# Hume Coal and Berrima Rail Project

Updated water assessment in response to recommendations R4, R5, R6, R7 and part of R8 within the Independent Planning Commission Assessment Report dated 27 May 2019

Prepared for Hume Coal Pty Ltd
April 2020

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Updated water assessment in response to recommendations R4, R5, R6, R7 and part of R8 within the Independent Planning Commission Assessment Report dated 27 May 2019

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**Client**

Hume Coal Pty Ltd

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6 April 2020

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6 April 2020

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# Executive Summary

Hume Coal Pty Limited (Hume Coal) proposes to construct and operate an underground coal mine and associated mine infrastructure in the Southern Coalfield of New South Wales (NSW) (the Hume Coal Project). The mine will produce metallurgical coal with a secondary thermal coal product. Around 50 million tonnes (Mt) of run-of-mine coal will be extracted from the Wongawilli Seam via a non-caving mining system, resulting in approximately 39 Mt of saleable coal over a project life of about 23 years, including construction and rehabilitation.

The development applications and accompanying EISs for the Hume Coal Project (EMM 2017a) and the Berrima Rail Project (EMM 2017b) were submitted to the NSW Department of Planning and Environment (DPE) (now the Department of Planning, Industry and Environment (DPIE)) on 29 November 2016 for adequacy review. Following feedback and some modification, the two EISs were deemed adequate for exhibition, which occurred between 31 March 2017 and 30 June 2017.

Following public exhibition of the EISs, Hume Coal prepared a combined Response to Submissions (RTS) report for the Project, responding to submissions received from government agencies, organisations and the public. One of most commonly raised technical issues in the submissions related to water resources, and in particular the potential impacts to groundwater and privately owned bores. Given the focus on groundwater in the submissions, substantial additional groundwater modelling and impact assessment work was undertaken as part of the RTS. This included an additional independent review of the groundwater model by DPE's expert Mr Hugh Middlemis of HydroGeoLogic Pty Ltd. The RTS report was submitted to the DPE in June 2018.

The DPE subsequently prepared a preliminary assessment report (PAR) for the Project which was released in December 2018. In relation to water, the PAR assessed that the Project will have significant drawdown impacts on numerous privately owned bores. They also advised that due to the level of opposition to the Project in the local area, the proposed make good process would inevitably result in a large number of negotiations and disputes, leading to delays to the Project and disruption to the community.

The Independent Planning Commission released an 'Independent Planning Assessment Report' in May 2019, which included several findings and recommendations relating to groundwater and surface water. The IPC recommendations R4, R5, R6, R7 and R8 that relate to water resources and in summary are:

- R4 - Groundwater modelling, referencing DoI Water advice to the IPC;
- R5 - Groundwater modelling – request for additional peer review;
- R6 – Make good strategy;
- R7 – Surface water (confirmation of water treatment plan requirement); and
- R8 - surface water, water balance confirmation request.

This Water Technical Report clearly discusses the data availability and the fact that there is adequate data available to undertake the assessment, as previously discussed during consultation with the NSW Government.

One of the key additional studies undertaken for this response to the IPC is the adoption of their recommendation to undertake an additional independent peer review of the groundwater model. This is in addition to reviews previously conducted by Dr Noel Merrick, Franz Kalf (Kalf and Associates) and Hugh Middlemis (HydroGeoLogic). This additional review by Dr Lloyd Townley further concurs that the groundwater model is 'fit for purpose', and suitable for assessment of this Project.

Ongoing groundwater modelling (post-RTS modelling) has occurred in the past 12 months and has further confirmed the model as fit for the purpose. Additional work on the model (unpublished) suggests that the hydraulic parameters adopted for the various layers are suitable and the conceptual hydrogeological understanding is well represented in the numerical model. It also suggests that the current RTS calibration statistics (scaled root mean square, RMS) can be significantly reduced when the rate of landholder pumping is reduced below the licensed entitlement. The history match remains valid (calibration) and the mine inflow and number of bores predicted to experience drawdown remain largely the same. This model will continue to evolve over time (as per the guidelines for ongoing review and refinement of all models) and will be published in the future, as required.

The make good strategy is considered in further detail in respect of the three main aspects of make good as raised by the IPC:

- Technically feasible: as demonstrated in the RTS and agreed to by Hugh Middlemis (and subsequently discussed in detail with DPIE Water);

- Implementable: with a method outlined in the flow charts and discussed as to how it will be undertaken (aligning with other very similar make good programs successfully being implemented at Tahmoor); and

- Dispute resolution pathways: which have been researched further since the RTS as to the legal framework and 'opt in' arrangement that is how 'make good' is interpreted legally within the relevant water legislation and regulations.

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# 1 Introduction

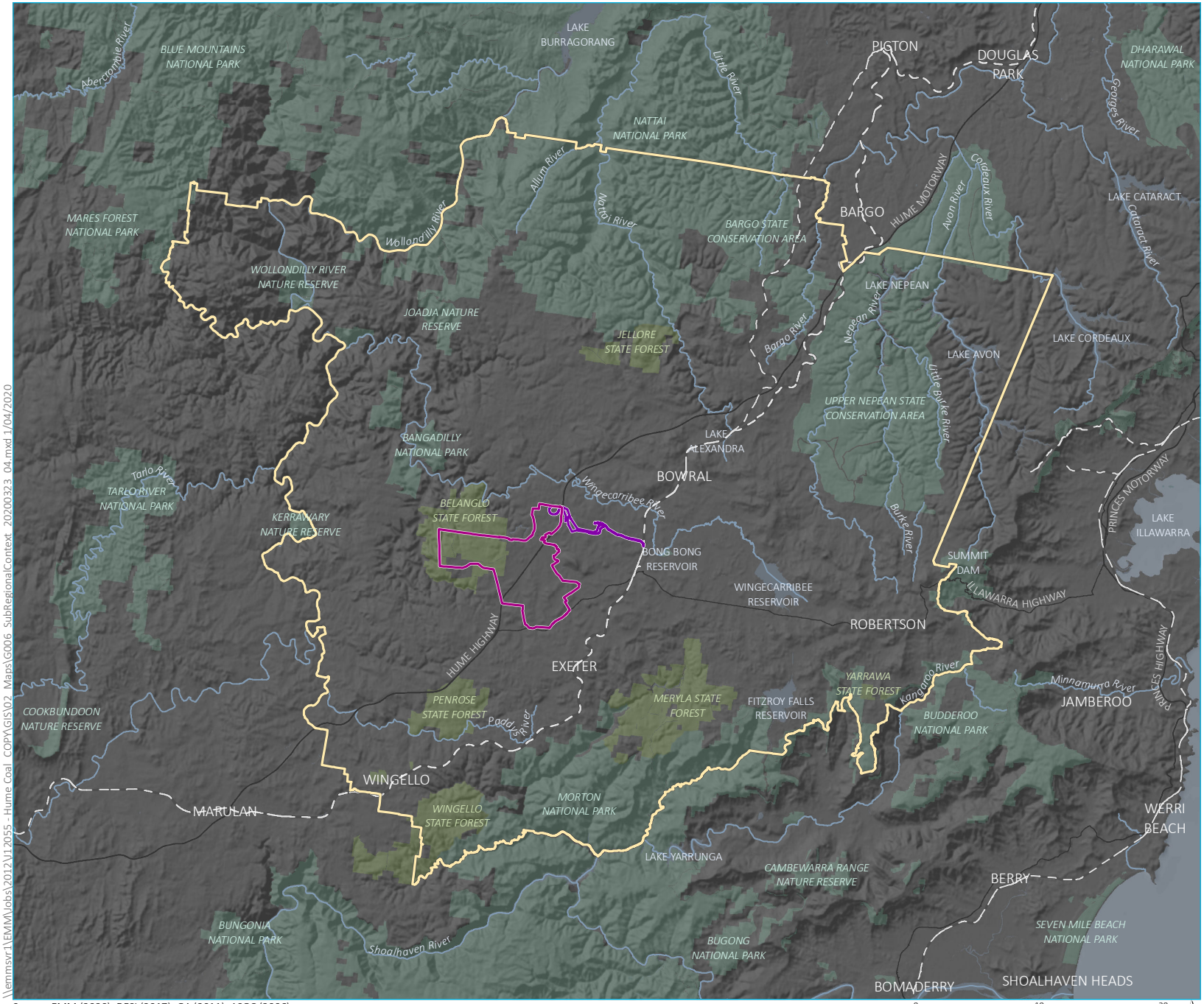
## 1.1 Overview of the Hume Coal Project

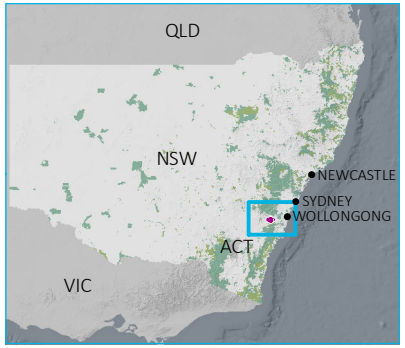
Hume Coal Pty Limited (Hume Coal) proposes to construct and operate an underground coal mine and associated mine infrastructure in the Southern Coalfield of New South Wales (NSW) (the Hume Coal Project). The mine will produce metallurgical coal with a secondary thermal coal product. Around 50 million tonnes (Mt) of run-of-mine coal will be extracted from the Wongawilli Seam via a non-caving mining system, resulting in approximately 39 Mt of saleable coal over a project life of about 23 years, including construction and rehabilitation. The Project area is located to the west of Moss Vale, in the Wingecarribee local government area (LGA). Figure 1.1 illustrates the location of the Hume Coal Project at a regional scale.

Hume Coal is also seeking approval in a separate development application for the construction and operation of a new rail spur and loop, known as the Berrima Rail Project. Coal produced by the Hume Coal Project will be transported to port by rail for export or to domestic markets also by rail via this new rail spur and loop. The project areas for the Hume Coal Project and the Berrima Rail Project are shown on Figure 1.2. The Hume Coal Project and the Berrima Rail Project are collectively referred to as 'the Project' in this report.

Indicative mine and surface infrastructure plans for the Hume Coal Project are provided in Figure 1.3. A full description of the Hume Coal Project, as assessed in this report, is provided in Chapter 2 of the main environmental impact statement (EIS) report (EMM 2017a).

Approval for both the Hume Coal Project and the Berrima Rail Project is sought under Part 4 Division 4.1 (State significant development) of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).




KEY

- Hume Coal Project area
- Berrima Rail Project area
- Wingecarribee Shire local government area
- Rail line
- Motorways and primary roads
- River
- Named waterbody
- NPWS reserve
- State forest

Source: EMM (2020); DFSI (2017); GA (2011); ASGC (2006)

0 10 20 km

GDA 1994 MGA Zone 56

N

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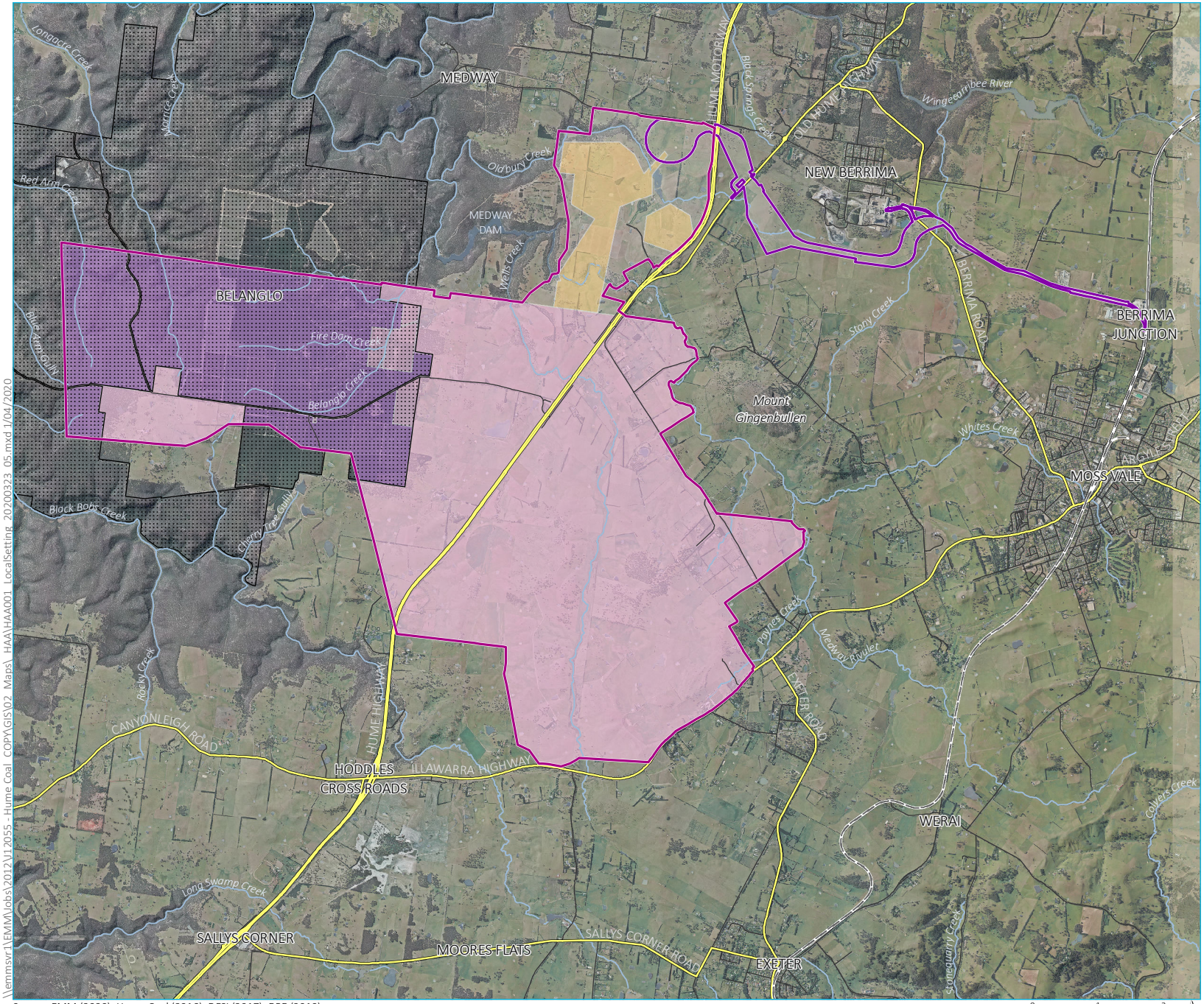
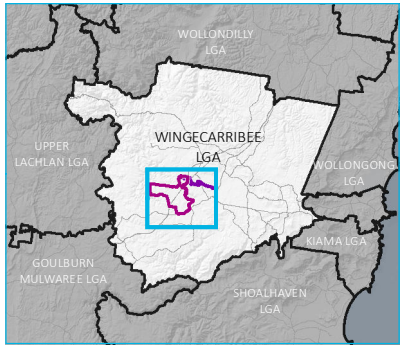
# Regional setting

Hume Coal and Berrima Rail Project
Updated water assessment
Figure 1.1

HUMECOAL PROJECT

EMM creating opportunities




KEY

- Hume Coal Project area (5,051 ha, 44,740 m perimeter)
- Berrima Rail Project area (181 ha, 23,201 m perimeter)

Mining lease application area

- MLA 527
- MLA 528
- MLA 529

Existing environment

- Rail line
- Major road
- Minor road
- Named watercourse
- Waterbody
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 1 2 km

GDA 1994 MGA Zone 56

N

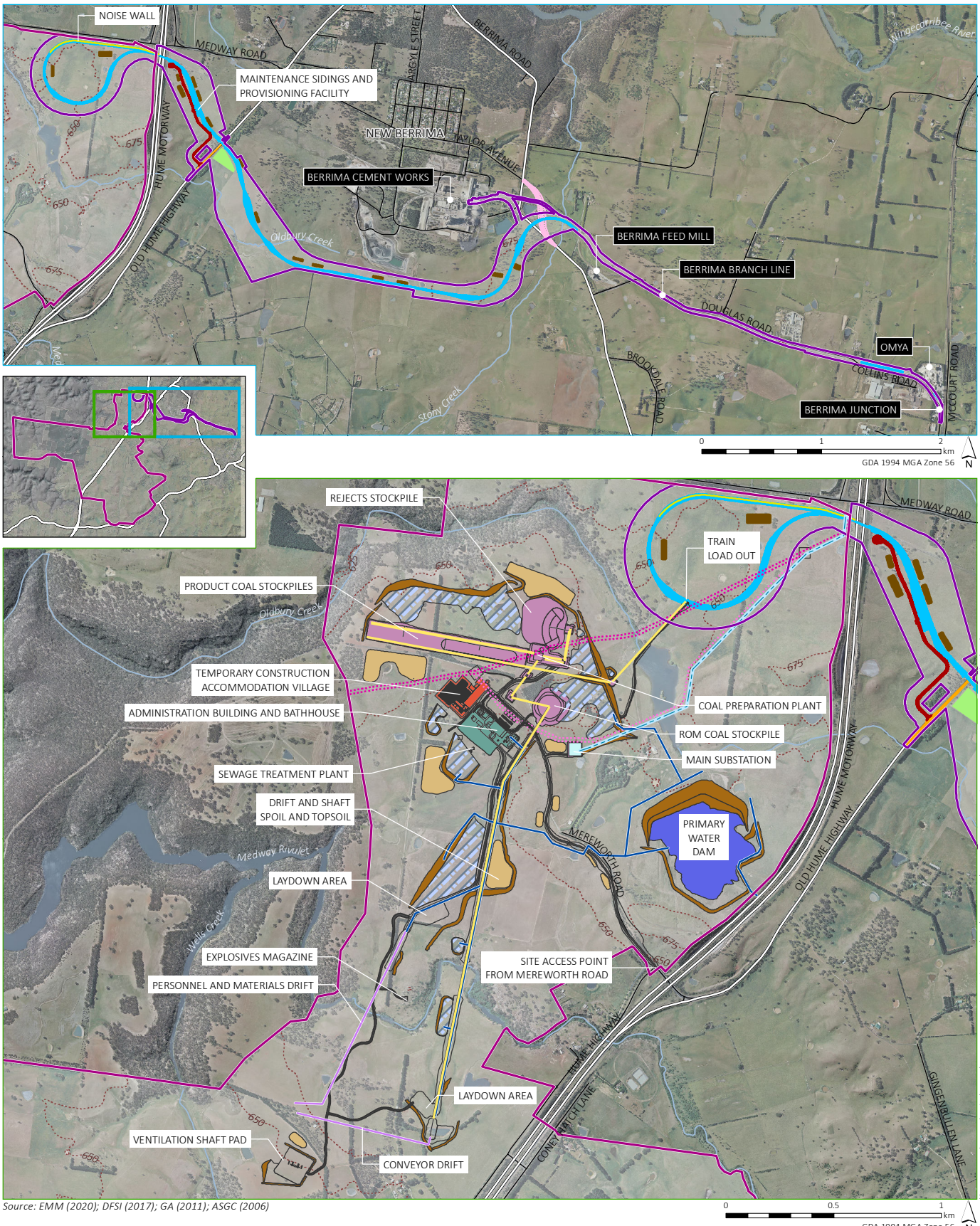
\\emmsvr1\EMM\Jobs\2012\V12055 - Hume Coal COPY\GIS\02 Maps\ HAA\HAA001 LocalSetting 20200323 05.mxd 1/04/2020

# Local setting

Hume Coal and Berrima Rail Project
Updated water assessment
Figure 1.2

HUMECOAL PROJECT

EMM creating opportunities

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*Source: EMM (2020); DFSI (2017); GA (2011); ASGC (2006)*

## KEY

- Major road
- Minor road
- Contour (25 m increments)
- Named watercourse
- Waterbody
- Berrima Rail Project area

Berrima Rail Project elements

- Noise wall
- New rail line
- Rail maintenance facility access road
- Berrima Road relocation (works by Wingecarribee Shire Council)
- Topsoil stockpiles
- Rail temporary construction facility
- Turning lane/shoulder
- Hume Coal Project area

Hume Coal Project elements

- Conveyor
- Drift (underground)
- Powerline route
- Water pipeline
- Proposed powerline and pipeline easement
- Existing WSC easement
- Temporary construction accommodation village
- Administration/bathhouse/workshop
- Main substation
- Internal road
- CPP and stockpiles
- Topsoil stockpiles
- Stormwater management earthworks
- Water management area
- Top water level

# Hume Coal Project layout plan

Hume Coal and Berrima Rail Project
Updated water assessment
Figure 1.3

HUMECOAL PROJECT

EMM creating opportunities

## 1.2 Background and assessment approach

Plate 1.1 outlines the assessment process to date.

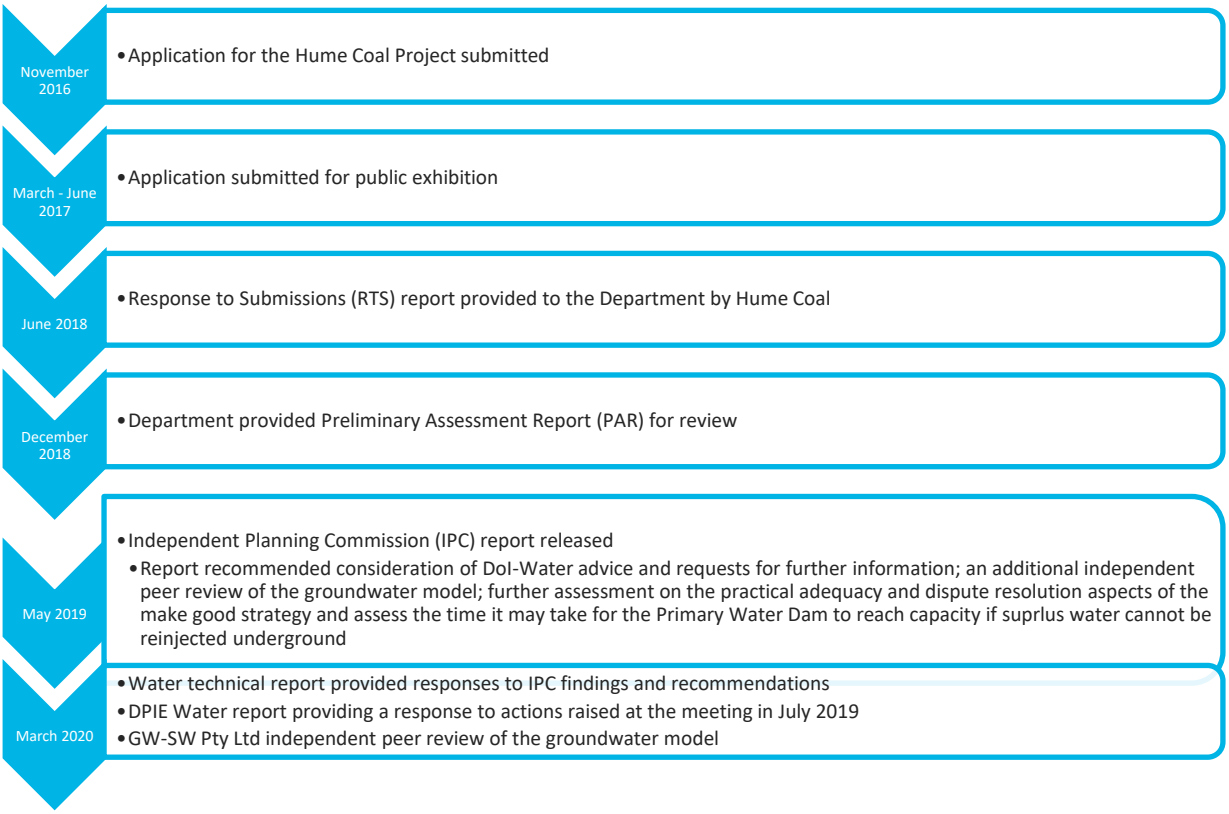



**Plate 1.1 The assessment process to date**

**Application for the Hume Coal Project and Berrima Rail Project submitted**

The development applications and accompanying EISs for the Hume Coal Project (EMM 2017a) and the Berrima Rail Project (EMM 2017b) were submitted to the NSW Department of Planning and Environment (DPE) (now the Department of Planning, Industry and Environment (DPIE)) on 29 November 2016 for adequacy review. Following feedback and some modification, the two EISs were deemed adequate for exhibition, which occurred between 31 March 2017 and 30 June 2017.

A water assessment report (EMM 2017b) was prepared and submitted to the DPE as part of the EIS for the Hume Coal Project. The water assessment was prepared in accordance with the appropriate guidelines, policies and industry requirements, the Secretary's Environmental Assessment Requirements (SEARs) and in consultation with relevant government agencies.

**Response to submissions report**

Following public exhibition of the EISs, Hume Coal prepared a combined Response to Submissions (RTS) report for the Project, responding to submissions received from government agencies, organisations and the public. A total of 12,666 submissions were received on both projects, the majority of which (89%) were form letter submissions, totalling 11,241. 1,354 individual submissions were received from individual community members, of which 419 were in support and 929 objected. 23 submissions were received from special interest groups, and 36 from businesses. The remaining 12 submissions were from government agencies. Of the total submissions received (including form letters), 12,212 objected to the Project, 436 were in support and 18 provided comment.

One of most commonly raised technical issues in the submissions related to water resources, and in particular the potential impacts to groundwater and privately owned bores. Given the focus on groundwater in the submissions, substantial additional groundwater modelling and impact assessment work was undertaken as part of the RTS. This included an additional independent review of the groundwater model by DPE's expert Mr Hugh Middlemis of HydroGeoLogic Pty Ltd (HydroGeoLogic).

Impacts to surface water resources were also commonly raised. The revised aspects of the surface water assessment demonstrated that the Project will meet the Neutral or Beneficial Effect (NorBE) criteria for surface water quality across all aspects of the Project.

The RTS report was submitted to the DPE in June 2018.

**Preliminary assessment report**

The DPE subsequently prepared a preliminary assessment report (PAR) for the Project which was released in December 2018. In relation to water, the PAR assessed that the Project will have significant drawdown impacts on numerous privately owned bores. They also advised that due to the level of opposition to the Project in the local area, the proposed make good process would inevitably result in a large number of negotiations and disputes, leading to delays to the Project and disruption to the community.

Hume Coal provided a detailed submission to the Independent Planning Commission (IPC) in response to the PAR and identified that the potential impacts on water resources can be effectively managed and mitigated. It also highlighted that the Department of Industry (DoI)-Water and DPE submissions and PAR contain incorrect assumptions and do not consider the findings of the DPE's independent expert Mr Hugh Middlemis of HydroGeoLogic.

**Independent Planning Commission**

As the number of submissions objecting to the Project were greater than 25, the Minister for Planning referred the Projects to the IPC to conduct a public hearing, assess the merits of the Project, and prepare a report outlining the Commission's findings on the Project, including any recommendations.

The IPC 'Independent Planning Assessment Report' (the IPC assessment report), released in May 2019, included several findings and recommendations relating to groundwater and surface water. Table 1.1 lists IPC recommendation R4, R5, R6, R7 and R8 that relate to water resources.

### Table 1.1 IPC recommendations for further assessment

| Submission | Category | IPC recommendation |
|---|---|---|
| R4 | Groundwater modelling | That the Department review the advice of Department of Industry - Water dated 24 April 2019 and the Applicant's correspondence of the 17 May 2019 and gives consideration to requesting the completion of the revised groundwater flow model, taking into consideration the advice provided. |

**Table 1.1 IPC recommendations for further assessment**

| Submission | Category | IPC recommendation |
|---|---|---|
| R5 | Groundwater modelling | Because the Applicant and Department of Industry - Water remain a considerable distance apart regarding their positions on the groundwater modelling, the Commission suggests that the Department or the Applicant, or both of them jointly (and in any case in consultation with Department of Industry - Water), engage a new independent expert (or alternatively a small technical group with Chair) with experience in groundwater modelling with a view to resolving ongoing differences of opinion. The independent expert/Chair should consider:<br>• what practical steps, if any, can be taken to make the model a class 2 model or seek agreement on the class of the model;<br>• what additional work is required to establish the extent to which the emplacement of water in mined-out voids will reduce the level of drawdown in the later years of the project;<br>• the range used for the input parameters in the modelling sensitivity/uncertainty analysis and recommend if a wider range is required so that there is no unreasonable truncation of results; and<br>• if additional geological information is required. |
| R6 | Make Good strategy | That the Department give close attention to the practical adequacy of make good provisions during the final assessment process, with an independent review if necessary. This should include the practical aspects such as dispute resolution and economics as well as the technical. |
| R7 | Surface water | The Applicant is to confirm whether the provisional Water Treatment Plant does form part of the Project – and if so, provide suitable information to permit an appropriate assessment of its impacts. |
| R8 | Surface water | Should underground emplacement and water impounded have to cease for any reason, the Applicant is to confirm **how long under normal mining operations it would take for the** reject emplacement stockpile and **Primary Water Dam to reach capacity**. |

## 1.3 Purpose

The purpose of this water technical report is to respond directly to the IPC findings and recommendations as published in the IPC assessment report released in May 2019. This report considered the additional investigations undertaken since May 2019 and also seeks to provide additional reasons and logic (supported by data) on the underlying concerns (volume of data, conceptual understanding and numerical modelling, and make good).

Specifically, this water report addresses and responds to IPC recommendations R4, R5, R6, R7 and R8 as described in Section 1.2. Discussion related to potential impacts on non-native vegetation, including cultural heritage gardens, exotic plants and private gardens (R16 and R19) are discussed in the *Groundwater dependence assessment for cultural heritage landscapes and gardens* report (EMM 2020a).

Where necessary, this study also addresses items presented in the IPC assessment report that informed the IPC findings and assessment that the applicant feels are erroneous, unsubstantiated or are otherwise worthy of response.

Table 1.2 describes where this report addresses each water related item raised by the IPC.

## Table 1.2 Response to IPC report on water related matters

| Reference number | IPC assessment considerations | Location where addressed |
|---|---|---|
| 86 | Submissions, speakers at the public hearing and experts have raised concerns regarding the lack of **geological information** and the Commission agrees with those reservations. Extrapolating some geological data from the Berrima coal mine, some five km away, carries with it uncertainty. More closely spaced geological information is desirable to improve the geological confidence in the conceptual mine plan. When the Applicant has been questioned about this the reply has been that a detailed mine plan is not usually prepared this stage of a mining project. This is a problem that will have to be addressed and resolved. The Commission also notes the view of some adjoining landowners that access would not be provided to enable geological investigation. The implications of this will need to be considered. | Section 2 |
| 136 | There is significant Agency and public concern relating to the accuracy and robustness of the Applicant's **groundwater modelling**. | Section 3 |
| 137 | It is noted that the groundwater flow model is a semi-regional model and as such it does not contain local **geological data such as faults, fracture zones, basalt intrusions** (sills and dykes) and that local geological conditions will have an effect on groundwater flow conditions, including both mine inflow predictions and drawdown impacts on private bores. | Section 2 |
| 139 | Advice from DoI Water (2019) stated that the **calibration of the model** against four data sets does not necessarily reflect the quality of the model in replicating the existing environment or predicting future impacts. They point out that a visual analysis of the groundwater calibration hydrographs concludes that the vast majority of bores are uncalibrated with only 21% of all the calibration bores having a residual <2m and 50% of the bores exceed 10m residual between the observed and modelled results. They conclude that there is an insufficient number of calibrated bores to provide **confidence in the model predictions**. | Section 3 |
| 140 | Of particular interest to the Commission is the possibility that the **Hawkesbury Sandstone hydraulic conductivity (Kh and Kv) is highest immediately above the coal seam to be mined**. There was no representation of this in the model realizations, despite apparently being requested by DoI-Water at a previous modelling meeting. This work would have been useful to check the possibility of larger water inflows to the mine. Likewise, a larger range of drainage conductance values could have been modelled to eliminate the speculation about the interburden layer acting as a bottleneck to flow. | Section 3 |
| 141 | The Commission notes that water balance errors associated with the revised (Merrick, 2018) model are now at an acceptable level of 0.2%. The model calibration performance for predicted versus measured groundwater levels remains higher than desirable (SRMS = 10.7%) with only 30% of the uncertainty realisations achieving less than 10% SRMS. Advice from DoI-Water (2019) considers that the **SRMS modelling error statistic should be less than 5%** for a model to be used for such an important water resource. For this and other reasons DoI-Water does not consider the revised model to be **fit for the purpose** of assessing drawdown impacts resulting from mining, to an adequate level of certainty. DoI-Water considers that revised model resembles a Level 1 model which incorporates some Level 2 and Level 3 elements. | Section 3 |
| 143 | The Commission notes the disagreement between the comments of the Department's expert and those of DoI-Water in terms of the level of model and the accuracy of prediction of groundwater drawdown. The **level of groundwater model (class)** and the effectiveness of its predictions need to be resolved. | Section 3 |
| 145 | Whilst several reviewers have labelled the [make good] strategy as technically feasible there are some residual risks for irrigation bore owners as constructing deeper bores, or even multiple bores of larger diameter may not equate to losing a high yielding bore in the HS. | Section 4 |
| 146 | DoI-Water consider that the **make good arrangements** for irrigation bore owners is uncertain as there is little knowledge about the water supply quality and yields from deeper formations. | Section 4 |

## Table 1.2 Response to IPC report on water related matters

| Reference number | IPC assessment considerations | Location where addressed |
|---|---|---|
| 147 | The Department's PAR considers that given the significant opposition to this Project the **make good strategy** would inevitably lead to a large number of disputes requiring resolution and causing disruption to the community. | Section 4 |
| 152 | The Commission finds that the Applicant and Department have not adequately assessed or considered the potential impacts of the Project on groundwater because of the **uncertainty around the modelling** undertaken to date and the associated uncertainty this might create in understanding the potential groundwater impacts, and the lack of certainty around the practical application of the Applicant's make good proposal. | Section 3 and 4 |
| 155 | The Commission considers that speculation about the conservatism of the revised model can only be tested by appropriate sensitivity and uncertainty analysis on a **fit for purpose model**, and the Commission considers that it is possible that the current model might underestimate mine water inflow and impacts to existing groundwater users. The extent of any underprediction is unknown. Balanced against this is the conservative effect of not considering the positive influence of the return of water and waste materials to the mined-out sections of the mine. | Section 3 |
| 157 | At this stage of its assessment the Commission finds that it is not satisfied with the information provided up to this point regarding groundwater impacts because of the **uncertainty about the extent of groundwater drawdown and the capability of 'making good'**. | Section 3 and 4 |
| 185 | At this stage of its assessment the Commission finds that it is not satisfied with the information provided up to this point regarding surface water impacts because of disagreement over the **acceptability of the mine design and the consequent ability to store water underground**. | Section 5 |

# 2 Conceptual understanding

The conceptual hydrogeological understanding has been described and presented in the water assessment submitted in support of the EIS (EMM 2017a) and the revised water assessment submitted in support of the RTS (EMM 2018a).

The data available for the assessment of the Hume Coal Project is fit for purpose and there is sufficient information to inform the conceptual hydrogeological model for the Project. Site specific data for the Project has been collected since 2009 and continues to be collected. Commonwealth and NSW Government databases for climate, geology and water have also been assessed to incorporate into the assessment for the Project.

Hume Coal refute the suggestion that there is insufficient data available to inform the conceptual hydrogeological understanding and groundwater model development and calibration.

This section provides a summary of data available and used to inform the assessments (Table 2.1) and provides a summary of the conceptual hydrogeological understanding. It also offers a comparison of the available hydraulic data for the Hume Coal Project in comparison to other approved coal mines in NSW (Table 2.2).

## 2.1 Available data

The water assessment submitted as part of the EIS (EMM 2017a) and RTS (EMM 2018a) present the baseline data used to assess the potential impacts of the Project on water resources and receptors. The sources of available data used to inform the water assessments are summarised in Table 2.1.

**Table 2.1 Summary of data availability**

| Data type | Source | Data period |
|---|---|---|
| Climate | Temp: Moss Vale BoM station 068045 | 1871 – 2015 |
| • Temperature | Rainfall: Moss Vale BoM station 068045 | 1871 – 2015 |
| • Rainfall | Rainfall: Berrima West BoM station 68186 | 1970 – 2015 |
| • Evaporation | Pan evaporation: Goulburn TAFE BoM station 070263 | 1971 – 2015 |
| | SILO Data Drill historical rainfall and evaporation data | Jan 1889 to Jan 2015<br>Oct 1870 – Jan 2016 |
| | Rainfall: 9 BoM rain gauges | February 2012 - present |
| | Rainfall: Hume Coal weather station | |
| Topography | LiDAR from aerial laser survey | 25 October 2013 |
| | LiDAR from ELVIS (https://elevation.fsdf.org.au/). | Mix of 2013, 2014, 2016, 2018 |
| Hydrological mapping | Field geomorphology surveys based on River Styles® Framework (WSP PB 2016c) | May 2012 – Oct 2015 |
| Existing bore details (bore yields, depth, status, water quality, hydraulic testing data) | WaterNSW NSW Water Register database | Dec 2015 and April 2018 |
| | Bore census | March and April 2014; May and June 2015 |
| Groundwater levels (heads) | Hume dedicated groundwater monitoring network – 54 groundwater monitoring bores at 22 nested locations and 3 landholder bores | Nov 2011 – present |

## Table 2.1 Summary of data availability

| Data type | Source | Data period |
|---|---|---|
| Groundwater quality | Hume dedicated groundwater monitoring network – initial sampling following installation; quarterly sampling from 23 monitoring bores for the EIS. Subsequently sampling has continued at a reduced frequency. | Oct 2011 – present |
| | Isotope analysis - 15 groundwater monitoring locations | Isotope analysis: Oct/Nov 2011 and Dec 2013 |
| Groundwater pressure | Hume dedicated groundwater monitoring network – 11 vibrating wire piezometer sensors at 3 locations | May 2013 - present |
| Hydrogeological properties - local | Slug testing – 42 project groundwater monitoring bores | Slug tests: Nov 2011 to Sept 2015 |
| | Pumping tests - 2 constant rate pumping tests: a 24-hour test at HU0098PZ and a 7-day test at GW108194 | Pumping tests: June/July 2014 |
| | 28 Packer tests (conducted on 3 open boreholes by Strata Control Technology) | Packer testing: Sept 2013; March/April 2015; and Oct 2017. |
| | Core testing – 39 samples from 16 core hole locations | Core testing: Oct 2013; April/July 2015, Dec 2019-Feb 2020 |
| Geophysical | Downhole geophysical logging of 20 deep project bore holes at nested locations | Sept 2011 to Oct 2014 |
| Surface water quality | Hume dedicated monitoring network – 24 water quality monitoring locations | April 2012 – present |
| | WaterNSW monitoring stations – 1 on Wingecarribee River and 1 on Wollondilly River | April 2002 – present |
| | Isotope analysis – 3 surface water monitoring locations | Isotope analysis: Dec 2013 |
| Surface water flows | Hume dedicated monitoring network – 11 stream flow gauging locations | Jan 2012 – present |
| | WaterNSW/SCA flow gauging stations – 3 along Wingecarribee River | Oct 1989 – present |
| Surface geology | Southern Coalfield Regional Geology 1:100,000 Geology Map (Moffit 1999) | 1999 |
| Structural geology | Southern Coalfield Regional Geology 1:100,000 Geology Map (Moffit 1999) | 1999 |
| Stratigraphy and lithology | Hume mineral exploration drilling | |
| | Groundwater investigation drilling | Sept 2011 to Oct 2014 |
| | Hume geological model | |
| | Brian Jones geological review | December 2019 to February 2020 |

## Table 2.1 Summary of data availability

| Data type | Source | Data period |
|---|---|---|
| Groundwater dependent ecosystems (GDEs)<br>• Terrestrial<br>• Aquatic<br>• Subterranean | Water Sharing Plan for the Greater Metropolitan Region, Groundwater Sources 2011 | 2011 |
| | National Atlas of Groundwater Dependent Ecosystems (BoM) | 2012 |
| | EMM field surveys | 2013 - 2014 |
| | Stygofauna sampling – 19 groundwater monitoring bores (8 within Project area and 11 outside) | |

## Table 2.2 Comparison of available hydraulic data across NSW coal projects

| Project | Stage | Date | Slug tests | Packer tests | Core analysis | Pumping test | Notes |
|---|---|---|---|---|---|---|---|
| **Sydney Basin Southern Coalfields - Hume Coal Project** | **EIS (IPC)** | **2020** | **42 bores** | **28 tests (3 bores)** | **128 samples (37 bores and drillholes)** | **2 test locations (one 24hr, one 72 hr)** | |
| Sydney Basin - Hunter /Wallarah 2 Coal Project | EIS (approved) | 2018 | 16 bores | 170 tests (31 bores) | 59 samples | - | |
| Gloucester Basin Rocky Hill Coal Project | EIS (refused) | 2017 | 15 bores | - | - | - | Also reference data from nearby investigations (AGL) |
| Sydney Basin – Hunter Wilpinjong Extension Project | EIS (approved) | 2017 | y | - | y | y | Reference to tests but no details on locations and number of tests |
| Sydney Basin – Hunter Drayton South Coal Project | EIS (refused) | 2017 | 3 tests | | | | References numerous historical tests but no details on location on number of tests |
| Sydney Basin – Hunter Airly Mine Extension Project | EIS (approved) | 2016 | 5 bores | 9 tests (9 bores) | - | 1 test | |
| Minerals/metals (not coal) Nyngan Scandium Project | EIS (approved) | 2016 | - | - | - | 1 test (36 hr) | |
| Sydney Basin – Hunter Mount Owen Continued Operations Project | EIS (approved) | 2016 | y | y | | y | Reference to tests but no details on locations and number of tests |

## Table 2.2 Comparison of available hydraulic data across NSW coal projects

| Project | Stage | Date | Slug tests | Packer tests | Core analysis | Pumping test | Notes |
|---|---|---|---|---|---|---|---|
| Minerals/metals (not coal) Balranald Mineral Sands | EIS (approved) | 2016 | - | - | - | Numerous tests (6 hr to 48 day) | Testing focused on reinjection trials. 4 tests (6 hr); 7 tests (15 hr - 7 day); numerous injection/ production bores (48 day) |
| Sydney Basin – Hunter Warkworth Mt Thornley Continuation Project | EIS (approved) | 2015 | 6 bores | y | - | - | Packer testing referenced - details not provided |
| Mandalong Southern Extension Project | EIS (approved) | 2015 | - | 5 tests (1 bore) | - | - | Reference to other tests but no details on locations and number of tests |
| Sydney Basin – Western Coalfields Springvale Mine Extension project | EIS (approved) | 2015 | y | 22 tests (2 bores) | - | y | Reference to numerous slug and pump tests - appear to be at one bore |
| Tasman Extension Project | EIS (approved) | 2013 | 23 tests (historical) | 9 tests (1 bore) | 10 samples (historical) | 3 (historical) | |
| Sydney Basin – Hunter Chain Valley Colliery Mining Extension 1 | | | - | - | y | - | Cores analysis from other local projects referenced - no details of number of tests |
| Sydney Basin – Western Coalfields Springvale Western Coal Services | EIS (approved) | 2014 | 2 bores | - | - | - | Reference to hydraulic properties derived from 2 other studies in the area (undefined sources) |
| Minerals/metals (not coal) Atlas-Campaspe Mineral Sands Project | EIS (approved) | 2014 | - | - | - | 1 test | |
| Gunnedah Basin Vickery Coal Project | EIS (approved) | 2014 | 9 bores | - | 29 samples (5 bores) | Low flow CRT at 4 monitoring bores | Reference to hydraulic properties derived from 2 other studies in the area |
| Sydney Basin – Hunter Bulga Optimisation Project | EIS (approved) | 2014 | | 63 tests (11 bores) | 37 samples (2 bores) | | Reference to hydraulic properties derived from prior modelling |
| Gunedah Basin Watermark Coal Project | EIS (approved) | 2015 | 82 bores | 60 tests (12 bores) | 59 samples (8 bores) | 8 tests | |

**Table 2.2 Comparison of available hydraulic data across NSW coal projects**

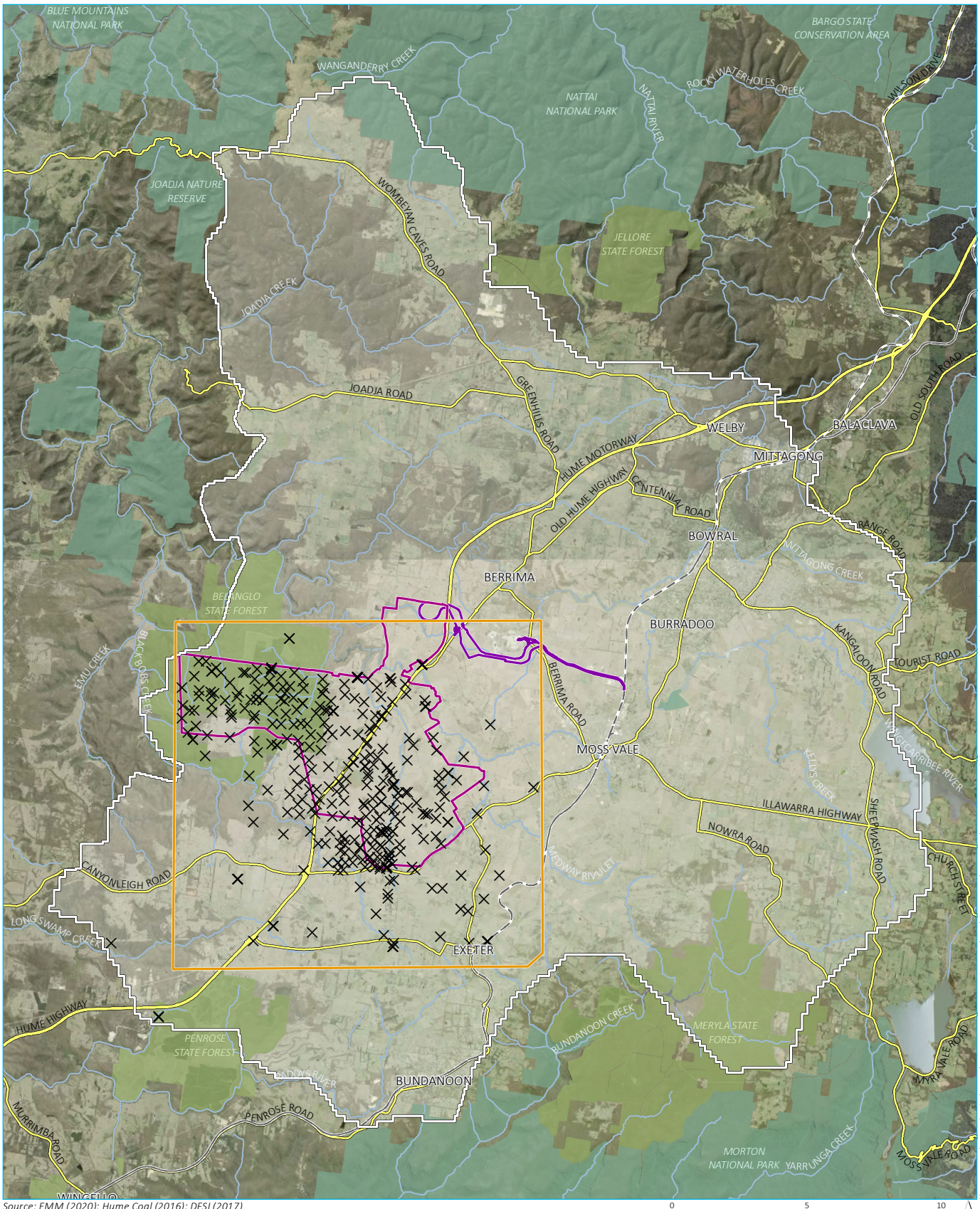
| Project | Stage | Date | Slug tests | Packer tests | Core analysis | Pumping test | Notes |
|---|---|---|---|---|---|---|---|
| Gloucester Basin Stratford Extension project | EIS (approved) | 2015 | 5 bores | - | 31 samples (5 bores) | 1 test (6 day) | Reference to hydraulic properties derived from other studies in the area |

### 2.1.1 Local geological data

In his response to DPE's PAR, Dr Bruce Hebblewhite (2019) commented that the amount of data provided was quite considerable and is consistent with similar mining projects at this stage of evaluation and development. Geological data and information will continue to be gathered as the Project proceeds, and detailed mine planning may be modified as required to accommodate any new or additional information.

