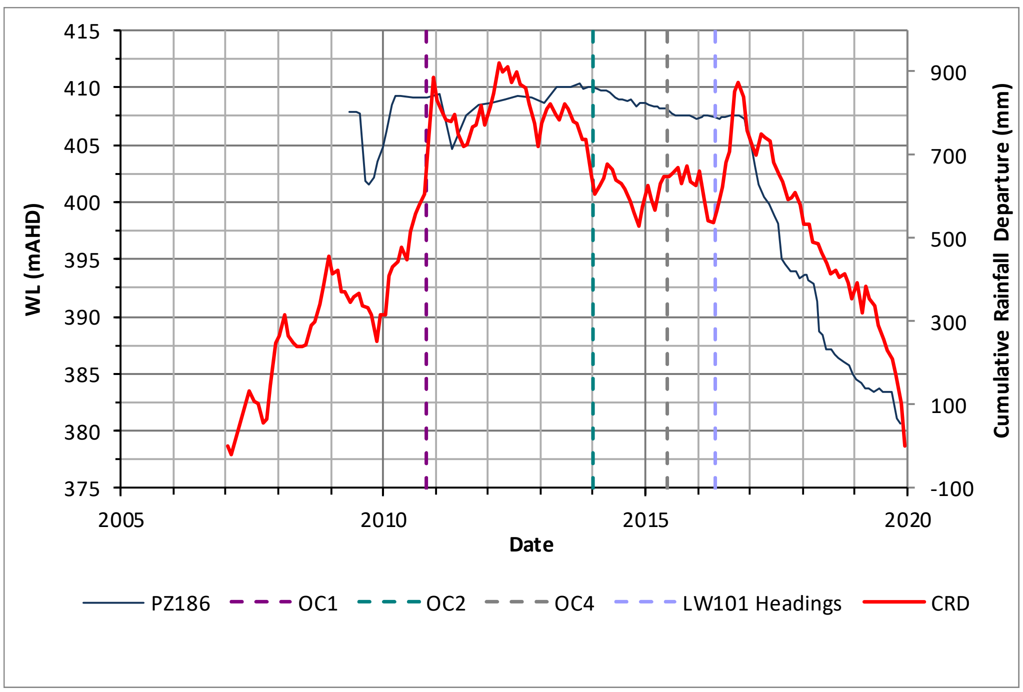

Figure 18 Groundwater Level Hydrograph for Permian Overburden Monitoring Bore PZ186

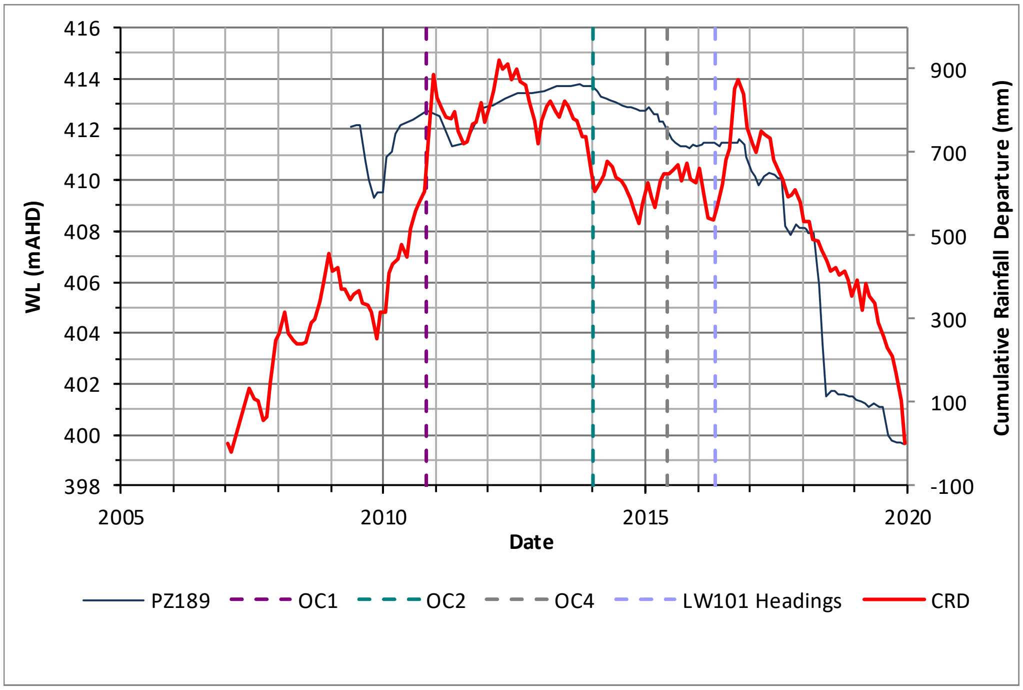

Figure 19 Groundwater Level Hydrograph for Permian Overburden Monitoring Bore PZ189