The decision that there is sufficient data to inform the Project was made in 2017 by the Division of Resources and Geoscience. They assessed that the Hume Coal EIS adequately addressed the SEARs. In addition, the Division of Resources and Geoscience (2017) found that "a number of factors constrain the mine plan, extraction methodology and therefore the resource recovery at the Project. These include geological, mining and environmental constraints. The Proponent has considered a large variety of underground mining techniques and mine plans for the Project." The geological and hydrogeological data for the Project is extensive, with 345 individual holes drilled within the Project area (179 of which are within the proposed mining area, see Figure 2.1). All Hume Coal drillholes have been geophysically logged, core photographed and used to develop a robust geological model. In addition to the drilling of boreholes, extensive aerial magnetic and radiometric surveys have been conducted over the Project area. Surface magnetic surveys were also undertaken targeting specific geological structures that were located by the aerial surveys. Surface seismic surveys were undertaken in the Belanglo State Forest and property owned by the proponent. In total, approximately 36 linear km of data was obtained. Geological mapping was undertaken on accessible properties and where drilling was undertaken.

Figure 2.1 shows the extent of the Hume Coal geological model, mineral drillhole data locations and the extent of the groundwater model. Cross sections have been cut within the geological model and groundwater model for comparison purposes, as requested by DPIE Water at a meeting held in July 2019. These cross sections are discussed further in Annexure A (DPIE Water report).




Source: EMM (2020); Hume Coal (2016); DFSI (2017)

0 5 10 km

GDA 1994 MGA Zone 56

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KEY

- Hume Coal Project area
- Berrima Rail Project area
- Groundwater model extent
- Geological model extent
- Hume drill holes

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

# Comparison of groundwater model and Hume Coal geological model extents

Hume Coal and Berrima Rail Project
Updated water assessment
Figure 2.1

HUMECOAL PROJECT

EMM creating opportunities

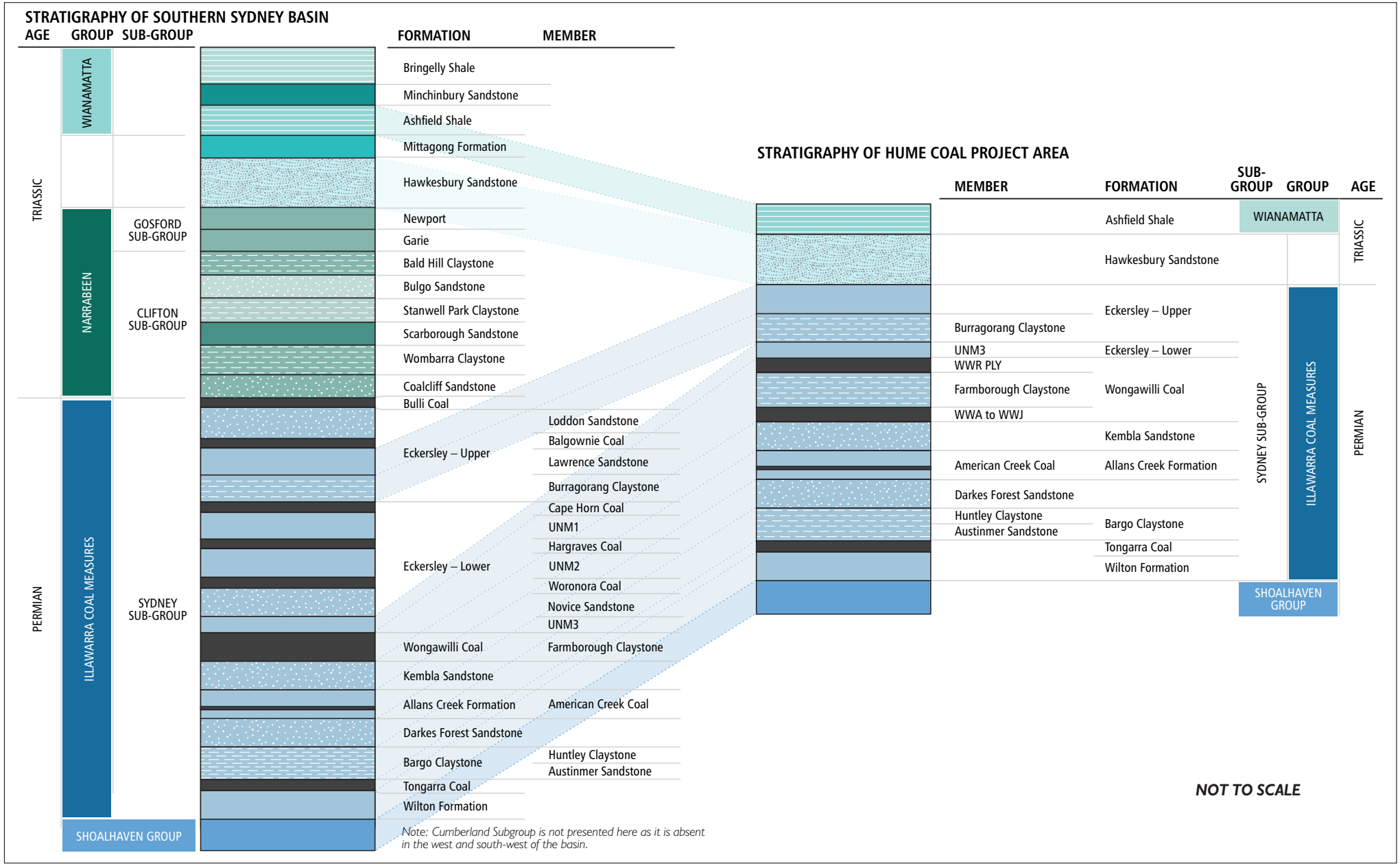
## 2.2 Geological setting

### 2.2.1 Regional geology

The Project is located in the Southern Sydney Basin, within the Southern Coalfields, on the south-western edge of the sedimentary Permo-Triassic Sydney Basin. The Sydney Basin extends north to south along some 350 km of central NSW coastline (from Newcastle to just north of Batemans Bay), and extends to the Great Dividing Range in the west. About one quarter of the basin is offshore to the east of the shoreline (Brunker and Rose 1967). The onshore sedimentary units are thickest (up to 4.5 km) in the northern part of the basin (Geoscience Australia 2016).

### 2.2.2 Stratigraphy

The stratigraphy of the broader Southern Sydney Basin is presented with a comparison to the stratigraphy of the Project area in Figure 2.2. Further discussion on the depositional environment and local geological setting is described in the following sections.




South Sydney Basin vs Project area stratigraphy

Hume Coal Pty Ltd

Updated water assessment

Figure 2.2

### i Illawarra Coal Measures

The Illawarra Coal Measures (ICM) consists of two subgroups: the basal Cumberland Subgroup and the Sydney Subgroup, which contains all of the economic coal seams (Moffitt 1999). The Cumberland Subgroup is absent in the west and south-west of the Sydney Basin and therefore only the Sydney Subgroup is considered further.

The geological units of the ICM, from oldest to youngest, are described by Moffitt (1999) and summarised below:

- The basal formation of the Sydney Subgroup is the Marrangoo Conglomerate which is widespread across the Sydney Basin and has been observed as far south as Sutton Forrest. In the south-west of the Basin, the Marrangoo Conglomerate consists of pebble to cobble conglomerate that fines upward to coarse-grained sandstone that are derived from the Lachlan Fold Belt.

- The Wilton Formation is dominated by dark claystone and siltstone, interbedded with sandstone. It extends over most of the northern half of the Southern Sydney Basin and thickens to the north and north-east.

- The Tongarra Coal conformably overlies the Wilton Formation where present in the northern and central areas of the Southern Coalfield. The unit consists of coal, carbonaceous siltstone and claystone and tuffaceous claystone.

- The Bargo Claystone conformably overlies the Tongarra Coal and consists of dark, interlaminated claystone, siltstone and minor thin tuffaceous beds. It ranges in thickness from a few centimetres in the south-west to greater than 50 m in the north-east.

- Darkes Forest Sandstone is present over most of the central, north-western and north-eastern parts of the Southern Coalfield. It is reported to be absent in the western margin and south-west of Mittagong, however it has been observed in Hume Coal drilling. The unit consists of medium to fine-grained lithic sandstone with minor interbeds of siltstone and claystone.

- Allans Creek Formation commonly overlies the Darkes Forest Sandstone, however it is absent in the south-west and is around 1 m thick in the Berrima, Mittagong and Robertson area where it consists of coal and carbonaceous claystone. The unit thickens up to 45 m to the north-east.

- The Kembla Sandstone overlies the Allans Creek Formation with an erosive contact. It is comprised of distinct coarse to medium-grained lithic sandstone with interbeds of claystone and siltstone. This unit is regionally extensive and is referred to by Bamberry (1991) as being the most extensively developed fluvial unit in the Sydney Subgroup.

- Wongawilli Coal is the thickest and most widespread coal interval in the Southern Coalfield and has been correlated with the Middle River Coal Member in the Western Coalfield. The unit contains coal, siltstone, tuffaceous claystone and kaolinitic claystone. The Farmborough Claystone member of the Wongawilli Coal is a tuffaceous claystone that is typically up to 2 m thick.

- The Eckersley Formation overlies the Wongawilli Coal and consists of coarsening upward sequences of interbedded claystone, siltstone, coal, carbonaceous and tuffaceous claystone and minor, medium-grained lithic sandstone. The Formation contains the following members: Novice Sandstone, Woronora Coal, Hargraves Coal, Cape Horn Coal, Burragorang Claystone, Lawrence Sandstone, Balgownie Coal and Loddon Sandstone. The Formation has been eroded during deposition of the Hawkesbury Sandstone in places in the south-west of the Southern Coalfield.

### ii Narrabeen Group

The Narrabeen Group consists of two main subgroups, the basal Clifton Subgroup and the Gosford Subgroup (Moffitt 1999). The Clifton Subgroup includes the Coal Cliff Sandstone, Wombarra Claystone, Scarborough Sandstone, Stanwell Park Claystone, Bulgo Sandstone and Bald Hill Claystone. The Gosford Subgroup includes the Garie and Newport Formations.

Consistent with other units of the Sydney Subgroup, the units within the Narrabeen Group are thin or absent in the south-west of the Southern Coalfield, with thicknesses increasing to the north-east. The Narrabeen Group does not specifically occur within the Hume Coal mine footprint area.

### iii Hawkesbury Sandstone

The Triassic Hawkesbury Formation outcrops over much of the Illawarra area and forms cliffs along the Illawarra escarpment and around Kangaroo Valley (Moffitt 1999). This unit is regionally extensive and varies in thickness from 100 m to 250 m, increasing in thickness to the north-east. Two major facies of the Hawkesbury Sandstone are described by Moffitt (1999):

- Sheet facies: characterised by small to large scale planar to trough crossbeds that range from a few centimetres to 5 m or more; and
- Massive facies: characterised by massive bedding, mostly structureless poorly sorted sandstone, containing higher portions of clay and less chemical cements and quartz overgrowth than the sheet facies.

The Hawkesbury Sandstone is a medium to coarse grained quartz arenite (sedimentary rock with more than 90% detrital quartz) with minor siltstone, shale, mudstone and laminate lenses (McLean and David 2006; Scheibner and Basden 1998).

### iv Mittagong Formation

The Mittagong Formation consists of fine-grained quartzose sandstone interbedded with dark grey siltstone and laminate in beds up to 1 m thick. It conformably overlies the Hawkesbury Sandstone and appears to grade into it in places. It varies in thickness up to 15 m (Herbert and Helby 1980). The unit is derived from floodplain sediments deposited at the end of the Hawkesbury Sandstone depositional episode.

The Mittagong Formation is difficult to identify in borehole logs due to it being a transitional until and very similar in appearance to both the Hawkesbury Sandstone and overlying Ashfield Shale. It is generally not mapped as surface outcrop, likely due to the difficult identification in situ.

### v Wianamatta Group

The Wianamatta Group represents the last phase of the sedimentation directly related to development of the Sydney Basin (Moffitt 1999).

The basal formation of the Wianamatta Group is the Ashfield Shale, which comprises dark grey to black shale and siltstone interbedded with lithic sandstones and siltstone, and very minor coal bands.

The Minchinbury Sandstone is a quartz-lithic sandstone unit and forms a mappable unit that separates the underlying Ashfield Shale from the overlying Bringelly Shale. The Bringelly Shale consists of claystone and siltstone, laminate and sandstone.

#### vi Igneous rocks

A number of igneous bodies that vary in age, form, lithology and stratigraphic emplacement occur in the Southern Coalfield. Relevant to the Hume Coal Project is the Robertson Basalt which includes a number of extensive, thick flows over a large area of the Southern Tablelands near Robertson, Berrima and Wingello.

The hills in the southern part of the Project area and immediately outside are capped with remnant, isolated Tertiary Robertson Basalt flows (Moffit 1999). Some 15% of the Project area is observed to have basalt outcrop (Coffey 2016a). There is also a notable igneous Jurassic intrusion, the Mount Gingenbullen dolerite sill, that has formed a steep hill immediately east of the Project area (Thomas, Biggin and Schmidt 2000). Smaller igneous intrusions have been observed during drilling programs and as lineaments in aerial photography (R. Doyle 2015, pers. comm., September). The Tertiary basalt outcrops are unrelated to the Mount Gingenbullen intrusion.

### 2.2.3 Depositional environment of the Permo-Triassic Sydney Basin

#### a Overview

During the early stages of basin development, marine volcanic sediments and the Permian Shoalhaven group were deposited (Blevin et al. 2007). Swamp environments during a colder climate in the late Permian allowed for deposition of the ICM, which contain the coal seam proposed to be mined – the Wongawilli Coal seam. Subsequent to this depositional environment, very large rivers then deposited the Triassic Hawkesbury Sandstone (Moffit 1999; Rust and Jones 1987). Following the deposition of the sandstone, shallow marine sediments, and later more river sediments, continued to accumulate in the Basin (Wianamatta Group). This depositional environment continued during the Jurassic, although most of these younger rocks have since been eroded (Blevin et al. 2007). Although significantly eroded in places, the Ashfield Shale of the Wianamatta Group is present in the east of the Project area. Post-Triassic volcanism emplaced Jurassic intrusions and Tertiary basalts (McLean and David 2006).

#### b Discussion

Bamberry (1991) describes three main delta depositional systems (A, B and C) of the ICM in the Southern Sydney Basin:

- The lowermost depositional unit Deltaic System A records a continuation of a regressive trend in the upper part of the marine Shoalhaven Group. The upper part of the Deltaic System A was reworked during a transgression which resulted in the deposition of extensive, sandy, subtidal to middle shelf facies in the Shallow Marine System. This system also consists of sediments deposited from meandering rivers and alluvial fan, floodplain and fan-delta systems.

- Deltaic System B consists of several delta systems, ranging from higher energy channel deposits to low energy lake-type deposits.

- Growth of the complex delta-system, Deltaic System C, resulted from expansion of the New England Orogen. The lower half of this system records deposition on a lower deltaic plain that includes the pro-delta, delta front and inter-deltaic (areas between deltas) sequences of the Bargo Claystone, Darkes Forest Sandstone and Allans Creek Formation respectively:

    - The Kembla Sandstone was deposited by a complex network of channels (distributaries) that flowed across the Basin.

    - The Wongawilli Coal formed on abandonment of the earlier fluvial system and transition into the lake-fill deposits (between the delta channels) of the Lower Eckersley Formation.

- Sandstone is the dominant component of the Upper Eckersley Formation which was deposited by meandering rivers in extensive fluvial tracts.

Deposition of the Sydney Basin coal-bearing sequence occurred during a time of volcanic activity from an offshore volcanic belt associated with subduction along the east coast of Gondwana. A lot of the volcanism was explosive and resulted in the formation of widely spread airfall tuffs that generally thin towards the western margin of the basin (Carr et al. 2003).

### c Hawkesbury Sandstone

The Hawkesbury Sandstone was deposited in a large braided fluvial system with sediment derived from the Lachlan Fold Belt. The palaeo-flow direction was from the south-west to the north-east. The dominance of monocrystalline quartz, and the alteration of feldspar grains suggest that the source area underwent a long period of intensive chemical weathering in a warm humid climate (Zaid and Gahtani 2015).

Due to the large-scale nature of the fluvial depositional environment, the facies of the Hawkesbury Sandstone range from fine-grained overbank/flood sediments and coarser grained channel deposits (Jones B 1983, 2020).

Freeze and Cherry (1979) provide a discussion on fluvial depositional environments, including the differences between meandering rivers and braided river systems, such as the Hawkesbury Sandstone. The following is a summary of the discussion from Freeze and Cherry (1979). Figure 2.3 illustrates the nature of deposits formed in the braided-river environment (taken from Freeze and Cherry 1979).

Due to the shifting position of river channels and the ever-changing depositional velocities, river deposits have characteristic textural variability that causes much heterogeneity in the distribution of hydraulic properties. Braided rivers generally occur in settings where the sediment available for transport has considerable coarse-grained sand or gravel and where velocities are large because of steep regional topographic slopes. Shifting positions of channels and bars and changing velocity can result in extensive deposits of bedded sand and gravel with minor zones of silty or clayey sediments filling in abandoned channels. Meandering rivers and their associated floodplain environments also tend to have coarse and fine-grained deposits. The relative abundances and stratigraphic relations of the sediments, however, are generally different in meandering rivers than in braided-river deposits. Silty or clayey channel-till deposits are more abundant than in braided-river deposits. Cross-bedded sand, which is commonly fine- or medium-grained with variable contents of silt and clay, is deposited on the levees and floodplains. Coarse sand and gravel commonly form along point bars. Gravel deposits develop as channel lag.

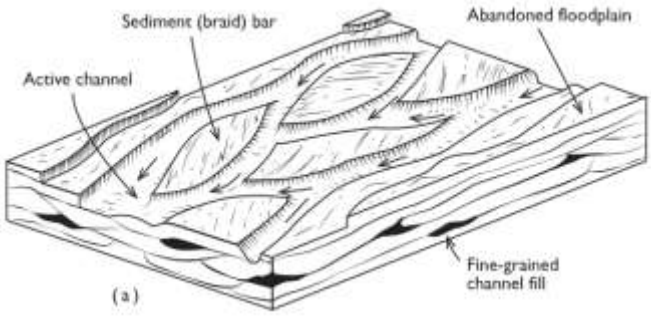



**Figure 2.3 Surface features and nature of deposits formed in the braided-river environment (from Freeze and Cherry 1979)**

The generic description of a braided river system from Freeze and Cherry (1979) frames up the conceptualisation of the Hawkesbury Sandstone recorded in drilling logs for Hume Coal. The differences in permeabilities with depth is not consistent across boreholes at different locations. The braided river depositional environment as described above explains why this is so, and explains that there is no consistent layering at a regional scale within the

Hawkesbury Sandstone. The consistent three layered sandstone theory proposed by John Lee (2009) is disputed for this area – it is not evident in the data and does not align to the depositional environment or the reality of the findings from the investigations at the site.

In some locations, deposition of the Hawkesbury Sandstone has eroded the entire Narrabeen sequence and portions of the underlying ICM. Variation between different facies is consistent with rising and falling flood cycles comparable to the depositional environment of the Brahmaputra River in India (Moffitt 1999).

### 2.2.4 Local geological setting

Hume Coal engaged Professor Brian Jones of University of Wollongong to conduct a review of Hume geological information (including investigation of core photographs and examination of geological outcrops in the area). The objective of the review was to specifically describe and investigate the characteristics of the lithology between the Wongawilli Coal seam and the lower Hawkesbury Sandstone in the Project area (Jones 2020). This additional work was commissioned primarily to address the ongoing questions raised by the community in regard to the geological interpretation of the layers immediately above the Wongawilli Coal seam. The information presented below is a summary of the work completed by Jones (2020). The full report by Professor Brian Jones is provided in Annexure B.

The stratigraphic succession of the Wongawilli Coal in the south-western Sydney Basin is poorly documented in the literature. In the area near and east of Bundanoon, typical medium to coarse-grained Hawkesbury Sandstone lies disconformably above the Wongawilli Coal as seen at the Erith Coal Mine and at Meryla Pass. However, in the Project area in the Belanglo State Forest and to the west of Sutton Forest, the stratigraphy has not been described in detail.

The Wongawilli Coal, below the Farmborough Claystone, consists of Plys A to J with Ply E to I making up the mining section at the Hume Coal Project. The R Ply is located above the Farmborough Claystone.

The elevation of the workable section of the Wongawilli Coal (below the Farmborough Claystone, if present) rises from 480 mAHD in the eastern area of the Hume Coal Project to 630 mAHD in the west (Jones 2020). A 2−4 km wide north-south zone in the central part of the Hume Coal Project area shows a much lower gradient probably due to faulting and diapiric intrusions. Hume Coal have also proposed faulting through this zone based on a variety of exploration techniques. The preserved thickness of the Wongawilli Coal (including the Farmborough Claystone and the roof plies) shows a general increase from the south-west to the north-east. This decrease in thickness in the west and south-west may be partly attributed to depositional thinning towards the margin of the basin, however Jones (2020) advises it is probably mainly due to post-depositional erosion of the upper plies in the coal seam. Over most of the Hume Coal Project area, the Wongawilli Coal shows local variations of several metres in seam thickness but shows no clear evidence of broad river channel incision beneath the Hawkesbury Sandstone (Jones 2020). Evidence for erosion in the western and south-western parts of the Hume Coal Project area is also provided by the low number of coal plies preserved in this area. In this area of thin Wongawilli Coal, only the lowest 2 or 3 plies are preserved. The number of coal plies preserved increases both to the north and to the east where moderately extensive areas have the Farmborough Claystone preserved above the workable coal seam (Jones 2020).

The contact between the Hawkesbury Sandstone and the ICM has been described as erosional by Bos (1988) with the amount of erosion increasing towards the south-west. This has resulted in the Hawkesbury Sandstone directly overlying the Wongawilli Coal along the escarpment to the south of Moss Vale. Various literature (see Jones 2020) report units of the Eckersley Formation (including the Burragorang Claystone) being present beneath the Hawkesbury Sandstone and the upper Wongawilli Coal and, in places, the Burragorang Claystone directly overlying the Wongawilli Coal.

The Unnamed Member 3 (UNM3) represents the basal unit of the Lower Eckersley Formation and is observed in the Hume Coal Project area (Jones 2020). This unit consists predominantly of carbonaceous mudstone or shale, ranging from structureless to weakly or well laminated. It is very similar in character to the shales in the underlying

Wongawilli Coal. However, in places it contains thin sandstone interbeds at the base or within the unit representing higher energy pulses of deposition. The unit commonly ranges in thickness from 1-3 m but ranges up to 7.7 m locally (Jones 2020).

The findings of Jones' work (2020) are summarised below:

- Along the south-western margin of the Project area, the top of the Wongawilli Coal has been removed by erosion that progressively decreases to the north-east. This erosion started in the lower Eckersley Formation prior to the emplacement of the Burragorang Claystone. In the central part of the Project area, the Hawkesbury Sandstone has also eroded down onto the Wongawilli Coal along the south-western margin.

- In the Project area, the Wongawilli Coal is separated from the Hawkesbury Sandstone by a fine-grained succession including some or all of the Farmborough Claystone, UNM3, lower Eckersley Formation, Burragorang Claystone and upper Eckersley Formation (and possibly some Narrabeen Group equivalent) that ranges in thickness from 0−7.7 m.

- The Eckersley Formation (and possibly Narrabeen Group equivalents) in this part of the Sydney Basin have also been derived from the Lachlan Fold Belt to the south-west and are lithologically similar to, but finer grained than, the Hawkesbury Sandstone.

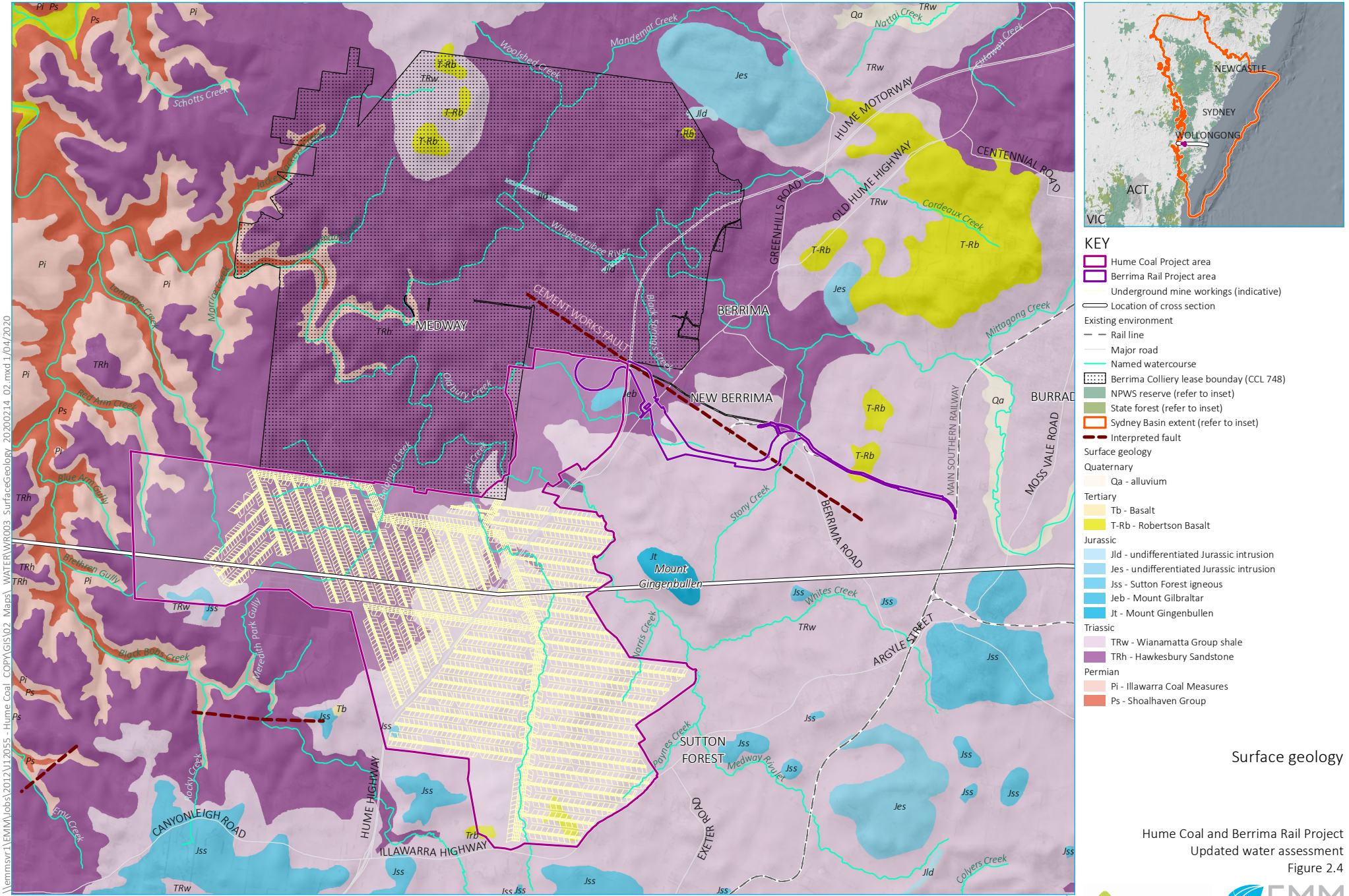
- A north-northeast trending zone about 2−2.5 km wide extends through the middle of the Project area and represents a major river axis of the Hawkesbury Sandstone. A tripartite subdivision (as described by Lee (2009)) of the Hawkesbury Sandstone may be apparent in this area.

- The north-western and south-eastern portions of the Project area are characterised by deposition by smaller river systems and contain numerous low permeability fine-grained floodplain deposits that provide at least local vertical permeability barriers to groundwater movement.

- The irregular distribution of oxidised zones within the Hawkesbury Sandstone suggests that most oxidised groundwater ingress into the Hawkesbury Sandstone occurs through joints and faults rather than vertical percolation through the unit because of the presence of numerous thin vertical permeability barriers in the form of overbank deposits.

Sedimentary units of the Wianamatta Group outcrop over much of the eastern part of Project area while the Hawkesbury Sandstone is exposed over much of the western part. The Hawkesbury Sandstone has been incised by creek channels and, as a result, Permian coal outcrops next to drainage lines in the west. The hills to the immediate south of the Project area comprise remnants of thick Tertiary Robertson Basalt flows that overly the Ashfield Shale (Moffit 1999). Surface geology, or outcrop, is shown in Figure 2.4 and is an important consideration for the conceptualisation of the groundwater recharge mechanisms at the site.

The observations from the assessments, including the work completed by Jones (2020) and the conceptual understanding of the local geology is presented in Figure 2.5 below.




Source: EMM (2020); Hume Coal (2016); Palaris (2016); DFSI (2017); DRE (2013); DPI (1999); Moffitt (1999)

\\emmsvr1\EMM\Jobs\2012\J12055 - Hume Coal COPY\GIS\02 Maps\ WATER\WR003 SurfaceGeology 20200214 02.mxd 1/04/2020

# Surface geology

Hume Coal and Berrima Rail Project
Updated water assessment
Figure 2.4

HUMECOAL PROJECT

EMM creating opportunities

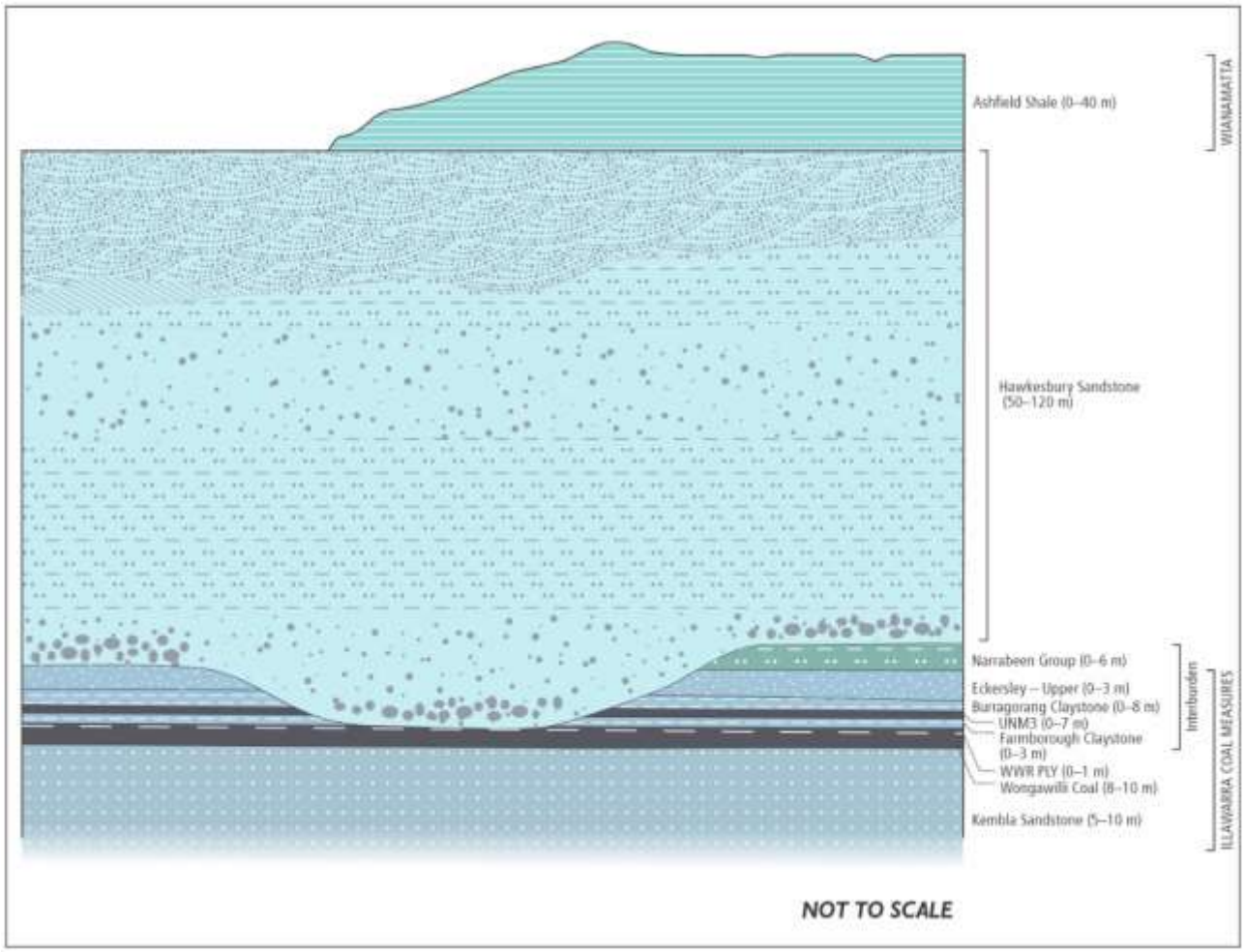



**Figure 2.5 Conceptual diagram of the geological units in Hume Coal Project area**

## 2.3 Hydrogeological setting

The groundwater resources of the Project area are within Nepean Management Zone 1 of the Sydney Basin Nepean Groundwater Source, which is managed under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*.

The groundwater units within the Project area are defined as:

- localised low permeability groundwater systems associated with the Robertson Basalt and Wianamatta Group shales;
- regional porous fractured rock groundwater system located in the Hawkesbury Sandstone; and
- localised water bearing zones associated with the ICM and the Shoalhaven Group.

The Hawkesbury Sandstone is the main groundwater bearing unit used for water resources in the Project area. Groundwater within the Hawkesbury Sandstone is generally fresh with varying bore yields (the median bore yield of registered bores in the area is 2 L/sec).

Table 2.3 summarises the hydrostratigraphic units (HSUs) identified in the Project area and what layer they are represented by in the groundwater model.

**Table 2.3 Hydrostratigraphic units**

| HSU number | Type | Stratigraphy | Layer(s) in groundwater model | |
|---|---|---|---|---|
| 1 | Unconfined aquifer – minor, localised | Alluvium associated with watercourses | - [1] | |
| 2 | Aquitard - localised | Robertson Basalt | - [1] | |
| 3 | Aquitard – semi regional | Sediments of the Wianamatta Group | 1 [2] | |
| 4 | Unconfined to semi confined aquifer – regional | Hawkesbury Sandstone | 2 – 7 | |
| 5 | Aquitard – semi regional | Narrabeen Group | 8 [2] | INTERBURDEN |
| | | Upper Eckersley Formation | | |
| | | Burragorang Claystone | | |
| | | Lower Eckersley Formation, including UNM3 | | |
| | | Farmborough Claystone | | |
| 6 | Aquitard - leaky | Upper Plys of the Wongawilli Coal (above mining section) | 9 and 10 | |
| 7 | Aquifer – low yielding, regional | Wongawilli Coal – mining section | 11 | |
| 8 | Aquifer – regional | Kembla Sandstone | 12 | |
| 9 | Aquitard - regional | Shoalhaven Group | 13 | |

Notes:

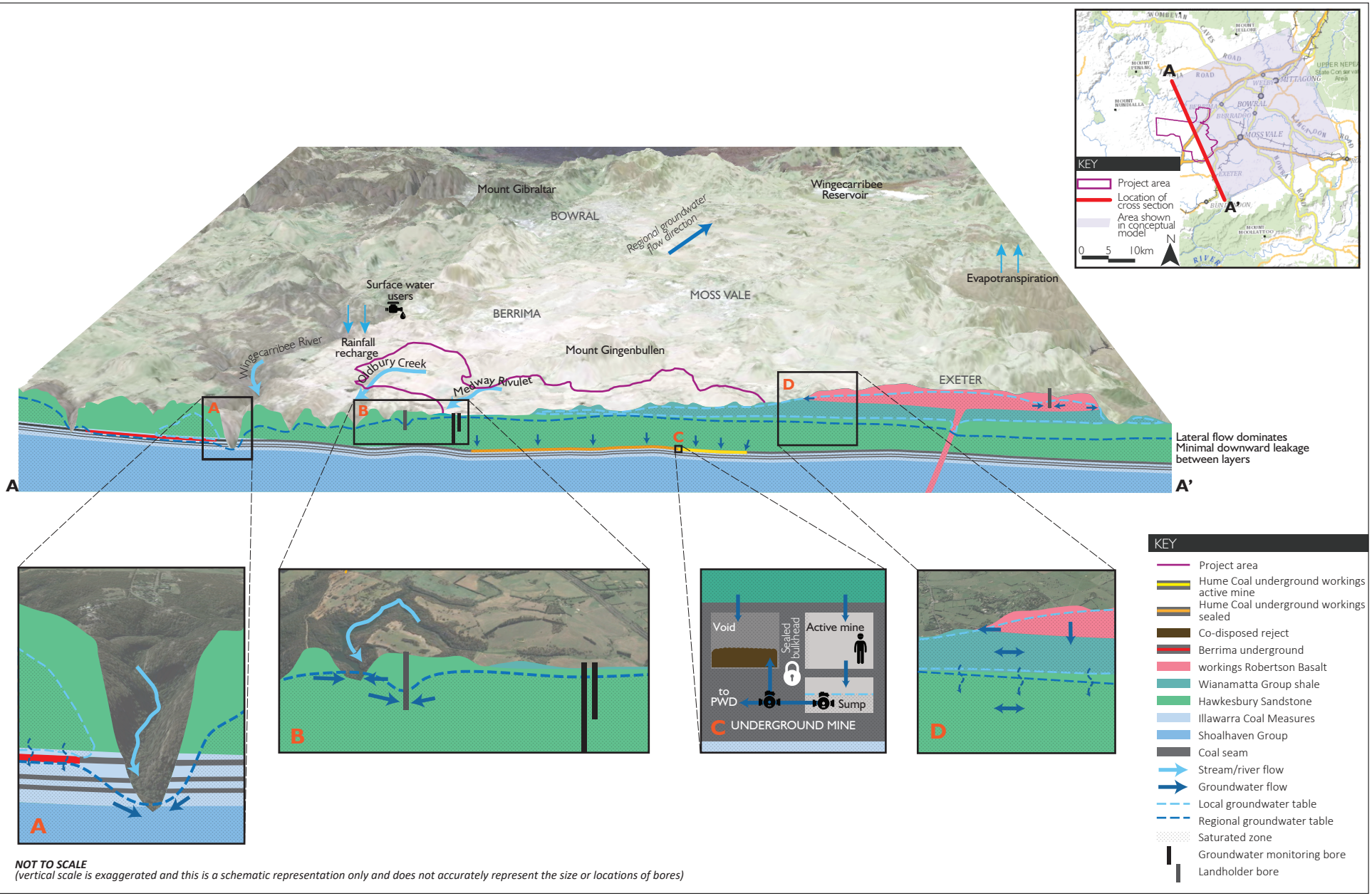
1. The alluvium and Robertson Basalt are not simulated in the regional scale impact assessment groundwater model due to the localised nature of these units;
2. To be conservative hydrogeological properties (K and Ss/Sy) of the Wianamatta Group and interburden units are not explicitly simulated in the groundwater model.

## 2.4 Conceptual hydrogeological understanding

### 2.4.1 Introduction

The conceptual hydrogeological model provides an illustration of the various interacting components of the hydrological cycle. It includes the groundwater systems, surface water systems, flow paths, recharge and discharge mechanisms, and the interaction between these various hydrological components and geological units. It forms the basis for developing the numerical groundwater flow model.

The conceptual model has been presented in the revised water assessment (EMM 2018a), described below and is shown in Figure 2.6.




***NOT TO SCALE***
*(vertical scale is exaggerated and this is a schematic representation only and does not accurately represent the size or locations of bores)*

EMM HUMECOAL PROJECT

Conceptual hydrological model
Hume Coal Project
Updated water assessment
Figure 2.6

### 2.4.2 Conceptual model components

#### i Rainfall, evaporation and evapotranspiration

- The area experiences high average annual rainfall (approximately 960 mm/yr);
- evaporation exceeds rainfall, on average, from September to March (pan evaporation 1,264 mm/yr); and
- evapotranspiration occurs from vegetated areas.

#### ii Surface water use

- Landholder diversion pumps and storages for licensed water supply, mostly for irrigation;
- basic landholder rights (harvestable rights dams/riparian access for stock and domestic supply); and
- harvestable rights dams for irrigation; and
- there is currently no use of surface water for town water supply, via storages (including Medway Reservoir), although water licences do exist for this purpose.

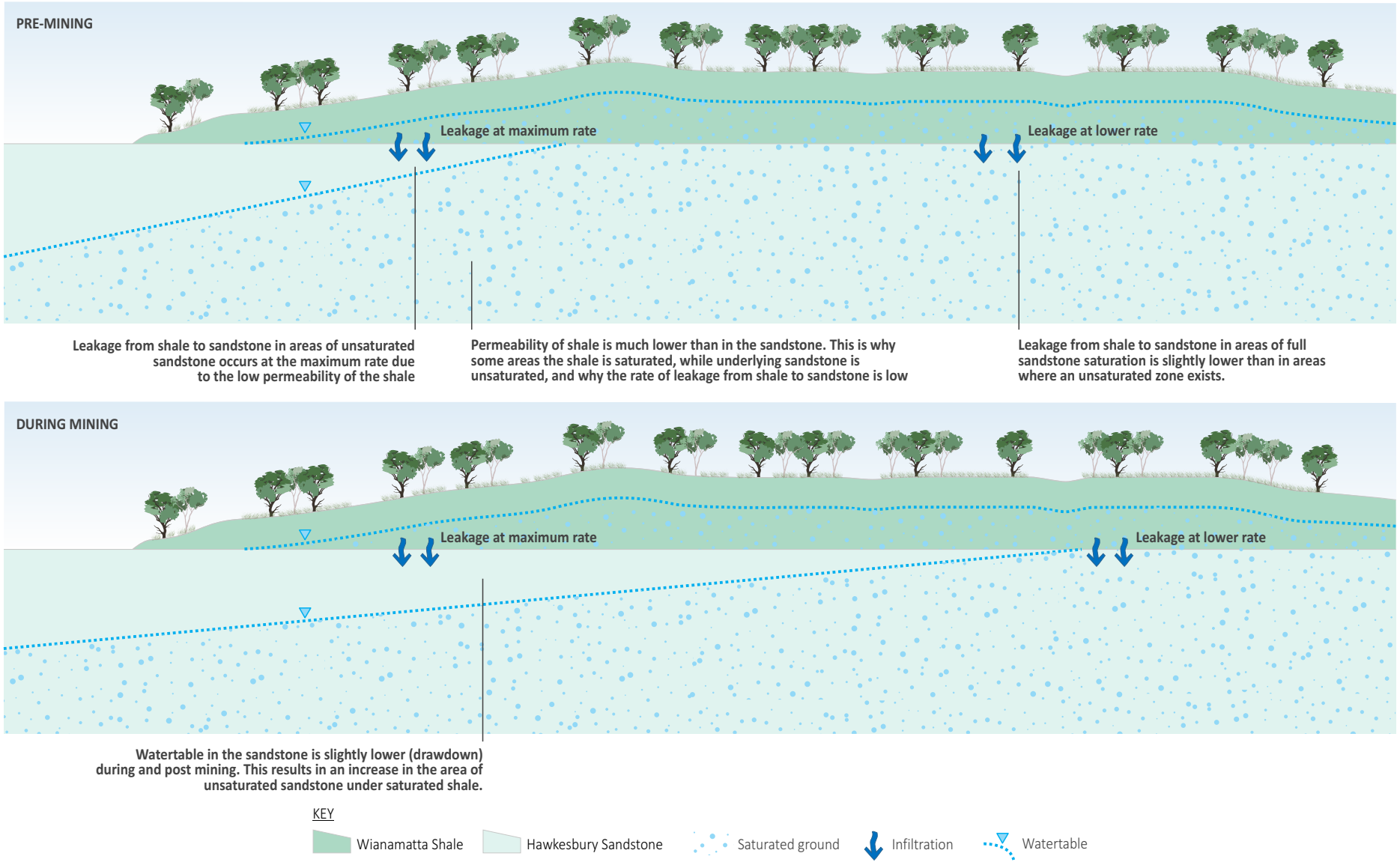
#### iii Groundwater systems

Localised, low permeability, unconfined groundwater systems are present in Robertson Basalt and sediments of the Wianamatta Group, including the Ashfield Shale (insert D in Figure 2.6).

Sediments of the Wianamatta Group acts as a regional aquitard, retarding downward flow into the Hawkesbury Sandstone.

In areas where the Wianamatta Group shale is weathered and thin (in the south and west of the Project area), the shale is likely to be unsaturated (ie dry with no groundwater), with the regional watertable located within the Hawkesbury Sandstone underlying the shale. Where the shale thickens (in the east and the north), the watertable is present at varying depths depending on topography and hydrogeological properties of the shale.

There is limited natural vertical connectivity between the Wianamatta Group shale and the underlying Hawkesbury Sandstone aquifer, as evidenced by lower water levels in the sandstone. At groundwater monitoring sites such as at the HU035A and B, groundwater in the shale is perched above the regional watertable and there are areas of unsaturated Hawkesbury Sandstone underlying the saturated shale (refer to Figure 2.7 and Figure 2.8). At HU035, the difference in hydraulic head between the Wianamatta Group shale and the underlying Hawkesbury Sandstone is around 15 m (Figure 2.8). In areas where hydraulic connection between these two units may occur, groundwater would leak from the shale to the sandstone at a low rate. Where there is no hydraulic connection between these two units (ie where the sandstone is unsaturated below the saturated shale), downward groundwater leakage would already be occurring at a maximum rate (refer Figure 2.7). Therefore, mining induced drawdown would not result in increased leakage (vertical downward movement) of groundwater from the shale to the sandstone.




Conceptual schematic representation of Wianamatta Group – Hawkesbury Sandstone relationship

Hume Coal Project

Updated water assessment

Figure 2.7

EMM creating opportunities

HUMECOAL PROJECT

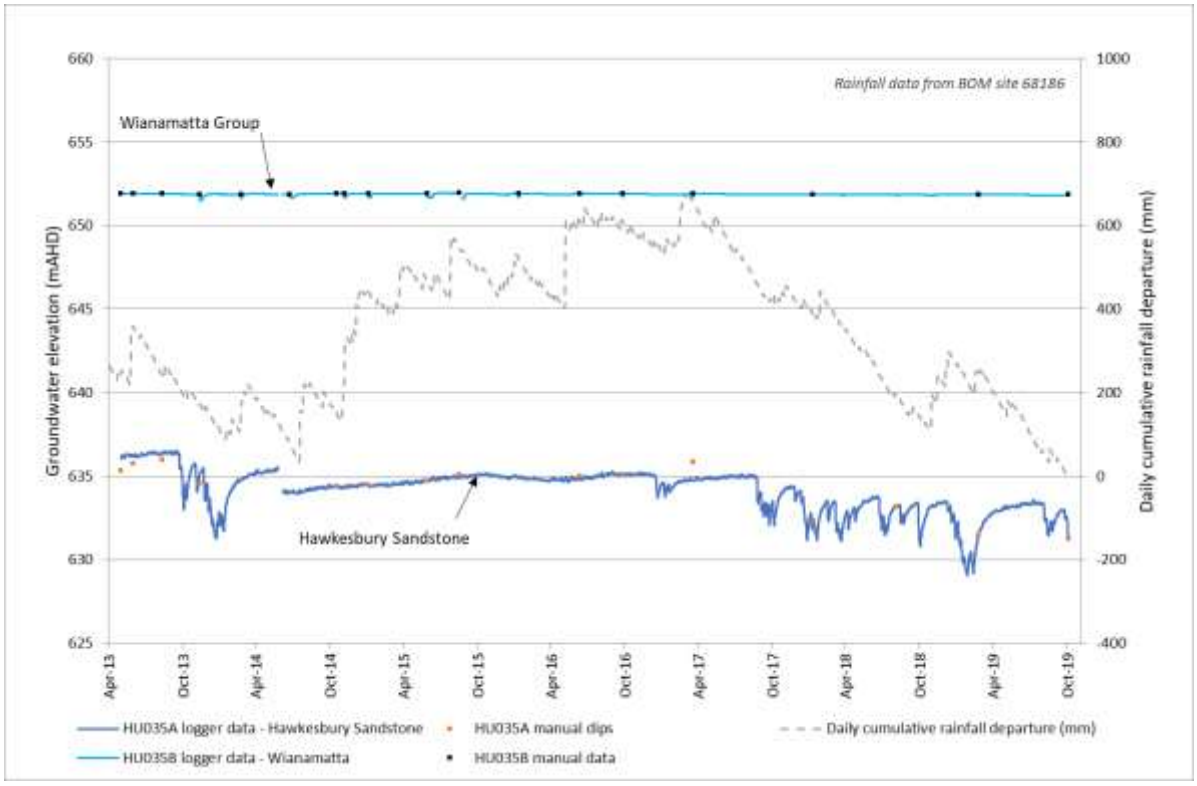



**Figure 2.8 Groundwater monitoring hydrographs for HU035A and HU035B**

Other points summarising the conceptual hydrogeological understanding related to groundwater systems include:

- groundwater in the Robertson Basalt is typically low yielding (unless localised fractures are intercepted), and quality is fresh;
- groundwater in the Wianamatta Group shale is typically poor quality and low yielding;
- the Hawkesbury Sandstone contains the major groundwater system in the region; groundwater is typically fresh and bore yields range from low to high depending on the secondary permeability (ie intercepted fractures); and
- low permeability water bearing zones in the ICM and Shoalhaven Group generally restrict groundwater flow.

### iv Recharge

- Average rainfall recharge is assessed to be around 2% of annual rainfall;
- rainfall recharge occurs mostly where Hawkesbury Sandstone and Robertson Basalt are exposed at the ground surface;
- minor recharge occurs where Wianamatta Group outcrops; minor recharge to Wianamatta Group also occurs from overlying basalt, where present; and
- recharge to Hawkesbury Sandstone is mostly from infiltration of direct rainfall on outcrop and only very minor volumes occur as downward leakage from the Wianamatta Group shale, where present.

### v Groundwater discharge

- Drainage to surface water (baseflow) is the largest groundwater discharge component;
- extraction from landholder bores (insert B in Figure 2.6);
- evaporation from watertable occurs where the watertable is shallow, and from surface water features;
- evapotranspiration occurs within the unsaturated (or soil) zone and can also occur where the watertable is sufficiently close to the surface for vegetation to access groundwater and from watercourse pools where the streambed intersects the watertable;
- seepage/springs and evaporation occurs along escarpments. Spring discharge occurs at the contact between basalt and underlying Wianamatta Group shale (insert D in Figure 2.6);
- deep drainage to the old Berrima Colliery occurs, and subsequently into Wingecarribee River (insert A in Figure 2.6; discussed further in Attachment A of Annexure A); and
- regional groundwater throughflow in the Hawkesbury Sandstone and ICM is generally to the south-east.

### vi Groundwater flow

- Lateral flow dominates, with minimal downward flow between layers (insert D in Figure 2.6);
- groundwater flow in Hawkesbury Sandstone is via dual porosity: pores and minor structural features (fractures, joints, bedding planes);
- regional groundwater flow is influenced by stratigraphic dip and topography, generally towards the east;
- minor localised flow to the north and west associated with local topographic gradients, as presented in Figure 2.9; and
- faults typically do not appear to influence groundwater flow on a regional scale within the Project area as demonstrated by long-term pumping tests. As outlined in the Annexure B (Townley 2020), regional scale groundwater flow systems are sensitive to and depend on average values of hydrogeological properties, with properties averaged over relatively large distances.

### vii Groundwater levels

- Groundwater levels are generally stable regionally;
- groundwater levels in bores show variable influence close to pumping landholder bores, and in the Hawkesbury Sandstone reflects climatic trends over time (this is either due to lower recharge and or increased pumping form bores due to reduced availability of surface water or rainfall for irrigation); and
- around Berrima Colliery, significant localised groundwater depressurisation and desaturation of the Hawkesbury Sandstone as a result of full extraction mining, and continual discharge to the Wingecarribee River.

### viii Vertical gradients and connectivity

- Downward trending gradients have been observed in the north-western part of Project area;
- steep vertical gradients occur along escarpments and seepage faces are observed where groundwater discharge occurs;
- the top of the Hawkesbury Sandstone is often unsaturated, both where exposed and where it underlies the Wianamatta Group shale (insert D in Figure 2.6);
- downward vertical gradients between the Wianamatta Group shale and the underlying Hawkesbury Sandstone results in minor downward leakage from the shale to the sandstone (limited by the low hydraulic conductivity of the shale); and
- hydraulic connection between Hawkesbury Sandstone and ICM occurs where there is minimal interburden between these units (ie in the western edge of the basin).

### ix Groundwater use

Numerous landholder bores are located in the Project area associated with small acre lifestyle blocks, boutique industries and some farmland. Many properties extract groundwater from the Hawkesbury Sandstone (and a smaller number source groundwater from the Robertson Basalt to the south) mostly during dry climatic periods. Most of the bore yields are for stock and domestic use, however some use groundwater for irrigation purposes.

Groundwater use is not metered in stock and domestic bores or in irrigation bores in this area.

### x Surface water/groundwater interaction

- Most streams in the Project area are classified as gaining streams with groundwater providing baseflow to streams;
- some are gaining from the regional groundwater systems and some gaining from shallow groundwater systems (ie in shale and basalt areas) which may be perched and/or disconnected from the underlying regional groundwater system;
- in some (isolated) locations, streams may provide groundwater to the underlying Hawkesbury Sandstone; and
- regionally, the volume flux from surface water into groundwater is minor.

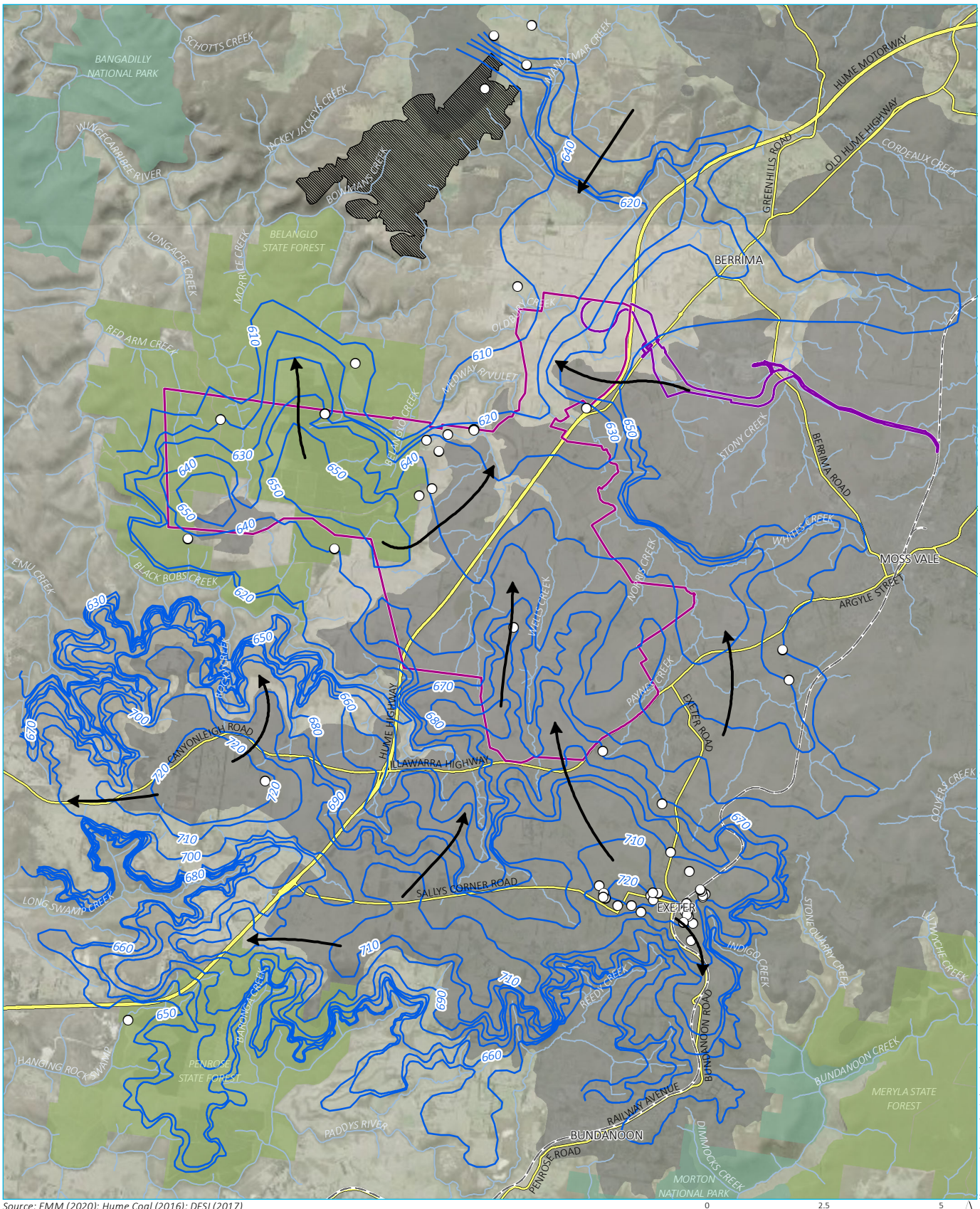
### xi Ecosystems that potentially rely on surface and/or groundwater

- There are no high priority GDEs identified within the Project area; the closest one is Long Swamp, a temperate highland peat swamp, 7 km to the south;
- there is minimal habitat for dense native fauna;
- drainage lines and creeks may provide surface water for in-stream ecosystems during times of flow;
- ecosystems may rely on surface expressions of groundwater at: creeks, where baseflow contribution is significant; springs along the basalt hills in the south; and upland swamps in the south;

- vegetation root zones may rely on shallow groundwater (<10 mbgl) near some creeks; and
- stygofauna is unlikely to be significant in the area.

### xii Hume Coal mine / water interaction

- Groundwater will flow to the active underground mine during active mining and will be collected and removed to allow safe mining conditions. This water will then be recycled and reused for mining operations (stored in the primary water dam) (insert C in Figure 2.6);
- once mining ceases in the panels, rejects will be emplaced underground, bulkheads will be installed and excess water at the surface will be pumped into the sealed panels.
- groundwater which flows into sealed panels forms part of the recovery process and remains within the groundwater source. Figure 2.10 provides a conceptual diagram of the mine progression, reject emplacement and water injection for the Project;
- rainfall onto the infrastructure area (disturbed area) is harvested and stored in a series of mine water dams and stormwater basins for use in mining operations; and
- water excess to mining operations is pumped from the primary water dam (PWD) into the void underground (this mitigates depressurisation and drawdown and allows faster recovery of the groundwater system).




*Source: EMM (2020); Hume Coal (2016); DFSI (2017)*

0 2.5 5 km

GDA 1994 MGA Zone 56

N

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KEY

- Hume Coal Project area
- Berrima Rail Project area
- Berrima Colliery
- Monitoring bore
- Inferred watertable elevation (mAHD; 5m interval)
- Inferred groundwater flow direction

Existing environment

- Rail line
- Major road
- Watercourse/drainage line
- Named waterbody
- NPWS reserve
- State forest
- Shale (250K statewide geology)

# Watertable elevation plan (November 2018)

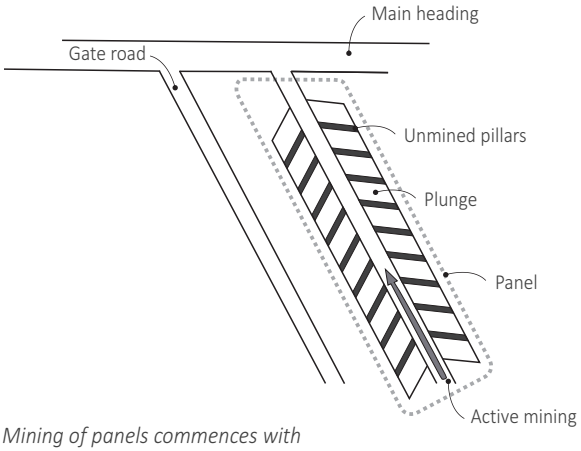
Hume Coal and Berrima Rail Project
Updated water assessment
Figure 2.9

HUMECOAL PROJECT

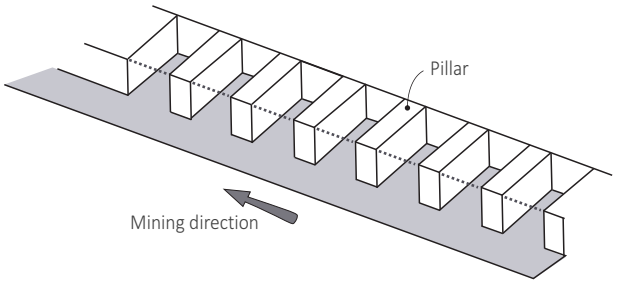
EMM creating opportunities

**PLAN VIEW** | **SECTION VIEW**

## ACTIVE MINING

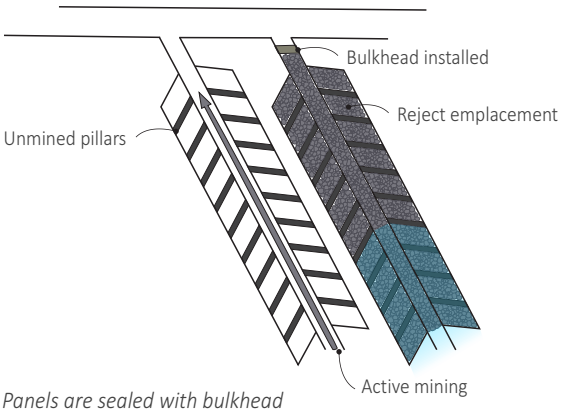



*Note: Mining of panels commences with establishing the gate road, then mining in the plunges back to the main heading*

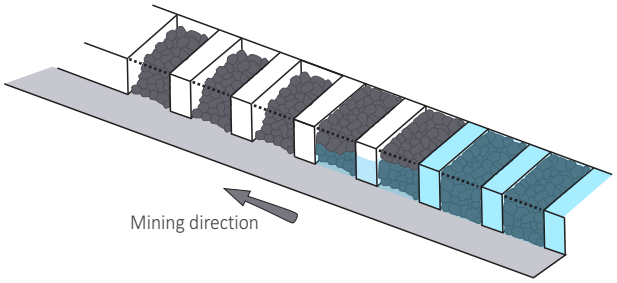



*Note: Active dewatering occurring*

## REJECT EMPLACEMENT

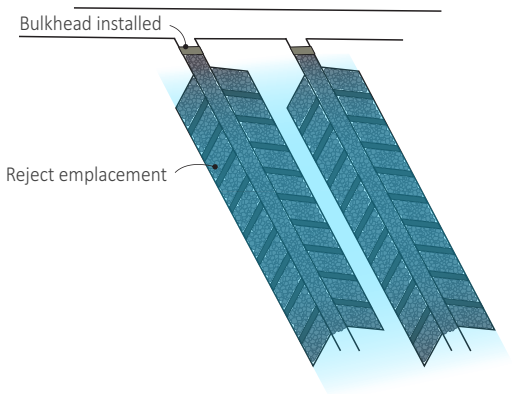


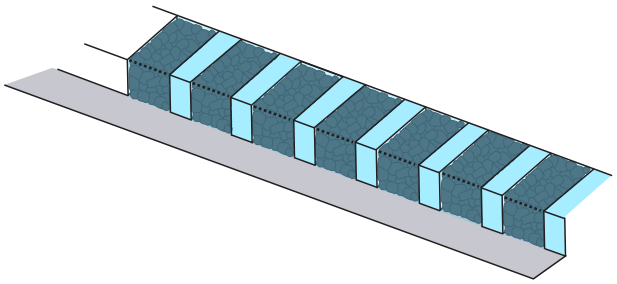

*Note: Panels are sealed with bulkhead immediately after rejects are emplaced in mined plunges*




*Note: Co-disposal reject emplacement occurs in previously mined plunges. Excess mine water is pumped into sealed panel and receives natural groundwater inflow*

## END OF MINING



*Note: Void space in panel becomes full and groundwater system becomes fully saturated.*
*In times of water deficit, water in sealed panels may be accessed to meet mine water requirements*

***NOT TO SCALE***
*(This is a schematic representation only and does not accurately represent the size or plan for all panels)*

Hume Coal mine progression, reject emplacement and water injection

Hume Coal Pty Ltd
Updated water assessment
Figure 2.10

# 3 Groundwater model

## 3.1 Introduction and background

DPIE, DPIE Water (previously DoI Water) and community groups have been openly opposed to the Hume Coal Project and have criticised the accuracy and appropriateness of the Hume Coal groundwater model, stating that it is not fit for purpose and cannot be used to assess impacts of the Project. The groundwater modelling, uncertainty analysis and overall assessment of water resources for the Hume Coal Project is world class and has been undertaken by world class modellers. The NSW Government's own independent peer reviewer, Mr Hugh Middlemis of HydroGeoLogic Pty Ltd (HydroGeoLogic), has also deemed it to be fit for purpose.

The ongoing criticism of the model is underpinned by a privately funded groundwater model (by Pells Consulting) referred to in item 134. EMM (2018b) completed a review of this privately funded Pells model and the review determined that the Pells model:

- is a Class 1 model under the Australian Groundwater Modelling Guidelines (Barnett et al 2012);
- the conceptualisation is flawed and the groundwater model is poorly calibrated;
- is not fit for purpose for the assessment of mining impacts and is therefore not suitable for predicting drawdown impacts on bores, inflow volumes to the mine or general impacts on the different groundwater systems and surface water resources across the modelled area; and
- due to above, it cannot be used as a comparison to the Hume Coal groundwater model developed as part of the EIS and RTS.

The following work has been undertaken for the response to the IPC report:

- additional independent review of the numerical groundwater model by Dr Lloyd Townley of GW-SW Pty Ltd;
- independent review of Hume Coal's geological information (including investigation of core photographs and examination of geological outcrop in the area) by Professor Brian Jones of University of Wollongong to describe the characteristics of the lithology between the Wongawilli Coal seam and the lower Hawkesbury Sandstone in the Project area; and
- extraction of additional information from the RTS groundwater modelling and groundwater assessments to provide detailed responses to the IPC and DPIE Water.

It is worth noting that since submission of the RTS report, HydroSimulations have been acquired by SLR Consulting (SLR). However, the same modelling team (led by Dr Noel Merrick), has continued to undertake and lead the modelling work for the Project and to support Hume Coal with various groundwater modelling and conceptualisation related tasks.

Following submission of the RTS, SLR Consulting conducted additional model verification work by extending the model history match period to July 2018 and comparing to Project monitoring data. The results of the verification are consistent with the RTS groundwater modelling. Future improvements to the Hume Coal groundwater model will be undertaken as and when new data become available. As mining progresses, a need for further model updates will be assessed regularly based on evaluation of groundwater monitoring data and findings of impact verification. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater obtained from the monitoring program. This is consistent with International

Organisation for Standardisation (ISO) continuous improvement guidelines. The process for continuous improvement related to groundwater modelling is illustrated in Figure 3.1.

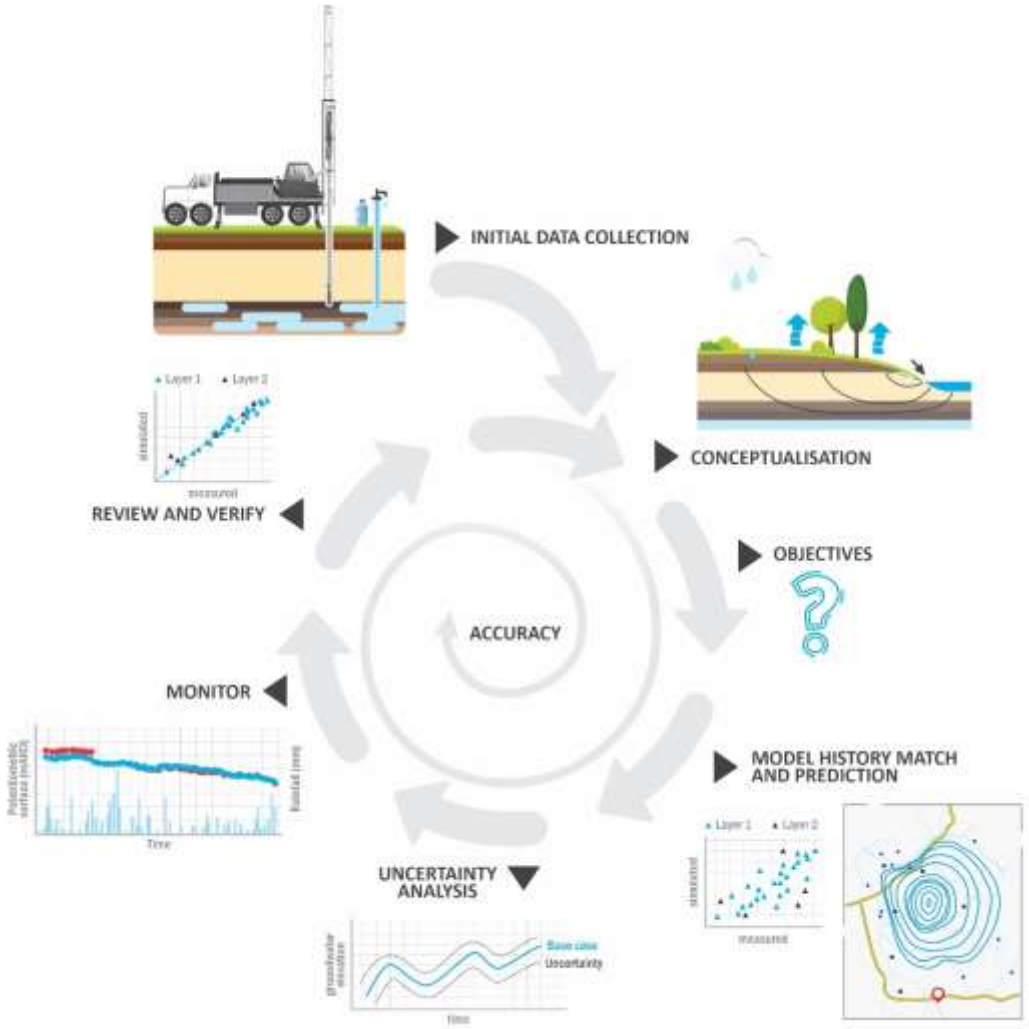



**Figure 3.1 Groundwater modelling continuous improvement**

In addition to the verification work, SLR and Hume Coal have continued to review the groundwater model assessing varying scenarios. This groundwater modelling work is continual and aligns to best practice in groundwater modelling. The post-RTS modelling includes assessing the watertable response to potential injection of surplus water, refinements to topography, influence of the interburden HSU on groundwater flow and watertable response to mining. This post-RTS modelling has not been undertaken for the purpose of responding to the IPC recommendations or DPIE Water requests, but has incorporated learnings over time from other projects, and incorporated additional data as it continues to become available. The post-RTS modelling is not a requirement of the NSW Government, because the RTS groundwater model has been determined fit for purpose and appropriate for assessing the potential impacts of the Project on groundwater users (HydroGeoLogic 2017 and 2018; Townley 2020).

The post-RTS modelling work can be made available to the NSW government either via a presentation or via a report at a later date as required.

## 3.2 Model reviews

As presented in earlier submissions, the Hume Coal groundwater model has undergone numerous reviews by many leading experts in groundwater modelling in Australia, including a review by the then DPE's expert Mr Hugh Middlemis.

As outlined by EMM in the RTS (2018) and Dr Townley (2020), the groundwater model has undergone greater than 10 reviews and include:

- on behalf of Hume Coal: Dr Noel Merrick, Dr Frans Kalf, Neil Manewell, Liz Webb and Dr Lloyd Townley;
- on behalf of regulators: Hugh Middlemis (HydroGeoLogic; twice), representatives of IESC, DoI – Water hydrogeologists and WaterNSW hydrogeologists; and
- on behalf of the community: Dr Steven Pells, Doug Anderson, Chris Jewell and John Lee.

The following reviewers found that the groundwater model is fit for purpose and appropriate for assessing the impacts of the Hume Coal Project:

- Dr Noel Merrick, acting as independent reviewer of the Coffey (2016b) work and prior to taking ownership of the groundwater model;
- Dr Frans Kalf, independent reviewer of the EIS and RTS groundwater model;
- Neil Manewell who conducted an audit of the EIS groundwater model;
- HydroGeoLogic, acting as an expert reviewer for the then DPE and conducted reviews of the EIS and RTS groundwater model versions; and
- Dr Townley (2020) who conducted an expert review of the groundwater modelling work conducted as part of the EIS and RTS.

Hume Coal engaged Dr Lloyd Townley of GW SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the RTS groundwater model. The full review is contained in Annexure C of Appendix B to this report (Townley 2020).

DPIE advised Hume Coal, following the release of the IPC report, that they would not be willing to jointly engage an independent expert, but Hume Coal proceeded to engage Dr Lloyd Townley for that role in order to respond to the IPC.

Dr Townley's review finds that the modelling undertaken for the Project is fit for purpose, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the Project area (Townley 2020).

## 3.3 Model class

As an author of the Australian Groundwater Modelling Guidelines (Barnett et al 2012), Dr Townley (2020) provides the following comments:

- The authors (of the Australia Groundwater Modelling Guidelines) did not intend to imply that uncertainty in values of model parameters and uncertainty in predictions are so great that models are not useful. On the contrary, the authors hoped to explain that professional groundwater modellers gain skills through training and experience to develop models that can be used to make useful predictions. Modellers endeavour to develop the best possible model, given available resources (modelling effort and budget), taking into account all available information. They set out to develop models that have low uncertainty, so that stakeholders can have more confidence in the predictions.

- The authors did not intend the concept of "confidence level classification" to be prescriptive. The Australian Groundwater Modelling Guidelines do not state that a model must have any specific "Class" for any specific purpose. This notion seems to have been adopted by some stakeholders, but this practice was not anticipated by the authors. Table 2-1 of the Australian Groundwater Modelling Guidelines lists "key indicators" characteristic of models with different confidence level classifications. The length of time for which predictions are made, relative to the period for which calibration has been possible, is one key indicator. The maximum stress experienced during the prediction period, relative to the maximum during the calibration period, is another. Most "greenfields" mining projects have few data over a short calibration period with stresses much lower than during future proposed mining, so this almost automatically implies that confidence in predictions is less, and such a model would have a confidence level classification of Class 1. The Guidelines never suggest that this is not acceptable, or that these models would automatically default to Class 1. They simply explain that confidence will be less.

The findings of the HydroGeoLogic determined that the groundwater model is a Class 2 confidence level and is fit for purpose.

The findings of the review conducted by Dr Townley (2020) determined that the groundwater model is a Class 2 confidence level and has some elements of Class 3.

Dr Townley (2020), in his assessment of the model, places emphasis on two key indicators related to (i) the length of time for which predictions are made relative to the time period of calibration, and (ii) the magnitude of future stresses relative to historical stresses during the calibration period. Given the use of available transient data from historical mining at the Berrima Colliery, Dr Townley (2020) advised that the modelling undertaken for the Hume Coal Project should be judged to be Class 2. These two key indicators often lead to models of greenfields mining projects being considered Class 1, but this conclusion is not reasonable for the Hume Coal Project.

Dr Townley (2020) continues in his review stating:

- that the modelling approach is appropriate and consistent with the Australian Groundwater Modelling Guidelines;

- the calibration methodology is consistent with the Australian Modelling Guidelines. The calibration is impressive because this is one of the first times that four separate types of data have been used for calibration in a model for a proposed mining project. This is a challenging but robust way to calibrate and has been done in an attempt to balance the different sources of information;

- the calibration methodology is supported by the Australian Groundwater Modelling Guidelines, which explains in Recommendation 5.4 that over-emphasis on fitting a model to observations of piezometric heads using an arbitrary value of SRMS is not appropriate. Therefore, the use of four separate data sets for model

calibration is aligned to the recommendations of the Australian Groundwater Modelling Guidelines, as it is not focused on piezometric heads only; and

- regional scale groundwater models can never predict watertable elevation or piezometric heads with an accuracy of less than 1 m. No reference to this requirement was provided, and it is unreasonable to suggest that this level of accuracy is ever possible.

The Guiding Principle in Section 7.4 of the Australian Groundwater Modelling Guidelines indicates that groundwater models are far more effective at producing differential effects (mining induced drawdown) rather than absolute. The Australian Modelling Guidelines also state that:

> 'It is not unusual for modellers to find that the calibration does not allow all aspects of historical measurements to be reproduced. Sometimes absolute values of heads are too high or too low, suggesting that hydraulic conductivities and recharge are not in balance, but trends are reasonable, suggesting that the relationship between hydraulic conductivity and storage coefficient is reasonable, or that the relationship between perturbations in recharge and specific yield are reasonable. In such cases calibration may be considered reasonable if differences in heads seem to be reasonable. There may be no theoretical reason to support this conclusion, but sometimes there appears to be no alternative.'

Dr Townley (2020) also provided expert advice regarding how mining has been simulated in the groundwater model:

> In their response to IPC's Question 6 about the approach taken to decide on drain conductance values used in the modelling, DoI Water claimed to have "recommended that wells are alternatively used also instead of drains to effect dewatering".
>
> In the opinion of the author of this review, the manner in which mining has been represented is appropriate and completely consistent with the way mining has been represented in models for many years. The sequence of mining can be represented using prescribed head (Dirichlet or 1st Type) boundary conditions or mixed (Cauchy or 3rd Type boundary conditions). In each of these, the elevation of mining is specified as part of the boundary condition, as a function of time, and the flow of water towards the boundary nodes is computed at the end of every time step. Since the flow to each node is unknown a priori, it is impossible and completely inappropriate to suggest that mining can be represented using flux (2nd Type) boundary conditions, ie wells.

## 3.4 Model calibration

The hydraulic conductivity data in the model calibration is extensive and all available data for the Project and surrounding mines was utilised in this calibration. The data set was extensive and the groundwater model set-up and calibration followed best practice in that all data and natural variations were considered.

There is natural variation in testing methods, with pumping tests bias towards higher conductivities (due to bores used for pumping tests always being the highest yielding bores in the district, ie those that intercepted localised fractures). Core permeability provides the lower end range of conductivity. Figure 3.2 and Figure 3.3 present the distribution of measured and modelled hydraulic conductivity with depth that has been considered in developing the model. The model calibration was in line with best practice and considered all of this data. DPE's expert states that:

> 'Calibration of aquifer property values (Kh, Kv, S, Sy) has been well constrained by pumping test estimates of property values, and by simultaneously honouring observed groundwater levels, along with the measured Berrima mine inflow (deep system) and inferred stream baseflows (shallow system)'.
>
> On model calibration 'This is a best practice approach that reduces model non-uniqueness problems'.

'My professional opinion is that the Hume Coal model is fundamentally a good example of best practice in design and execution'.

'It is fit for mining project impact prediction purposes and the results presented are reasonable in terms of inflows and drawdown predictions.'

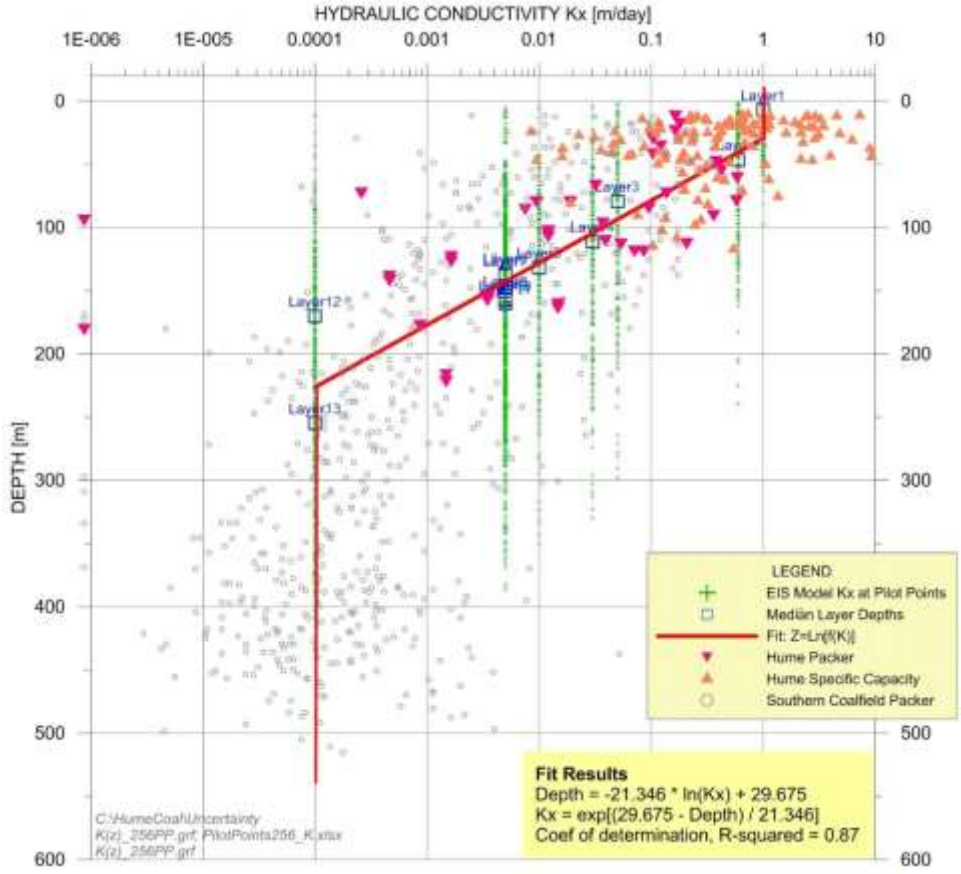



**Figure 3.2 Hydraulic conductivity (horizontal) with depth (HydroSimulations 2018)**

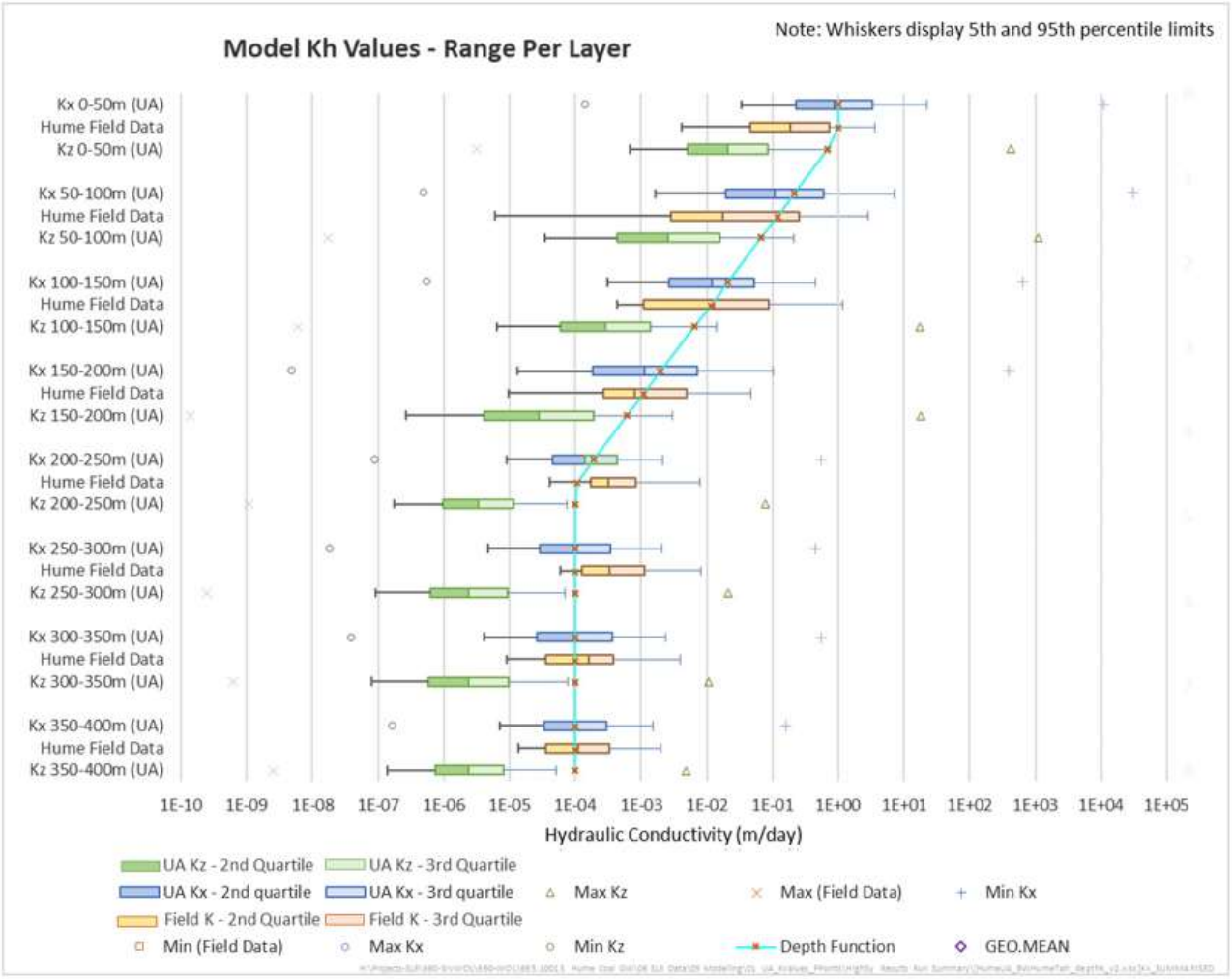



**Figure 3.3** **Hydraulic conductivity with depth box and whisker plot – Kx, Kz and Project field data (SLR Consulting 2020, Pers. Comm.)**

The IPC appeared interested in the usage from individual private bores as a percentage of their entitlement. This question was asked of many landholders during the public hearings held on 26 and 27 February 2019 and also asked of Hume Coal in terms of the assumed percentage adopted in the groundwater model.