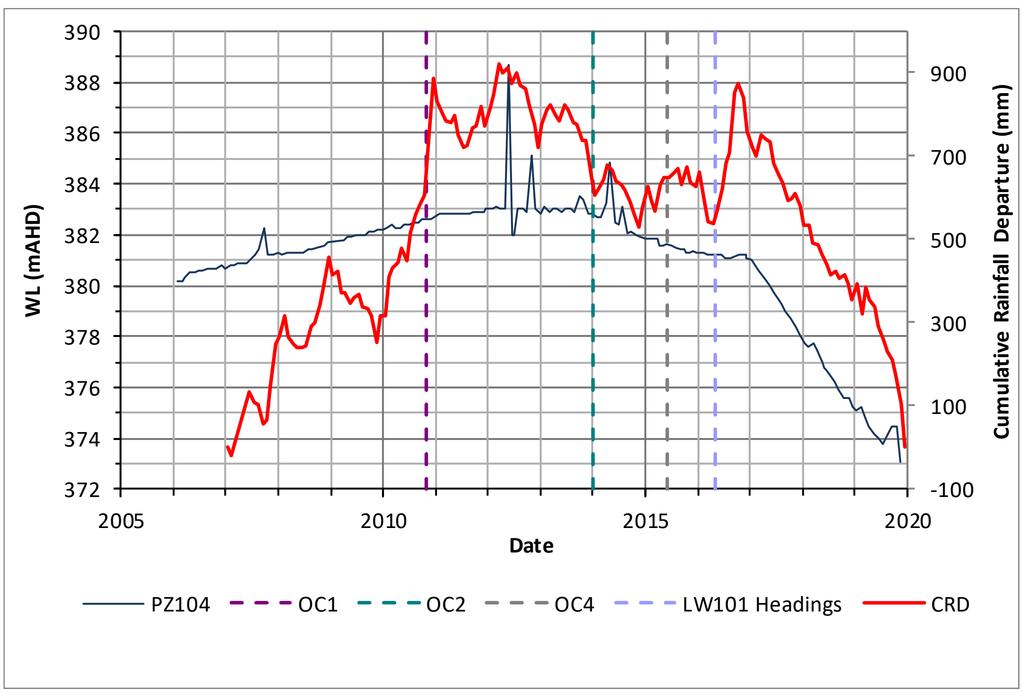

Figure 20 Groundwater Level Hydrograph for Ulan Seam Monitoring Bore PZ104

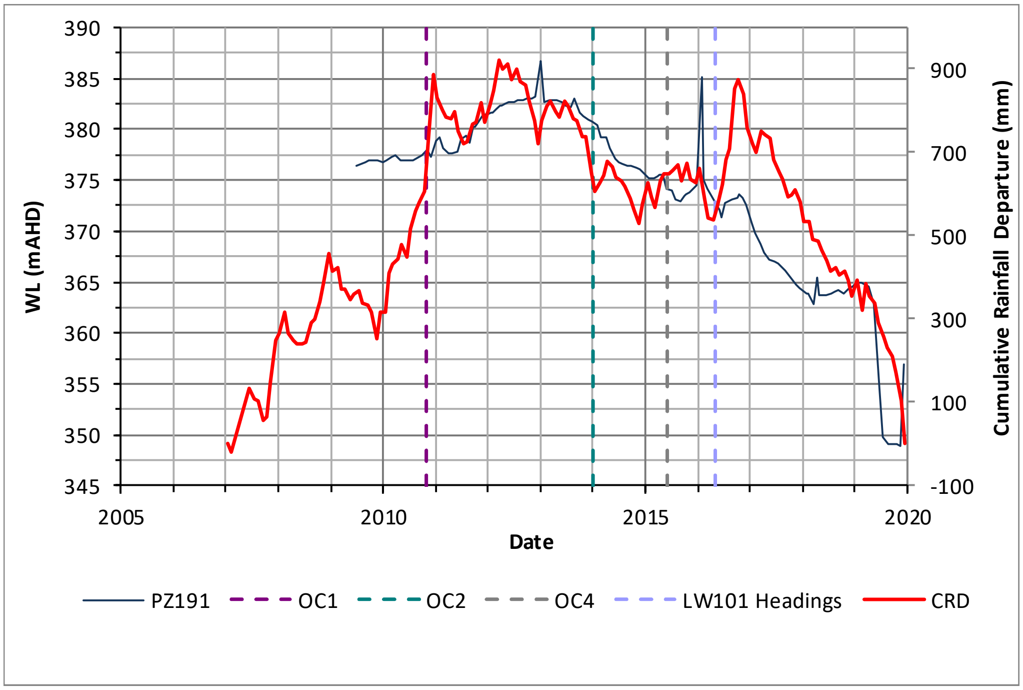

Figure 21 Groundwater Level Hydrograph for Ulan Seam Monitoring Bore PZ191

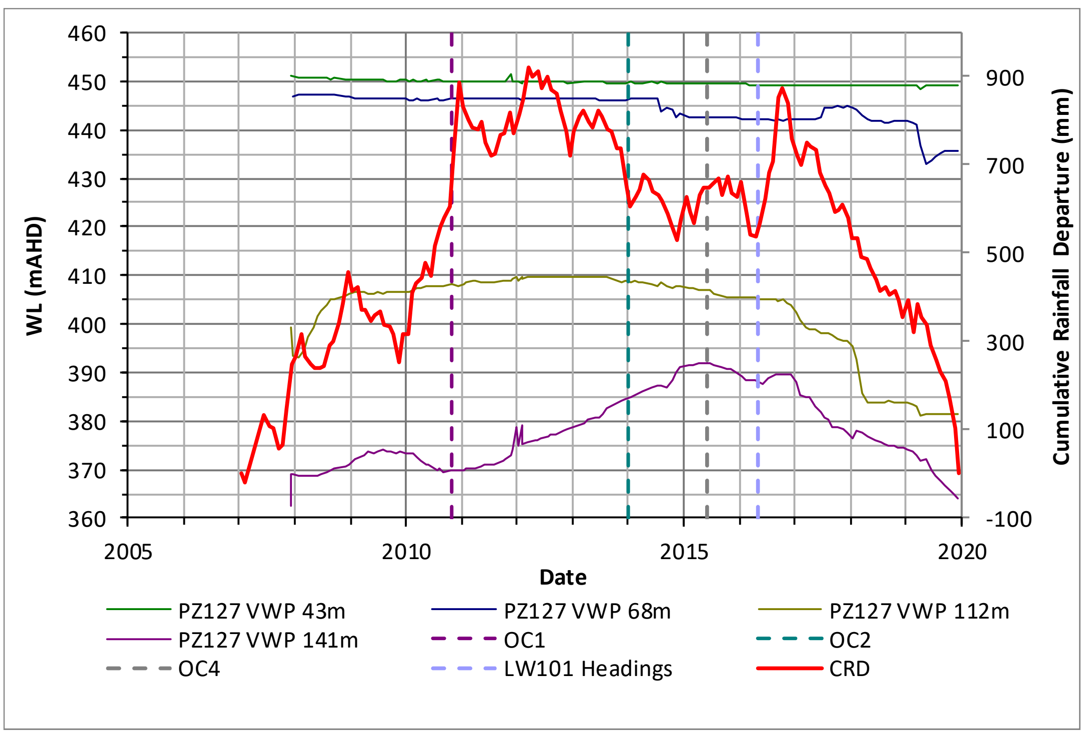

Figure 22 Groundwater Level Hydrograph for VWP Bore PZ127

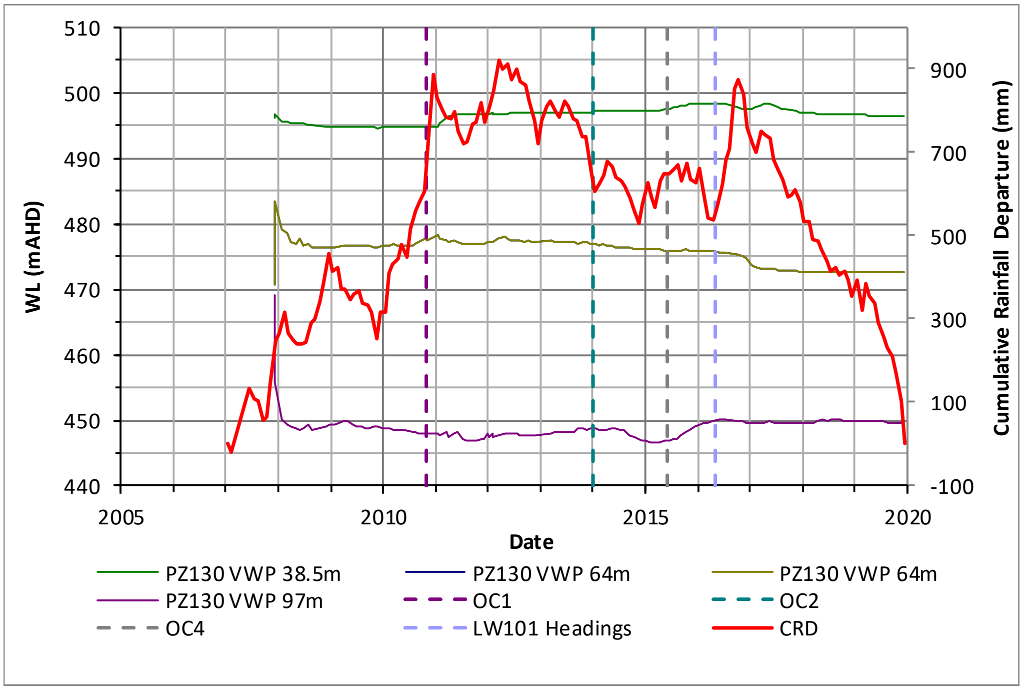

Figure 23 Groundwater Level Hydrograph for VWP Bore PZ130