At the public hearing, most of the landholders declared that they use their full licence entitlement, and that during dry years they always use all of their entitlement. These statements from landholders aligns to the model assumptions on usage for the EIS and RTS. The groundwater model noted that although there was no metering of usage data, pumping from stock and domestic bores was estimated at 3 ML/yr. Pumping from high yield bores was varied during calibration with an optimal rate equivalent to 97% of the entitlement selected. It is noted that this percentage appears relatively high, but was determined as such based on verbal reports from landholders and also to take into account known pumping from unlicensed bores and potential over-extraction from some bores (as most bores do not have meters, and ones that do are not officially recorded by the NSW Government).

The post-RTS groundwater modelling work (unpublished) that has occurred in the past 12 months has further confirmed the model as fit for the purpose. The additional work indicates that the current RTS calibration statistics (scaled root mean square, RMS) can be significantly reduced when the rate of landholder pumping is reduced below the licensed entitlement. The history match remains valid (calibration) and the mine inflow and number of bores

predicted to experience drawdown remain largely the same. This model will continue to evolve over time (as per the guidelines for ongoing and refinement of all models) and will be published in the future as required.

## 3.5 Model layers and representation of geology

As outlined in Section 2.3, the geological units between the base of the Hawkesbury Sandstone and the top of the Wongawilli Coal seam have been extensively investigated throughout the assessment of the Hume Coal Project. Commonly termed the 'interburden', these units are conceptualised as a single HSU in the groundwater model, and this layer includes the following geological units and formations, where present within the model domain (in order of oldest to youngest):

- Farmborough Claystone – regionally extensive and present in most of the Project area, except where the Hawkesbury Sandstone has eroded down to the top of the Wongawilli Coal ash and coal lithological units;
- Wongawilli R Ply (above the mined seam – it is a ply (layer) within the interburden);
- Lower Eckersley Formation, including the UNM3 which consists predominantly of carbonaceous mudstone or shale ranging from structureless to weakly or well laminated;
- Burragorang Claystone member of the Eckersley Formation – observed to be an important stratigraphic marker in the Hume Coal Project area (Jones 2020). It is a very fine grained massive to weakly laminated tuffaceous deposit. Professor Brian Jones of the University of Wollongong (2020) states that the presence of this unit clearly illustrates that the Hawkesbury Sandstone has not eroded down to the Wongawilli Coal over most of the Project area;
- Upper Eckersley Formation – identified in some drillholes in the Hume Coal Project area but it is difficult to differentiate this fine- to medium-grained sandstone where the Burragorang Claystone is absent; and
- Narrabeen Group sediments – observed to be present in the north-east of the model domain, but absent in the Hume Coal Project area.

The interburden HSU is represented in the groundwater model by layer 8. Layer 9 and 10 represent the unmined sections of the Wongawilli Coal. As presented in previous submissions, the hydrogeological properties (hydraulic conductivity, storage parameters (storativity/specific yield)) are not explicitly simulated. The hydraulic conductivity of the aquifer properties of layer 8, 9 and 10 in the model are identical for the basal subdivision of the Hawkesbury Sandstone (model layer 7). Therefore, these layers do not provide a barrier to simulated drawdown in the Hawkesbury Sandstone as a result of mining.

Table 3.1 provides a summary of the groundwater model layers and their representation.

**Table 3.1 Groundwater model layers**

| Layer number | Layer representation | Median Hydraulic Conductivity (Kh) assigned in RTS model (m/day) |
|---|---|---|
| 1 | Wianamatta Group shale * | 1 |
| 2 | Hawkesbury Sandstone | $5 \times 10^{-1}$ |
| 3 | Hawkesbury Sandstone | $1 \times 10^{-1}$ |
| 4 | Hawkesbury Sandstone | $2 \times 10^{-2}$ |
| 5 | Hawkesbury Sandstone | $8 \times 10^{-3}$ |

## Table 3.1 Groundwater model layers

| Layer number | Layer representation | Median Hydraulic Conductivity (Kh) assigned in RTS model (m/day) |
|---|---|---|
| 6 | Hawkesbury Sandstone | $7 \times 10^{-3}$ |
| 7 | Hawkesbury Sandstone | $6 \times 10^{-3}$ |
| 8 | Interburden *<br>• Narrabeen Group (where present)<br>• Upper Eckersley Formation<br>• Burragorang Claystone<br>• Lower Eckersley Formation, including unnamed member 3<br>• Wongawilli R Ply<br>• Farmborough Claystone | $3 \times 10^{-3}$ |
| 9 | Wongawilli Coal – unmined section | $3 \times 10^{-3}$ |
| 10 | Wongawilli Coal – unmined section | $3 \times 10^{-3}$ |
| 11 | Wongawilli Coal – mined section | $2 \times 10^{-3}$ |
| 12 | Kembla Sandstone and other basal units of the Illawarra Coal Measures | $1 \times 10^{-3}$ |
| 13 | Shoalhaven Group sediments | $1 \times 10^{-4}$ |

Note: * To be conservative hydrogeological properties (K and Ss/Sy) of the Wianamatta Group and Interburden units are not explicitly simulated in the groundwater model

Item 140 queries the assertion by community groups that the Hawkesbury Sandstone is in direct contact with the coal seam to be mined and that the hydraulic conductivity is highest in this area. As presented in previous submissions, listed above and as described by Professor Jones (2020), there are geological units that make up the hydrostratigraphic unit of the interburden present between the base of the Hawkesbury Sandstone and the Wongawilli Coal mining seam across most of the Project area.

As stated in EMM (2018b), there are no compelling data sets to confirm there is any uniform regional layering or an increase in hydraulic conductivity of the sandstone strata at the base of the Hawkesbury Sandstone. The braided stream depositional environment of the Hawkesbury Sandstone explains why there are no consistent regional layers, and why the hydraulic conductivity within the unit varies spatially and with depth (but not in a uniform manner). The Hawkesbury Sandstone is a dual porosity system, and regional studies completed for the Kangaloon Borefield project to the east of the Hume Coal Project area confirm that the hydraulic conductivity and yield from bores drilled through the whole Hawkesbury Sandstone sequence are not directly related to the depth of the bores, but to the degree and depth of fracturing and fracture interconnection (URS Australia 2007, URS Australia 2008).

Yields from water bores that intercept deeper fractures can be very high yielding across localised areas of the Southern Highlands (URS Australia 2007 and Parsons Brinckerhoff 2009). With the added advantage of significant available head, deep bores can pump high volumes (up to 50 L/s) at selected locations. This leads to the Hawkesbury Sandstone to have higher hydraulic conductivity at depth however, this trend is more related to (localised) secondary hydraulic conductivity features such as fractures, and the fact that bores designed for large yields are generally constructed as fully penetrating large diameter bores, rather than high (regional) primary permeability.

### 3.5.1 Geological structures

Faults and igneous intrusions can operate as both barriers and conduits to flow on a local scale; however, at a regional scale faults and fractures rarely influence groundwater flow in a significant way. This is consistent with what has been observed for the Project. The equivalent porous medium approach has been adopted for the Project. That is, at a regional scale, such as a Project impact assessment scale, the influence of structures such as faults and intrusions is minor and groundwater flow is consistent with porous media. As outlined in Annexure C (Townley 2020), regional scale groundwater flow systems are sensitive to and depend on average values of hydrogeological properties, with properties averaged over relatively large distances.

In terms of the influence of major geological structures such as faults and dykes on mining, the mine layout as shown in the EIS in its entirety has been developed around currently known or inferred features, as well as the Hume Highway which cuts across the proposed mining area. It has never been intended or even suggested that web pillars will be formed up in close proximity to major structures and the layout fully confirms this intent.

## 3.6 Model conservatism related to reject emplacement and injection of surplus water

There have been submissions from the NSW Government that the groundwater model is not conservative in its simulation of mining and reject emplacement. Figure 2.10 presents a conceptual schematic of the mine progression, reject emplacement and water reinjection for the Hume Coal Project.

The review by HydroGeoLogic for the NSW Government advised that the approach to simulating mining in the groundwater model is conservative for assessing the potential impacts of the proposed mining operation on the groundwater system. The inclusion of more water underground will mean that less groundwater has to drain from the overlying, adjacent or underlying strata to fill the void space. If this was simulated, there would be less drawdown.

The review by Dr Townley (2020) also confirms that the approach is conservative. Dr Townley (2020) states:

> The Modified EIS Model already includes some representation of the construction of bulkheads and of refilling of the mined voids behind these bulkheads. By deactivating drain cells and changing hydraulic conductivities and storage parameters after the end of mining in each pine feather panel, some account is taken of the dynamics of refilling. This means that each model simulation during uncertainty analysis already partially includes the effect of backfilling and emplacement of water.
>
> In the opinion of the author of this review, the approach taken is conservative, in the sense that if backfilling were simulated in more detail, including injection of water into voids behind bulkheads, the model would predict faster recovery after the end or mining and smaller values of maximum drawdown. This would be apparent in every individual simulation undertaken during uncertainty analysis, and therefore in the statistics of the ensemble.

# 4 Make Good

## 4.1 Overview

The Project RTS recognises that 400 landholder bores are registered within a 9 km radius of the proposed mine (WaterNSW 2018). The dominant licensed purpose of these bores is for domestic and stock use, but irrigation bores are also present.

The RTS groundwater model predicts the degree and duration of drawdown in each registered landholder bore that have current Works and Use Approvals, both during and post mining. Drawdown is defined as the change in water level (pressure head) in a bore over a period of time. Drawdown can occur due to a combination of stresses on the groundwater system. Existing stresses on the groundwater system prior to the start of the Project can include climatic changes, existing landholder pumping and/or ongoing take of water by Berrima Colliery. These stresses are considered part of the baseline conditions.

The AIP requires that the Project considers its own effects on bores and whether the Project will exceed the minimal impact criteria on landholder bores, which is 2 m as measured in the landholder bore. It is critical to note that:

- minimal impact considerations relate to a 'water dependent asset' and not the groundwater system itself (ie a project can create drawdown in excess of 2 m, but when that occurs at a landholder bore it triggers further investigation);

- a 2 m drawdown in a landholder bore is not necessarily considered an 'impact' to that bore. The bore may be fully functioning and largely unaffected with this level of drawdown (and at levels of significantly more drawdown). Whether there is an 'impact' to the use of the bore involves many variables such as bore depth, pump depth, level of drawdown actually experienced, climatic conditions; and

- the AIP policy states that:

  > Where the predicted impacts are greater than the Level 1 minimal impact considerations by more than the accuracy of an otherwise robust model, then the assessment will involve additional studies to fully assess these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long-term viability of the relevant water-dependent asset, as defined in Table 1, **then the impacts will be considered to be acceptable.**

In NSW, a project can have impacts on other users that are deemed 'greater than minimal impact', but these impacts must be managed and mitigated via 'make good provisions'. Hume Coal acknowledge that there will be changes to groundwater levels in excess of the 'minimal impact criteria' proposed by the AIP at some landholder bores. Therefore, Hume Coal commits to negotiate make good arrangements with these users, in accordance with any relevant conditions of consent. The presence of the mine will not threaten the ability of local businesses to access water for their operations and will therefore not influence the property market. Hume Coal is committed to the principle of maintaining existing users' access to water and making good any impacts deemed to be greater than minimal impact.

Partial depressurisation of the Hawkesbury Sandstone aquifer overlying the mine will occur as mining progresses, with some dewatering near the watertable. Shallow bores in the sandstone that are not fully penetrating will be the most impacted as drawdown occurs (they may not experience the greatest drawdown but because of their shallow depth they may go dry). Greater water level drawdowns will occur in the deeper sandstone, but groundwater will still occur in these rocks (ie they will remain saturated). The majority of the Hawkesbury Sandstone will remain saturated throughout mining. The Hawkesbury Sandstone aquifer will not be 'drained', 'cracked through' or 'destroyed'. It is depressurised, and as a result the watertable will experience some drawdown, but not

total dewatering. The integrity of the Hawkesbury Sandstone is not compromised and will not be 'damaged', as the mine is designed to result in minimal levels of overburden deformation. There will be no irreversible damage to the Hawkesbury Sandstone, and groundwater levels will fully recover in time.

The make good analysis considers both the depressurisation and drawdown/dewatering impacts of the Project on individual landholder bores (ie reduced yields and water levels) and has used the detailed uncertainty analysis from the groundwater modelling to provide greater confidence in the predictions for each individual landholder bore.

The conclusion of the NSW DPI in respect to impacts on landholder bores is that the proposed strategies are "reasonable considering the circumstances".

## 4.2 Hume Coal drawdown predictions on landholder bores

The RTS groundwater model predicts that there will be 94 landholder bores on 72 properties that will experience drawdown in excess of the AIP Level 2 impact criteria of 2 m as a direct result of the Project.

Hume Coal realise that there remains ongoing concern from the community and the NSW Government about the total number of bores that are predicted to experience drawdown as a result of the Project. It is important to note that the number of bores is not directly related to the significance of the Project impact.

The reason there is such a high number of bores experiencing drawdown is because there is a high density of bores directly overlying the Hume Coal mine area. Bores in this area are common due to high quality water at shallow depths, however, most bores provide a secondary (back-up) water supply, and many are also used to top up constructed surface water features used for water storage or garden aesthetics. Some bores are used for stock and domestic purposes and a small percentage are used for irrigation.

It is important to note that most other coal mines have purchased all the overlying land (ie so effectively removed the overlying users) resulting in a much smaller number of active overlying and adjacent bores.

The key message of the Project is that **although the number of bores experiencing drawdown in excess of 2 m is high in comparison to other approved mining projects, the actual impacts are not.** The Project impacts have been statistically compared to other approved coal mining projects in the NSW and the following has been summarised from the data (see Figure 4.1 to Figure 4.3):

- the predicted peak annual inflow to Hume Coal mine is equivalent to the average inflow from a group of 29 mines;
- the predicted maximum extent of the 2 m drawdown contour at Hume (2 km) is less than half the average 2 m drawdown extent (4.7 km) from a group of 10 mines; and
- the predicted time for groundwater recovery back to 2 m at the Hume Coal Project is less than a fourth of the average from a group of 15 mines.

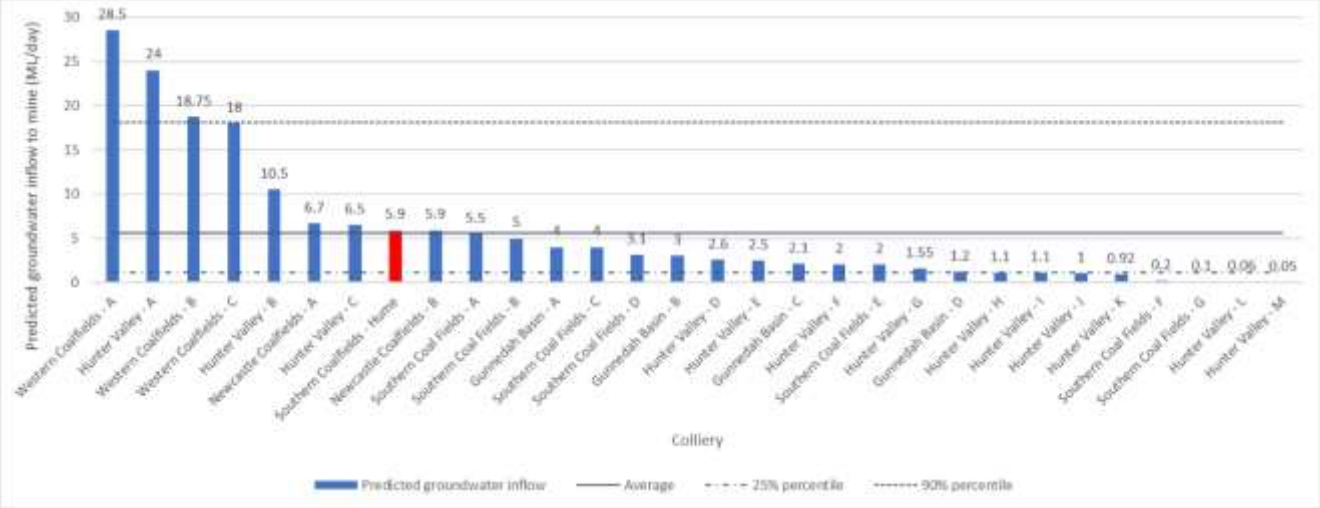



**Figure 4.1** **Groundwater inflow to open cut or underground workings –comparison between Hume Coal and other projects**

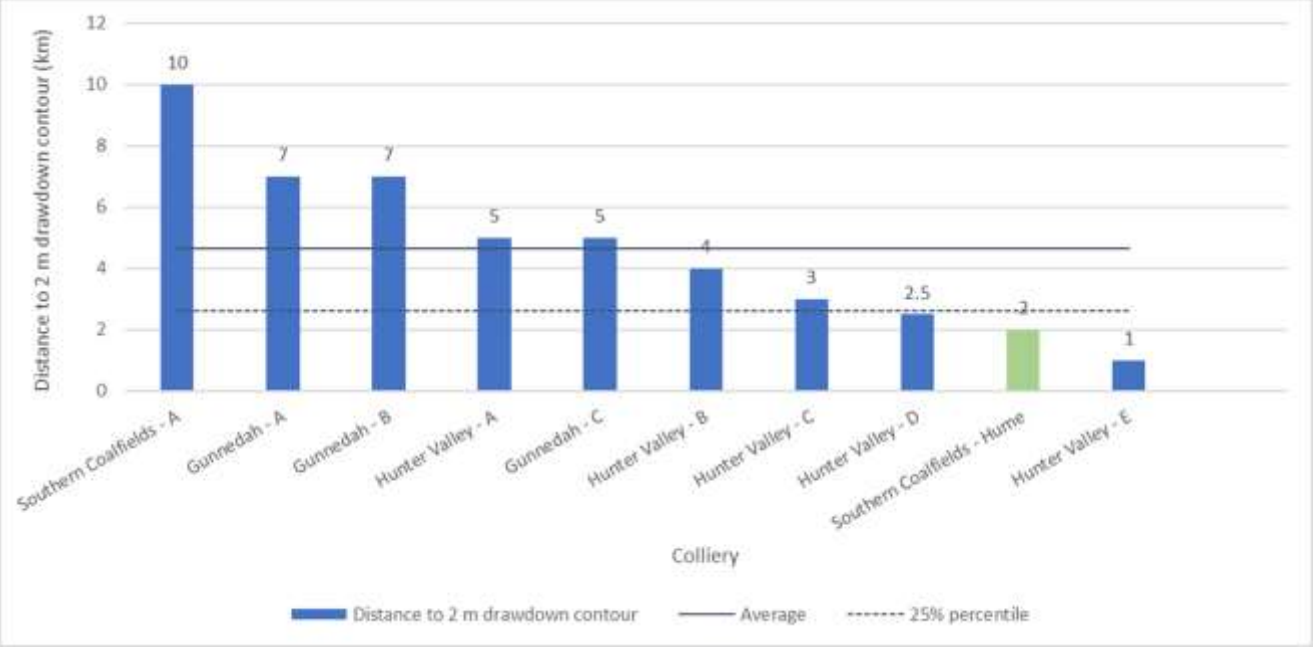



**Figure 4.2** **Distance to 2 m drawdown contour–comparison between Hume Coal and other projects**

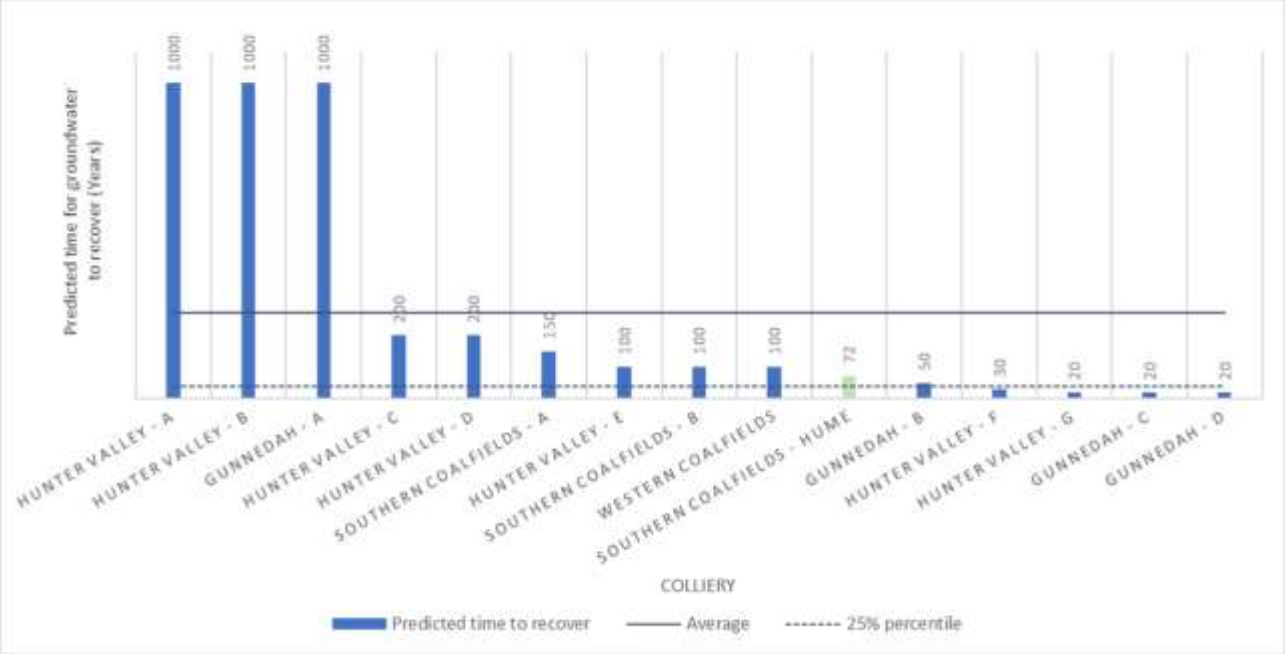



**Figure 4.3 Predicted time for groundwater recovery – comparison between Hume Coal and other projects**

The number of bores affected may be considered large in comparison to other similar size projects but this should be considered in conjunction with the minimal number of property purchased by Hume Coal, the small landholding sizes overlying the mine area, and the moderate to high density of water bores in the area. The number of landholder bores likely to be affected is not indicative of a widespread environmental impact or larger than average drawdown from the mine itself.

The RTS groundwater model predicts full recovery of groundwater pressures over a relatively short period of time (ie decades for the Hume Coal Project compared to many other mines that are either hundreds or thousands of years before full recovery). In addition, the very detailed uncertainty analysis provides a high degree of scientific certainty. The uncertainty analysis conducted for the groundwater modelling has reduced the uncertainty of the Project's impact significantly.

## 4.3 Make good – maintaining access to water

### 4.3.1 Trigger for make good

The AIP requires that if there is predicted to be a greater than minimal impact (ie in excess of 2 m drawdown) then it is a trigger for further investigation. Should that investigation then determine that there is a likely 'impact' to the bore, then 'make good' provisions apply.

Hume Coal has adopted a very conservative approach to make good due to the community concern about the number of bores impacted. In the groundwater modelling for the Project, the most likely level of impact is the 50$^{th}$ percentile results from the uncertainty analysis, which indicate approximately 84 bores will experience drawdown of greater than 2 m. Hume Coal has gone further by stating that bores for consideration of make good will be at the 67$^{th}$ percentile case, which is a total of 94 bores. Statistically, the 67$^{th}$ percentile case is 'unlikely' and not expected to occur under normal conditions (HydroSimulations 2018).

The make good approach for Hume Coal Project assumes that all of the 94 bores predicted to experience greater than 2 m impact will be incorporated into the 'Hume Coal Make Good Program'. All 94 bores have been subject to

further detailed desktop investigations. Hume Coal has committed to providing access to water for existing users throughout mining and during recovery of groundwater levels, and to providing compensation (or alternatives) to ensure impacts to existing users can be managed. Full recovery of the groundwater system will occur post mining. Therefore, the long-term viability of water supply from bores in the Hawkesbury Sandstone is guaranteed with either existing bores or new bores.

### 4.3.2 Perceived concerns of Hume Coal's ability to 'make good'

The specific concerns raised by the IPC with respect to groundwater and make good provisions are presented in Table 4.1, with additional commentary provided. It is noted that the definition of 'make good' is not articulated in the AIP or other NSW legislation. Guidance has been sought from an AIP Fact Sheets (DPI Water 2013) and, in the absence of NSW guidelines, the Project has looked further afield to other states for guidance.

**Table 4.1 Make good provision concerns raised by the IPC**

| Page | Item | Concern | Response |
|---|---|---|---|
| 52 | 145 | Whilst several reviewers have labelled the strategy as technically feasible there are **some residual risks** for **irrigation bore owners** as constructing deeper bores, or even multiple bores of larger diameter may **not equate to losing a high yielding bore in the Hawkesbury Sandstone**. | The make good arrangements for bore owners needs to be tailored for each bore owner. Hume Coal do not want to be prescriptive and will work with individuals to arrive at tailored solutions that work at the local scale.<br>There are many options at each site to provide access to water, drilling deeper bores into deeper formations is only one option, and although it may not provide the full solution for irrigation, it may very well provide a percentage of the water requirements and therefore remains a part of the solution. Access to deeper formations will provide good solutions for low yield stock and domestic users. Other options for irrigation bores may include several of the following:<br>• relocating bores further away from the mine area (for large properties this is often an option);<br>• several bores to replace one (to maintain bore yields);<br>• drilling several shallower bores into the mid section of the Hawkesbury Sandstone, which remains saturated throughout mining and recovery (see Figure 4.5);<br>• construction of additional storage (dams and tanks); and<br>• financial compensation for part or all of the duration of impact. |
| 52 | 146 | DoI-Water consider that the make good arrangements for **irrigation bore owners is uncertain** as there is little knowledge about the **water supply quality and yields from deeper formations**. | |
| 52 | 147 | The Department's PAR considers that given the significant opposition to this Project the make good strategy would inevitably lead to a **large number of disputes** requiring resolution and causing disruption to the community. | Hume Coal has continuously considered the needs of the community throughout the preparation of the EIS for the Project. The mine design is an example of the innovation and consideration invested to minimise the impacts of the Project. The adoption of very detailed make good considerations and a conservative approach to inclusion of all bores within the 67$^{th}$ percentile predicted 2 m drawdown extent should also be noted.<br>It is noted that the significant opposition to the Project is largely based on the community concerns about coal mining generally and foreign ownership. Not the actual environmental impacts of the Project.<br>Therefore, the loosely defined pathway for proponents to manage conflict resolution of 'make good' in NSW means that projects such as Hume Coal have the potential for uncertainty and disruption. However, Hume Coal have been aware of this throughout the planning of the process and have designed a detailed strategy for resolving conflict at every stage.<br>Hume Coal have mapped out the potential areas of conflict in this process and have a solid approach to dispute resolution (see Figure 4.4). |

## Table 4.1 Make good provision concerns raised by the IPC

| Page | Item | Concern | Response |
|---|---|---|---|
| **53** | **R6** | That the Department give close attention to the **practical adequacy of make good provisions** during the final assessment process, with an **independent review** if necessary. This should include the practical aspects such as **dispute resolution and economics** as well as the technical. | The practical adequacy of make good has been considered by Hume Coal in the make good assessments for the EIS and the RTS. Hume Coal has developed an industry leading approach to make good which considers and maps out three components being:<br>• practical, technically feasible options as endorsed by the independent peer reviewer and DPIE, being a combination of:<br>– financial compensation for increased pumping costs;<br>– deepening of pumps;<br>– redrilling bores (or several bores);<br>– associated earth works and water storages;<br>– water management infrastructure; and<br>– other options as negotiated with individual landholders.<br>• the process for implementation of the make good measures:<br>– landholder engagement via meetings, letters, etc;<br>– negotiation pathway for tailored solutions of maintaining water supplies for landholders;<br>– measurement, monitoring and verification of impacts over time;<br>– installation of new monitoring bores at strategic locations to provide for monitoring of baseline and changing conditions over time prior to and during and post mining - these locations will be targeted between the mine and key landholders (ie irrigators); and<br>– process for conflict resolution.<br>• dispute resolution for make good measures between landholders and Hume Coal:<br>– mapping out areas and reasons that conflict may occur; and<br>– providing a structured process for resolution of disputes.<br>See Figure 4.4. |
| 53 | 157 | At this stage of its assessment the Commission finds that it is **not satisfied with the information provided** up to this point **regarding groundwater impacts** because of the uncertainty about the extent of groundwater drawdown and the capability of 'making good'. | As described in earlier sections of this report, the groundwater model has undergone multiple reviews over the years, including a review by independent expert Mr Hugh Middlemis of HydroGeoLogic on behalf of the NSW Government and Dr Lloyd Townley of GW-SW in response to R5 by the IPC. The findings of both the HydroGeoLogic (2017 and 2018) and Townley (2020) reviews determined that the groundwater model, including the calibration, predictions, sensitivity and uncertainty analysis is:<br>• fit for purpose;<br>• at a Class 2 level, with elements of Class 3;<br>• consistent with and in some areas, leading industry practice; and<br>• appropriate for assessing the potential impacts of the Hume Coal Project on the groundwater resource.<br>Regarding Hume Coal's capability of 'making good', this has been addressed above. |

## 4.4 Make good strategy

Landholder bore assessments and make good provisions were proposed as part of the EIS, and then revised again and proposed a second time in the RTS.

The make good report included as part of the revised water assessment in the RTS refines 'make good' strategies for individual bores using the drawdown outputs from the RTS groundwater model. By applying the concept of make good for landholder bores, the drawdown effects are mitigated, and a landholder's access to water for farming and other purposes are not compromised.

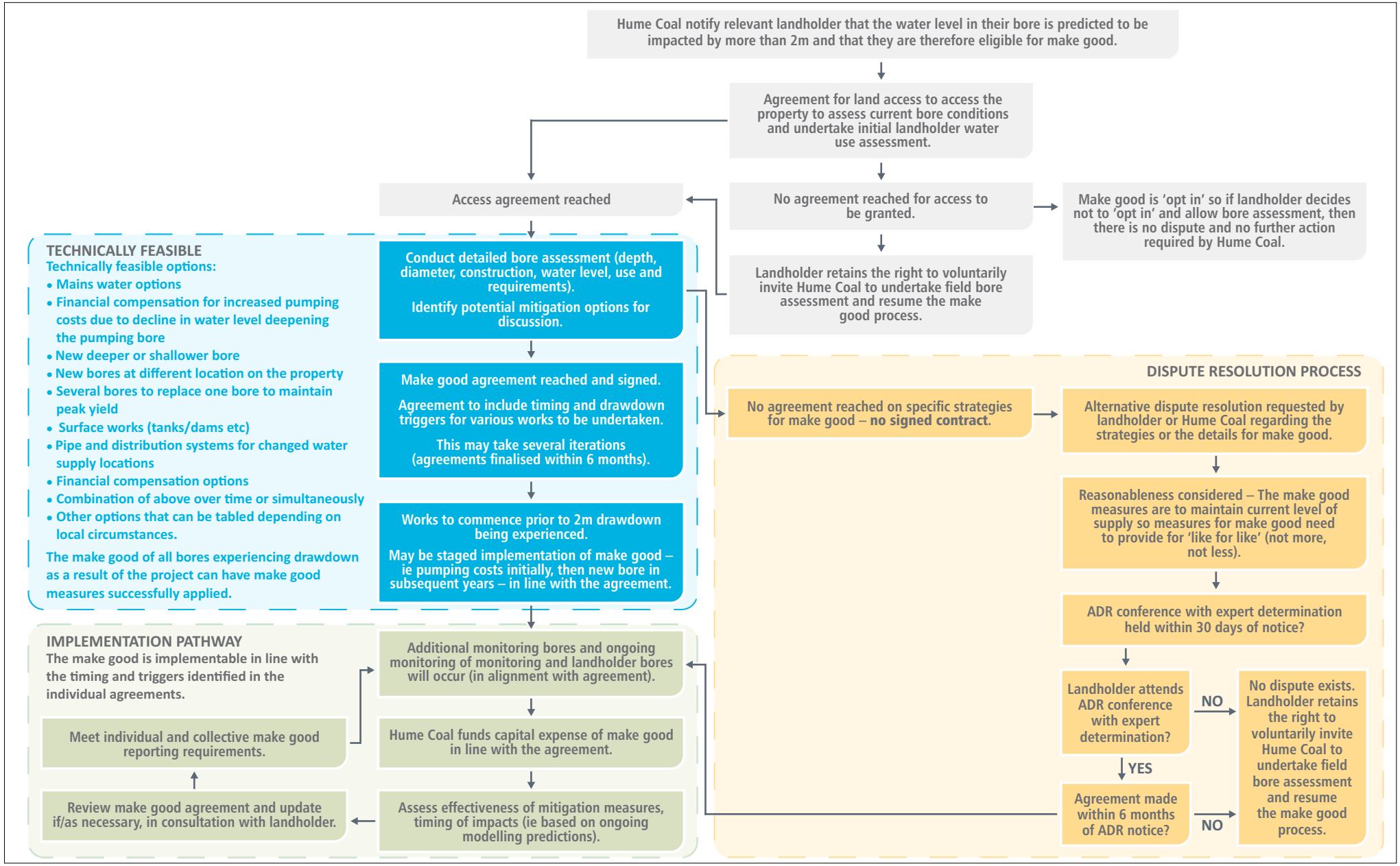
The perceived concerns about make good are considered throughout the RTS and the IPC process and these concerns generally fall into three categories, being:

1. Technical feasibility;

2. Ability to implement; and

3. Identification of conflict resolution pathways.

A flow chart has been prepared (Figure 4.4) which outlines the make good process and allocates the key actions and decisions into the three categories for ease of conceptualisation.




Make good flow chart

Hume Coal Pty Ltd

Updated water assessment

Figure 4.4

### 4.4.1 Technical feasibility of make good

The NSW DPE and DoI Water did not raise any major concerns about the technical feasibility of the proposed options for make good. Section 6.2.5 of the DPE PAR states that:

> 'while the Department agrees that the options of deepening or replacing the bores may present challenges, the department generally accepts that the Applicants proposed make good options are technically feasible.'

On the subject of technical feasibility of make good, DPE's expert (Hugh Middlemis of HydroGeoLogic) states:

> 'all these arrangements are reasonable in principle'
>
> 'Dewatering of one horizon (the mined coal seam), does not preclude the occurrence of saturated aquifer conditions above';
>
> 'Depressurisation does not dewater an aquifer unit, it simply lowers the groundwater pressure level'; and
>
> 'Berrima Colliery demonstrates that depressurization and or dewatering of coal seams does not preclude access to viable aquifer resources, even overlying the mined area'.

The schematic in Figure 4.5 illustrates the manner in which depressurisation of a groundwater source can occur without dewatering. Although bores above the mine will be depressurised (ie experience drawdown), the formation will remain saturated throughout mining and bores will continue to operate, albeit at a lower pressure head and likely at a lower yield.

The make good strategy is very flexible in its approach and will be tailored for each individual landholder depending on their respective and individual needs, as well as their location (ie are they immediately above the workings or adjacent). Some landholders may require a make good agreement that replaces one deep bore with several shallower, larger diameter bores to maintain the required yield, whereas some landholders with lower yield requirements may prefer a large above ground tank or dam, with assistance with increased pumping costs to run the pump more frequently.

Options are many and varied and may include one or more of the following:

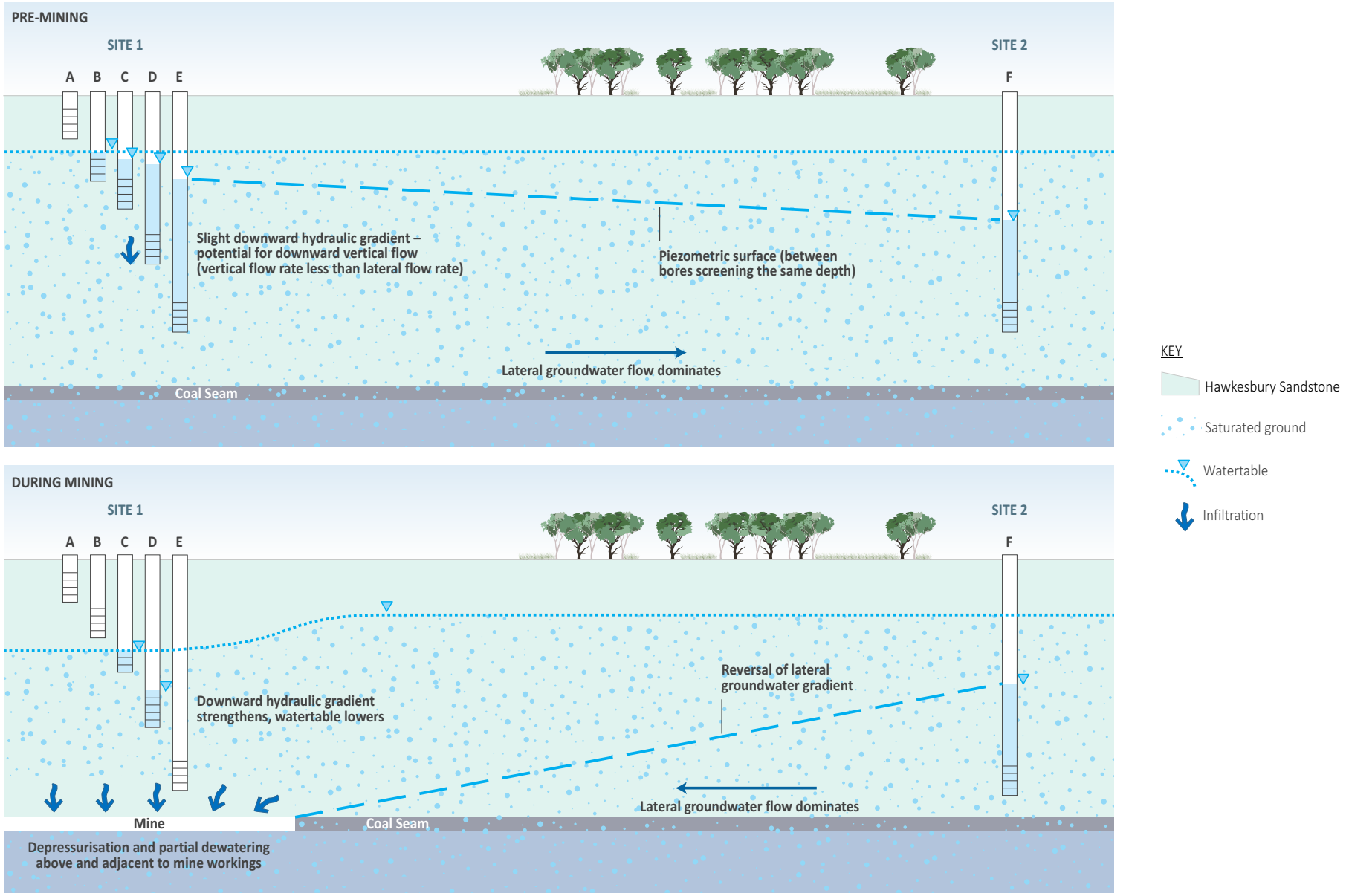
- financial assistance to cater for increased pumping costs (ie for increased electricity requirements from having to pump from a bore with a lower head);
- deepening of pump inside bore casing (this may or may not be feasible depending on bore construction and current condition);
- replacement bore/s, which may include:
  - several bores to maintain required yield;
  - larger diameter bores (providing higher yields than narrow diameter bores);
  - deeper bores (ie below the coal seam), providing either/or:
    - larger storage volume of water;
    - greater available pumping head; and
    - larger yields if deep fractures encountered;

- bores located on other areas of the property (ie for some larger properties, moving the bore away from the mine will be sufficient to avoid impacts);

- enhancing surface water storage capacity to mitigate lower bore yield (ie larger storage tanks or dams to hold peak flow requirements – this may be a particularly valid solution for irrigation properties); or

- alternate water supply options as mutually negotiated.

It is noted that whilst DPIE/DPIE Water agrees the options of deepening or replacing the bores may present administrative challenges, the Department generally accepts that Hume Coal's proposed make good options are technically feasible.




Hydraulic head in bores schematic – pre-mining and mining

Hume Coal Project

Updated water assessment

Figure 4.5

EMM creating opportunities

HUMECOAL PROJECT

### i Practical implementation

There is agreement from DPE's expert that make good is technically feasible. Hume Coal have investigated an approach to then practically implement make good. This process adopts a staged approach, as shown in Figure 4.4. This is similar to how other mines such as Tahmoor implement their make good requirements for landholder bores that experience drawdowns in excess of 2 m.

The implementation of make good measures for impacted bores is perceived to be difficult when communities are opposed to the overall Project. However, community opposition to the Project does not preclude logical make good measures from being implemented successfully. As previously reported, Hume Coal have already begun negotiations with local residents and currently:

- access arrangements with over 20 landholders have already been agreed and monitoring is underway;
- the average drawdown for all bores in the area is only 6 m; and
- only 16 bores are required to be made good in the first five years of mining.

Implementation of make good will be greatly enhanced upon project approval, because at that point, the Project will be openly endorsed by the NSW Government.

Hume Coal will work with the NSW Government to provide clear policies on reasonableness and dispute resolution to assist make good for this Project. These policies would be applicable for others in NSW.

The key issues with the make good as stated by the DPE are disruption to the community, disagreement on the actual impacts and optimal 'make good' measures. These are not concerns related to whether the make good strategy is technical feasible or implementable.

### ii Staging implementation of make good

Disruption to the community has been carefully considered and Hume Coal proposes a staged approach.

There are 16 bores predicted to be impacted by more than 2 m within the first five years of mining (see Table 4.2) and these landholders have been contacted and advised of the predicted impact. The advice included outlining the fact that they are likely to be impacted by more than 2 m, explaining the associated hydrograph prediction of their level of impact throughout mining and recovery, and advising them that they are eligible to opt in for make good arrangements.

Hume Coal continues to offer and recommend a site visit and bore assessment for all landholders predicted to be impacted, so that discussions around what would constitute a suitable and tailored make good arrangement for each individual landholder can commence.

In summary, pragmatically implementing make good for landholders is a straightforward process. The staged approach, as outlined in Table 4.2, will minimise disruption to the community and involves:

- make good activities staged in five years lots (other operations do this in line with extraction management plans);
- a flexible strategy and suitable operational arrangements to provide tailored solutions for each individual landholder - for irrigation bores and large users this is likely to consist of a combination of several options (ie a replacement bore, above ground tanks, and compensation for increased pumping costs);
- the legal construct for 'make good' is landholder entitlement. Therefore, if individual landholders do not choose to exercise that right, then there is no dispute. It is an 'opt in' arrangement; and

- 64 bores (68% of all affected bores) can be made good with minor strategies such as increased pumping costs and lowering pumps.

**Table 4.2 Make good staged approach**

| Time when bore first impacted by 2 m drawdown | 0–5 yrs | 5–10 yrs | 10–15 yrs | 15–20 yrs | 20–25 yrs | +25 yrs | Total |
|---|---|---|---|---|---|---|---|
| 1. Increased pumping costs * | - | 3 | 7 | 9 | 5 | 7 | 31 |
| 2. Deepen bore * | 6 | 9 | 13 | 3 | 2 | - | 33 |
| 3a. Replace stock/ domestic bore* | 5 | 4 | 2 | 2 | 1 | 1 | 15 |
| 3b Replace an irrigation bore* | 5 | 8 | 1 | 1 | - | - | 15 |
| **Totals** | **16** | **24** | **23** | **15** | **8** | **8** | **94** |

Note: * These make good options are not exhaustive and have been used to provide an example of the make good measures that could be applied as part of the mitigation of impacts.

### a Dispute resolution

The legal construct for 'make good' is that it represents a landholder entitlement. Therefore, if individual landholders do not choose to exercise that right, then there is no dispute. This is an 'opt in' arrangement.

It should also be noted that the change from the *Water Act 1912* to the *Water Management Act 2000* was drafted following a decree from the Council of Australia Government (CoAG) regarding the reformation of the Australian water industry which commenced in the 1980's. One of the key principles driving the water reforms stems from a CoAG meeting in 1994 where it stated:

> 'that water be used to maximise its contribution to national income and welfare, within the social, physical and ecological constraints of catchments'

The *Water Management Act 2000* then decoupled water rights from land rights and provided a pathway to allow water to be traded and extracted for the 'highest value use'. Hume Coal therefore have a legal right to intercept water for mining purposes (as they hold appropriate water access licences to do so) and are legally allowed to create drawdown. Equally, Hume Coal have a legal obligation to commit to undertaking make good arrangements in situations where their activity causes an impact to existing users of that water.

In order to make good and for Hume Coal to meet that obligation, landholders are required to 'opt in' to make good arrangements. The flow chart presented in Figure 4.4 outlines the process for make good and illustrates key areas of that process where dispute may occur. It includes disputes over:

- access for initial bore assessment surveys. Make good is an 'opt in' arrangement and if Hume Coal are prohibited from undertaking these assessments then no further action is required for that bore. However, Hume Coal are committed to providing a process whereby a landholder with a bore that is impacted can re-enter into the make good process at any stage; and

- the 'reasonableness' of make good proposals may occur once negotiations commence. However, Hume Coal is committed to ensuring landholders maintain their level of access to water. Therefore, provided landholders do not have unreasonable levels of expectations and demands, there should be no dispute. If the NSW Government does have a draft paper or a policy on reasonableness of make good, then this would be very beneficial for not only the Hume Coal Project, but also other aquifer-interfering projects (tunnels, mines, quarries etc) as a benchmark.

It appears that there are concerns from the NSW Government that there may be dispute from landholders who are recognised as experiencing greater than 2 m of drawdown, but are opposed to the Project and therefore do not 'opt in' to the make good process. Due to the arrangements being 'opt in' and the fact that Hume Coal will continue to allow potentially impacted users to enter the make good process at any stage, there appears to be no reason why disputes outside of the above two reasons could occur legally.

### b Disagreement on the actual impacts and optimal 'make good' measures

The predicted drawdown impacts at individual bores has been modelled using the regional model developed to predict mine inflow and regional depressurisation and drawdown. The model predicts results for bores with reference to the nearest model cell for the location of the bore, and the bore screened depth is attributed to one or more model layers. The model is very accurate at the regional scale, but there will be differences between model predictions and reality at a local scale (ie at a bore level). This does not mean that the groundwater model cannot be used to assess impacts. The groundwater model is consistent with industry standards.

As outlined in Section 3, future improvements to the Hume Coal groundwater model will be undertaken as and when new data becomes available. As mining progresses, a need for further model updates will be assessed regularly based on evaluation of groundwater monitoring data and findings of impact verification. It is expected the confidence level of model predictions will increase over time as the model is updated to reflect the observed effects on groundwater obtained from the monitoring program.

Over time with additional data from individual landholder bores and inclusion of local refinements to the model, the differences between predicted and measured (levels and flows) will converge. It is also noted that the model has been based on conservative assumptions, and as such the actual impacts are also anticipated to be less than predicted.

The model results are based on average climate data, with consideration for wet and dry sequences. This is best practice because the 'impact' of the mine is being assessed (ie the difference). Therefore, the results for drawdown in bores as a standing water level (SWL) below ground will depend on the climatic sequence. For example, if under average climate conditions a bore has a SWL of 10 m below ground surface, and the impact from the mine is 5 m of head in that bore, then the maximum groundwater level it will experience is 15 m below ground. If this same bore is in a dry sequence, its SWL may be naturally at 15 m, and then with the mine the reduction is the same (5 m), but in this dry sequence the maximum groundwater level will be 20 m below ground (ie 5 m due to dry climate and 5 m due to the mine). Conversely, in wet years the actual drawdown levels will be less.

Model verification, and fine tuning of the model over time is a firm commitment that Hume Coal has made and is a key component of the make good strategy. Hume Coal wants to work with the community as much as possible to ensure the model accuracy at the local scale can be matched to actual impacts and therefore minimise the disagreements and community concern surrounding impacts.

As stated above, the regional model is very accurate, and the level of depressurisation and drawdown in bores is accurate at this regional scale. Therefore, although differences do occur, the differences are most likely to be in areas of steep slopes (ie high/low topographic relief areas), localised (metre scale) variation in hydrogeological properties, climate averages and / or lack of data to confirm bore depth, screened interval and SWL. However, the total drawdown (ie the maximum change in water level) has been predicted with high confidence. Hume Coal are confident that even with local differences, the regional impacts and number of bores that will require make good is accurate. This is demonstrated via the uncertainty analysis which shows a modest increase in the number of bores when moving from 67$^{th}$ percentile (unlikely to occur) to 90$^{th}$ percentile (very unlikely to occur). This small increase in the number of bores provides a high level of confidence in the accuracy of the model and predicted impacts to bores.

Make good measures will be negotiated openly with individual landholders. Provided both parties are agreeable and not unreasonable in demands, Hume Coal sees no reason why suitable make good arrangements cannot be made with each landholder. Hume Coal understands that the NSW Government has undertaken some work and

potentially has a draft paper that considers the ‘reasonableness’ of make good measures. This work is understood to set out a process and consider what a reasonable request is (ie from a landholder) for access to water or compensation, and considers examples where landholders may claim make good for levels in excess of current entitlements or current use. Equally, it sets out what is reasonably expected to be offered by the proponent in options for individuals to make good. This paper is yet to be released for discussion.

# 5 Site water balance

## 5.1 Introduction

Site water management for the proposed Hume Coal Project relies on four sediment basins (SBs), four mine water dams (MWDs), one primary water dam (PWD), and an underground mine sump (sump). Further details are documented in the following reports:

- EMM 2018c. Volume 2B, Hume Coal Project and Berrima Rail Project, Response to Submissions, Appendix 2. Report prepared for Hume Coal Pty Limited, June 2018.
- WSP 2018. Hume Coal Project Response to Submissions – revised surface water assessment. Hume Coal. Report Number PS106597-WAT-REP-001 Rev009.docx. June 2018.
- Parsons Brinckerhoff, 2016. Hume Coal Water Balance Assessment for Hume Coal Project. Report Number 2200539A-SW-REP-001 Rev10. 22 December 2016. Appendix A to WSP (2018).

The PWD, which has an operational capacity of 724 ML, is essentially a balancing storage, which receives and stores surface water runoff and groundwater abstracted from underground mine workings, in excess of operational requirements, and supplies water to satisfy mining and other project related water requirements, except for potable water.

The operational objective of the PWD is to buffer periods of water deficiency and excess, particularly stormwater runoff generated within the Project site, to avoid uncontrolled release of water from the Project site. Therefore, whenever possible, the operational storage is maintained at low volumes to provide the required buffering storage for periods of excess, while still supplying the required water demands.

The void spaces behind the bulkheads will be utilised to emplace the coal rejects in the form of co-disposed reject as well as excess water from the underground sump. If required, water stored within the void spaces can be pumped to the PWD to meet water demands.

If reinjection from the sump to the sealed mined-out panels is prevented during mining operations, the PWD is the only storage that can be utilised to store excess water from the underground mine sump. Therefore, more details about the potential risk of the PWD reaching its maximum capacity during the life of mining operations was requested in Recommendation 8 (R8) of the IPC report, which states: “Should underground emplacement and water impounded have to cease for any reason, the Applicant is to **confirm how long under normal mining operations it would take for the** reject emplacement stockpile and **Primary Water Dam to reach capacity**.”

The following sections provide a brief summary of the water balance assessment undertaken to address IPC R8.

## 5.2 Water balance modelling

### 5.2.1 RTS Goldsim model

The RTS Goldsim water balance model, which was originally developed by WSP for the Hume Coal Project (WSP, 2018), was amended to simulate water accumulation in the PWD if reinjection to the sealed mine panels is prevented at any stage during the 19-year period of proposed mining. The water balance model was used to estimate the length of time it would take for the PWD to reach its operational capacity after excess water reinjection is stopped.

It should be noted that the Goldsim model can be used to simulate water storage within the PWD. However, the potential reject volume build-up, resulting from not being placed within the mined-out panel, is beyond the scope of the water balance model and has been assessed by Palaris (2020).

### 5.2.2 Rainfall and evaporation data

The RTS Goldsim model was based on a daily time series of rainfall and evaporation data obtained from Data Drill historical records, which were available for the period 1 January 1889 to 1 January 2015. For modelling purposes, the mining was assumed to occur over a 19-year period from 2021 to 2039.

To assess the potential impacts of climate variability on water availability and storage, over the life of the mine, the site water balance was simulated for 107 climate realisations (or sequences) of rainfall and evaporation data. These data sequences were developed by shifting through the daily timeseries from 1 January 1889 to 1 January 2015 at an annual interval; i.e. the first 19-year realisation started on 1 January 1889, the second realisation started on 1 January 1890 and the last realisation (ie realisation 107) started on 1 January 1995.

This assessment therefore addresses the potential influence of natural climatic variability, based on observed information, but does not account for potential climate change impacts.

### 5.2.3 Surface runoff simulation

The Australian Water Balance Model (AWBM) was used to simulate daily surface water runoff, for each of the daily rainfall and evaporation data sequences. Refer to Chapter 2 of Appendix A of WSP (2018) report for details of the model.

### 5.2.4 Project water requirements and net demands

Daily project water requirements were calculated from annual average demands, as detailed in Chapter 4 of Appendix A in WSP (2018) report.

## 5.3 Modelling methodology

If reinjection (ie disposal of excess water) is not possible for any reason during the life of mining operations, the volume of water in the PWD will increase if there is a net surplus of water supply, ie water generated through dewatering and underground sump collection are greater than the project raw water demand.

The RTS Goldsim water balance model was used to estimate the length of time it would take for the PWD to reach capacity, if the option of reinjection of surplus water to underground voids is prevented or unavailable. This water balance assessment of the time to reach the PWD storage capacity was run for each of the 107 climate (rainfall/evaporation) sequences summarised in Section 5.2.2, with different initiation dates for ceasing reinjection.

No modifications or changes have been made to the RTS Goldsim model (WSP 2018) with respect to key input datasets, infrastructure design assumptions or the water management operational logic and philosophy. The only change to the RTS Goldsim model has been the inclusion of a trigger to simulate the stoppage of surplus water reinjection into the available mined-out panel void space. The time from the date of ceasing reinjection until the volume in the PWD reaches 720 ML has been recorded for each of the climate sequences with stoppage of reinjection applied on the first day of the year for each year of the 19-year mining life.

For example, the water balance assessment applies 107 climate scenarios assuming reinjection is unavailable on day one of Year 1 of mining, then the same 107 climate scenarios are applied assuming reinjection is unavailable on day one of Year 2 of mining and so on over the 19-years of mine operation.

The resulting simulation runs produced 19 sets of 107 data points (one for each climate sequence) recording the duration, under normal mining operations, before the PWD reaches capacity. Each data point represents a different climatic sequence, which included wet, dry and average climate periods. Note that statistics reported for Years 18 and 19, as shown in in Table 5.1 and Figure 5.1 below, include only scenarios where the PWD reaches the maximum capacity before the end of the simulated mining period, ie the PWD reaches the 720 ML capacity before the end of Year 19. This includes 102 of 107 climate scenarios for Year 18 and only 14 of 107 climate scenarios for Year 19 reinjection cessation years.

## 5.4 Results

A statistical analysis was undertaken to derive the minimum, maximum, median and average time durations for the PWD to reach a capacity of 720 ML based on the 107 climate scenarios applied to each year of the 19-year mine life. The box and whisker plot presented in Figure 5.1 summarises the distribution of duration results for each mining year, including the 25th and 75th time duration percentiles (the box) as well as the maximum and minimum duration range (the whiskers extending up and down from the box). The average time duration for each year is included as the plotted line on the 19-year mining period. The x-axis of Figure 5.1 represents the mining year in which reinjection to the sealed panel void was stopped and did not recommence for the remainder of the 19-year mining period.

Key statistics of the water balance simulations are presented for each year on the mining period in Table 5.1 showing the minimum, maximum and average duration to reach the PWD capacity. The number of scenarios (out of 107 climate scenarios) within the reinjection cessation year resulting in a duration of less than one year are also reported.

The statistical summary of the modelling results presented in Figure 5.1 and Table 5.1 show the following:

- The average duration (over the 107 data sequences) for the PWD to reach capacity (without reinjection) decreases throughout the life of the mining operation. For example, if reinjection were to cease in the first year (Year 1) of mining operations and water collected in the underground mine sump is diverted to the PWD, the average time to fill the PWD is estimated to be 14 years (5,120 days). This average duration to fill the PWD reduces to approximately 8 years (2,930 days) if reinjection is ceased in the seventh year of mining, and falls to approximately 0.8 years (280 days) if reinjection is ceased in the final year of the 19-year period of operations.

- The longest duration for the PWD to reach capacity is estimated to be 16.5 years (6,015 days), if reinjection were to cease in the first mining year. However, it is important to note that this only occurs for one of the 107 climatic data sequences. As detailed above, the average duration to reach the PWD capacity if the reinjection ceases at the start of the first year (based on the 107 climatic sequences) is 14 years (5,120 days).

- The shortest duration for the PWD to reach capacity is estimated to be 0.5 years (197 days), if reinjection ceases at the start of the last year (Year 19) of mining. Once again, it is important to note that this minimum duration only occurs for one of the 107 climatic data sequences. As detailed above, the average duration for the PWD to reach capacity if reinjection ceases at the start of the last year (based on the 107 climatic sequences) is 0.8 year (280 days).

- The decreasing trend of the duration for the PWD to reach capacity (Figure 5.1) reflects the relative influence of the changes in the water supply-demand balance over the life of mine. Net water deficits exist during the earlier years of mining which transitions to a net water surplus dominant situation over the later years of mine operation. The variability of duration presented in the box plots for each of the respective reinjection cessation years provides a reflection of the relative influence of climatic variability, ie wet or dry rainfall sequence scenarios, on the time to reach PWD capacity.

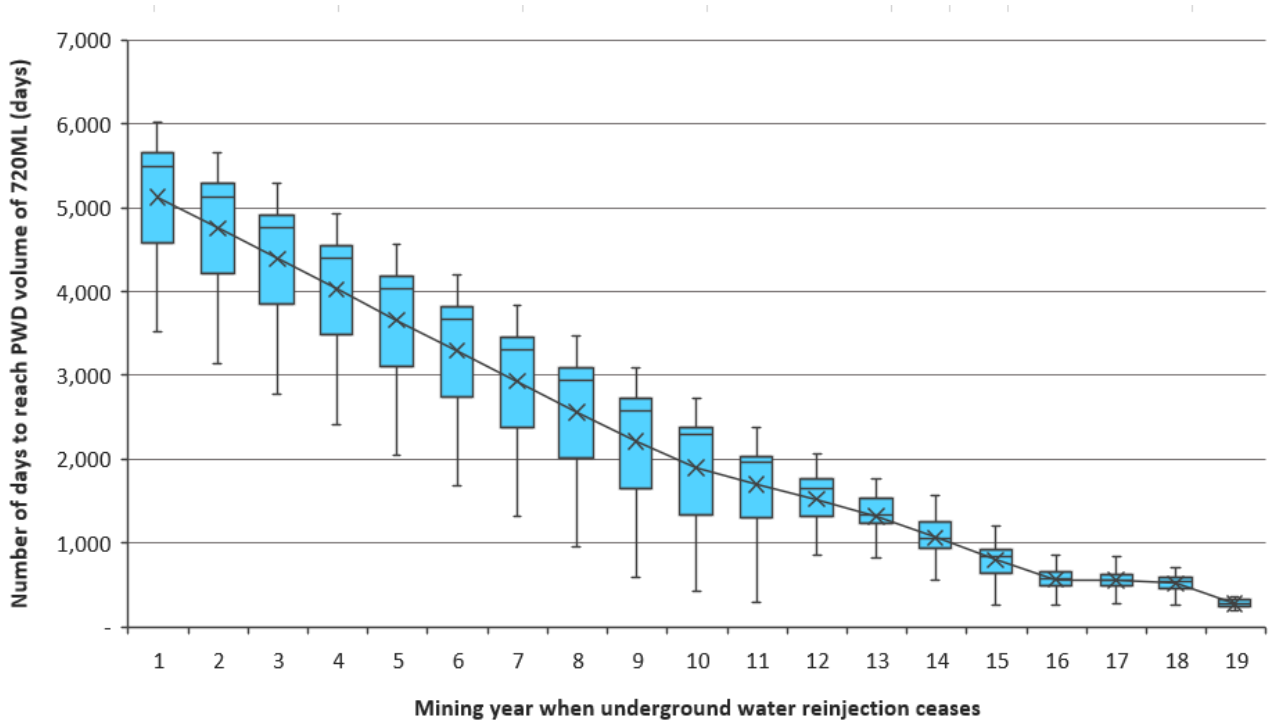



**Figure 5.1** Box and whisker plot of duration to reach PWD capacity from year of ceasing reinjection

**Table 5.1** Key simulated statistics of duration to reach PWD capacity from year of ceasing reinjection

| Simulated mining year when reinjection to mine void ceases | Minimum number of years to reach PWD operational capacity | Maximum number of years to reach PWD operational capacity | Average number of years to reach PWD operational capacity | Number of occurrences of duration < 1 year [1] |
|---|---|---|---|---|
| 1 | 9.6 | 16.5 | 14.0 | |
| 2 | 8.6 | 15.5 | 13.0 | |
| 3 | 7.6 | 14.5 | 12.0 | |
| 4 | 6.6 | 13.5 | 11.0 | |
| 5 | 5.6 | 12.5 | 10.0 | |
| 6 | 4.6 | 11.5 | 9.0 | |
| 7 | 3.6 | 10.5 | 8.0 | |
| 8 | 2.6 | 9.5 | 7.0 | |
| 9 | 1.6 | 8.5 | 6.1 | |
| 10 | 1.2 | 7.5 | 5.2 | |
| 11 | 0.8 | 6.5 | 4.6 | 1 |
| 12 | 0.7 | 5.6 | 4.2 | 1 |
| 13 | 0.8 | 4.8 | 3.6 | 1 |
| 14 | 0.8 | 4.3 | 2.9 | 1 |
| 15 | 0.7 | 3.3 | 2.2 | 1 |

**Table 5.1 Key simulated statistics of duration to reach PWD capacity from year of ceasing reinjection**

| Simulated mining year when reinjection to mine void ceases | Minimum number of years to reach PWD operational capacity | Maximum number of years to reach PWD operational capacity | Average number of years to reach PWD operational capacity | Number of occurrences of duration < 1 year [1] |
|---|---|---|---|---|
| 16 | 0.6 | 2.3 | 1.5 | 11 |
| 17 | 0.6 | 2.3 | 1.5 | 10 |
| 18 [2] | 0.6 | 2.0 | 1.4 | 12 |
| 19 [2] | 0.5 | 1.0 | 0.8 | 14 |

Notes: [1] Represents a count of the number of climate scenarios out of a total of 107 climate scenarios resulting in a time to reach the PWD capacity of less than 1 year from the date of stopping underground surplus water reinjection.
[2] Statistics only reported for climate scenarios where PWD reaches capacity before the end of Year 19. This represents 102 scenarios for Year 18 and only 14 scenarios for Year 19.

## 5.5 Water balance results summary

This section assesses the potential duration that the mine can operate under normal conditions before the PWD reaches capacity (720 ML), if reinjection of surplus water underground has to cease for any reason at any time during the 19-year operating period.

The assessment is based on the Goldsim water balance model, which was updated by WSP for the RTS report (WSP 2018). Additional functionality has been incorporated into the RTS Goldsim model to control the date at which reinjection to mine void ceases, but no other changes were made to original model structure input data or water management logic.

Statistics derived from 19-sets of 107 climatic data sequences were calculated to estimate the potential range and distribution of time durations for the PWD to reach its operational capacity of 720 ML.

As expected, the average duration for the PWD to reach capacity is largely dependent on the year in which surplus water reinjection ceases. In the early stages of mine operations, the average duration for the PWD to reach capacity is longer than in the later stages of mining. This is a function of several factors, but generally reflects a net water deficit in the early stages of mining and a water surplus in the later stages.

# 6 Summary

The outstanding concerns raised by the IPC have been reviewed in detail and further clarification and discussion is provided.

The report clearly discusses the data availability and the fact that there is adequate data available to undertake the assessment and that this was also discussed with the NSW Government as part of the consultation on the Project. The data has been thoroughly referenced and discussed in this overall assessment and provide a strong baseline for the Project conceptualisation and predictions of potential impacts.

One of the key additional studies undertaken for this response to the IPC is the adoption of their recommendation to undertake an additional independent peer review for comparison with advice provided by the Hume Coal modeller, Noel Merrick (SLR Consulting), Franz Kalf (Kalf and Associates) and Hugh Middlemis (HydroGeoLogic). This additional review by Dr Lloyd Townley further concurs with the groundwater model is 'fit for purpose', and suitable for assessment of this Project.

The make good strategy is also investigated in more detail with a focus on the three main aspects of make good as raised by the IPC:

- Technically feasible: as demonstrated in the RTS and agreed to by Hugh Middlemis (and subsequently discussed in detail with DPIE Water);
- Implementable: with a method outlined in the flow charts and discussed as to how it will be undertaken (aligning with other very similar make good programs successfully being implemented at Tahmoor); and
- Dispute resolution pathways: which have been researched further since the RTS as to the legal framework and 'opt in' arrangement that is how 'make good' is interpreted legally within the relevant water legislation and regulations.

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Annexure A

# DPIE Water report

# DPIE Water Report

Actions from 30 July 2019 meeting

Prepared for Hume Coal Pty Ltd
March 2020

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# DPIE Water Report

Actions from 30 July 2019 meeting

**Report Number**

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**Client**

Hume Coal Pty Ltd

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31 March 2020

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Principal Hydrogeologist
31 March 2020

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# 1 Introduction

Hume Coal Pty Limited (Hume Coal) proposes to construct and operate an underground coal mine and associated mine infrastructure in the Southern Coalfield of New South Wales (NSW) (the Hume Coal Project). The mine will produce metallurgical coal with a secondary thermal coal product. Around 50 million tonnes (Mt) of run-of-mine coal will be extracted from the Wongawilli Seam via a non-caving mining system, resulting in approximately 39 Mt of saleable coal over a project life of about 23 years, including construction and rehabilitation.

The development applications and accompanying EISs for the Hume Coal Project (EMM 2017a) and the Berrima Rail Project (EMM 2017b) were submitted to the NSW Department of Planning and Environment (DPE) (now the Department of Planning, Industry and Environment (DPIE)) on 29 November 2016 for adequacy review. Following feedback and some modification, the two EISs were deemed adequate for exhibition, which occurred between 31 March 2017 and 30 June 2017.

Following public exhibition of the EISs, Hume Coal prepared a combined Response to Submissions (RTS) report for the project, responding to submissions received from government agencies, organisations and the public. The most commonly raised technical issue in the submissions related to water resources, and in particular the potential impacts to groundwater and privately owned bores. Given the focus on groundwater in the submissions, substantial additional groundwater modelling and impact assessment work was undertaken as part of the RTS. This included an additional independent review of the groundwater model by DPE's expert Mr Hugh Middlemis of HydroGeoLogic Pty Ltd. The RTS report was submitted to the DPE in June 2018.

The DPE subsequently prepared a preliminary assessment report (PAR) for the project which was released in December 2018. In relation to water, the PAR assessed that the project will have significant drawdown impacts on numerous privately owned bores. They also advised that due to the level of opposition to the project in the local area, the proposed make good process would inevitably result in a large number of negotiations and disputes, leading to delays to the project and disruption to the community.

As the number of submissions objecting to the project were greater than 25, the Minister for Planning referred the Projects to the Independent Planning Commission (IPC) to conduct a public hearing, assess the merits of the project, and prepare a report outlining the Commission's findings on the project, including any recommendations. As part of their assessment, the IPC asked the Department of Industry - Water (DoI Water, now DPIE – Water) nine questions related to groundwater. DoI Water provided a letter response to the IPC, dated 24 April 2019. Hume Coal provided a response to the DoI Water letter on 17 May 2019, submitting that the DoI Water response to questions from the IPC contained errors and unsupported claims, and as such, should be given little weight.

Following the release of the IPC 'Independent Planning Assessment Report' (the IPC assessment report), released in May 2019, a meeting was held on 30 July 2019 between DPIE Water hydrogeologists, DPIE Planning and Assessment personnel, Hume Coal personnel, EMM and HydroSimulations/SLR Consulting hydrogeologists. Seven actions were discussed and agreed out of that meeting. The minutes were recorded by Hume Coal and distributed to all parties on 15 August 2019. The seven actions are shown in Table 1.1 and are addressed in each of the following chapters of this report.

## Table 1.1 Actions detailing additional information requirements

| No. | Item | Detail | Chapter where addressed in this report |
|---|---|---|---|
| 1 | Cross-section data | Hume Coal to provide additional north–south and east¬west sections to assist DPIE with making their assessment on impacts. | 2 |
| 2 | Hydraulic data with depth, spatially | Hume Coal is to re-evaluate original data from EIS and RTS graphs showing hydraulic conductivity with depth (Coffey's EIS graphs and refined HydroSimulations graphs in the RTS). The data is to be reproduced and charted spatially on a map or series of maps. | 3 |
| 3 | Berrima mine comparison | Hume Coal to provide an enhanced discussion of the similarities and differences between the existing Berrima Colliery and the proposed Hume Coal Project. | 4 |
| 4 | Calibration statistics | Hume Coal to provide more information on model calibration statistics. DPIE Water requested if the model predicts 70% of the monitoring bores hydrograph history match is in excess of 2 m, then what are the impacts of the 2 m drawdown on landowner bores. Hume Coal will provide information and discussion on this. | 5 |
| 5 | Uncertainty analysis | Hume Coal to describe the range of parameters explored and map them | 6 |
| 6 | Packer tests | Hume Coal to provide raw data from the packer tests conducted for the project. | 7 |
| 7 | DoI Water EIS submission | Hume Coal to reference the original submission from DoI Water to the EIS (and subsequent submissions) and consider the data and information requests from the original submission. This is to include data and information requested in the Appendix from the response to the IPC. | 8 |

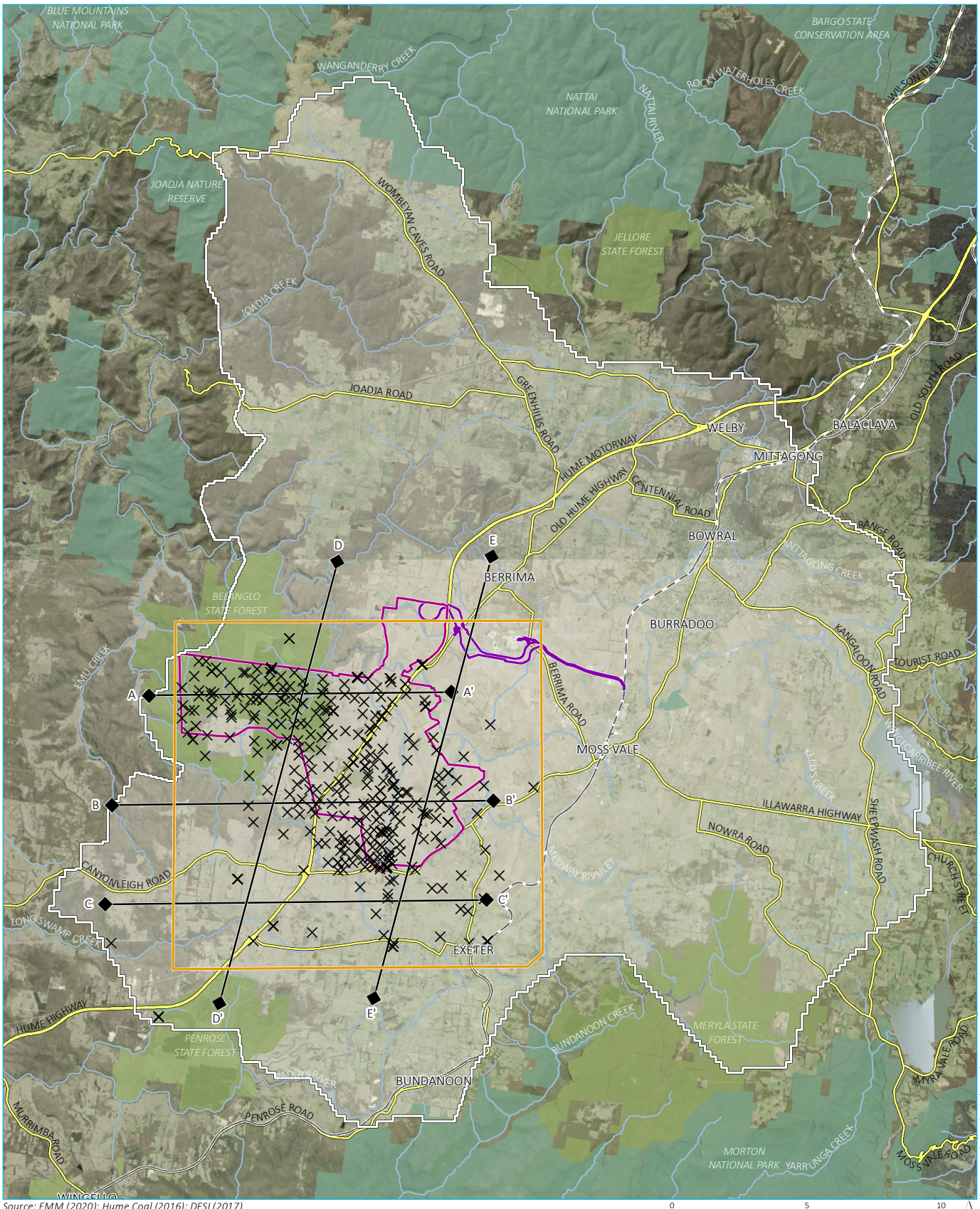
# 2 Cross-sections

The following information and cross-sections are included for delivery of action 1 (refer to Table 1.1).

Following the July 2019 meeting, Hume Coal attempted to coordinate with DPIE Water to select cross-section locations. In light of unsuccessful attempts to collaborate with the relevant parties, Hume Coal selected representative locations. Figure 2.1 shows a plan view of the cross-section locations. Sections A, B and C are east-west cross-sections, while sections D and E are in a north-east to south-west direction. Figure 2.2 to Figure 2.6 show comparisons between the Hume Coal geological model and the layers used in the numerical groundwater model (Coffey 2016b and HydroSimulations 2018). The cross-section images show geology/formations, groundwater model layers and the approximate location of the Hume Coal Project.

The cross-sections show that the thickness and general elevations of the Wianamatta Group, Hawkesbury Sandstone, Wongawilli Coal seam are consistent between the geological model and the numerical groundwater model. The groundwater model's representation of the topography does not replicate the detail of LiDAR, but rather used a more generalised representation of surface elevations. Use of a more generalised topography does not limit the regional impact predictions of the project. At a local scale, it is possible that groundwater flow could be misrepresented by using generalised topography; however, the overall potential project impacts would be similar, neglecting local scale heterogeneities. Representations of the geology and topography in the groundwater model as has been done for the Hume Coal Project is common practice, where layers are often approximated.

Since the purpose of the groundwater model is to predict wide-scale impacts and not site-specific issues, the resulting predictive modelling of the groundwater system are considered fit for purpose. The groundwater model has been reviewed numerous times by various industry experts that have all concluded that the groundwater model is a valid tool for the prediction of the effects of the proposed mine on the groundwater system (Townley 2020; HydroAlgorithmics 2016; Kalf and Associates 2016; and Hydrogeologic 2017, 2018).




Source: EMM (2020); Hume Coal (2016); DFSI (2017)

0 5 10 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMMJobs\2012\J12055 - Hume Coal_COPY\GIS\02_Maps_WATER\DPIE001_ModelComparison_20200401_01.mxd 1/04/2020

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Groundwater model extent
- Geological model extent
- Hume drill holes
- Cross section

Existing environment

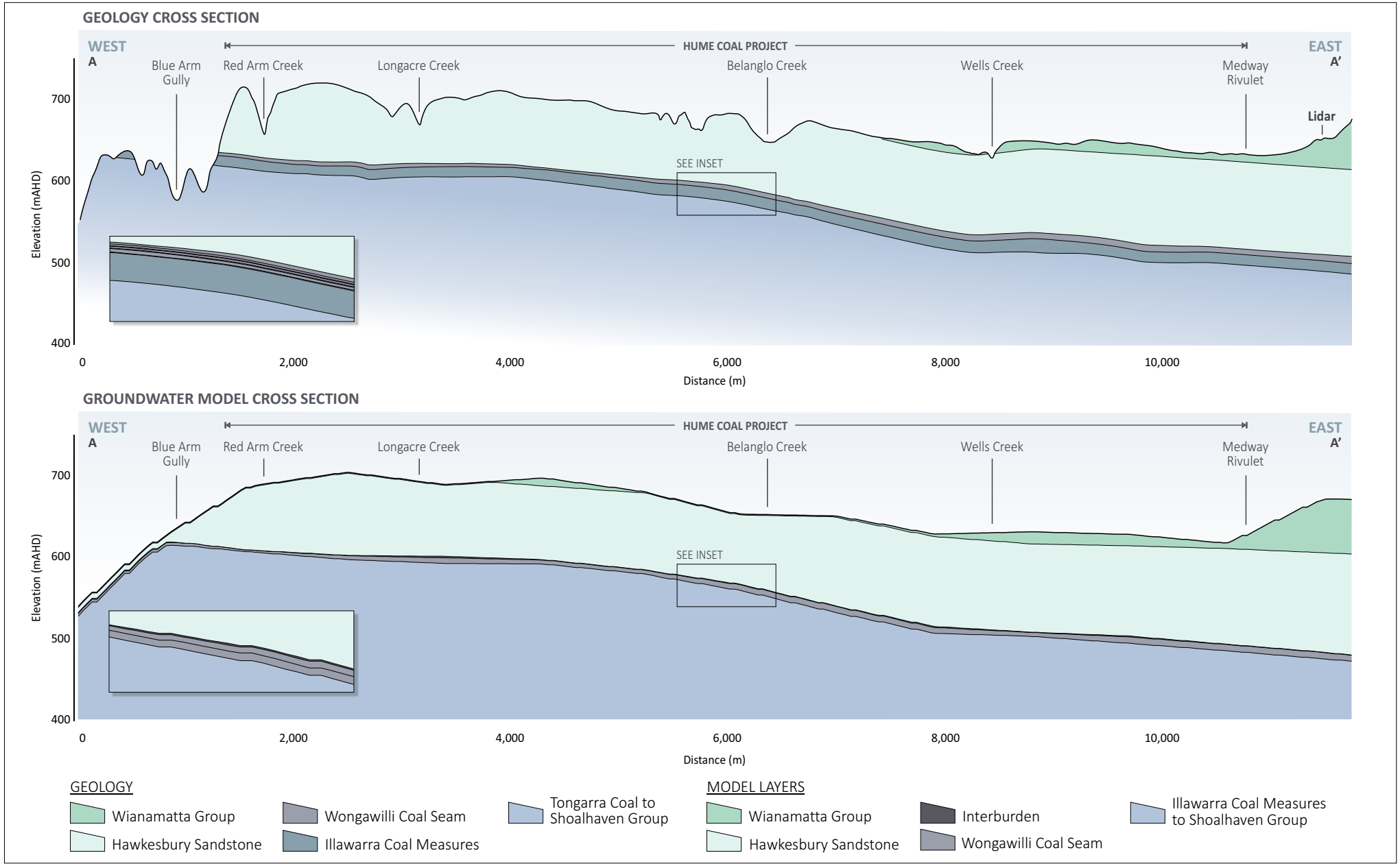
- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

# Hume Coal geological model extent and cross-section locations

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 2.1

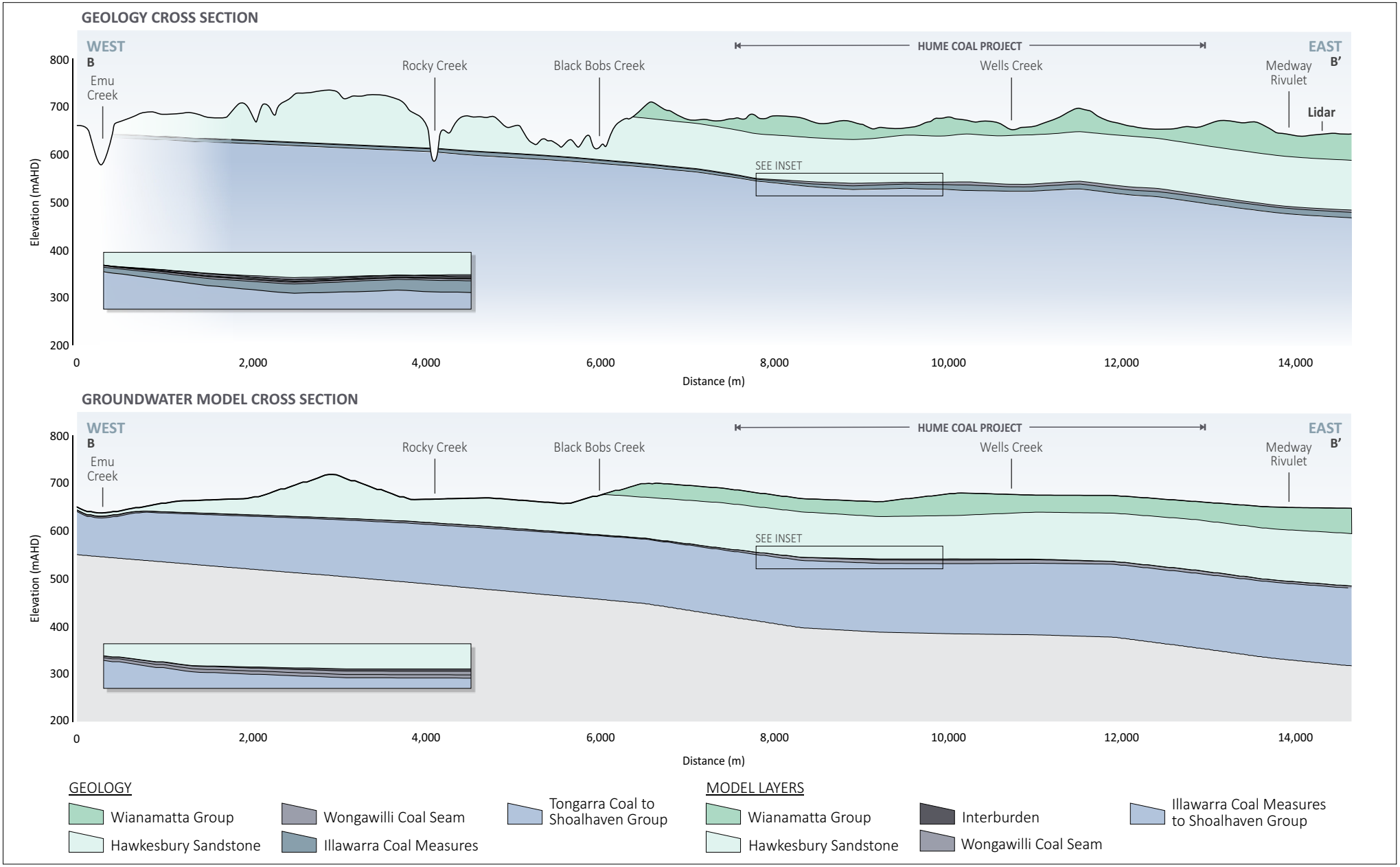
HUMECOAL PROJECT

EMM creating opportunities



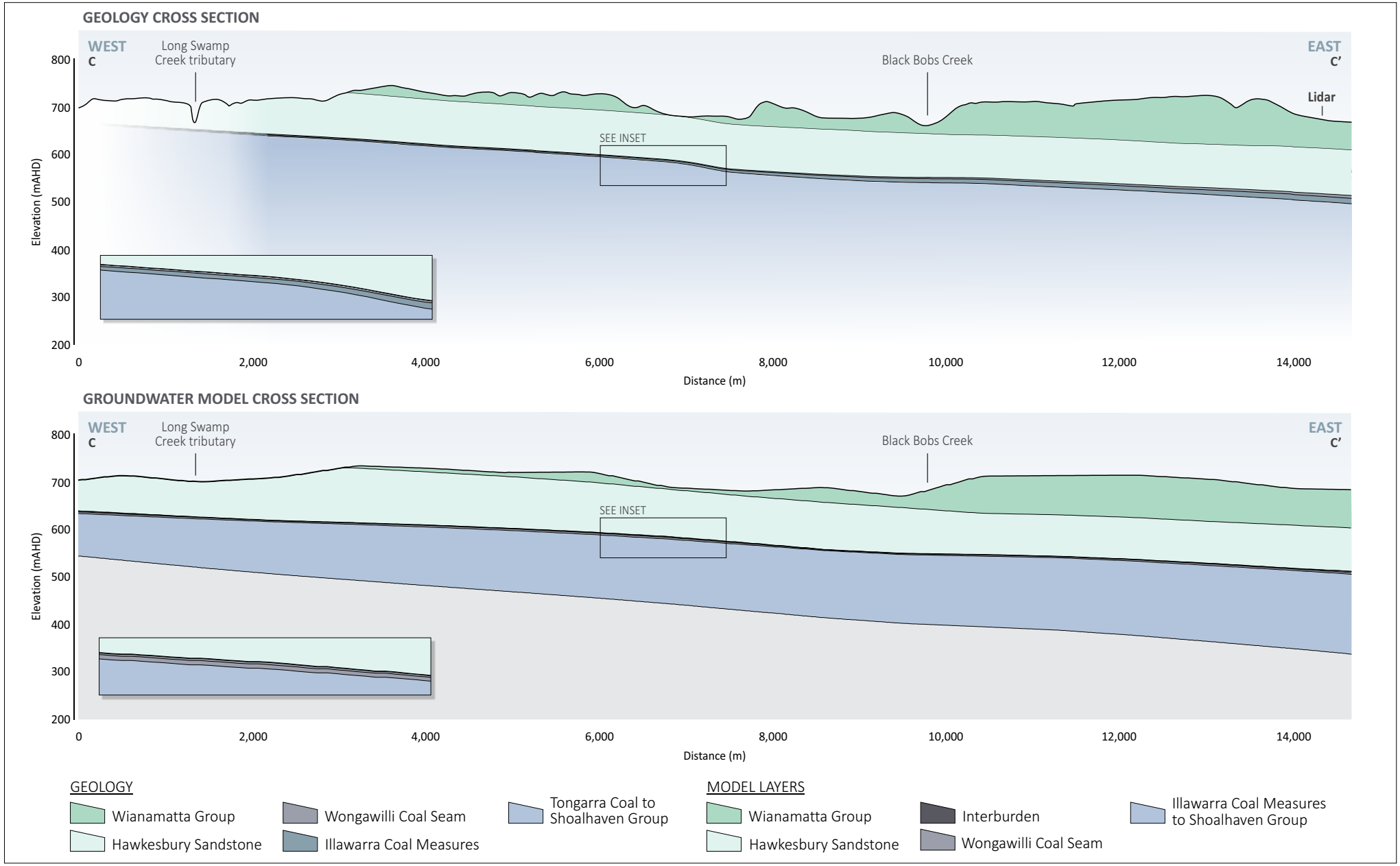

Section A–A'