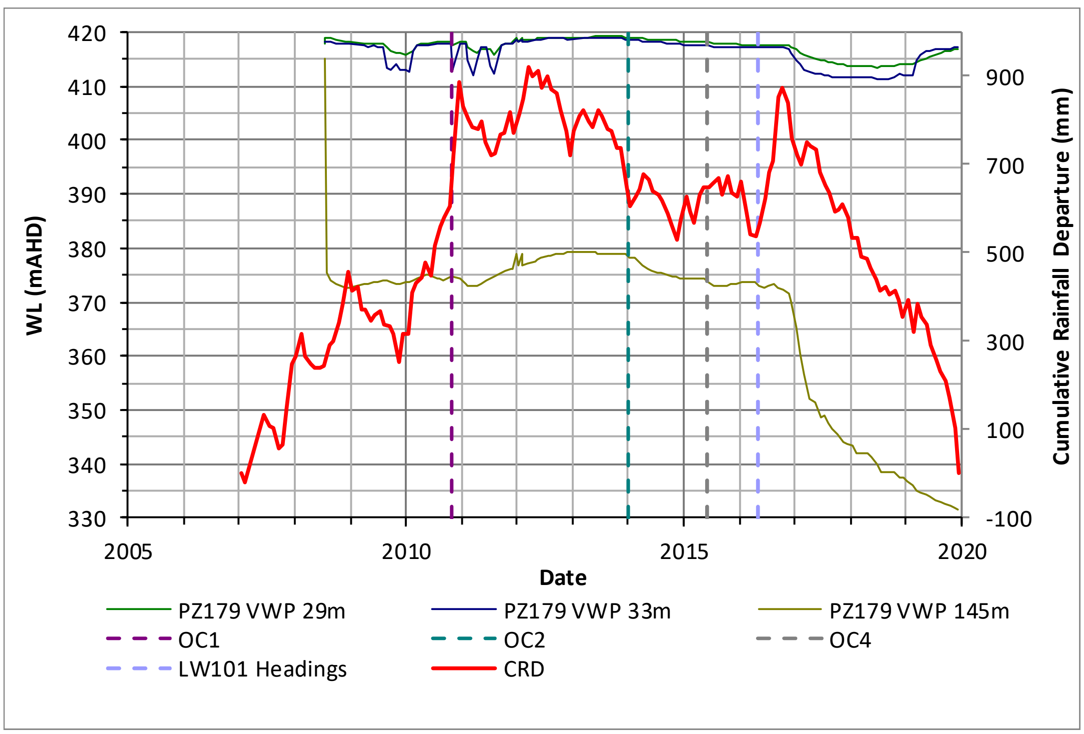

Figure 24 Groundwater Level Hydrograph for VWP Bore PZ179

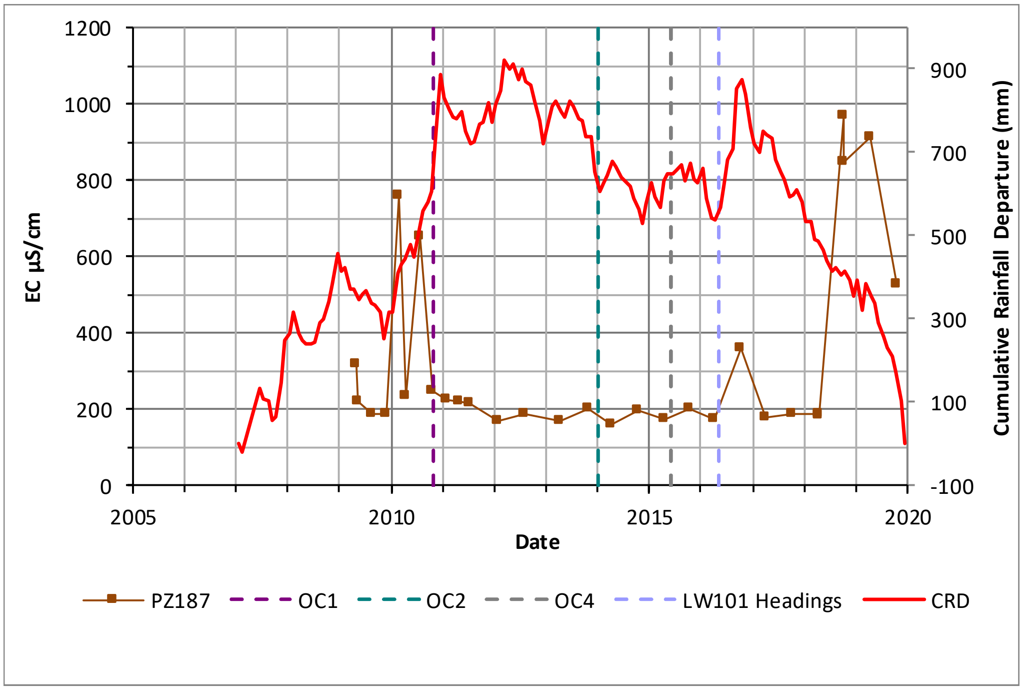

Figure 25 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ187

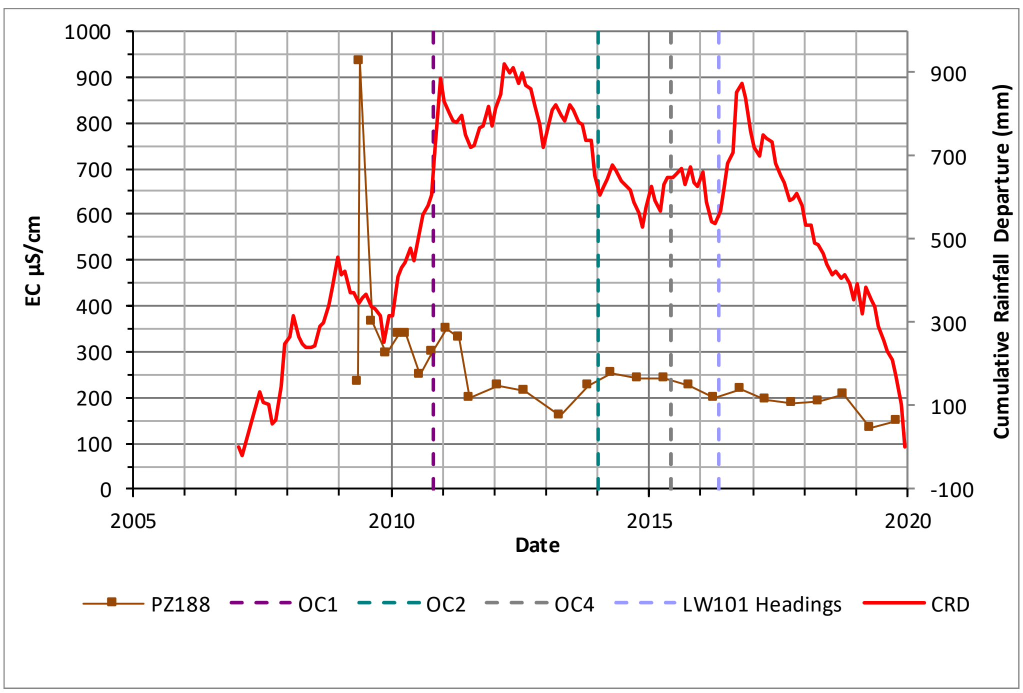

Figure 26 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ188

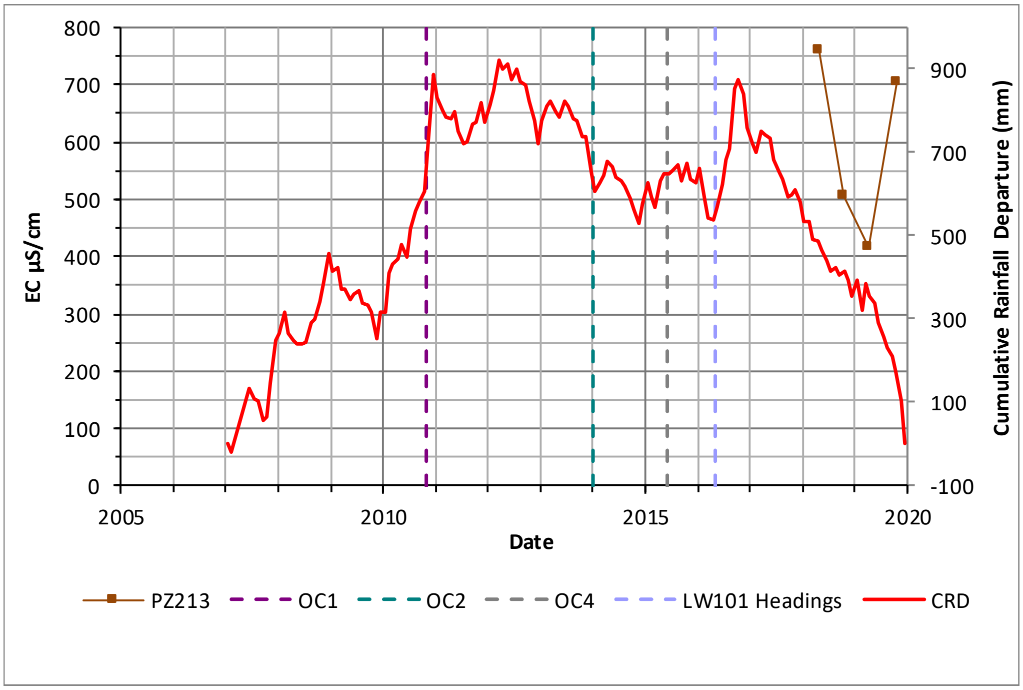

Figure 27 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ213