Hume Coal Pty Ltd
DPIE Water report
Figure 2.2



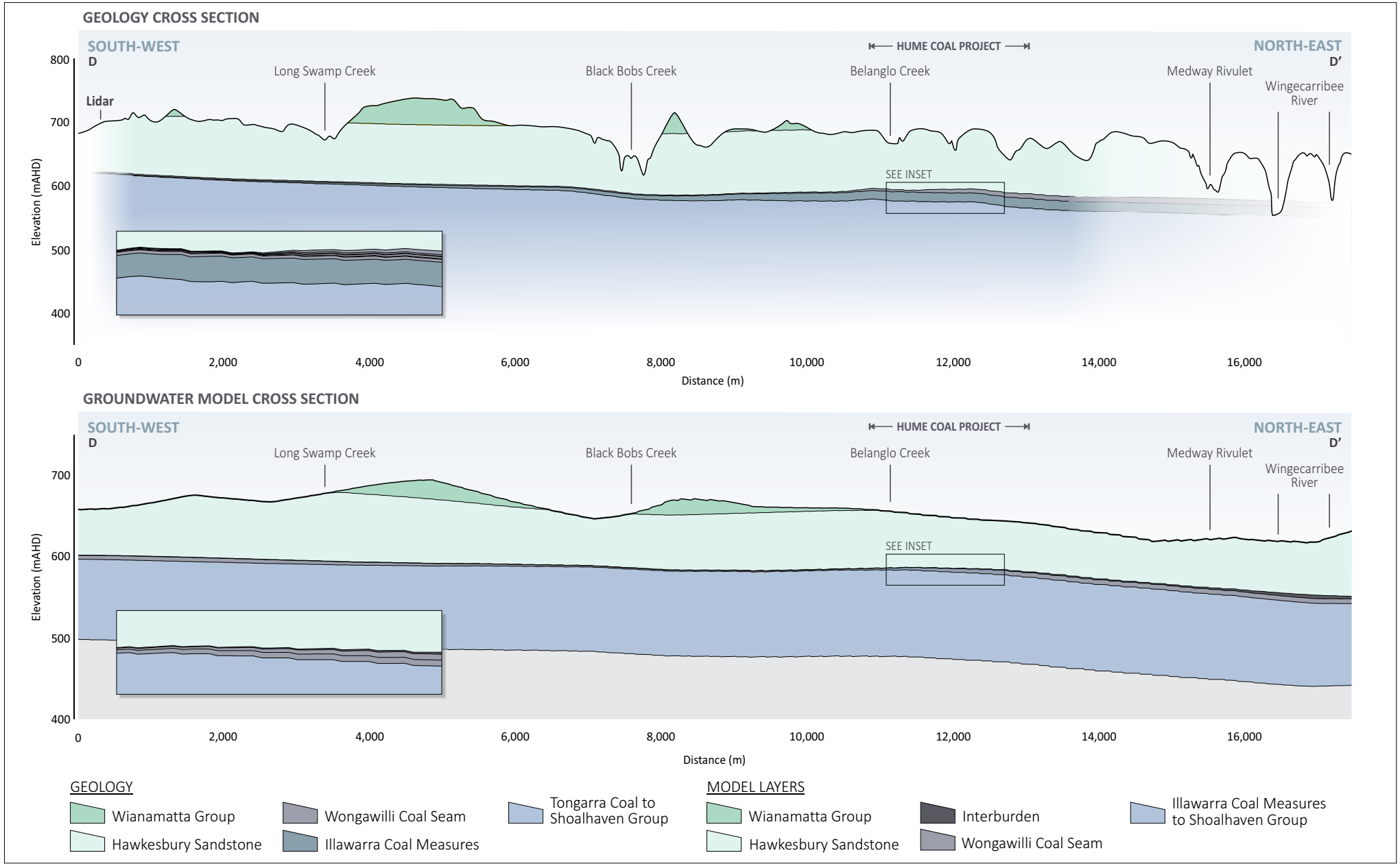

Section B–B'

Hume Coal Pty Ltd
DPIE Water report
Figure 2.3



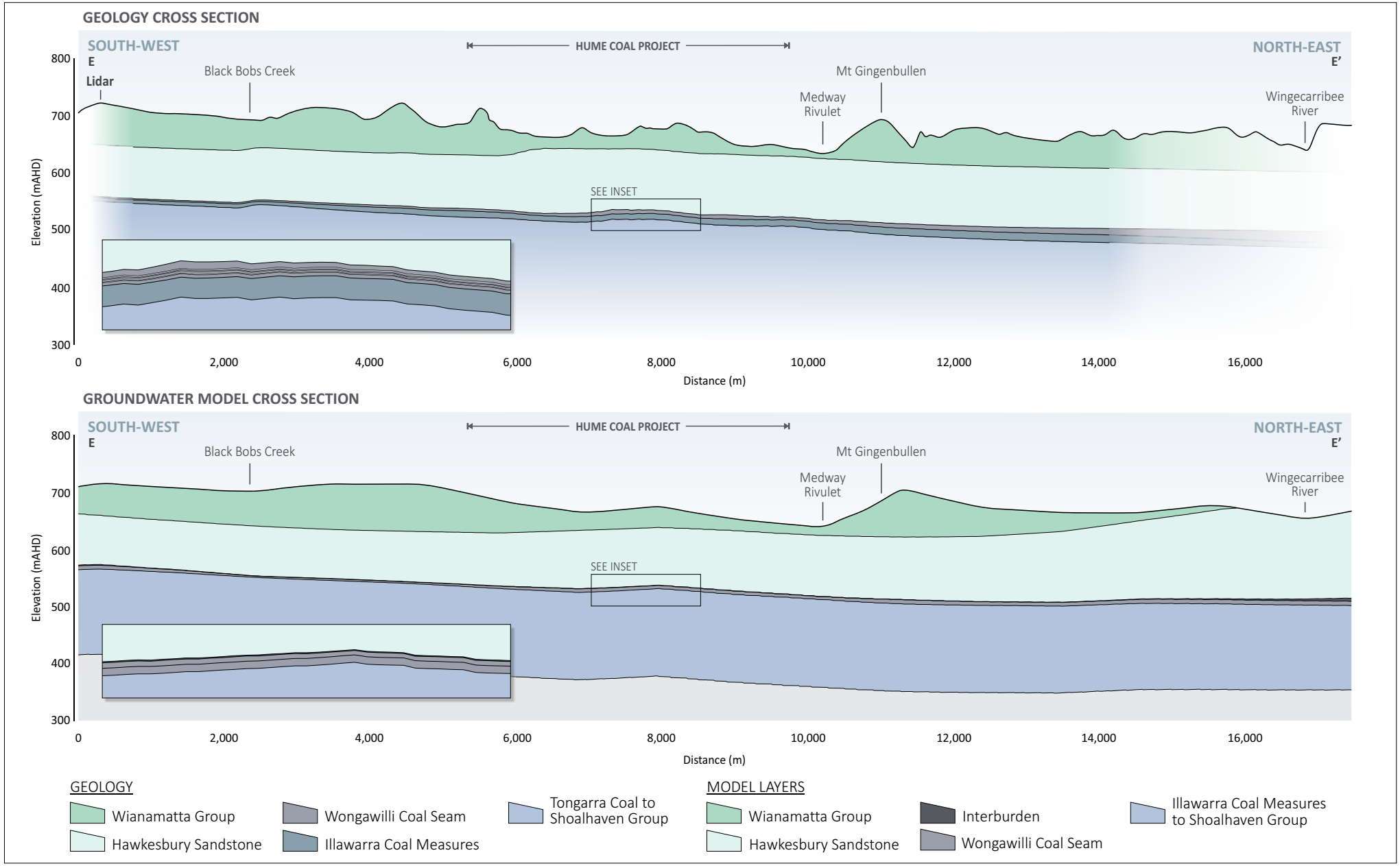

Section C–C'

Hume Coal Pty Ltd
DPIE Water report
Figure 2.4




Section D–D'

Hume Coal Pty Ltd
DPIE Water report
Figure 2.5




Section E–E'

Hume Coal Pty Ltd
DPIE Water report
Figure 2.6

# 3 Hydraulic data with depth spatially

The following data and information are included for delivery of action 2 (refer to Table 1.1).

Comments were made within the meeting between DPIE Water, Planning and Hume Coal and its consultants regarding the potential for different behavior of hydraulic conductivity (K) with depth spatially, and that a single depth function may not be appropriate for the whole model domain, particularly near the project area and near the model boundary.

In order to address these comments, the regional aquifer tests, used to inform the hydraulic conductivity values used in the EIS model, and the depth function for the uncertainty analysis have been plotted spatially. The aquifer tests were then subdivided in to three regional zones based on the elevation of the Wongawilli seam. The division of the Wongawilli seam elevation was selected somewhat arbitrarily in order to provide a useful division of aquifer test data. The seam dips to the east where generally greater thickness of Hawkesbury Sandstone is present, and there is a greater depth of cover. The selected zones (as seen in Figure 3.1) are as follows:

- zone 1: aquifer tests where Wongawilli seam elevation was > 580 mAHD (purple points on Figure 3.1);
- zone 2: aquifer tests where Wongawilli seam elevation was between 480 mAHD – 580 mAHD (blue points on Figure 3.1); and
- zone 3: aquifer tests where Wongawilli seam elevation was <480 mAHD (yellow points on Figure 3.1).

Figure 3.2 shows the aquifer test data for zone 1, where the Wongawilli seam floor elevation is greater than 580 mAHD. The data is divided by testing method. Figure 3.3 and Figure 3.4 show the measured hydraulic conductivity of all lithologies unit in zones 2 and 3, respectively. Figure 3.5 shows all test data from all the zones, and the EIS hydraulic conductivity data is also included for reference.

These subdivisions break up the aquifer test dataset so that there are similar number of locations (sites) sampled within each zone (refer to Table 3.1). However, at one site within the Hume Coal Project area multiple sample depths were taken for core and packer testing investigations; as such, there are a greater number of total tests in the zones overlying the project area. This is compared to the single test per hole for the Specific Capacity testing data derived from the NSW Government database which accounts for all tests in the eastern zone (Coffey 2016a).

**Table 3.1 Number of aquifer tests per zone**

| Wongawilli seam elevation | Number of aquifer test sites | Total number of aquifer tests * | Zone number |
|---|---|---|---|
| >580 mAHD | 45 | 76 | 1 |
| 480-580 mAHD | 48 | 116 | 2 |
| <480 mAHD | 40 | 40 | 3 |

Note: * multiple tests have occurred at test locations

The aquifer test results in the figures provided (Figure 3.2 to Figure 3.5) show no appreciable difference in the relationship between hydraulic conductivity and depth in different zones across the model domain. Therefore, a single depth-function was appropriate to use in the uncertainty analysis in the groundwater modelling for the whole model domain.

Figure 3.6 to Figure 3.9 shows the hydraulic conductivity data for the Hawkesbury Sandstone in 50 m depth increments estimated from Hume Coal slug tests, packer tests, core tests and pumping tests, as well as NSW Government database derived specific capacity tests.

The horizontal hydraulic conductivity data, used in the groundwater model, is presented in Figure 3.10. The horizontal hydraulic conductivity values used per layer in the groundwater model show a decreasing trend in the model layers. However, as shown in Figure 3.10, the values used in the model are slightly higher (more permeable) than the regional geometric mean of the data, while being slightly below the Hume Coal site specific data. Therefore, the model is conservative. Figure 3.11 shows the same data for the vertical hydraulic conductivity values used in the model domain.

Figure 3.12 shows box and whickers plots of the horizontal hydraulic conductivity data used in the groundwater model in relation to depth below ground surface. Also included in the figure is the horizontal and vertical hydraulic conductivity values used in the uncertainty analysis.

The field data provided in the box and whisker diagrams in Figure 3.12 includes hydraulic conductivity data from core (both horizontal and vertical tests), packer, specific capacity and pump testing from Hume Coal area as well as the Tahmoor Mine in the Southern Coalfield. The Tahmoor Mine dataset provides hydraulic conductivity data at greater depths than the Hume Coal data alone due to Tahmoor being a deeper mine.

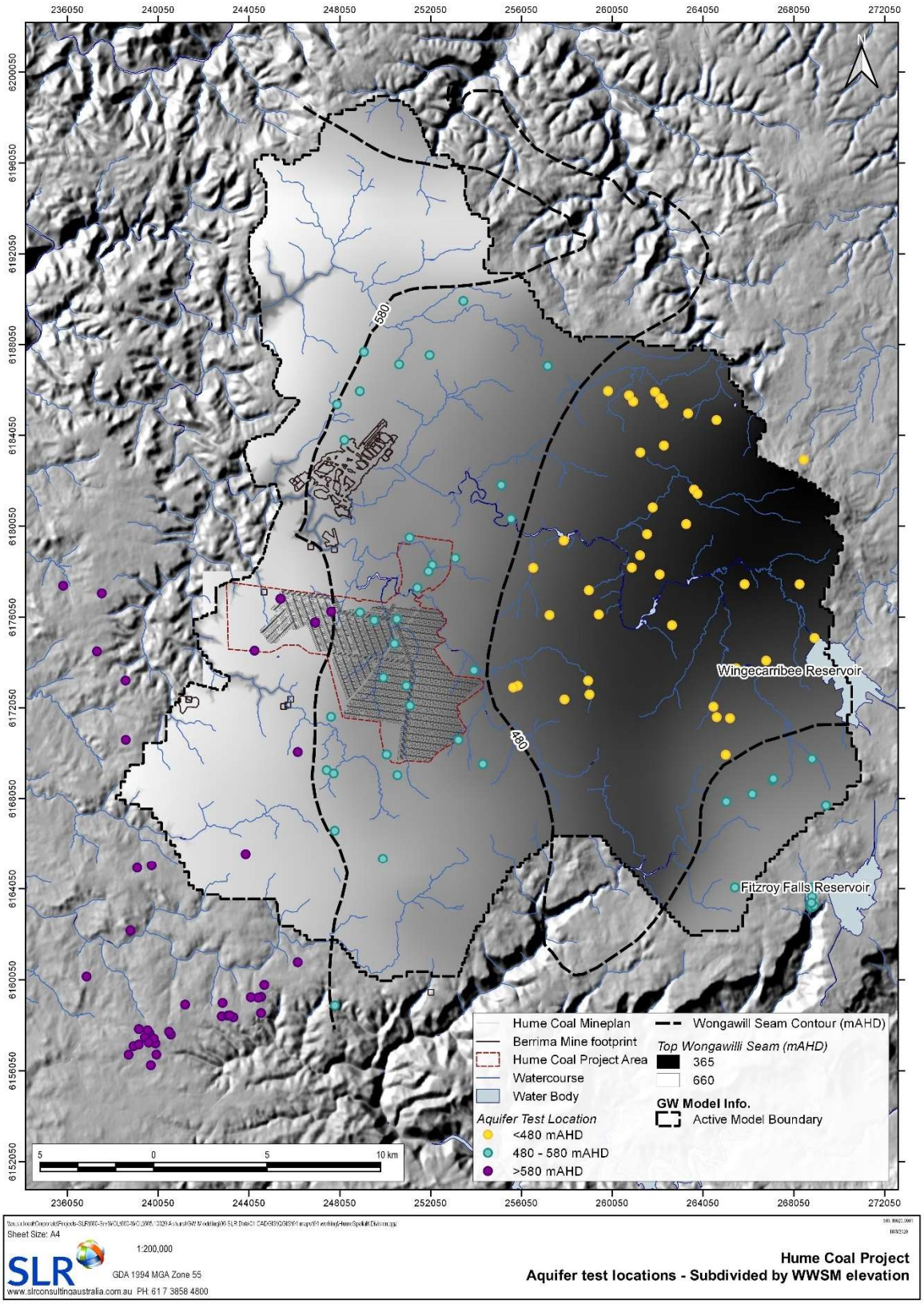



**Figure 3.1 Aquifer test locations subdivided by Wongawilli seam elevation**

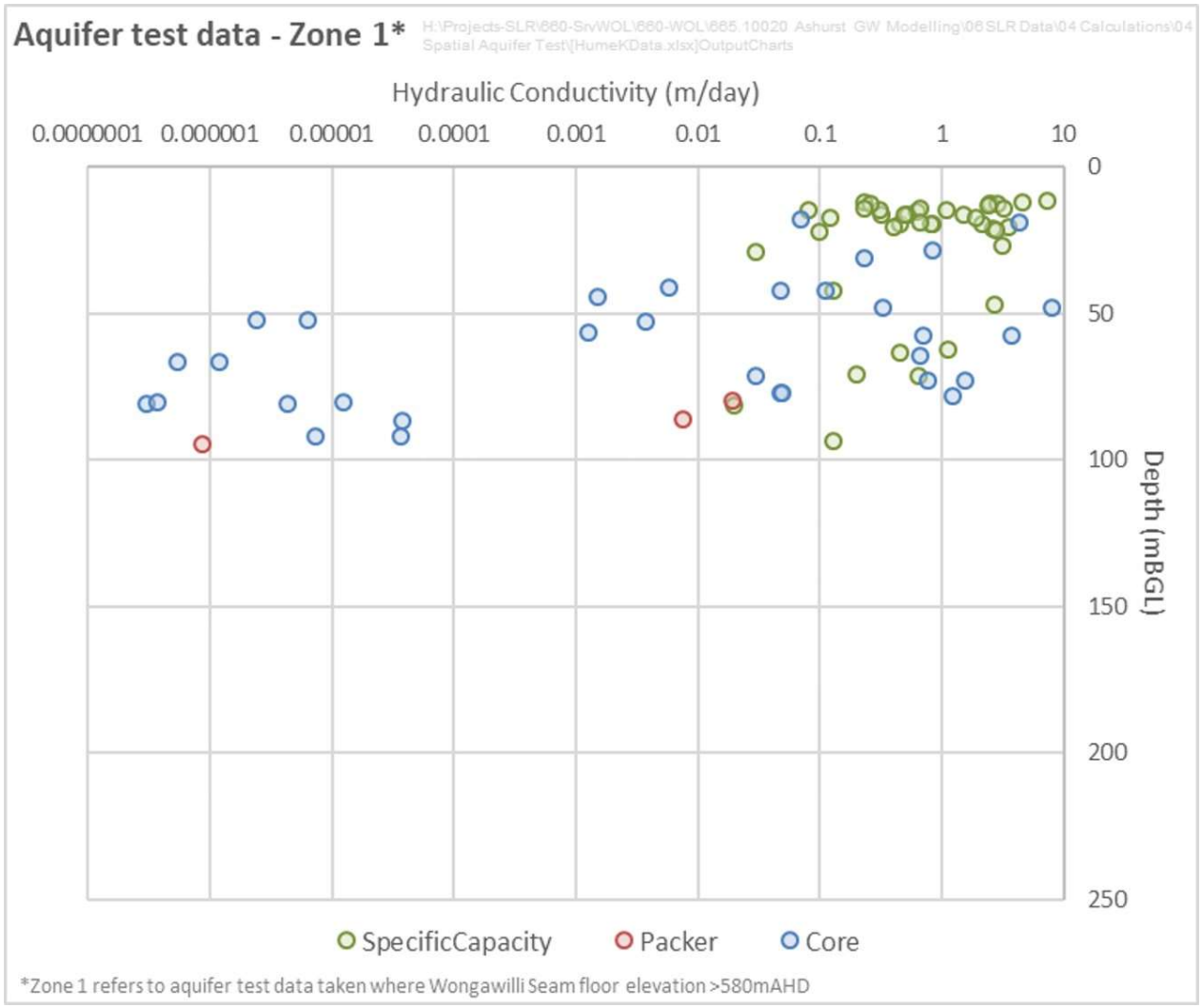



**Figure 3.2 Aquifer test data hydraulic conductivity with depth – Zone 1**

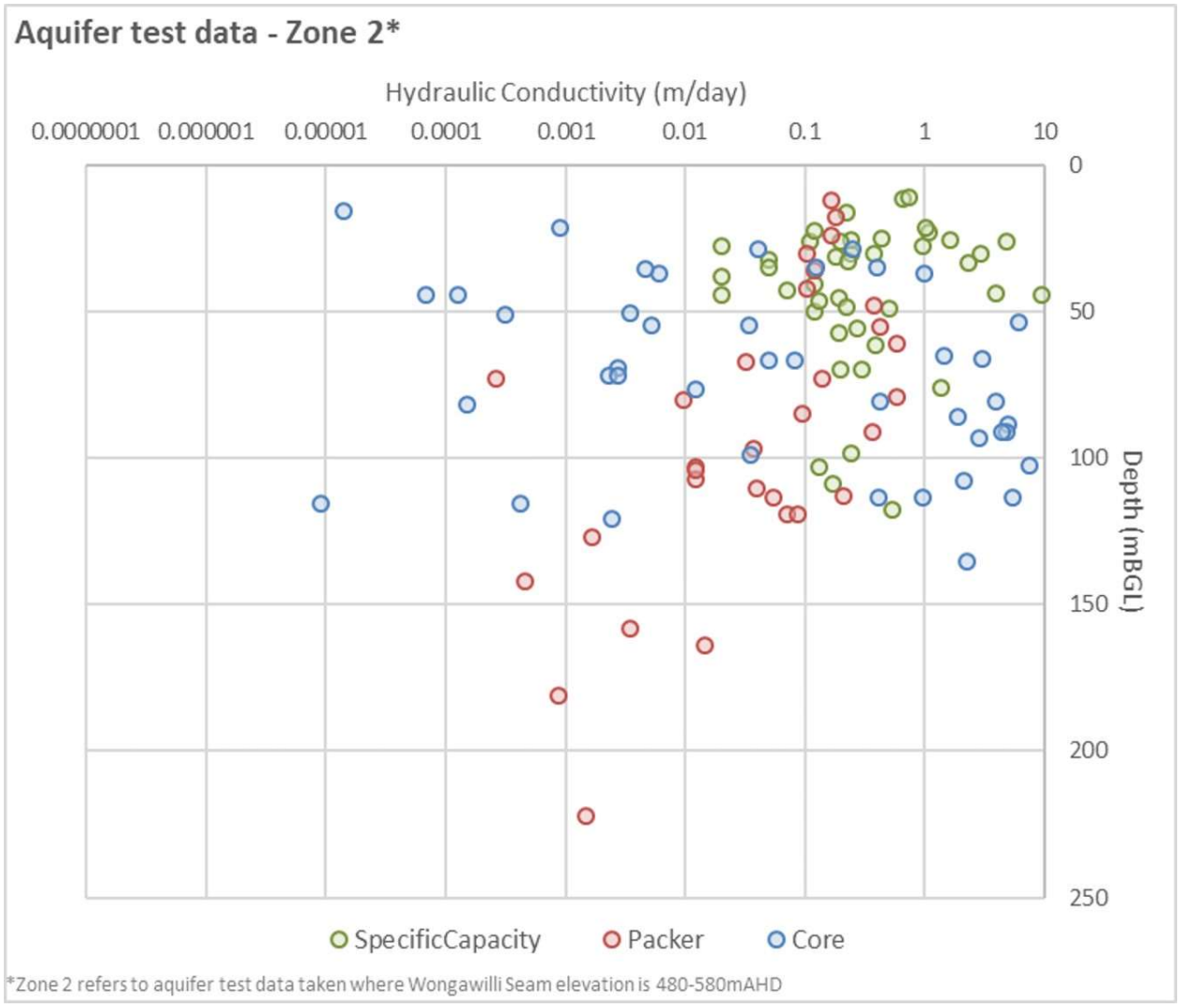



**Figure 3.3 Aquifer test data hydraulic conductivity with depth – Zone 2**

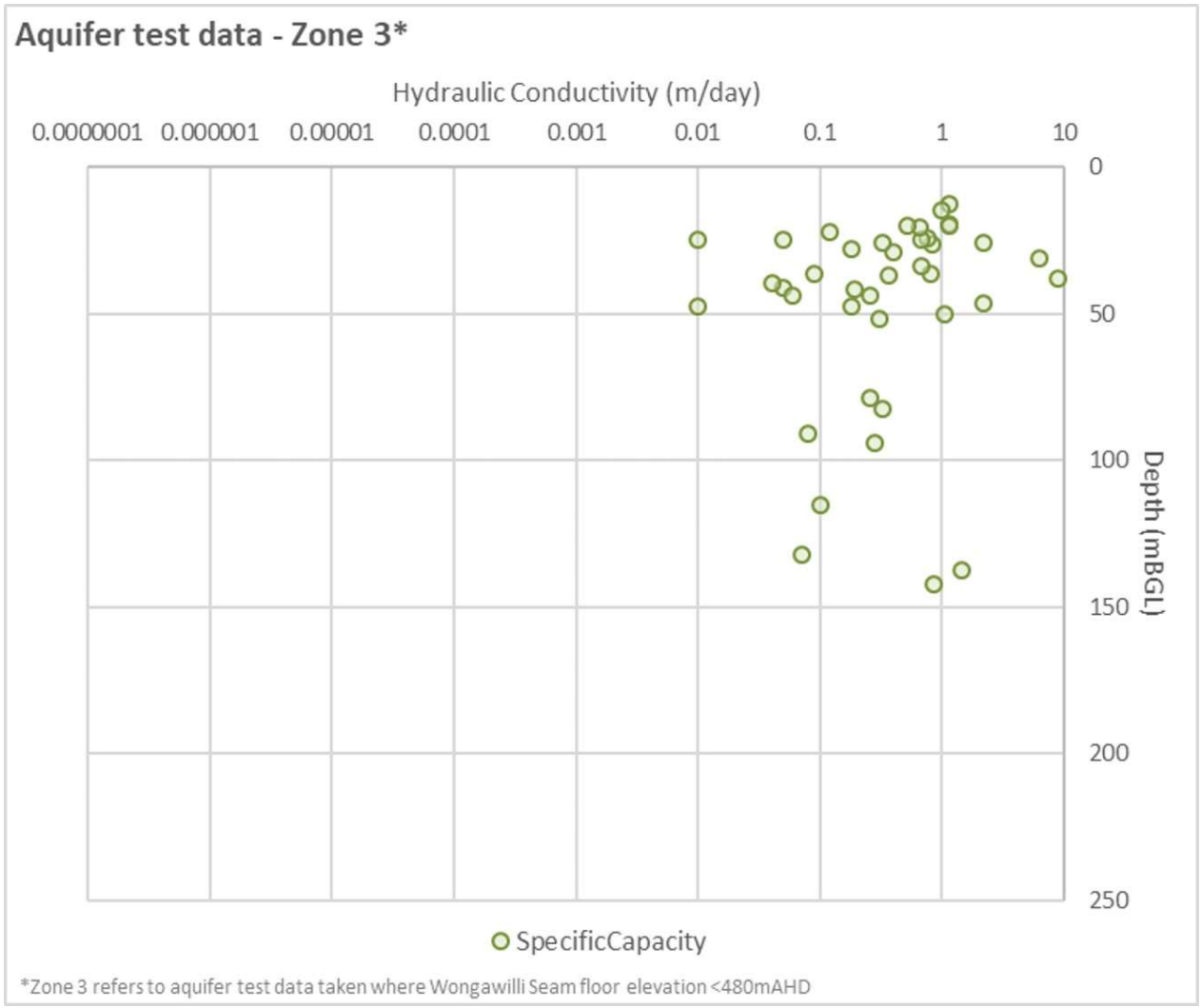



**Figure 3.4 Aquifer test data hydraulic conductivity with depth – Zone 3**

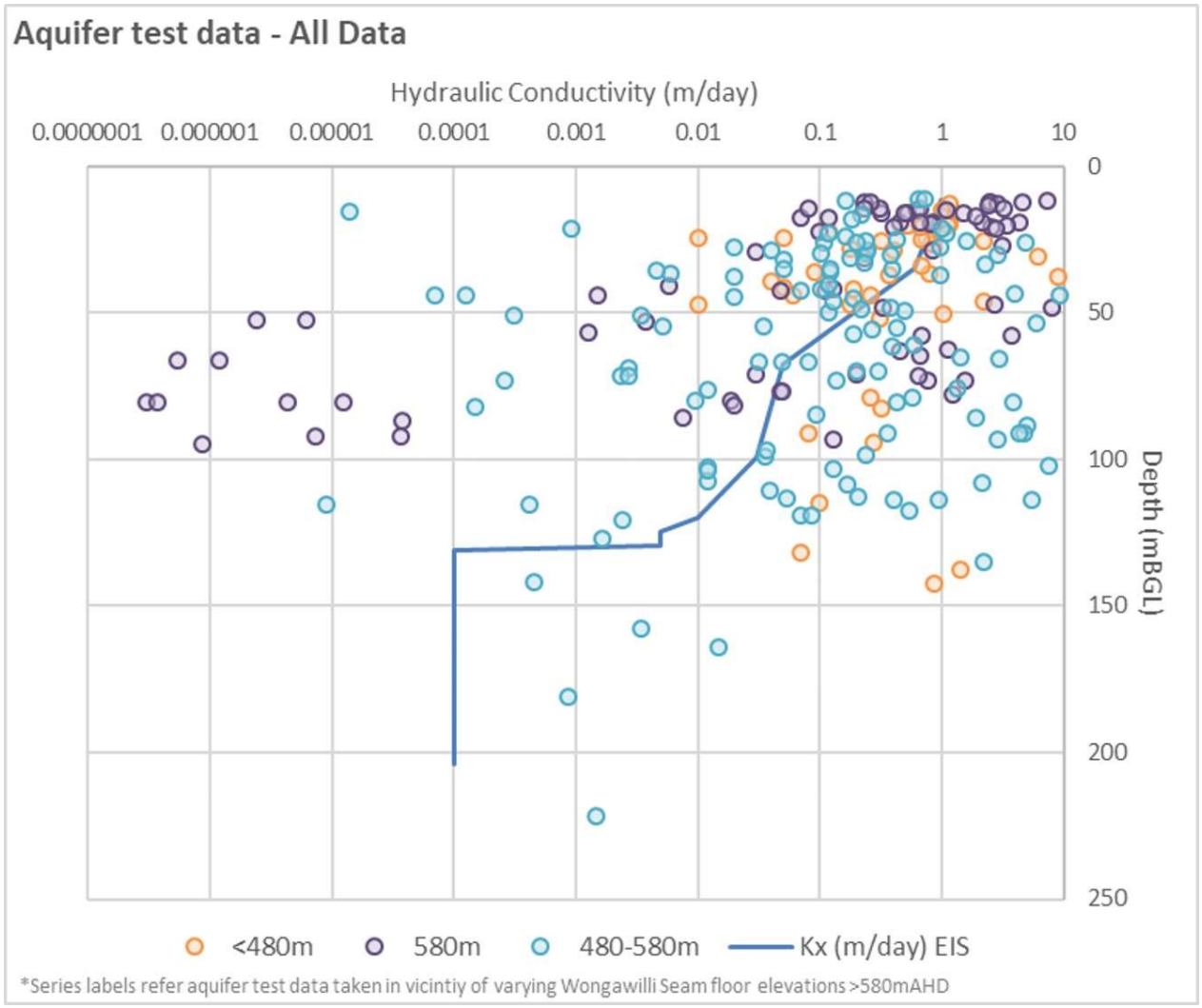
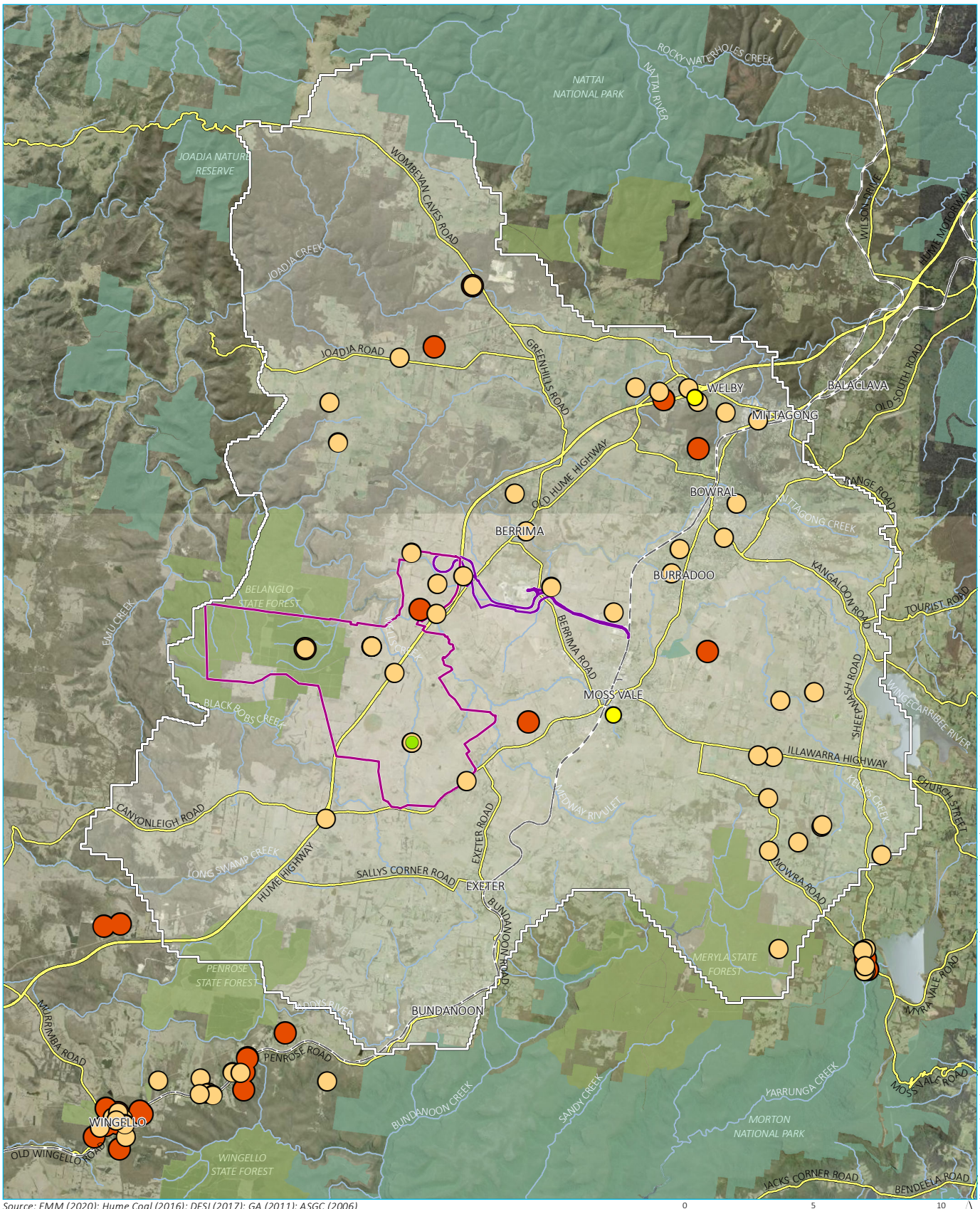



**Figure 3.5** **Aquifer test data hydraulic conductivity with depth**




Source: EMM (2020); Hume Coal (2016); DFSI (2017); GA (2011); ASGC (2006)

0 5 10 km

GDA 1994 MGA Zone 56

N

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KEY

- Hume Coal Project area
- Berrima Rail Project area
- Groundwater model boundary

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

Measured hydraulic conductivity 0-50m HBSS m/day

- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 1.0
- 1.0 - 20.0

# Hawkesbury Sandstone measured hydraulic conductivity plan (0-50 m below ground)

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 3.6

HUMECOAL PROJECT

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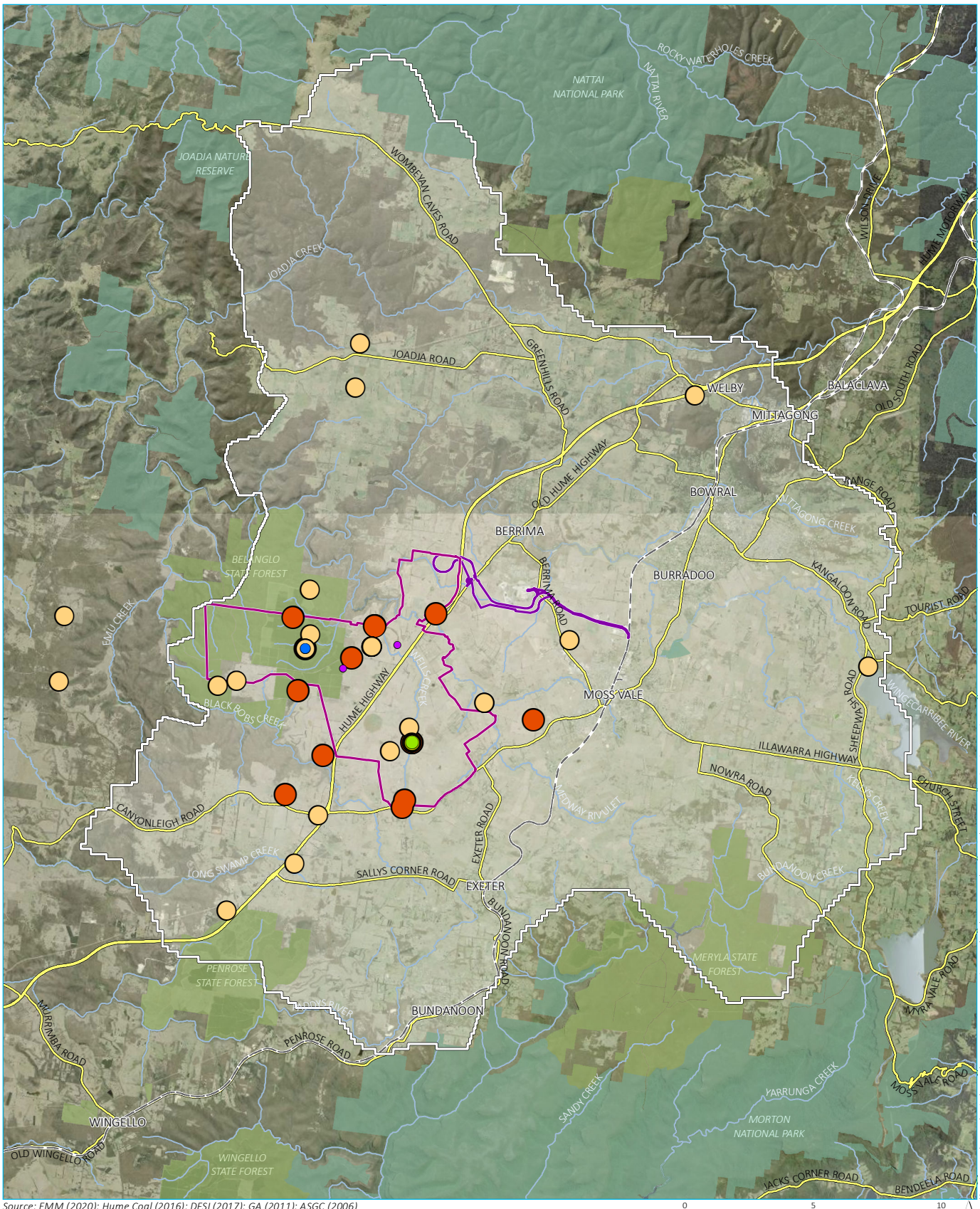


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*Source: EMM (2020); Hume Coal (2016); DFSI (2017); GA (2011); ASGC (2006)*

0 5 10 km

GDA 1994 MGA Zone 56

N

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Groundwater model boundary

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

Measured Hydraulic Conductivity 50-100m HBSS m/day

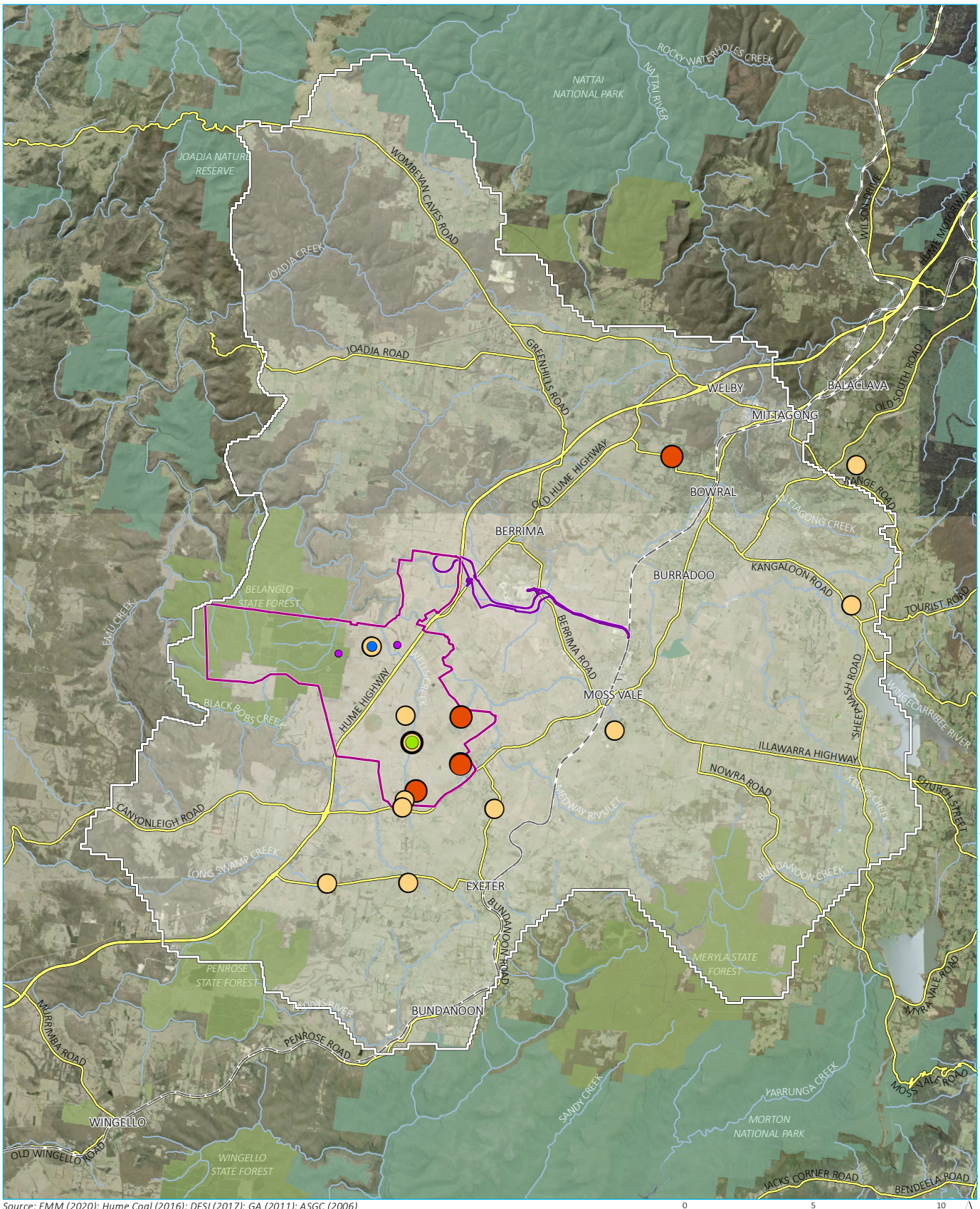
- <0.000001
- 0.000001 - 0.0001
- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 1.0
- 1.0 - 20.0

# Hawkesbury Sandstone measured hydraulic conductivity plan (50-100 m below ground)

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 3.7

HUMECOAL PROJECT

EMM creating opportunities

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*Source: EMM (2020); Hume Coal (2016); DFSI (2017); GA (2011); ASGC (2006)*

0 5 10 km

GDA 1994 MGA Zone 56

N

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Groundwater model boundary

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

Measured Hydraulic Conductivity 100-150m HBSS m/day

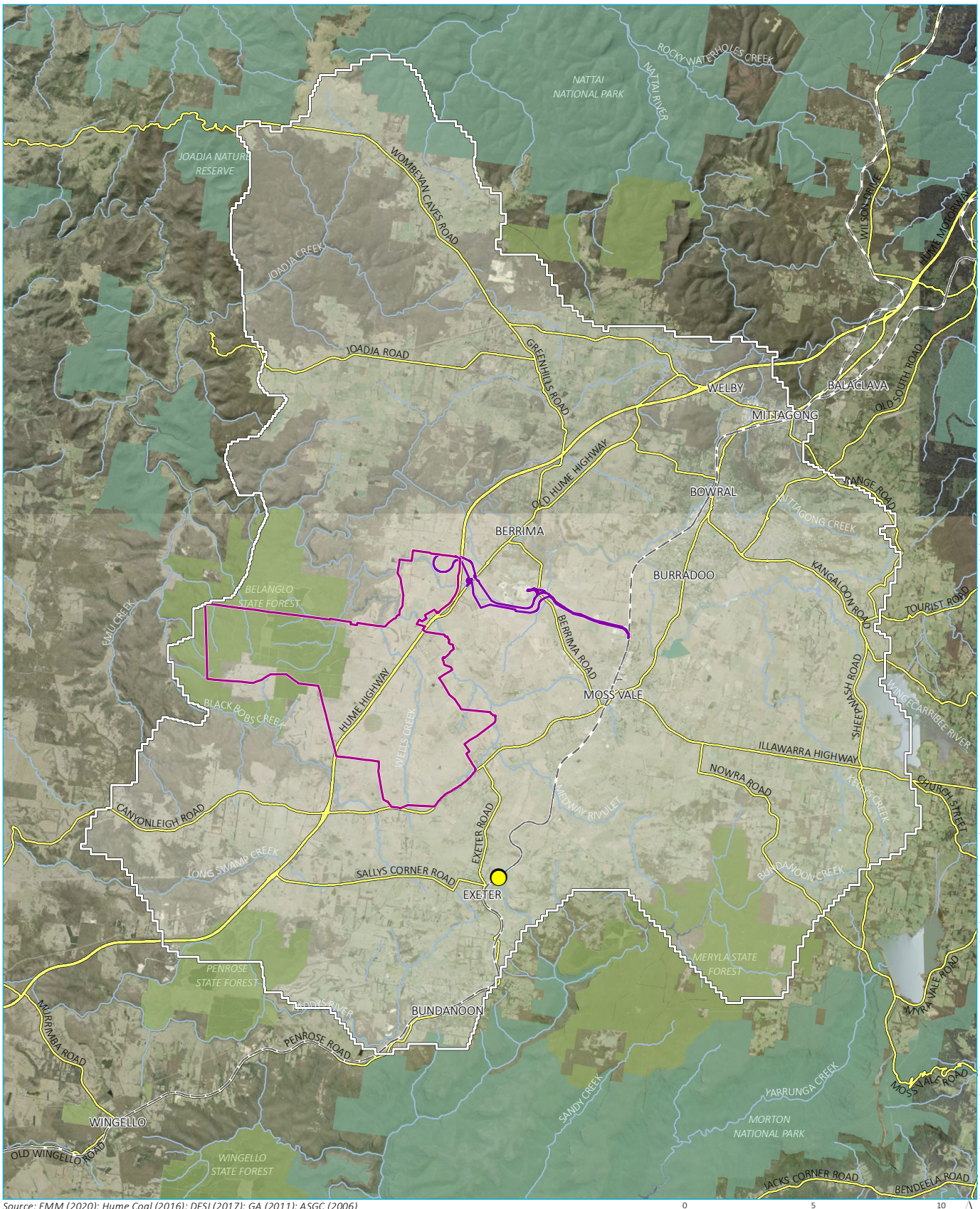
- <0.000001
- 0.000001 - 0.0001
- 0.0001 - 0.001
- 0.01 - 1.0
- 1.0 - 20.0

# Hawkesbury Sandstone measured hydraulic conductivity plan (100-150 m below ground)

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 3.8

HUMECOAL PROJECT

EMM creating opportunities




Source: EMM (2020); Hume Coal (2016); DFSI (2017); GA (2011); ASGC (2006)

0 5 10 km

GDA 1994 MGA Zone 56

N

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KEY

- Hume Coal Project area
- Berrima Rail Project area
- Groundwater model boundary

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest

Measured Hydraulic Conductivity >150m HBSS m/day

- 0.001 - 0.01

# Hawkesbury Sandstone measured hydraulic conductivity plan (>150 m below ground)

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 3.9

HUMECOAL PROJECT

EMM creating opportunities

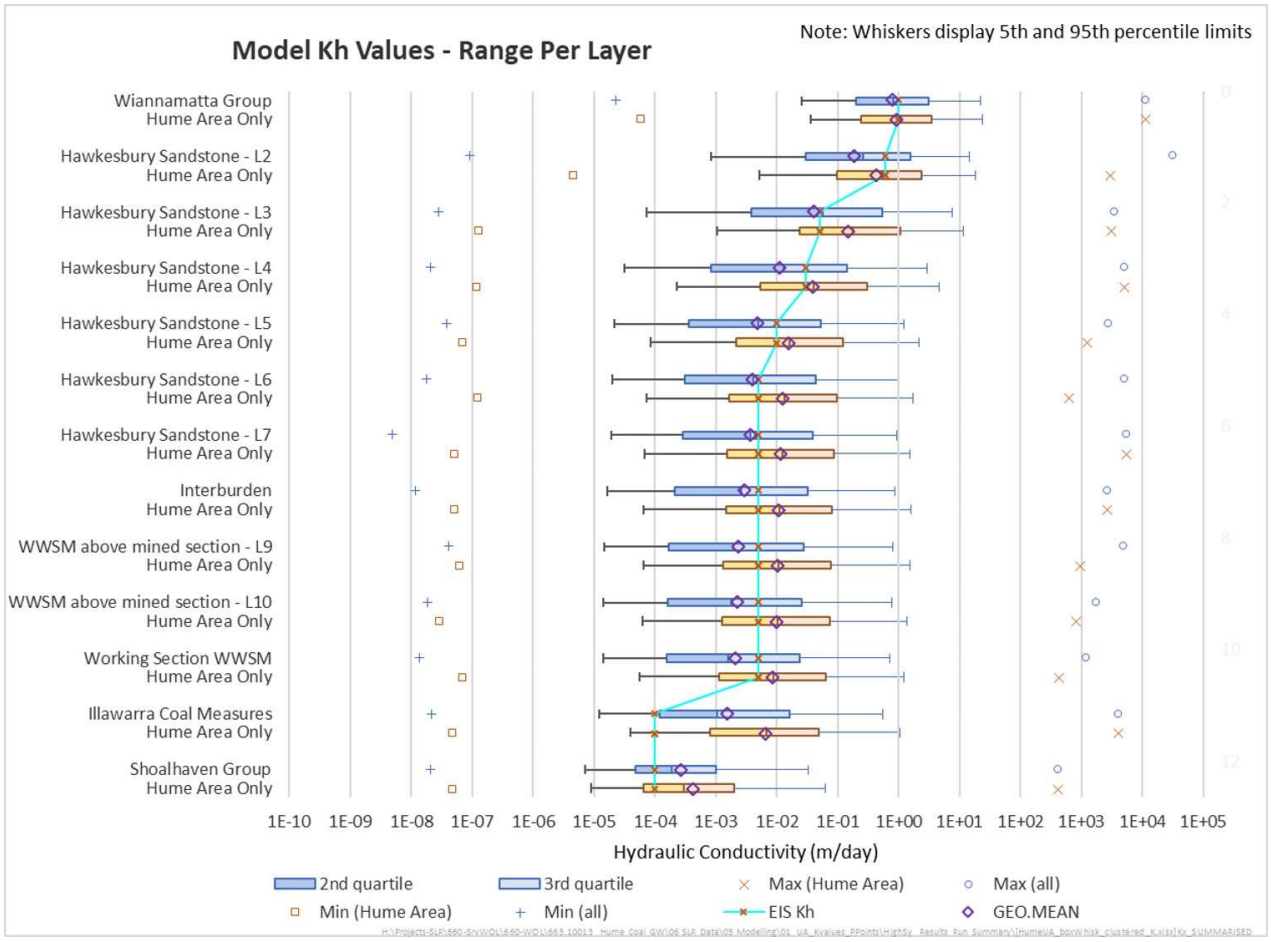



**Figure 3.10** **Box and whisker plots of the groundwater model horizontal hydraulic conductivity – all layers**

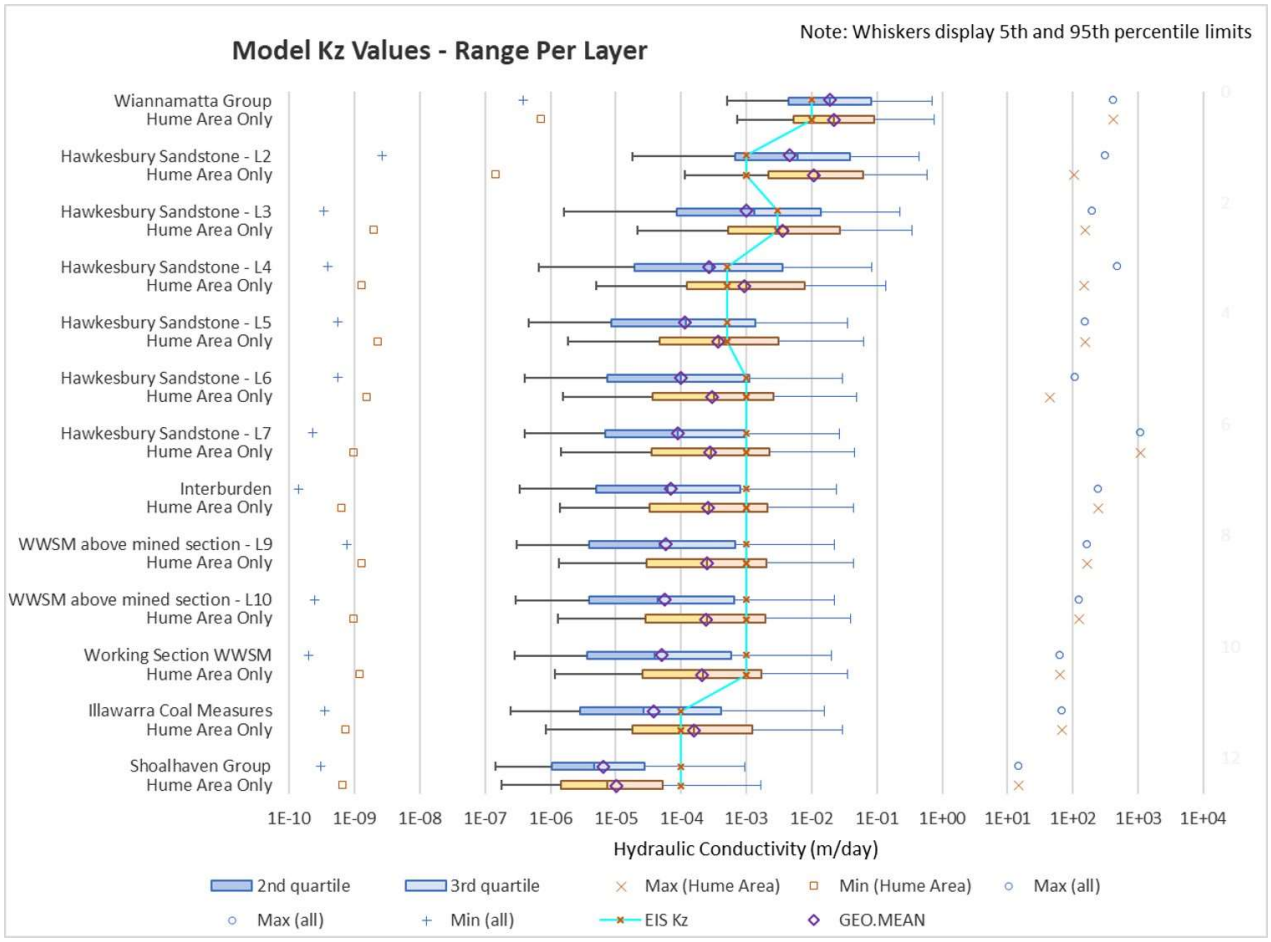



**Figure 3.11** **Box and whisker plots of the groundwater model vertical hydraulic conductivity – all layers**

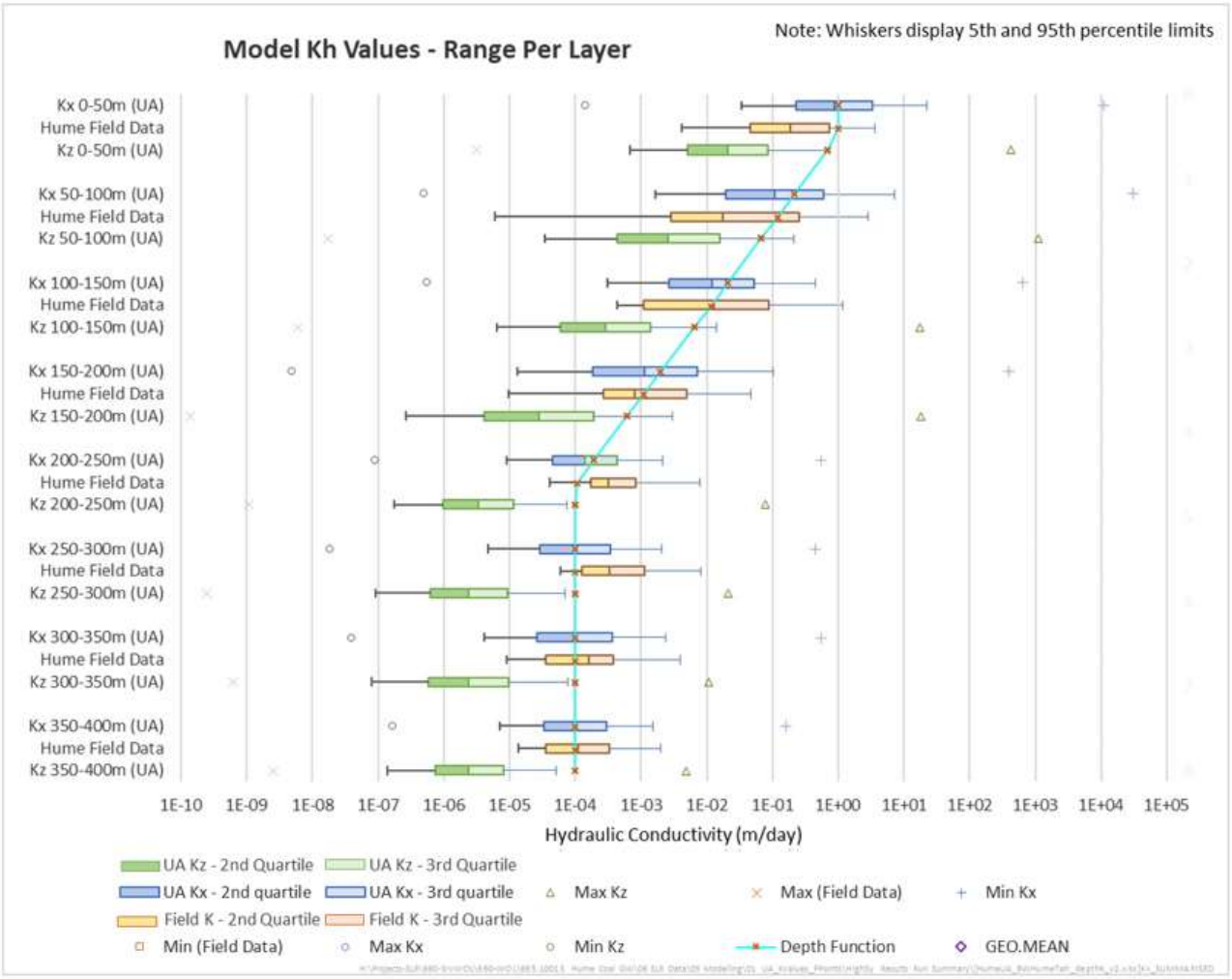



**Figure 3.12 Box and whisker plots of the groundwater model hydraulic conductivity with depth**

# 4 Berrima Colliery vs Hume Coal mine

The following is included for delivery of action 3 (refer to Table 1.1).

A comprehensive discussion paper on the similarities and differences between the existing Berrima Colliery and the proposed Hume Coal mine is included in Attachment A. A summary of the similarities and differences is shown below in Table 4.1.

**Table 4.1 Summary of Hume Coal and Berrima Colliery comparison**

| Feature | Similarities | Differences | Implications |
|---|---|---|---|
| Landscape location | Both locations are within the Southern Coalfield in the Sydney Basin. | • Berrima Colliery mine workings are in close proximity to Wingecarribee River.<br>• Due to original mine access via Wongawilli seam outcrop and due to mine water management, groundwater has been discharging from the Berrima Colliery drain adit into river for approximately 100 years.<br>• Hume Coal Project will access Wongawilli seam via drifts from ground surface.<br>• The distance of proposed Hume Coal mine from a surficial outcrop of the Wongawilli Coal Seam is at least 500 m, and to the north-west of the Project which is at a higher elevation than in the mine area. | • Due to Hume Coal Project distance to Wongawilli seam outcrop and difference in access, Hume Coal Project will not result in free drainage groundwater discharge to a watercourse.<br>• Depressurisation of Hawkesbury Sandstone at Hume Coal Project will be considerably less due to location in landscape and mining method. |
| Mining method | None. | • Berrima Colliery had some areas of full pillar extraction.<br>• Historical access to mine workings at Berrima Colliery was via an adit into outcropping Wongawilli seam.<br>• Hume Coal will maintain pillars to limit subsidence and goaf development.<br>• Hume Coal will progressively place rejects in mined panels and will actively inject water behind sealed bulkheads. | • Hume Coal Project mine will be more stable with low risk of subsidence.<br>• Groundwater recovery will occur faster at Hume Coal Project due to injection of water behind sealed bulkheads. |
| Geology | Stratigraphy is generally consistent at both locations. | • Wianamatta Group shale is absent at Berrima Colliery.<br>• Depth to mining the Wongawilli Seam is generally shallower at Berrima Colliery. | • See below (hydrogeology). |

## Table 4.1 Summary of Hume Coal and Berrima Colliery comparison

| Feature | Similarities | Differences | Implications |
|---|---|---|---|
| Hydrogeology | • Same dominant hydrostratigraphic units (aquifers and aquitards) at both locations.<br>• Hydraulic pressure in the lower Hawkesbury Sandstone will decline due to mining at both locations. | • Hume Coal Project has a substantially more spatially and temporally extensive monitoring network and hydraulic testing dataset compared with Berrima Colliery. | • Baseline monitoring at Hume Coal Project informs for a more robust conceptual understanding and allows continued verification of groundwater model and review of potential impacts. This also allows for a more accurate groundwater model, leading to better understanding and management of potential impacts in advance of them occurring.<br>• Observations (measured discharge) at Berrima Colliery can be used as proxy for mine water inflows to inform Hume Coal Project groundwater model calibration. |
| Mine water management | None | • Berrima Colliery discharged mine water to Wingecarribee River for approximately 100 years.<br>• Gravity flow of intercepted groundwater from workings to river discharge at Berrima Colliery.<br>• Hume Coal will progressively backfill panels with waste reject and inject water behind sealed bulkheads. | • Zero discharge planned at Hume Coal Project.<br>• Reduced groundwater infiltration to mine workings at Hume Coal Project due to progressive sealing of panels.<br>• Faster groundwater recovery at the Hume Coal Project. |

# 5 Calibration statistics

The following information is included for delivery of action 4 (refer to Table 1.1). The key points for this action relate to the calibration statistics, namely the root mean square (RMS) or scaled root mean square (SRMS), and the history match for bores used for calibration purposes (ie model derived compared to observed groundwater levels).

The following guiding principles from the Australian Groundwater Modelling Guidelines (AGMG; Barnett et al 2012) are relevant for the discussion on model calibration and prediction performance:

> Guiding Principle 5.2: The calibration process should be used to find model parameters that prepare a model for use during predictions of future behaviour, rather than finding model parameters that explain past behaviour.
>
> Guiding Principle 5.4: Performance measures should be agreed prior to calibration and should include a combination of quantitative and non-quantitative measures. The scaled root mean squared error (SRMS) is a useful descriptor of goodness of fit when the only objective is to fit historical measurements of heads but is less useful when automated calibration methods are used. A target SRMS of 5% or 10% is only meaningful when those setting the target know that it is achievable for a particular kind of problem and a particular environment with a known density of informative data.
>
> Guiding Principle 7.4: Analysis of uncertainty should recognise that there is more uncertainty when reporting confidence intervals around an **absolute** model output, and less uncertainty when a prediction can be formulated as a subtraction of two model results.

Following the release of the IPC report and as recommended by the IPC in recommendation 5 (R5), Hume Coal engaged Dr Lloyd Townley of GW SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the groundwater model. DPIE advised Hume Coal, following the release of the IPC report, that they would not be willing to jointly engage an independent expert. The full review is contained in Townley (2020), which is Annexure C of Appendix B of the IPC response report (EMM 2020).

Consistent with previous reviewers, Dr Townley's review finds that the modelling undertaken for the project is fit for purpose, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the project area (Townley 2020). A more detailed summary of the review can be found in the IPC response report in Section 5.4.1.

The NSW Government independent peer reviewer, Hugh Middlemis (HydroGeoLogic 2018), stated that, with reference to the calibration of the Hume Coal Project groundwater model:

> "Calibration of aquifer property values (Kh, Kv, S, Sy) has been well constrained by pumping test estimates of property values, and by simultaneously honouring observed groundwater levels, along with the measured Berrima mine inflow (deep system) and inferred stream baseflows (shallow system). **This is a best practice approach that reduces model non-uniqueness problems** (that many different sets of model inputs can produce nearly identical aquifer head distributions)."

All available data collected by Hume Coal has been used in developing the conceptual and numerical model. There are 345 individual exploration and groundwater monitoring drill holes for the project (179 of which are within the proposed mining area). The hydraulic conductivity data in the model calibration is extensive and all available data for the project and surrounding mines was utilised in this calibration. The data set is extensive and the groundwater model build and calibration followed best practice in that all data and natural variations were considered.

The groundwater hydraulic conductivity data used in the model is discussed in Section 3.

It is noted that there is no evidence or suggestion within the AGMG (Barnett et al 2012) that error statistic ranges (such as RMS or SRMS) should define the confidence class of a groundwater model or the ability of a groundwater model to serve as a functional predictive tool.

There were no pre-determined performance measures agreed upon by the proponent prior to calibration of the EIS groundwater model. There is a lack of informative data, particularly in relation to landholder pumping rates, that limit the ability for meaningful SRMS targets to be achieved for a groundwater model developed in the region of the proposed Hume Coal Project.

Section 5.4.5 of the AGMG (Barnet et al 2012) also describes circumstances where it may not be desirable to define specific target values for modelling performance measures, and that predefined performance measures may prevent a modeller from obtaining the best possible calibration, based on the information contained in all available data. A simple application of a strict SRMS error is deemed too simplistic an approach for mining models in particular.

Assessing model calibration using SRMS error alone is not a failproof approach to assessing model quality and representation of the conceptual hydrogeological understanding. It is possible to manipulate the model to produce a low SRMS error, however this may not result in a good quality model.

Greater confidence should be placed on differential predictions such as drawdown impacts (2 m drawdown extent and at licensed bores) and baseflow impacts on watercourses, rather than on the absolute outputs like groundwater elevations at observation and landholder bores. Head matches at calibration sites do not need to be perfect in order for a groundwater model to provide reliable predictions and be fit for purpose.

The AGMG (Barnett et al 2012) also state that:

> "It is not unusual for modellers to find that the calibration does not allow all aspects of historical measurements to be reproduced. Sometimes absolute values of heads are too high or too low, suggesting that hydraulic conductivities and recharge are not in balance, but trends are reasonable, suggesting that the relationship between hydraulic conductivity and storage coefficient is reasonable, or that the relationship between perturbations in recharge and specific yield are reasonable (refer section 5.4.1). In such cases calibration may be considered reasonable if differences in heads seem to be reasonable. There may be no theoretical reason to support this conclusion, but sometimes there appears to be no alternative."

This above text from the AGMG (Barnett et al 2012) suggests that to accurately predict impacts at landholder bores, the model does not need to be predicting simulated groundwater levels to within 2 m of observed groundwater levels. The AIP does not reference the 2 m measurement for absolute predictions of water levels. Instead, it suggests that if the relative impact of the mine is predicted to be greater than 2 m at a landholder bore, then that bore is subject to make good provisions.

Dr Townley (2020) in his review agrees that it is not reasonable to suggest that a groundwater model is required to have predictions accurate to a "sub-metre" scale. No reference to this requirement has been provided, and it is unreasonable to suggest that this level of accuracy is ever possible. Dr Townley (2020) also states:

> "An SRMS of 10% is not uncommon, nor is it evidence that a model is inadequate or not fit for purpose."

Table 5.1 shows a comparison between the reported calibration statistics from the EIS model and the RTS model conducted by HydroSimulations (2018). The simulated average water balance during the calibration period is presented in Table 5.2 by HydroSimulations (2018).

The average residuals at bores and model-derived watertable elevation at the end of the calibration period is presented in Figure 5.1. The spatial representation of the residuals does not show any distinct pattern where the model over or under predicts the groundwater elevation compared to the calibration targets. Regional groundwater impact models rarely simulate very accurate groundwater elevations at specific points in time or space.

Regional scale models are typically used to predict regional scale impacts on the watertable, and these predictions are used to explain possible impacts on landholder bores inside the cone of depression. It is often the case that there is little information about the depth of landholder bores, the hydrostratigraphic units in which they are screened, or the rate at which they are ever pumped. Regional models give general or generalised indications of possible impacts on watertable elevation. Their purpose is not to predict impacts at specific bores, because model grids are not typically refined near every pumping bore, and it is not practical to estimate hydrogeological properties at an appropriate spatial resolution for such highly refined models. The approach adopted for the Hume Coal Project is reasonable and consistent with industry best practices (Townley 2020).

The results at one specific location should not be referenced from one model only (a history match model) but should be interpreted based on the net effects of the proposed project.

### Table 5.1 Comparison of key calibration statistics

| Key statistic | EIS Model (Coffey 2016b) | Revised groundwater model (HydroSimulations 2018) |
|---|---|---|
| Number of data points | 49 | 2,502 |
| Residual mean (m) | 3.1 | 3.7 |
| Absolute residual mean (m) | 12.1 | 12.2 |
| Root Mean Square (m) | 17.1 | 15.4 |
| Scale Root Mean Square (%) | 11.9 | 10.8 |
| Correlation coefficient | 0.795 | 0.77 |

### Table 5.2 Simulated average water balance during the calibration period

| Component | Groundwater inflow (recharge) ML/day | Groundwater outflow (discharge) ML/day |
|---|---|---|
| Rainfall recharge | 37.8 | - |
| Evapotranspiration | - | 20.1 |
| Rivers | 11.7 | 7.6 |
| Drains | - | 33.4 |
| Constant head | 2.4 | - |
| Wells | - | 13.8 |
| **TOTAL** | **51.9** | **74.9** |

| | |
|---|---|
| Storage | 22.9 LOSS |
| Discrepancy (%) | 0.01 |

Notes:
"Rivers" = Wingecarribee River and Medway Dam
"Drains" = Creeks, Berrima Mine, Escarpment
"Constant Head" = Wingecarribee Reservoir
"Wells" = Landholder bores
ML/day = megalitres per day

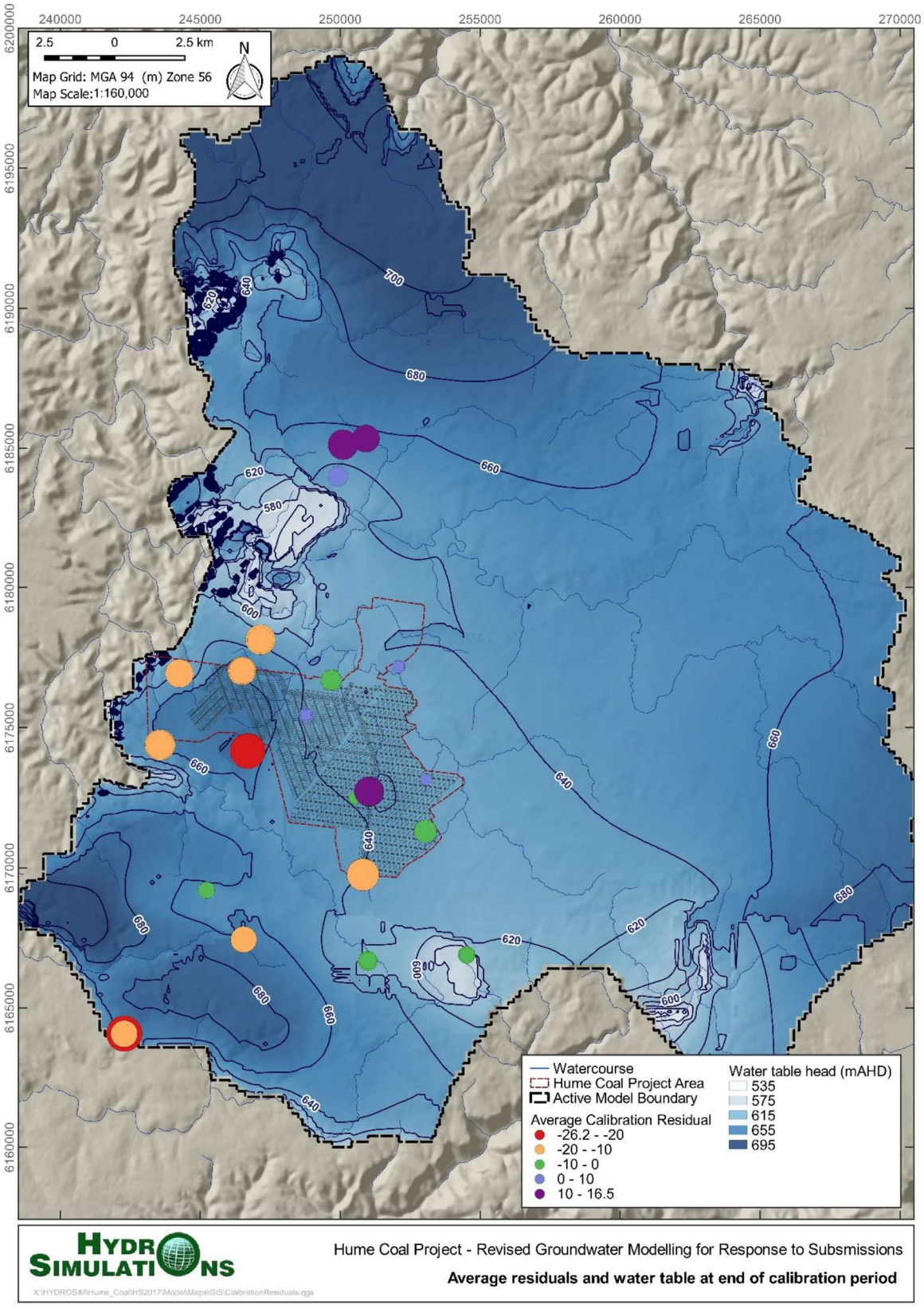



**Figure 5.1** **Average residuals at bore and water table elevation at the end of the calibration period (after HydroSimulations 2018**

# 6 Uncertainty analysis

The following text is included for delivery of action 5 (refer to Table 1.1), which relates to the range of parameters explored as part of the RTS groundwater model uncertainty analysis.

The groundwater modelling work completed as part of the RTS included Monte Carlo style uncertainty analysis, in line with the Independent Expert Scientific Committee (IESC) draft guidelines on uncertainty analysis (Middlemis and Peeters 2018). It is noted that this work was very complex, time consuming and onerous, and the results of the work provide an exceptional example of how to apply the IESC guidelines to undertake very detailed uncertainty analysis and reporting of results. The results of the revised groundwater modelling predict 94 landholder bores on 72 properties will observe groundwater level drawdown greater than 2 m as a result of the project, and the uncertainty analysis suggests the model has a narrow uncertainty range in regard to inflow and drawdown predictions.

Consultation with the NSW Government (DoI Water) occurred in August 2017, in the form of a meeting with DoI technical experts, Hume Coal groundwater modelling team, EMM and Hume Coal. This meeting specifically addressed the groundwater modelling components of the DoI Water submission and additional sensitivity and uncertainty modelling was discussed and agreed to at that meeting. The work was then undertaken by HydroSimulations and the results were included in the RTS for the Hume Coal Project (EMM 2018b).

The uncertainty analysis focused on hydraulic conductivity, the model parameter thought to be most sensitive and that also had a substantial set of field data to support the parameter distributions explored. While the uncertainty analysis tested a large range of hydraulic conductivity values from known data within the area, the results of the analysis produced a relatively 'tight' range of mine inflow volumes and drawdown, which means there is high confidence in model results (ie drawdown and inflow).

Guiding principle 7.4 AGMG (Barnett et al 2012) is of relevance to uncertainty analysis which states:

> "Analysis of uncertainty should recognise that there is more uncertainty when reporting confidence intervals around an absolute model output, and less uncertainty when a prediction can be formulated as a subtraction of two model results."

Regarding the appropriateness of the range of input parameters used, Townley (2020) notes that the uncertainty analysis has been undertaken with a large number of spatial distributions of hydraulic conductivities and concludes that the range of parameters is sufficient and should not be larger. Townley (2020) further notes that the value or validity of sensitivity analysis is not based on if the range of input parameters is large but, rather, it is based on how realistic the input parameters are. Variability within generated spatial fields of hydraulic conductivities and storage coefficients should be consistent with variability observed in the real world. Townley (2020) states that the range of the distributions of horizontal hydraulic conductivity (Kh) generated by HydroSimulations (2018) is probably large enough and may be too large; and the range of Kh/Kv may be too small, as it is not uncommon for Kh/Kv to be 1,000 or 10,000 in some materials in the Sydney Basin. However, if Kh/Kv were larger the predicted impacts on the watertable would tend to be smaller (Townley 2020).

The various reviews of the Hume Coal groundwater model conducted by industry experts (Mr Hugh Middlemis of HydroGeoLogic, Dr Lloyd Townley of GW-SW Pty Ltd, Dr Frans Kalf of Kalf and Associates and Dr Noel Merrick of HydroSimulations/SLR Consulting) have determined that the groundwater model is fit for purpose and appropriate for use to assess mining impacts on the groundwater resource. This includes the uncertainty analysis completed as part of the RTS (EMM 2018b).

Figure 6.1 to Figure 6.3 show the 95$^{th}$ percentile (upper 5%) of hydraulic conductivity values sampled in the uncertainty analysis, applied to the Hawkesbury Sandstone unit for models layers 2, 4, and 7, respectively. These figures display a surface that has been interpolated from this 95$^{th}$ percentile value at each pilot point locations and shows the spatial distribution of the parameter constraint assigned to pilot points used in the uncertainty analysis.

The information presented in these figures is complemented by the box and whisker plot in Figure 3.12, which includes the relationship of the hydraulic conductivity depth function in relation to the site data and the uncertainty data ranges. The maps and charts demonstrate that:

- the depth function is in agreement with the measured hydraulic conductivity data; and
- the horizontal hydraulic conductivity data is typically within the measured ranges with depth.

The field data provided in the box and whisker diagrams in Figure 3.12 includes hydraulic conductivity data from core (both horizontal and vertical tests), packer, specific capacity and pump testing from Hume Coal area as well as the Tahmoor Mine in the Southern Coalfield. The Tahmoor Mine dataset provides hydraulic conductivity data at greater depths than the Hume Coal data alone due to Tahmoor being a deeper mine.

Figure 3.12 also shows that the range of hydraulic conductivity values explored in the uncertainty analysis is adequate when compared to the field data, with the minimum and maximum values explored at each depth bin greater than has been measured in the field data. The 5th and 95th percentile and quartile boxes show that horizontal hydraulic conductivity values represent the field data well. The horizontal hydraulic conductivity values in the uncertainty analysis are generally higher in the uppermost 100 m than the field data, represent the field data well down to 200 m depth, and are then slightly lower than the field data from 250-300 m depth. The number of deep field points in the Hume Coal mine area means there is a minimum horizontal hydraulic conductivity value of $1 \times 10^{-4}$ m/d below 250 m depth, and this is well represented in the field data.

The above observations indicate that the depth function gradient overall provides a reasonable match with the maximum depths of the Hawkesbury sandstone over the Hume Coal project area (generally <200 m).

Refer to Section 7 of Appendix F in Volume 2D of the RTS report (EMM 2018a) and associated figures, and HydroSimulations (2018) for further details regarding the methodology and full range of hydraulic conductivity values explored in the uncertainty analysis.

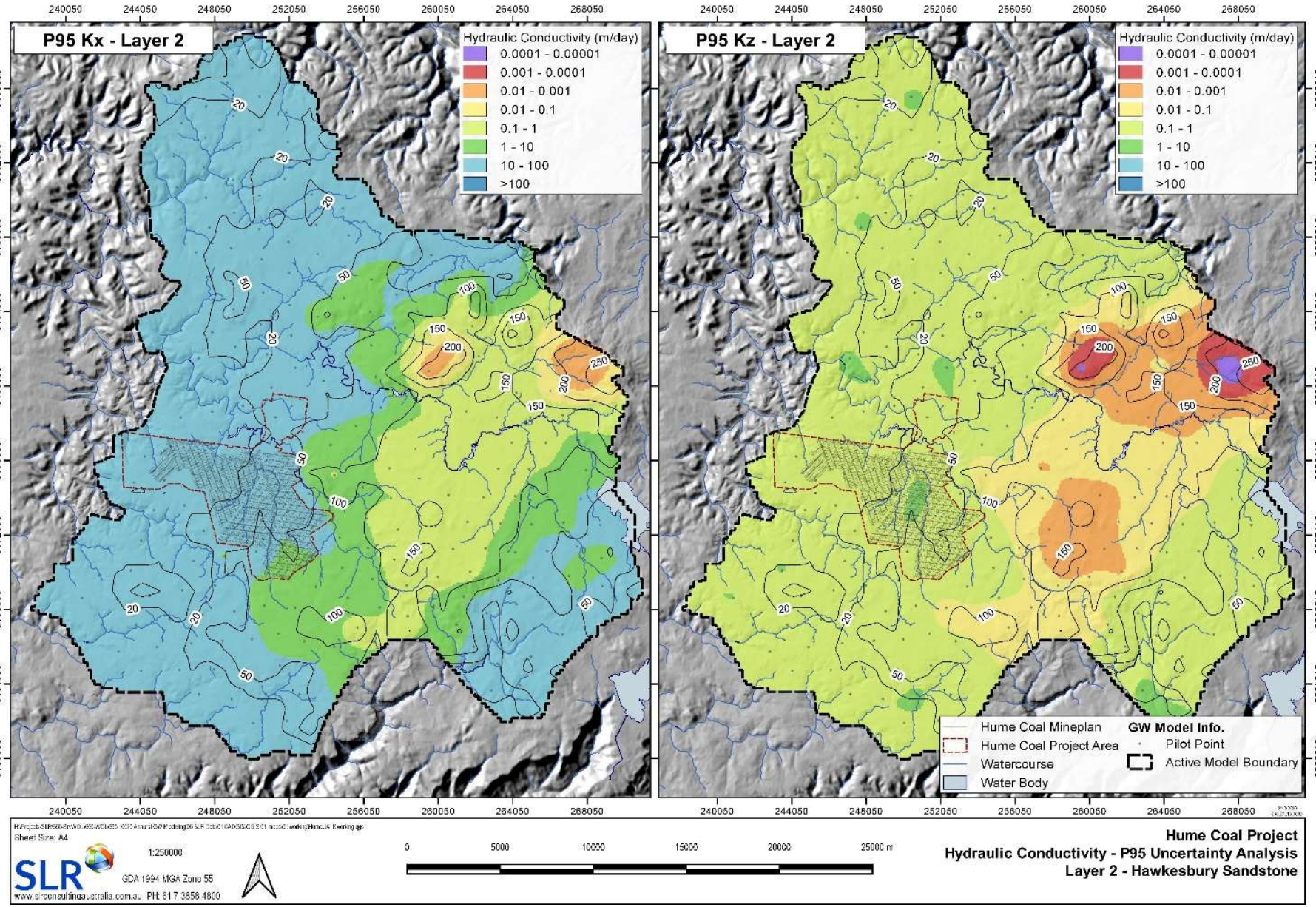



**Figure 6.1** **Maximum hydraulic conductivity from uncertainty analysis Layer 2 – Hawkesbury Sandstone**

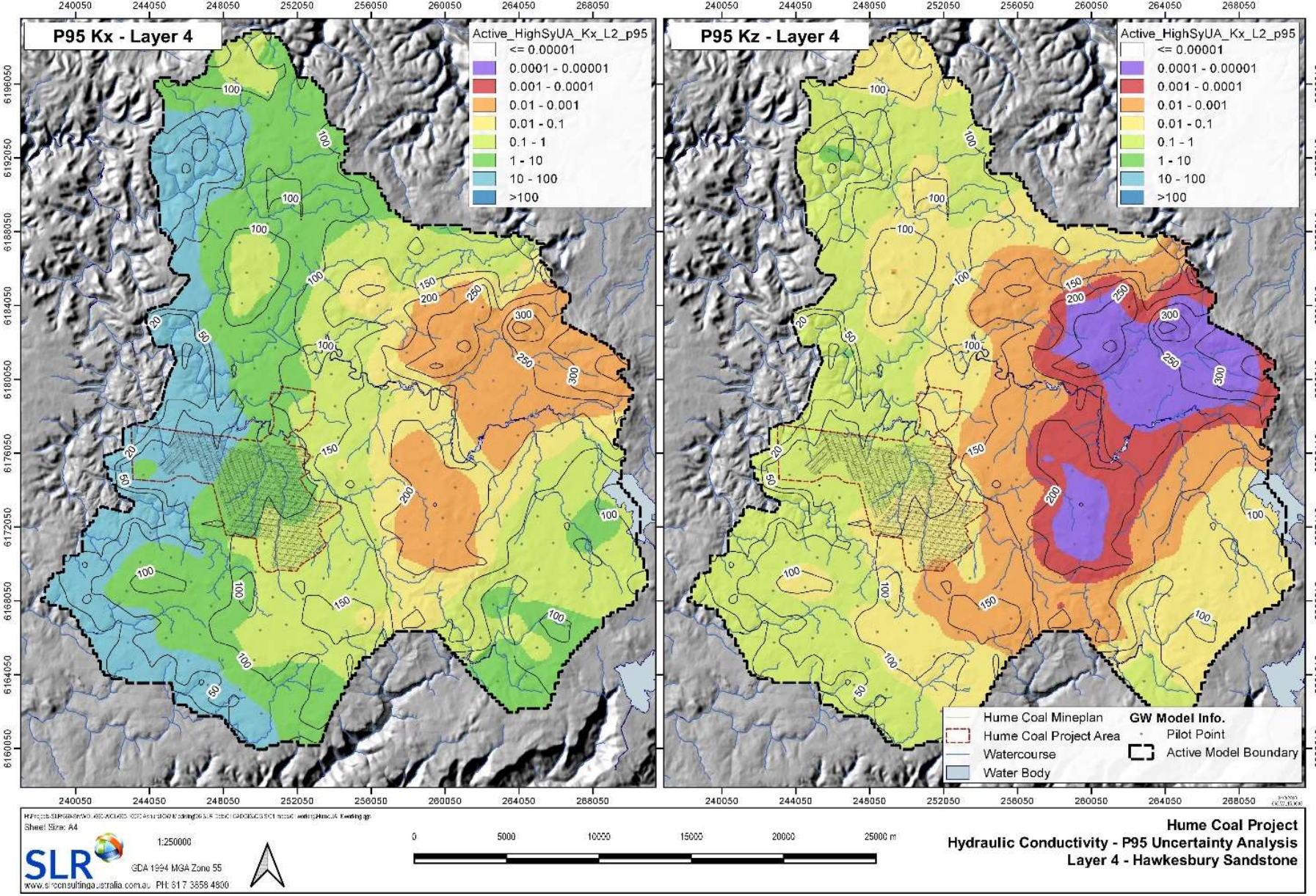



**Figure 6.2** **Maximum hydraulic conductivity from uncertainty analysis Layer 4 – Hawkesbury Sandstone**

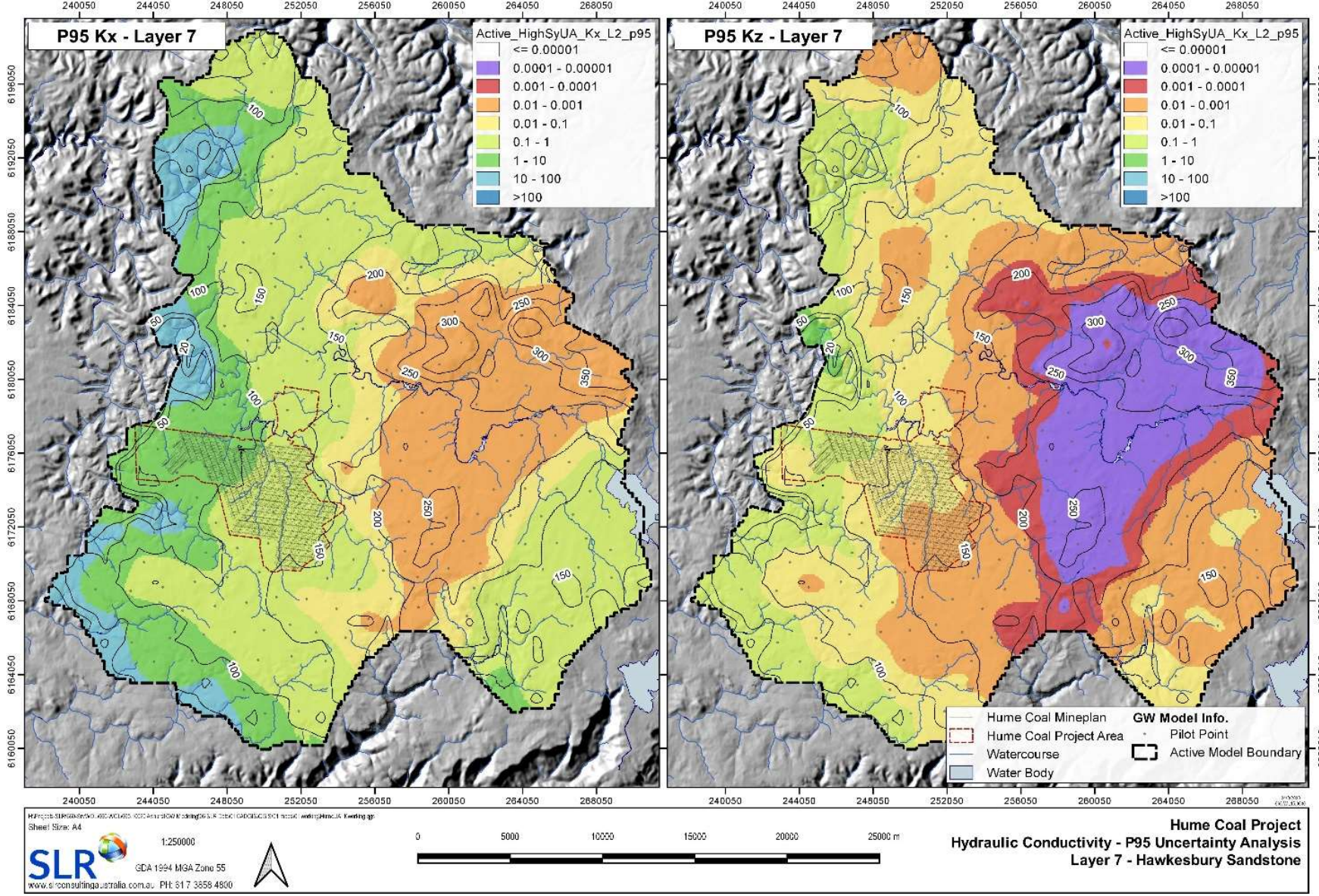



**Figure 6.3** **Maximum hydraulic conductivity from uncertainty analysis Layer 7 – Hawkesbury Sandstone**

# 7 Packer tests

The data and information following are included for delivery of action 6 (refer to Table 1.1).