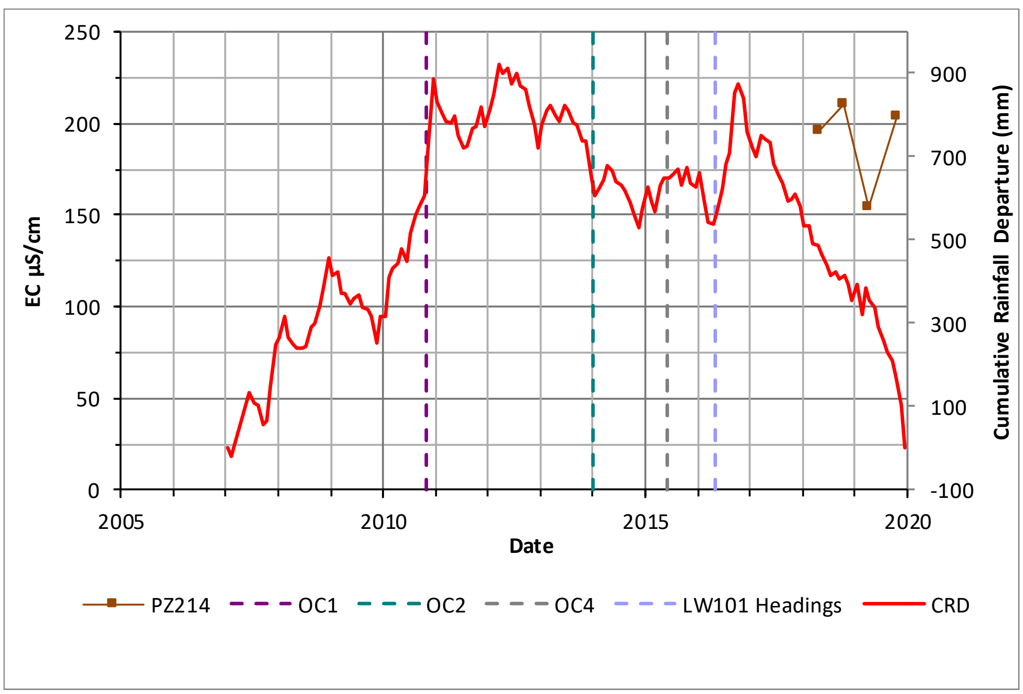

Figure 28 Groundwater Quality: Electrical Conductivity - Palaeochannel Alluvium Monitoring Bore PZ214

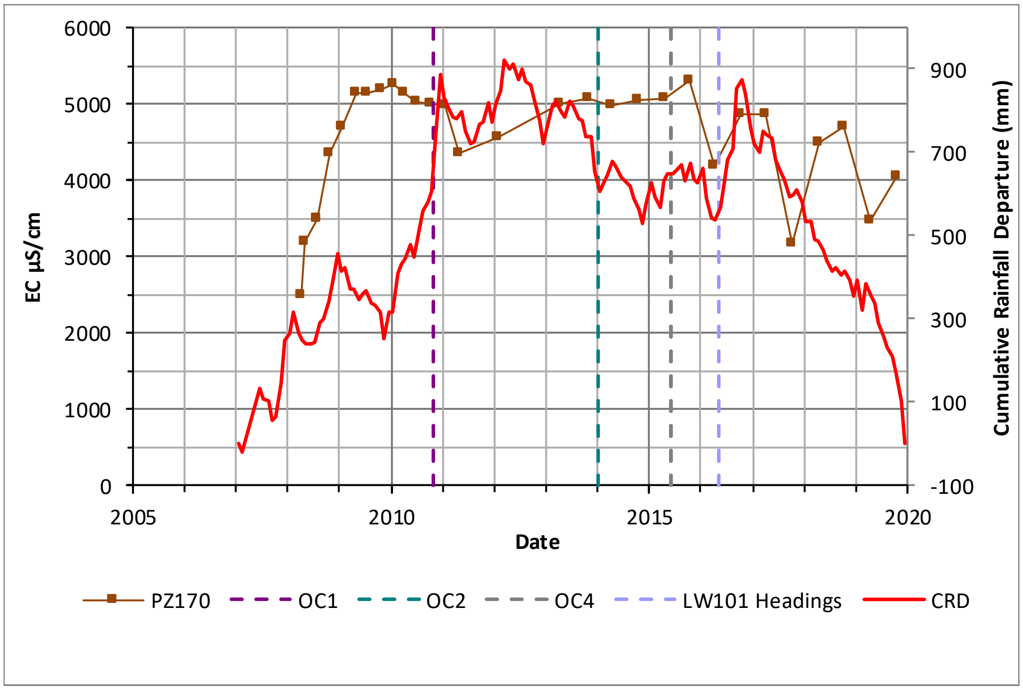

Figure 29 Groundwater Quality: Electrical Conductivity – Permian Overburden Monitoring Bore PZ170

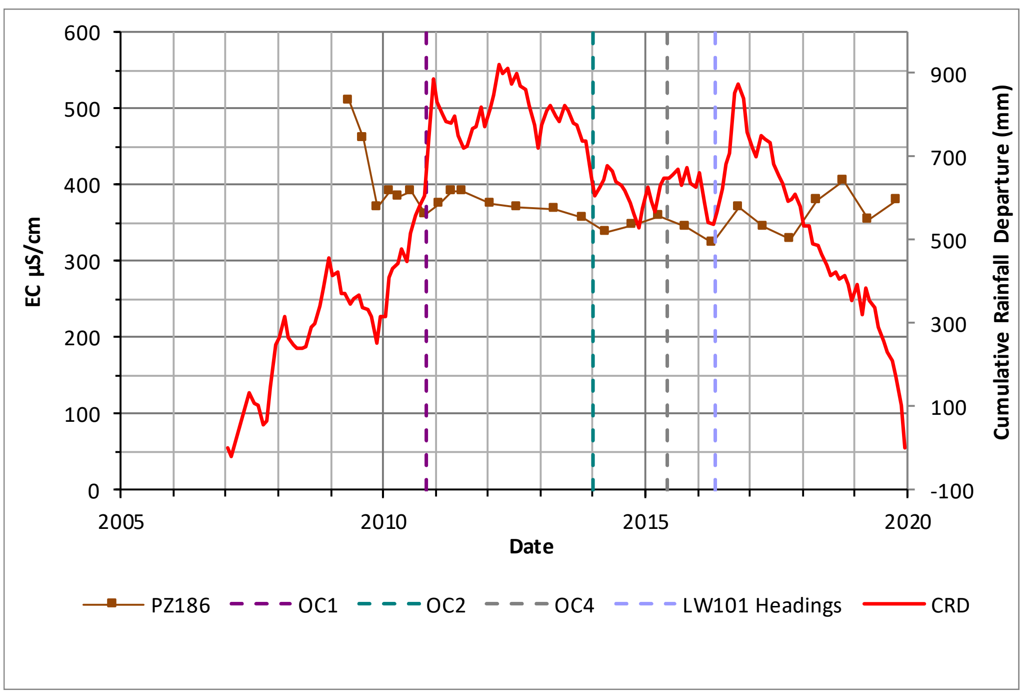

Figure 30 Groundwater Quality: Electrical Conductivity – Permian Overburden Monitoring Bore PZ186

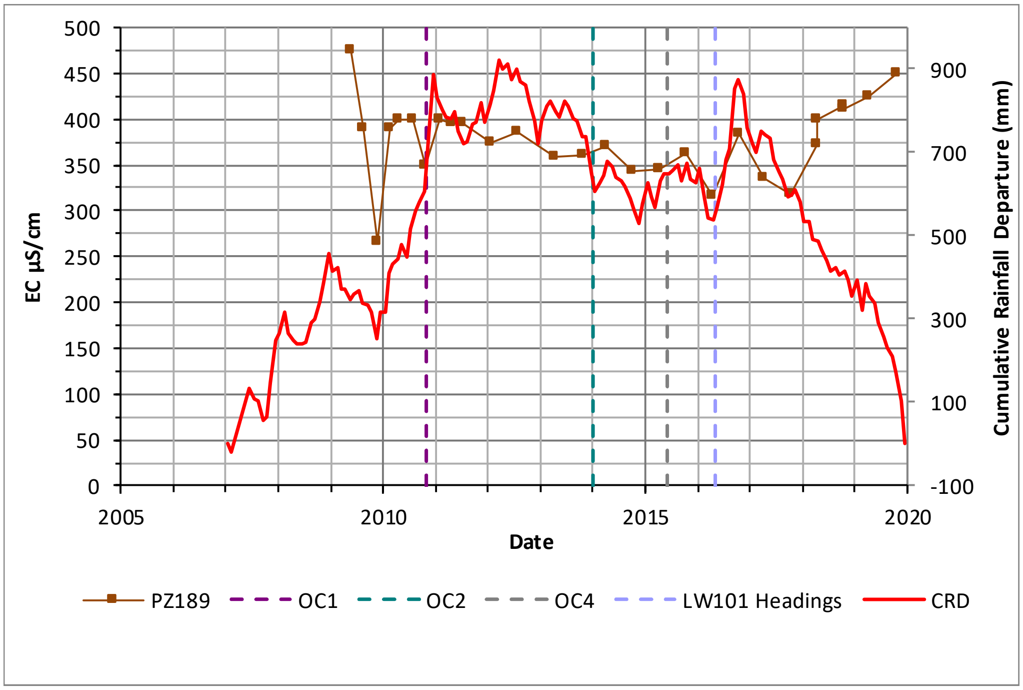

Figure 31 Groundwater Quality: Electrical Conductivity – Permian Overburden Monitoring Bore PZ189

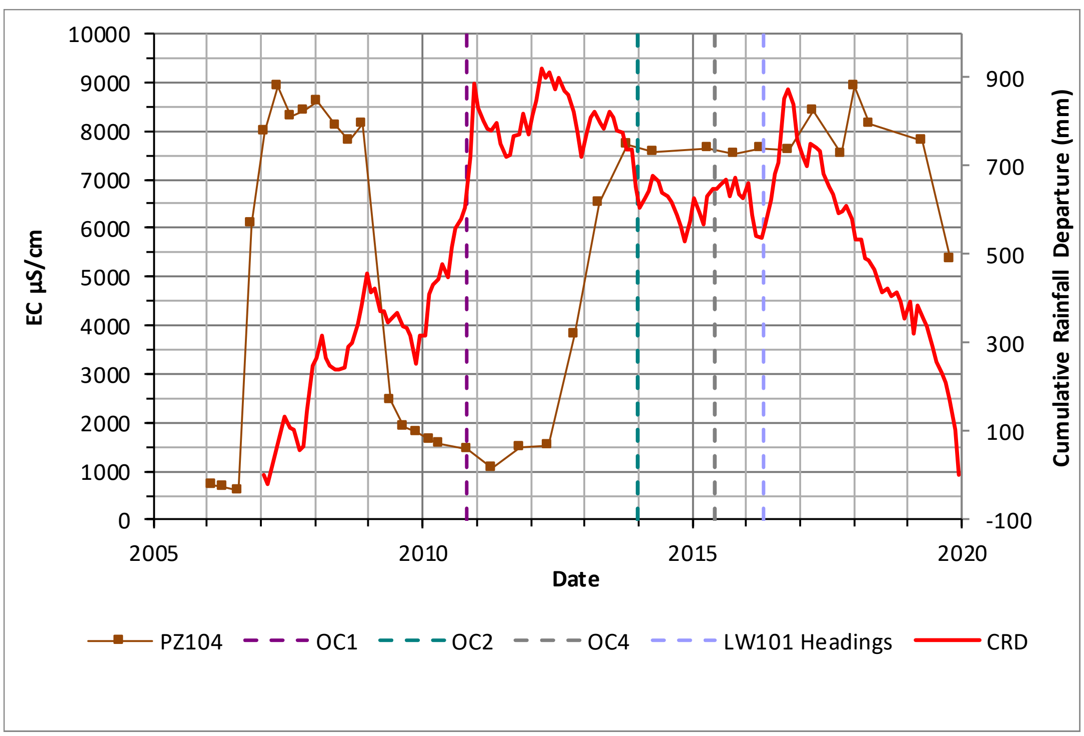

Figure 32 Groundwater Quality: Electrical Conductivity – Ulan Seam Monitoring Bore PZ104

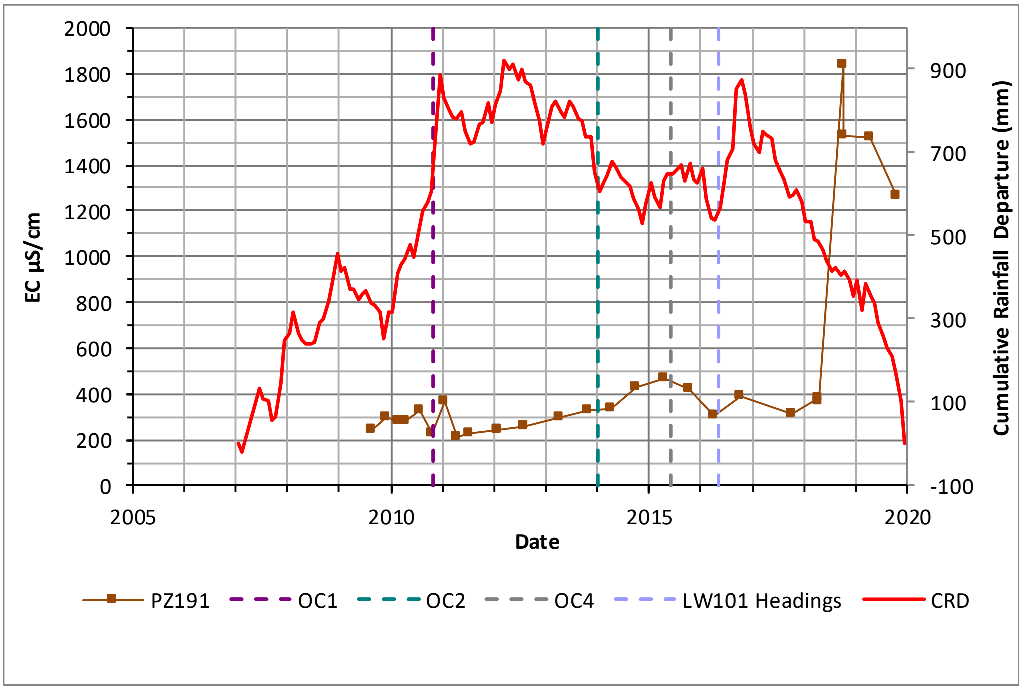

Figure 33 Groundwater Quality: Electrical Conductivity – Ulan Seam Monitoring Bore PZ191

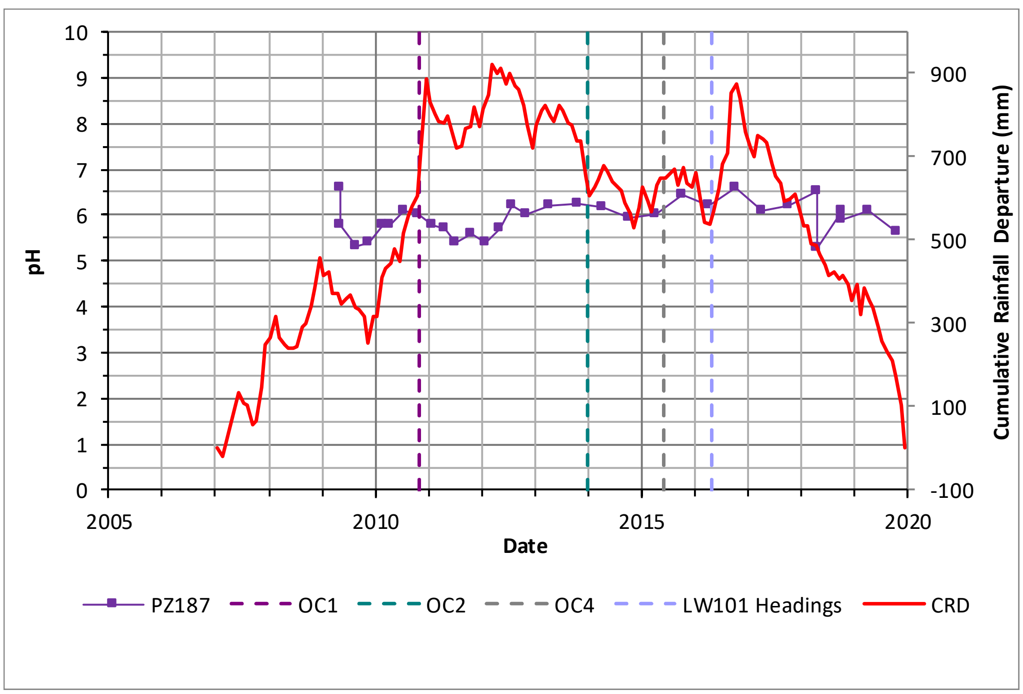

Figure 34 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ187

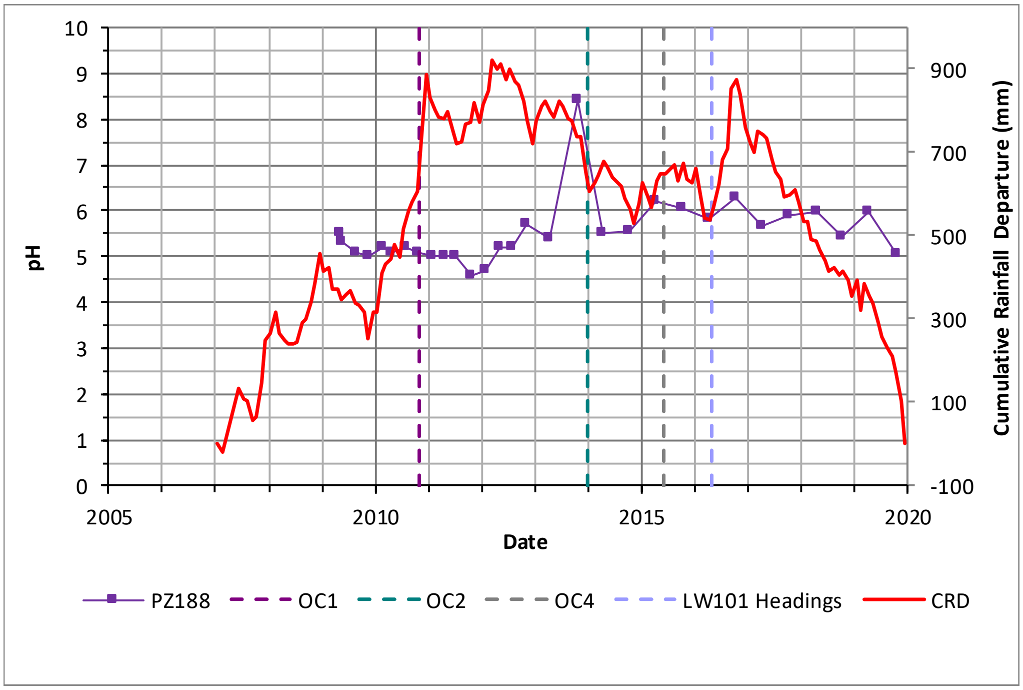

Figure 35 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ188

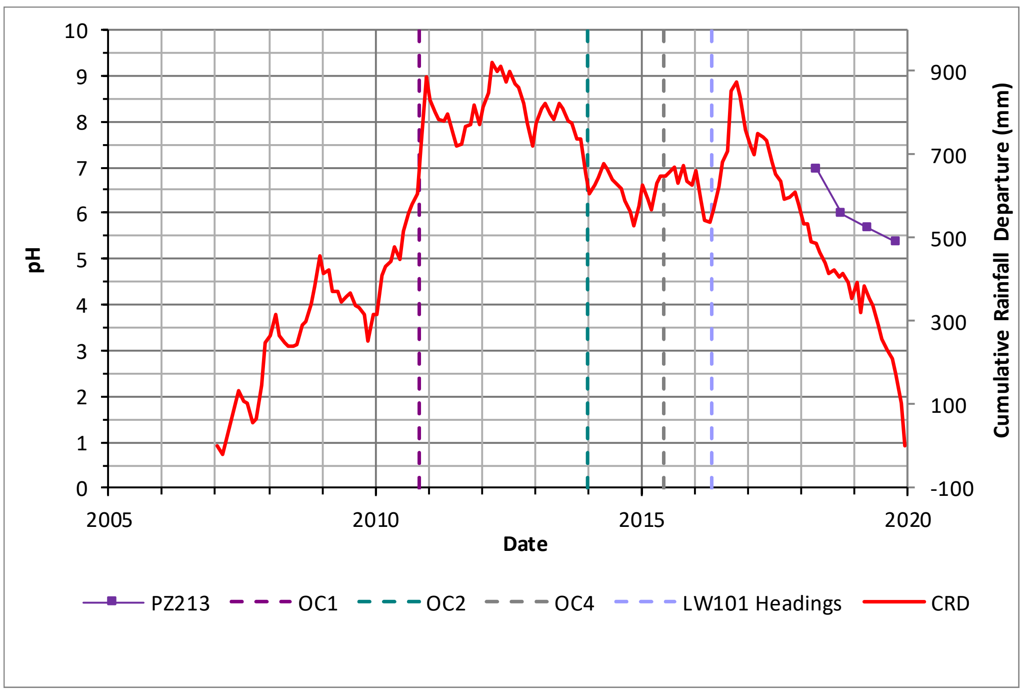

Figure 36 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ213

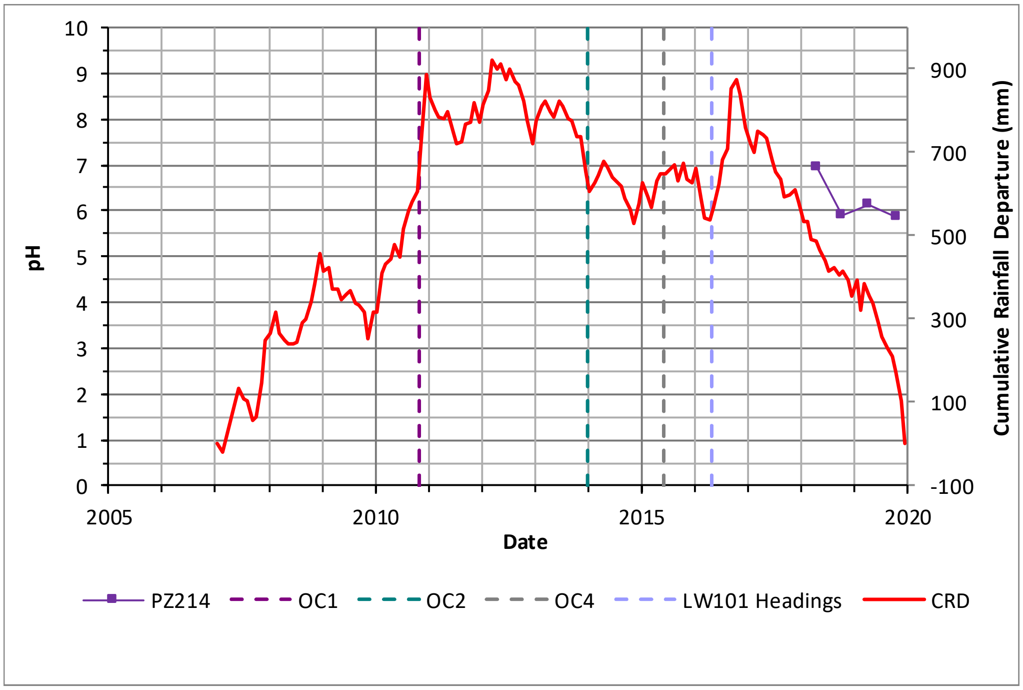

Figure 37 Groundwater Quality: pH – Palaeochannel Alluvium Monitoring Bore PZ214

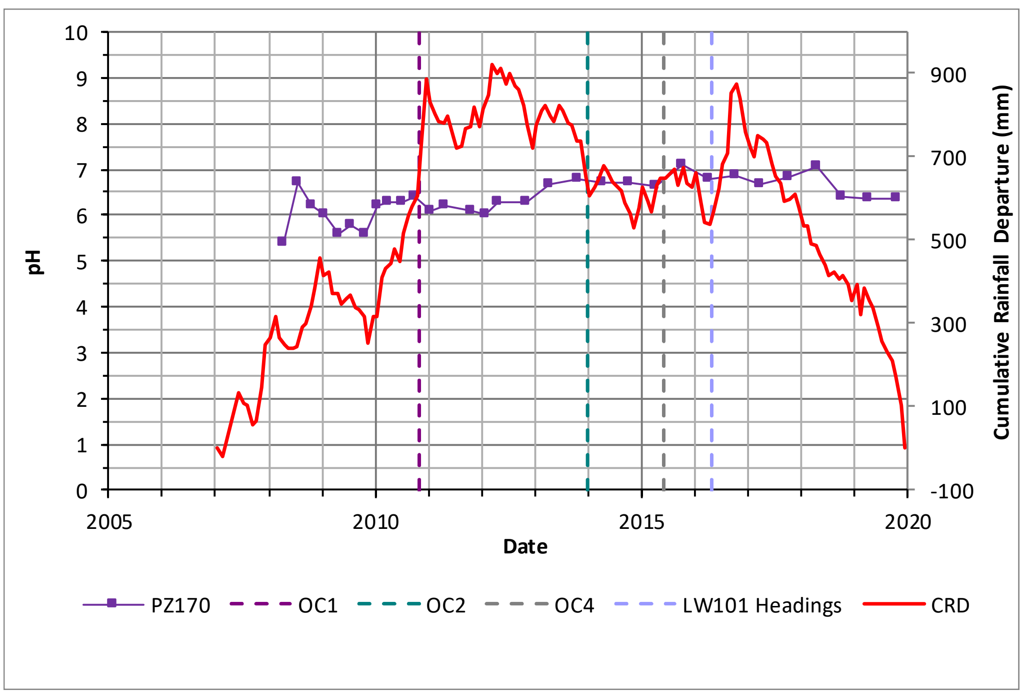

Figure 38 Groundwater Quality: pH – Permian Overburden Monitoring Bore PZ170

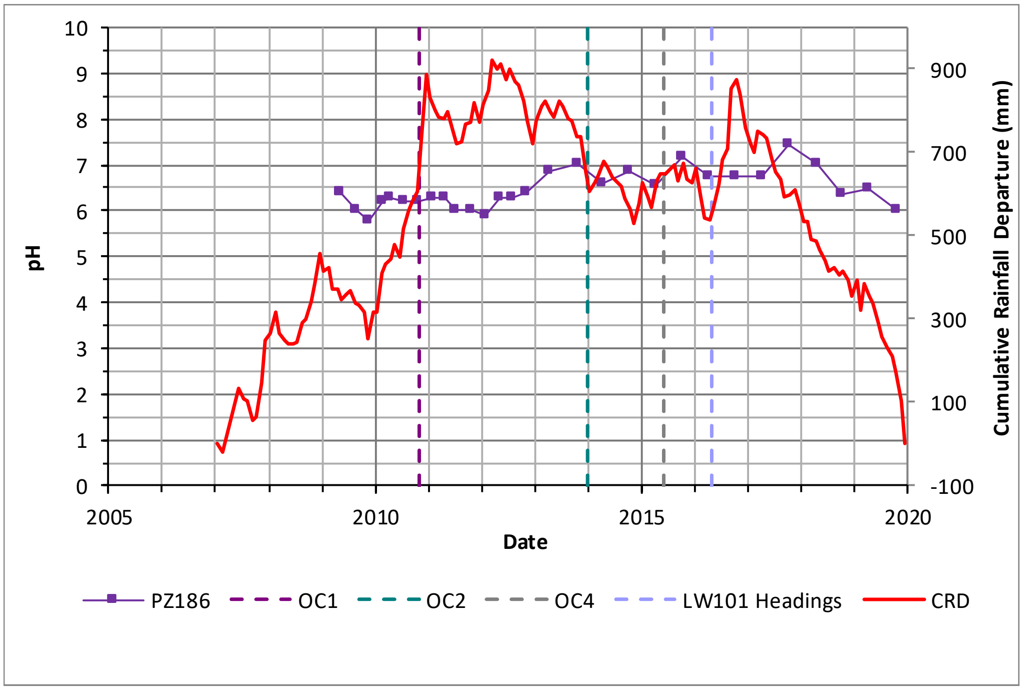

Figure 39 Groundwater Quality: pH – Permian Overburden Monitoring Bore PZ186

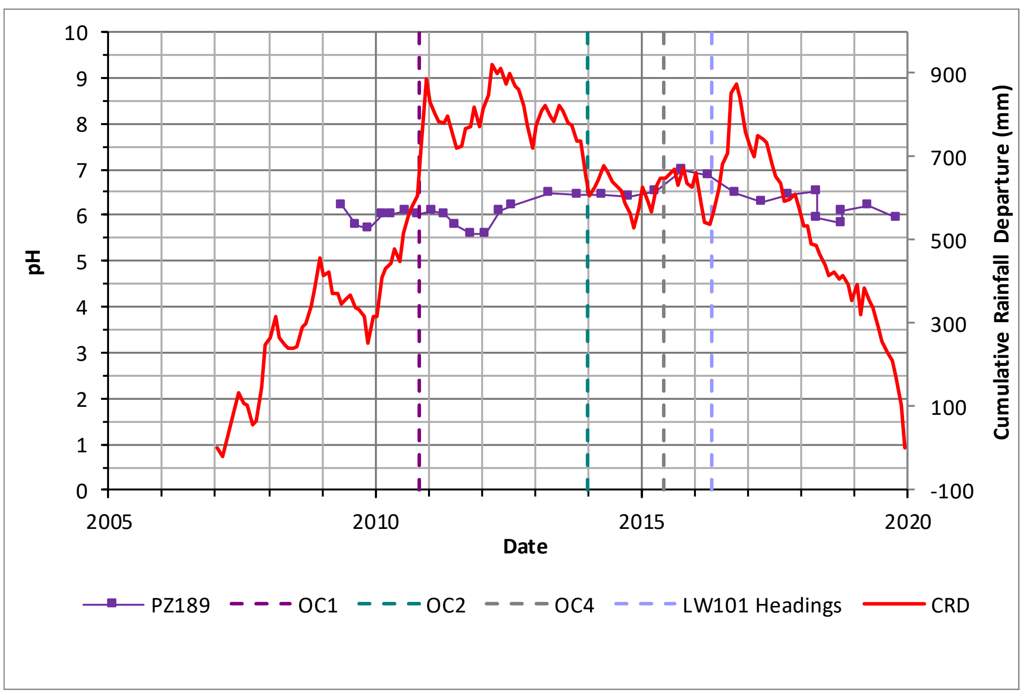

Figure 40 Groundwater Quality: pH – Permian Overburden Monitoring Bore PZ189

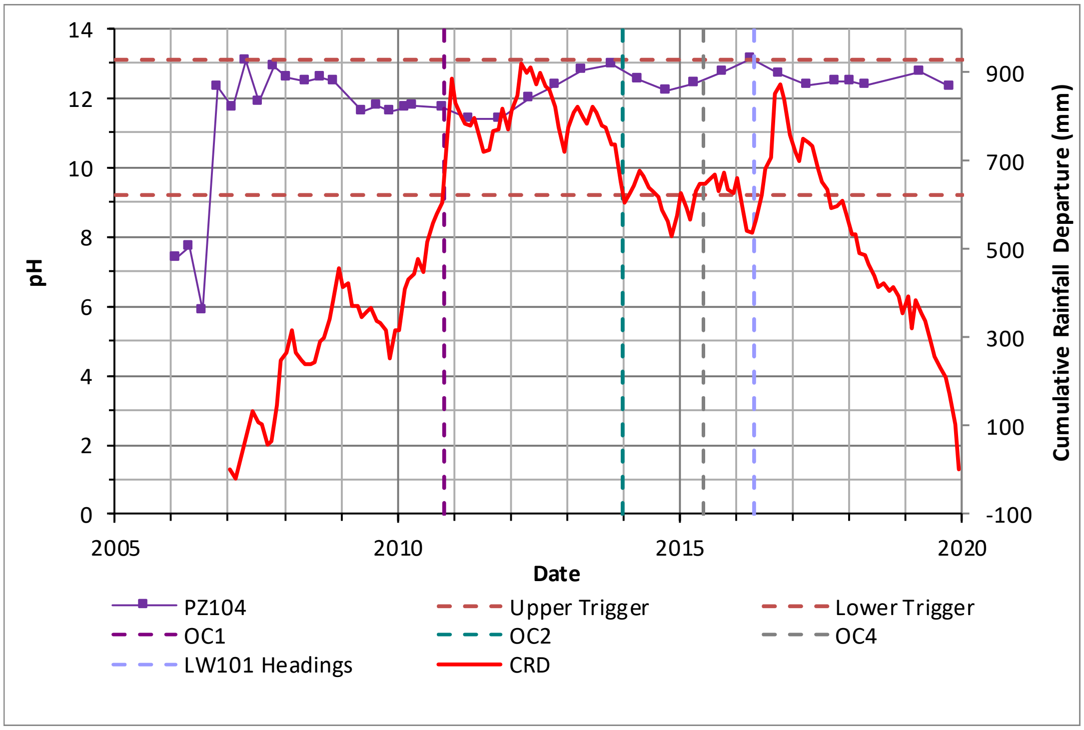

Figure 41 Groundwater Quality: pH – Permian Ulan Seam Monitoring Bore PZ104

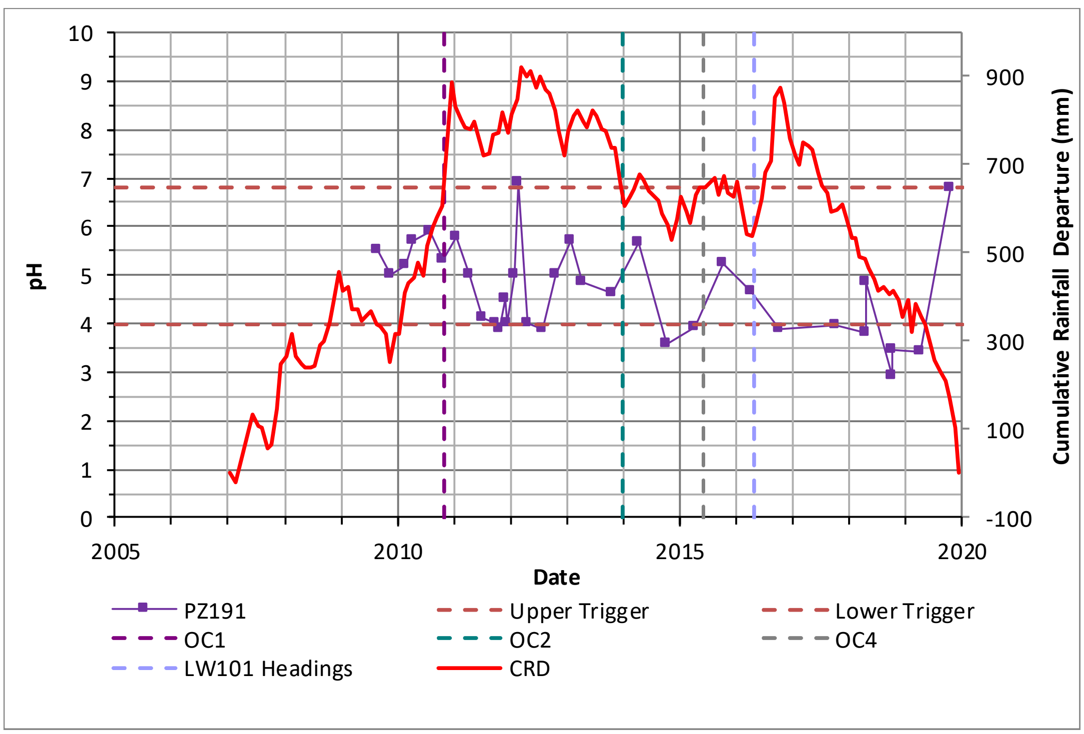

Figure 42 Groundwater Quality: pH – Permian Ulan Seam Monitoring Bore PZ191

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