Packer testing for the Hume Coal Project provided information on the hydraulic properties of the rock mass at specific depth intervals (generally at thicknesses of between 6.5 m and 8.5 m). The results are indicative of the primary permeability of the rock mass as well as secondary permeability that may be associated with joints and fractures. Packer testing was conducted on open boreholes by Strata Control Technology in September 2013, and March and April 2015. Packer testing at a newly drilled corehole (HU0147PZB) was also undertaken in October 2017.

Within three open boreholes, 28 depth intervals were tested, representing a range of geological conditions (Figure 4.5 of Attachment A). Packer testing used double packers and injected water into a sealed test interval and measured the rate of water flow (or pressure build up and decay) over a period of time. Packer test summary data is provided in Table 7.1.

Raw packer test data and interpretation are provided in Attachment B.

**Table 7.1 Packer test results summary**

| Borehole | Test interval (mbgl) | | Screen mid point | Interval length | Hydraulic conductivity | Horizon | No. of fractures |
|---|---|---|---|---|---|---|---|
| | From | To | mbgl | m | m/day | | |
| **September 2013** | | | | | | | |
| HU0040CH | 69.65 | 76.15 | 72.9 | 6.5 | $2.6 \times 10^{-4}$ | Sandstone | Not logged |
| HU0040CH | 75.65 | 84.15 | 79.9 | 8.5 | $9.5 \times 10^{-3}$ | Sandstone | Not logged |
| HU0040CH | 99.65 | 108.15 | 103.9 | 8.5 | $1.2 \times 10^{-2}$ | Sandstone | Not logged |
| HU0040CH | 108.65 | 117.15 | 112.9 | 8.5 | $2.1 \times 10^{-1}$ | Sandstone | Not logged |
| HU0040CH | 114.65 | 123.15 | 118.9 | 8.5 | $8.6 \times 10^{-2}$ | Coal | Not logged |
| HU0077CH | 75.7 | 84.2 | 79.95 | 8.5 | $1.9 \times 10^{-2}$ | Sandstone | 2 |
| HU0077CH | 81.7 | 90.2 | 85.95 | 8.5 | $7.5 \times 10^{-3}$ | Coal | Not logged |
| HU0077CH | 90.7 | 98.59 | 94.645 | 7.89 | $8.6 \times 10^{-7}$ | Sandstone | 5 |
| **April 2015** | | | | | | | |
| HU0146CH | 8.64 | 15.14 | 11.89 | 6.5 | $1.6 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 14.64 | 21.14 | 17.89 | 6.5 | $1.8 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 20.64 | 27.14 | 23.89 | 6.5 | $1.6 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 26.64 | 33.14 | 29.89 | 6.5 | $1.0 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 32.64 | 39.14 | 35.89 | 6.5 | $1.2 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 38.64 | 45.14 | 41.89 | 6.5 | $1.0 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 44.8 | 51.3 | 48.05 | 6.5 | $3.8 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 51.64 | 58.14 | 54.89 | 6.5 | $4.2 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 57.64 | 64.14 | 60.89 | 6.5 | $5.9 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 63.64 | 70.14 | 66.89 | 6.5 | $3.2 \times 10^{-2}$ | Sandstone | Not logged |

## Table 7.1 Packer test results summary

| Borehole | Test interval (mbgl) | | Screen mid point | Interval length | Hydraulic conductivity | Horizon | No. of fractures |
|---|---|---|---|---|---|---|---|
| | From | To | mbgl | m | m/day | | |
| HU0146CH | 69.64 | 76.14 | 72.89 | 6.5 | $1.4 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 75.64 | 82.14 | 78.89 | 6.5 | $5.8 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 81.64 | 88.14 | 84.89 | 6.5 | $9.5 \times 10^{-2}$ | Sandstone | Not logged |
| HU0146CH | 87.64 | 94.14 | 90.89 | 6.5 | $3.6 \times 10^{-1}$ | Sandstone | Not logged |
| HU0146CH | 93.64 | 100.14 | 96.89 | 6.5 | $3.7 \times 10^{-2}$ | Sandstone | Not logged |
| HU0146CH | 99.64 | 106.14 | 102.89 | 6.5 | $1.2 \times 10^{-2}$ | Sandstone | Not logged |
| HU0146CH | 105.64 | 109.14 | 107.39 | 3.5 | $1.2 \times 10^{-2}$ | Sandstone | 1 |
| HU0146CH | 108.64 | 112.14 | 110.39 | 3.5 | $3.9 \times 10^{-2}$ | Coal | 2 |
| HU0146CH | 111.64 | 115.14 | 113.39 | 3.5 | $5.4 \times 10^{-2}$ | Coal | 4 |
| HU0146CH | 114.64 | 123.6 | 119.12 | 8.96 | $7.1 \times 10^{-2}$ | Sandstone | 6 |
| **October – November 2017** | | | | | | | |
| HU0147PZB | 123.65 | 130.15 | 126.9 | 6.5 | $1.6 \times 10^{-3}$ | Coal | Not logged |
| HU0147PZB | 138.65 | 145.15 | 141.9 | 6.5 | $4.6 \times 10^{-4}$ | Coal | Not logged |
| HU0147PZB | 154.65 | 161.16 | 157.905 | 6.51 | $3.5 \times 10^{-3}$ | Coal | Not logged |
| HU0147PZB | 160.65 | 167.15 | 163.9 | 6.5 | $1.5 \times 10^{-2}$ | Standard rock | Not logged |
| HU0147PZB | 177.65 | 184.15 | 180.9 | 6.5 | $8.6 \times 10^{-7}$ | Higher density | Not logged |
| HU0147PZB | 216.65 | 227.18 | 221.915 | 10.53 | $1.5 \times 10^{-3}$ | Base of hole | Not logged |

Note: mbgls = metre below ground level

# 8 Responses to DoI Water submissions

The following information is included for delivery of action 7 (refer to Table 1.1).

In the following sections, text contained within blue boxes represents summaries of DoI Water original submissions. The issues raised by DoI Water are specifically addressed in each section and where possible, text from previously presented reports (eg EIS, RTS, submissions to IPC) has been used to respond to the issues.

## 8.1 Baseline groundwater level data

- DPI Water commented on the lack of analysis on the effect of stresses on hydrographs.

Comments regarding hydrograph analysis were addressed in the RTS main report Section 9.1.1 with the following response.

A detailed analysis of bore hydrographs was undertaken by Coffey (2016a); in summary, it was stated that hydrographs indicate that the groundwater levels in the Hume Coal Project area are relatively stable, but that monitoring bores do show periodic drawdown that is induced by landholder pumping. Slow recovery from sampling events as monitored in bores is noted.

Bores in the vicinity of the Berrima mine show depressurisation effects of the mine and significant hydraulic head gradients (ie significant differences in head between shallow and deep monitoring bores).

A detailed analysis of the hydrographs and in particular the vertical head gradients has been undertaken (Coffey 2016a), and results suggest a desaturated zone beneath the shale in the southern part of the lease. The vertical head gradients in the vicinity of the Hume Coal Project, particularly in areas overlain by Wianamatta Group Shales are small, suggesting minimal recharge from rainfall and a distance from existing mining areas and escarpments. In areas proximate to escarpments, the overlying shale is absent and rainfall recharges directly to Hawkesbury Sandstone. Discharge from escarpment features also occurs, causing an increase in the vertical head gradients in a westerly direction from the mining lease area.

In Appendix F, of the Hume Coal RTS Volume 2D Hydrosimulations (2018) presents time series hydrographs presenting the observed and modelled heads in Figures 5 to 15 which are included in Attachment C. The modelled hydrographs do show some effects of modelled stresses on the simulated (output) hydraulic head results.

## 8.2 Groundwater modelling

### 8.2.1 Model design

- DPI Water requested information on the model solver/solution method used.
- DPI Water requested information on the following model design parameters:
  - time steps
  - numerical precision

The RTS groundwater modelling was completed using Groundwater Vistas, MODFLOW-USG code with the Sparse Matrix Solver (SMS Solver). The software used a nonlinear and linear solution method, Newton-Raphson iteration scheme was used with under-relaxation for nonlinear solutions, while the unstructured pre-conditioned conjugate gradient solver of White and Hughes was used for linear solutions. The EIS groundwater modelling was completed using MODFLOW-SURFACT - V3 (HydroSimulations 2018).

The groundwater model used adaptive time stepping. If the solution of the groundwater flow equations converged at a particular timestep then a multiplier is used to increase the timestep size for the following iteration, however if the model fails to converge to a solution a reduction factor is applied to the timestep. The initial timestep was 2.44 days, the minimum timestep was $1x10^{-4}$ days, and a maximum timestep was 182.63 days. The timestep multiplier was 1.41 and a reduction multiplier was 2.83 days.

The head change (HCLOSE) criterion for convergence of the outer (nonlinear) iterations, is 0.1 m. When the maximum absolute value of the head change at all nodes during an iteration is less than or equal to this value, the iteration stops. Commonly, HCLOSE equals 0.01 according to the MODFLOW-USG v1.5- Description of model input and output (Panday et al 2019). The head change criterion for convergence of the inner (linear) iterations, is 0.01 m. When the maximum absolute value of the head change at all nodes during an iteration is less than or equal to this value, the matrix solver assumes convergence.

Further information regarding the two levels of iterations is provided below from Chapter 7 of MODFLOW-2005, the USGS Modular groundwater model- the groundwater flow process (Harbaugh 2005):

> Iteration can occur at two levels. The primary level, called outer iteration, is implemented in the Formulate and Approximate Procedure shown in the overall flow chart for MODFLOW (fig. 3–1). The Formulate Procedure begins by constructing the flow equation. Any head-dependent (nonlinear) terms, such as transmissivity of water-table layers, will change as a result of the head computed in the prior outer iteration. The Approximate Procedure then performs one partial solution of the flow equations. Each invocation of the Formulate and Approximate Procedures is an outer iteration. The second iteration level is called inner iteration. Inner iteration is incorporated within the Approximate Procedure of some solvers. Inner iteration is used to improve accuracy without changing the nonlinear terms. So, the overall flowchart does not directly indicate the possibility of inner iteration. The outer iterations are repeated until a satisfactory solution is obtained, which is called solver convergence, or until a user-specified maximum number of iterations is reached.

### 8.2.2 Conceptualisation

- Develop a database to support the development of a regional numerical groundwater flow model for the Hume Coal Project, by developing a hydrogeological conceptual model, with reduced uncertainty in model parameters of the numerical model.
- Simultaneously replicating hydraulic conductivity, hydraulic heads, shallow groundwater discharge, and deep groundwater discharge had been met to varying degrees of satisfaction. Considering the large (unacceptable levels) of water balance errors of the model, even if the replication is satisfactory, it can only be considered accidental.
- Is justification provided for omission or simplification of processes? For estimation of ET, stream flows and groundwater pumping.

Comments regarding the model conceptualisation were addressed in the RTS main report (EMM 2018a) Section 9.3.2 with the following response.

The EIS model was prepared in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and a conceptual model was prepared and revisited based on field data as it was collected and analysed. Hume Coal Long term hydraulic conductivity tests were performed at the Project site. The data derived from the tests was used to help model calibration, and constrained during uncertainty analysis. Aquifer parameters that were uncertain in the model were subject to a tailored uncertainty analysis, aimed at considering those parameters that were unknown and those that were likely to influence the drawdown and mine inflow results (ie those that were considered most sensitive to the model results).

The mass balance for the original EIS model was recalculated based on the revised model. With the updated software, a more elaborate numerical simulation was completed and this has led to a reduction in the mass balance error without the need to recalibrate the model. The calibration for the original EIS was robust and remains valid. This is confirmed by the NSW Government expert reviewer (Hydrogeologic 2017). The groundwater model has been deemed to be calibrated by the NSW reviewer, based on the small model water balance and the use of 4 calibration datasets. In response, the HydroSimulations' rerun of the EIS model using MODFLOW SURFACT V4 with more sophisticated solver software achieved a mass balance error of less than 0.2%. The improved solver settings has been carried forward in all groundwater modelling since. The water balance error remains well below the Australian Groundwater Modelling Guidelines (Barnet et al 2012) suggested water balance error (1%).

Common groundwater modelling practice relies on the simplification of some hydrogeologic processes. Actual measurements of certain parameters is problematic and quite often literature values are used in simulations, other times parameters are estimated based on known relationships such as ET, where based on vegetation an extinction depth can be estimated and used in numerical modelling. It was stated in the 2016 Coffey report that concurrent streamflow and stream electrical conductivity (EC) measurement are useful as an independent indicator of the flow range where groundwater seepage to the stream is a large proportion of the total flow. Relationships between EC and flow were derived and have been used as part of the assessments of baseflow in streams. Landowner groundwater pumping is included in the groundwater model, the calibration of the groundwater model is sensitive to the allocated volume of groundwater pumping from landowners. In the latest IPC groundwater model, the SRMS values improved to below 5% if landowner pumping was reduced to 43% of allocated volumes. Without specifics of the omissions and/or simplifications requested the above generalised statements should suffice for review.

### 8.2.3 Model class

- The Australian Groundwater Modelling Guidelines (pg. 19) state that "if a model falls into a Class 1 classification for either the data, calibration or prediction sectors, it should be given a Class 1 model irrespective of all other ratings. The mass balance errors for the calibrated model were within a Class 1 classification.
- DPI Water considers there is significant uncertainty in the model predictions and hence the impact on groundwater and connected surface water sources as the model is not considered by DPI Water to satisfy a Class 2 or Class 3 confidence level classification.
- Groundwater Modelling staff within DPI Water have undertaken a review of the relevant numerical model reports provided with the application against the Australian Groundwater Modelling Guidelines requirements and identified various shortcomings within a compliance checklist framework.

Comments regarding the model class were addressed in Section 9.3.3 (i) of the RTS (EMM 2018) with the following response.

The EIS groundwater assessment report (Coffey 2016b) states the model confidence level is Class 2/3 based on the Several submissions, including NSW DI Water and interest groups, contested this claim on various grounds. The EIS model has therefore subsequently been audited and revised by Dr Noel Merrick (HydroSimulations 2018).

The model classification in the modelling guidelines was developed to provide a non-technical term and a 'benchmark' or 'yardstick' for which to consider the reliability or confidence of predictions for a given model (Barnett et al 2012). However, for responses to the Hume Coal EIS and RTS, model class has become a key factor in answering the submissions due to the heavy reliance from both DoI Water and interest groups on this classification in terms of model adequacy, accuracy and reliability.

In the audit review, HydroSimulations (2018) maintains that the original EIS model is indeed a Class 2 model based on the Australian Groundwater Modelling Guidelines (Barnett et al 2012). The independent expert review by Hugh Middlemis (Hydrogeologic 2017) also concluded that the original EIS model a Class 2 model based on a holistic interpretation of these same guidelines. Middlemis (Hydrogeologic 2017) states that the original EIS model is 'improperly labelled as a class 1' by some critics, and further states:

> "cherry-picking one guideline comment rather than considering all the attributes suggested in the table does not constitute a valid agreement to support the claims by others of poor model performance."
>
> The development of the original EIS model and impact predictions are in accordance with best practice guidelines. The Middlemis (Hydrogeologic 2017) review of the original EIS model states that:
>
> "the Hume Coal model itself is suitable for the mining impact assessment purpose (Class 2 confidence level)' and 'the EIS presents reasonable predictions of dewatering volumes and drawdown extent/magnitude."
>
> "it is my professional opinion that the Hume Coal model is fundamentally consistent with best practice in design and execution, although the EIS documentation is deficient (not sufficient clear on some details). It is fit for mining project impact prediction purposes".

This statement from the independent expert reviewer that the model is 'best practice' and 'fit for purpose' should provide reassurance to the NSW Government and the community that the predicted mine inflows and drawdowns are the best available predictions.

Although the original EIS model is suitable for impact assessment purposes, there were some comments in submissions that prompted a model review. The combination of submissions; the report from independent expert reviewer, (Hydrogeologic 2017); and the EIS model audit (HydroSimulations 2018), have been used to refine the model.

The HydroSimulations (2018) audit and proposed refinements involved consultation with the EIS modeller, Paul Tammetta. The amendments were then endorsed by both the independent expert reviewer engaged by the NSW Government, Mr Hugh Middlemis, and the DoI Water technical specialists in a consultation meeting in August 2017.

The model revisions have meant that the model now has even more Class 2 and 3 attributes such as a significant reduction in the mass balance error, and less Class 1 attributes. The groundwater model is a regional scale model and NSW Government's own independent expert, Hugh Middlemis, advised that the groundwater model is 'fit for purpose'.

As per Hume Coal's submission to the IPC (March 2019), DPE's own independent peer review expert (Hugh Middlemis) agreed that the groundwater model is suitable for the mining impact assessment purpose (Class 2 confidence level) and that downgrading of the model to Class 1 is invalid.

DPIE comment suggests that DPIE have completed their own checklist that may contradict work by Hugh Middlemis. Hume Coal would like this to be shared to allow open and frank discussion against specific points of the checklist that DPIE believe differ to HydroSimulations review (within the RTS) and Hugh Middlemis' expert independent review.

Following the release of the IPC assessment report, Hume Coal engaged Dr Lloyd Townley of GW SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the RTS groundwater model. DPIE advised Hume Coal, following the release of the IPC report, that they would not be willing to jointly engage an independent expert, but Hume Coal proceeded to engage Dr Lloyd Townley for that role in order to respond to the IPC. Dr Townley's review finds that the modelling undertaken for the Project is fit for purpose, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the Project area (Townley 2020).

As an author of the Australian Groundwater Modelling Guidelines (Barnett et al 2012), Dr Townley (2020) provides the following comments:

> The authors did not intend the concept of "confidence level classification" to be prescriptive. The Australian Groundwater Modelling Guidelines do not state that a model must have any specific "Class" for any specific purpose. This notion seems to have been adopted by some stakeholders, but this practice was not anticipated by the authors. Table 2-1 of the Australian Groundwater Modelling Guidelines lists "key indicators" characteristic of models with different confidence level classifications. The length of time for which predictions are made, relative to the period for which calibration has been possible, is one key indicator. The maximum stress experienced during the prediction period, relative to the maximum during the calibration period, is another. Most "greenfields" mining projects have few data over a short calibration period with stresses much lower than during future proposed mining, so this almost automatically implies that confidence in predictions is less, and such a model would have a confidence level classification of Class 1. The Guidelines never suggest that this is not acceptable, or that these models would automatically default to Class 1. They simply explain that confidence will be less.

The findings of the review conducted by Dr Townley (2020) determined that the groundwater model is a Class 2 confidence level and has some elements of Class 3. Dr Townley (2020), in his assessment of the model, places emphasis on two key indicators related to (i) the length of time for which predictions are made relative to the time period of calibration, and (ii) the magnitude of future stresses relative to historical stresses during the calibration period. Given the use of available transient data from historical mining at the Berrima Colliery, Dr Townley (2020) advised that the modelling undertaken for the Hume Coal Project should be judged to be Class 2. These two key indicators often lead to models of greenfields mining projects being considered Class 1, but this conclusion is not reasonable for the Hume Coal Project.

### 8.2.4 Scale root mean square percent (SRMS) and mass balance

- The Australian Groundwater Modelling Guidelines identify key indicators for confidence level classifications as being a mass balance error of less than 0.5 % for Class 3 models, and less than 1 % for Class 2 models. Calibration review is required if model is to reach Class 2 confidence level.
- The model developer needs to attempt to reduce water balance errors, improve the confidence level classification and provide further details of the model calibration (including detailed discussion of the convergence before and after the reworking of the model).
- Once the mass balance error threshold is achieved, the model needs to be recalibrated and the scenarios re-run to improve the predictions of impacts.
- If the numerical model cannot be stabilised and calibrated in accordance with the guideline confidence levels, then detailed and prescriptive monitoring, management and mitigation plans (beyond the general approaches currently identified) must be provided prior to approval to provide assurance that potential impacts arising from the Project can be adequately identified, avoided or mitigated.
- Modelled average flow budget over the calibration and verification periods combined has a discrepancy of -2.2 ML/day or -4.1 % water balance error (page 25, Numerical Modelling and Impact Assessment report).
- Modelled average flow budget over the period of mine inflow (mining and simulation, years 1 to 22 inclusive) for the case of active Hume Coal Project mining has a discrepancy of -3.2 ML/day or -6.8 % water balance error (page 38, Numerical Modelling and Impact Assessment report).
- Modelled average flow budget over simulation years 1 to 22 inclusive for the null case where Hume Coal Project mining is inactive (Table 11) has a discrepancy of -2.8 ML/day or -6.0 % water balance error (page 39, Numerical Modelling and Impact Assessment report).
- DPI Water does not consider that the model has achieved convergence and calibration (or it has been poorly reported). As the model did not adequately solve the groundwater flow equation, it is not clear what reliance can be placed on the model outputs.
- Despite the intent to minimise uncertainty by simultaneously calibrating four different variables, the evidence provided to claim successful calibration with minimal uncertainty does not appear to be adequate.

Comments regarding SRMS and mass balance errors were addressed in the RTS main report Sections 9.3.3 (ii) and 9.3.3 (iii) with the following response.

Middlemis (Hydrogeologic 2017) states that based on the model audit by Merrick and refinements subsequently made, the SRMS has been reduced to less than 10%, and the water mass balance less than 1%, thereby removing the grounds for the Class 1 claim by others. The model calibration has been undertaken in accordance with the Australian Modelling Guidelines (Barnett et al 2012), was reviewed by HydroSimulations and the model calibration as undertaken by Coffey (2016b) in the EIS remains valid.

The model calibration statistics are improved following the audit and subsequent revised modelling. The uncertainty analysis by HydroSimulations in 2018 also provides improved calibration and mass balance errors from the original EIS model. The use of the Berrima mine inflow volumes for calibration of the EIS model is appropriate, and disputing the use of this data set is unjustified. Middlemis (Hydrogeologic 2017) provides comments directly on this calibration approach in his review, stating:

> "Calibration of aquifer property values (Kh, Kv, S, Sy) has been well constrained by pumping test estimates of property values, and by simultaneously honouring observed groundwater levels, along with the measured Berrima mine inflow (deep system) and inferred stream baseflows (shallow system).
>
> This is a best practice approach that reduces model non-uniqueness problems (that many different sets of model inputs can produce nearly identical aquifer head distributions). Uncertainties remain, and as the evapotranspiration discharge (a riparian zone flux) is unconstrained by measurement or estimates, sensitivity testing is warranted on the maximum ET rate and extinction depth (especially in high relief areas, including parts of the riparian zone)."

The model is calibrated in accordance with best practice for groundwater modelling, as outlined in the Australian Modelling Guidelines (Barnett et al 2012). Submissions on the EIS suggest the calibration should be undertaken in accordance with alternative methods and refer to Moriasi et al. (2007) and Nash and Sutcliffe (1970). These methods, although considered good practice, are not directly applicable to the calibration of a groundwater model.

Moriasi (2007) refers to model evaluation and verification methods for watersheds, focussing on surface water volumes, surface water quality and soil quality, and is considered suitable for agricultural settings. The Moriasi (2007) method is not suitable for model calibration of a groundwater model; rather, its use is for model verification (ie following project development) and applies to surface water/watershed models in agricultural settings – ie not generally applied to mining or groundwater.

The Nash and Sutcliffe (1970) coefficient of model efficiency is used to assess the predictive power of a hydrologic model. The researchers, techniques and the principles presented are technically sound, but again, are not directly applicable to the groundwater modelling and the calibration of the Hume Coal model. The paper by Nash and Sutcliffe (1970) referred to in the submissions is titled River flow forecasting through conceptual models part 1 – A discussion of principles, and the paper focuses on conceptual principles for modelling river flow. The paper presents valid findings. It is noted that the Hume Coal model follows the more recent Australian Groundwater Modelling Guidelines (Barnett et al 2012), and also follows many of the overarching principles for model development outlined in Nash and Sutcliffe (1970), being:

- develop a simple model that can be elaborated on (this is how the Hume Model has evolved);
- optimise parameters and study their stability (this is how the Hume Coal model was calibrated – ie optimising parameters, study their sensitivity and the overall stability of the model);
- measure the efficiency (this is done in the Hume Coal model by measuring SRMS and other calibration statistics);
- modify the model (this is what has occurred throughout the Hume Coal modelling process);
- choose desired modifications (as was undertaken for Hume Coal with the upgraded software and solvers selected for the revised model following the EIS submission); and
- compare model revisions against one another (this was done as the Hume Coal model evolved and these comparisons are outlined in detail in the Hume Coal revised water assessment (Appendix 2 of the RTS)).

In summary, the model is calibrated to best practice for groundwater modelling, using the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and, although other methods for model verification and validation exist and are potentially valid, the most appropriate method for calibration and verification of the model has been adopted for the Hume Coal model.

The model convergence was improved with the model revision due to a combination of the following alterations:

- updated solver settings (allows tighter convergence from 1 m to 0.1 m);
- upgraded software engine to MODFLOW-SURFACT v4 and then to MODFLOW-USG; and
- adoption of pseudo soil function.

The updated solver settings and upgrade to the latest software, MODFLOW-USG, allows for the use of more elaborate and tighter numerical solvers which provides for much better convergence in the model (see revised model report in Appendix 2).

The detailed uncertainty analysis also considered the required number of runs to ensure acceptable levels of convergence of results and this successful model convergence result is concluded in HydroSimulations (2018) as follows:

> "A new approach to uncertainty analysis has been introduced in this study which is compliant with directions advocated in a recent Explanatory Note issued by the IESC. In particular the approach (using AlgoCompute software in the cloud) demonstrates that convergence has been achieved for key outputs of interest by quantifying the uncertainty in nominated percentiles as the number of Monte Carlo runs increases."

The mass balance concerns have been addressed by HydroSimulations and are reported in their groundwater modelling report (HydroSimulations 2018). The groundwater modelling is determined to be fit for purpose and the impacts assessment can be used for the assessment of the Hume Coal Project.

### 8.2.5 Input data

- Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?
- It is not clear that the modelling has been applied to adequately understand the effects of mining during climatic (e.g. drought) or weather (e.g. below-average rainfall) conditions that would be expected to exacerbate the impacts of ongoing groundwater and surface water take.
- Clarification of the significance of the baseflow under these conditions is required to understand the potential impacts.
- The effect of initial conditions on key model outcomes is not assessed.
- Simulated heads in 2011 should be compared with the observed data.
- Information relating to other coal operations referred to in the Groundwater Assessment Data Analysis Report must be provided to identify the suitability of the data for the purposes of the current project and to enable the efficient and reasonable assessment of the Project by DPI Water.
- Are density and barometric effects taken into account in the interpretation of groundwater head and flow data?
- Is measurement error considered for directly measured quantities (piezometric level, concentration, flow etc.)?

#### i Conceptual model data

Volume 1 of the RTS report addresses the comment on the conceptual model with the following response from RTS Section 9.2 (EMM 2018a).

The conceptual model has been developed in accordance with the Australian Groundwater Modelling Guidelines (AGMG) and is based on geological and hydrogeological data collected as part of this project, data from government sources and publicly available data from other industrial projects in the region. The conceptual model is a strong data driven representation of the different groundwater systems that has been developed over the since 2011. The conceptual model in the EIS was developed collectively by project hydrogeologists and was peer reviewed by hydrogeological experts (Dr Frans Kalf and Dr Noel Merrick). Subsequent to the submissions process, NSW Government appointed an independent peer reviewer, Hugh Middlemis, who also reviewed the conceptual model, and agreed it is a suitable conceptualisation (Hydrogeologic 2017).

The conceptualisation of the geological layers is developed from geological mapping, historical geological logs and exploratory and monitoring bore drilling for the project. The geological formations and layer depths thicknesses (and local variations) is considered in substantial detail and all information has been included in the development of the conceptual model and then transitioned into the geological conceptualisation for the numerical model.

Information on layer thickness (ie interburden between the mined coal section and the overlying Hawkesbury Sandstone) is considered, analysed and then used to inform the conceptual model on a local scale. Therefore, the presence or absence of horizontal layers (and their relative and indicative hydraulic conductance) is based on regional knowledge, historical records and localised data collected and analysed during the various drilling programs.

The conceptual model in the Hume EIS is adequate, and has been developed in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). The NSW Independent peer review comments that:

> ”conceptualisation is sound..... report describe previous investigations and data sources, with reviews at many stages, along with reference to relevant papers...” (Hydrogeologic 2017)

Hume Coal has a data driven geological conceptualisation that accurately represents the coal seam, the overlying interburden and the Hawkesbury Sandstone. In respect to the specific issues raised around the conceptualisation of the interburden between the Wongawilli Coal Seam and the Hawkesbury Sandstone, the NSW Government Peer review states:

> “This review has found that the Hume Coal model has been set up with an appropriate representation of the interburden properties (e.g. appropriate thickness and no low permeability parameters to limit the potential connection between the coal seam and the Hawkesbury Sandstone).“ (Hydrogeologic 2017)

### ii Baseflow conditions

Section 4.3.7 of the RTS document stated that additional sensitivity analysis was also conducted for surface water flows, taking into account predictions of baseflow reduction during average, wet and dry climate scenarios output from the groundwater model. This sensitivity analysis was undertaken to address matters raised in submissions from government agencies to understand how sensitive the water balance model is with respect to changing climate.

The RTS report in Section 5.7 states that baseflow is the component of streamflow that is groundwater. Baseflow is defined as a withdrawal of groundwater from storage and is part of groundwater recession inflow to the stream (Domenico and Schwartz 1990).

The watertable (which in many areas is perched) in the Project area is generally higher than the beds of intersected streams for most of the stream length and for most of the time. Hence, the streams in the Project area are generally classified as gaining streams and receive baseflow from groundwater. In much of the Project area the drainage lines are also considered ephemeral. Ephemeral streams are defined as those streams that do not flow continuously year round, and mainly flow following rain.

Although most streams are classified as gaining, it is important to note that many are gaining from shallow perched or interflow groundwater which is disconnected from the regional watertable, while others are gaining from the regional watertable.

For the Hume Coal Project, most streams are classified as gaining streams which continue to be gaining streams throughout the Project (ie even after the regional watertable is lowered). This is due to many streams overlying perched shallow groundwater systems that are not affected by the regional watertable. The main exception is Medway Dam, which temporarily transitions from a gaining to a losing system during mining (likely due to the artificial elevation of the water surface).

The surface water impacts section of the RTS document states that the flow impact assessment undertaken for the Hume Coal Project EIS has been revised to include the revised baseflow reduction estimates from revised numerical groundwater modelling, including uncertainty analysis and climate sensitivity analysis, undertaken by HydroSimulations (2018). The flow impact assessment methodology (where the methodology differs from the EIS) and results are outlined in Section 4 of the Hume Coal Project Revised Surface Water Assessment (WSP 2018). Overall, there are negligible impacts to surface water flows as a result of the Project, and artificial augmentation of surface water supplies is not required or proposed.

Comments regarding the input data were addressed in the RTS main report (EMM 2018a) Section 9.3.4 with the following response.

### iii Berrima Colliery data

Data from the Berrima Colliery was adopted and considered in the development of both the conceptual and numerical model for the Hume Coal Project. Berrima Colliery is within the same geological unit as the Hume Coal mine, but geological settings are slightly different between Hume and Berrima, and the mining method is different but yet shares some similarities when considering the effects of bord and pillar mining with the mining proposed at Hume. There was full pillar extraction at Berrima Colliery and consequential fracturing of overlying strata in parts of the mine, but at the Hume Coal Project there is no material overburden deformation predicted, and certainly not enough to induce any significant levels of new fracturing or opening of existing joints. Therefore, there are differences in hydrogeological characteristics (recharge, mine inflow, discharge, etc), however the data and information from the Berrima Colliery can still be used to assist with model calibration and provide a better understanding of hydrogeological impacts. These differences explain why up-scaling from Berrima Colliery to Hume is not linear in terms of inflow and drawdown. Use of the Berrima Colliery data has been discussed as part of the historical independent expert reviews, including DPIE's own expert Mr Hugh Middlemis and Dr Lloyd Townley. As reported previously, all reviews have found the modelling, including calibration is fit for purpose and appropriate. A comparison of the Hume Coal mine to the Berrima Colliery is provided in Attachment A included with this report.

### iv Initial heads

The initial heads in the model are estimated using a nominal 32-year period of data. This dataset generated for initial starting heads is compared to actual levels in monitoring bores in 2011. The effect of initial conditions is not further assessed in the model. Initial heads in landholder bores across the Project area could not be measured due to an inability to survey most properties. The DI Water database cannot be used to determine initial heads in water bores due to the extremely variable time scale for the data (ie over decades and different climatic conditions) and the inability to quality assure or check the validity of the standing water level data at the time of bore completion.

A detailed landholder bore census was proposed and attempted for the Project, but without landholder consent this was not possible to complete. Regardless, the initial heads, as produced in the model from the expansive monitoring network, are considered more than adequate for model calibration. It is acknowledged that the starting point for drawdown as predicted in landholder bores will be important for determining mitigation and management (ie make good) options. This data will be collected post EIS approval if landholders are willing to work with Hume Coal on collecting baseline (pre-mining) water levels so that drawdown impacts (during mining) can be properly assessed and appropriate make good options proposed.

In the RTS main report (EMM 2018a) Section 9.1.1 i), it was reported that the groundwater level logger data collected, and calculation of summary statistics, for the Hume Coal Project was compensated for barometric pressure to accurately represent the natural climatic fluctuations. The data was not corrected for density with variations in water quality (across different hydrogeological units) as groundwater salinity was generally fresh, and there was insufficient variability to alter the groundwater levels/pressure or flow gradients. Generally, if total dissolved solids (TDS) concentrations are below 5,000 mg/L at 20 degrees Celsius, the freshwater equivalent hydraulic heads may vary by approximately 0.2 m difference between measured values.

### v Climate

The assessment of 'impact' from mining needs to consider the difference in water levels/water quality with and without the mine irrespective of climate; hence, the use of average climate is appropriate for this purpose. This is not to say climate variability is not considered, it is. Consideration of climate (both wet and dry periods) is included in the model as climate sensitivity analysis. Climate considerations are important and considered in detail for surface water, however, it is not as critical for large groundwater systems with a high storage volume to recharge volume ratio, and where project impacts are largely the same for groundwater, irrespective whether climate is wetter or dryer than average.

In extended dry periods, groundwater levels will be depressed, and this is often due to increased pumping and not necessarily just lower rainfall recharge. Access to groundwater is still available given the large storage to recharge ratio for the groundwater source; however, shallow bores occasionally need to be deepened. Landholders pump more groundwater due to the lack of rain and less surface water availability; this increased landholder extraction occurs irrespective of whether the mine is operating or not. With lower water levels there may be slightly lower inflows to the mine compared to average and wet seasons. The typical experience for other mines in the Southern Coalfield is that slightly higher inflows are experienced during and immediately after rain.

The natural groundwater baseflow contribution to surface water systems in dry periods is also lower due to depressed groundwater levels, and the model predicts that the mine's impact to baseflow (in terms of volume removed from the system) is less in dry periods than in wet periods.

Drought conditions were experienced in the area during much of the climate record period used for calibration (with the average climate statistics based on data between 1889 and 2014). Therefore, both wet and dry periods are already considered as they are included as part of the baseline data set for the model calibration.

### vi Climate sensitivity analysis

In accordance with standard practice, the EIS model predictions were based on average rainfall due to the impact assessment needing to determine the climate impacts with and without project. The use of average climate conditions for the model is considered appropriate. However, as requested by DI Water, scenario analysis has been conducted on the model using the same 108 climate sequences adopted for EIS and RTS surface water modelling.

The results of the sensitivity analysis on climate variability in the number of bores predicted to be affected by more than 2 m drawdown and mine inflow are very low (<10% change); indicating that the model results are insensitive to climate variability.

Landholder pumping is not metered and, therefore, data on actual usage over time is not available to be included in the model. An empirical approach was used to estimate landholder pumping with very conservative assumptions of usage from water bores: 3 ML/yr per bore for stock and domestic bores, and 97% of licensed entitlement extracted from all Water Access Licences (ie irrigation and industrial licences). The value of 97% was adopted based on the model calibration (Coffey 2016b). This equates to 9 ML/day (3,285 ML/yr) for the mining case and 11 ML/day (4,015 ML/yr) (Coffey 2016b) for the no mining case. These volumes are larger than the potential peak mine inflow (2,066 ML/yr) and intercepted baseflow volume of 461 ML/yr. It is worth noting that the reason the simulated volumes extracted from bores in the mining case and no mining case differ is due to bores going dry in the mining case and are therefore unable to continue to pump. Once the groundwater level drops below the simulated bore level, the bores are no longer able to extract groundwater.

In drought years, the volume of groundwater recharge is reduced and groundwater levels decline as discharges to springs, rivers and creeks continue and increased groundwater pumping occurs. In these dry periods, these discharge volumes are in excess of the recharge volumes. However, groundwater is still readily available, as declines are buffered by the large volume of groundwater in storage. The impact of the mine will be much the same in dry and wet periods, and mine inflows will not increase during droughts (in fact they may decrease). The greatest influence on declining groundwater levels will landholders pumping more groundwater than during normal to wet seasons. However, the EIS model is very conservative in that it assumes landholder pumping from irrigation bores is 97% of the entitlement, and stock and domestic use is 3 ML/yr per bore in every year. In normal to wet seasons, landholder pumping will be less than this, and therefore groundwater level declines are likely to be less than predicted.

### vii Rainfall recharge

Rainfall recharge for this area was suggested in Pritchard (2004) to be 5% for exposed sandstone and 0.5% for non-sandstone areas. The Berrima Mine is located mostly beneath exposed sandstone, with very little shale in the area. The Hume Coal mine model is approximately 50% exposed sandstone and 50% shale cover so it stands to reason that the rainfall recharge percentage across the Hume Coal model area will be slightly lower than the value adopted for the Berrima Mine model.

Rainfall recharge adopted in the EIS model (1.8%) is based on literature reviews, hydrograph analysis, and nearby mine data. No change to the rainfall recharge was considered necessary for the revised model as the value was constrained by calibration to baseflows.

### viii Presentation of data

The presentation of analysed data is undertaken in accordance with requirements of the Australian Groundwater Modelling Guidelines (Barnett et al 2012), and in accordance with best practice. The NSW Government independent expert reviewer, Hugh Middlemis, concludes that the reporting quality could be improved (Hydrogeologic 2017). These comments have been considered carefully and improvements have been made in the revised model reporting by Hydrosimulations (2018) within the revised water assessment (Appendix 2 to the RTS report). The revised model report provides additional detail and explanation on key model inputs, provides additional figures and addresses the independent expert reviewer Comments regarding reporting and presentation of input data.

The raw data files, model files and all information used to develop the conceptual and numerical models has been made available to the NSW Government independent expert reviewer. It is not a requirement that this same information be made available publicly, and/or provided to known objectors of projects in NSW.

Concerns from the community that the model "may have deficiencies" are noted. Hume Coal is confident the model is robust and accurately reflects the likely impact of the mine on the groundwater systems across the area. Independent expert review by Hugh Middlemis (Hydrogeologic 2017) concluded:

> ".... it is my professional opinion that the Hume Coal model is fundamentally consistent with best practice in design and execution, although the EIS documentation is deficient (not sufficiently clear on some details; see Appendix A). It is fit for mining project impact prediction purposes."

### ix Data correction

Data correction for barometric effects has been applied to data obtained from confined and semi confined bores as per best practice for correction of groundwater data. Data correction is not required for watertable bores and therefore was not applied to data from these shallow bores.

Density correction for bores in the Triassic Permian rocks were not required due to the very low salinities encountered in these units.

Pressure data recorded on vibrating wire piezometers and pressure transducer data loggers is corrected for barometric pressure, to derived water pressure which is used to assess seasonal variations in groundwater levels and effects from landholder pumping.

### 8.2.6 Accuracy and sensitivity

#### i Leakage from surface water

- The proponent should undertake a secure yield analysis in consultation with Wingecarribee Council to further assess impact to town water supply resulting from the reduction in yield and increased leakage predicted for Medway Dam.
- The Water Impact Assessment Report does not currently include the annual take volume from Lower Wingecarribee River, Medway Rivulet, their tributaries and the adjacent rivers and streams outlined by the numerical groundwater model.

Comments regarding the leakage from surface water were addressed in the RTS main report (EMM 2018a) Section 9.3.5 (ii) as well as in the Revised Water Assessment (EMM 2018b) Section 11.1.3 with the following response.

The overall changes to surface water flows are negligible. The main cause of surface water flow changes is a slightly reduced volume of baseflow. Streams will continue to be gaining streams and continue to receive baseflow (but at a slightly lower rate). There is a minor component of direct leakage from Medway Dam to the underlying groundwater system during and immediately following mining. These losses are considered in detail via the development of a localised model simulation and data analysis undertaken for Medway Dam. This local model ensured that the connectivity at the local scale was being considered at a local scale, and not totally reliant on the more regional model. In this localised model, based on flux analysis, there is a reversal of status from a gaining (ie baseflow reduction) to a losing system (ie leakage) at about 10 years since start of mining directly underlying Medway Dam.

The reduction in baseflow is considered within the overall reduction numbers for Medway Rivulet, and the additional leakage volume is a small percentage from the dam itself, when the watertable is lowered below the base of the dam (ie year 10). This leakage volume is calculated as an average leakage of 12 ML between years 11 and 35, and a peak of approximately 19 ML in year 21 since start of mining. The leakage volume over time is provided below in Figure 8.1.

The maximum rates of baseflow reduction as a result of the Project for each management zone are summarised in Table 8.1. The Lower Wingecarribee River and Medway Rivulet management zones have been subdivided into smaller, sub-catchments for the purpose of this assessment. The model results indicate no reduction in baseflow for the Belangalo Creek, Wells Creek and Wells Creek tributary sub-catchments, and negligible reduction in baseflow for the Nattai River management zones due to the Project.

The maximum rates of baseflow reduction are not consistent throughout the mining period. The time taken to reach the maximum rate for each management zone is shown in Table 8.1. The timing and duration of the baseflow impact for each management zone is presented in Figure 8.2. It can be seen that the rate of baseflow reduction gradually increases at the Medway Rivulet water source to a peak in year 19. A sharp decline in baseflow reduction occurs after year 20 (ie 20 years from start of mining and following cessation of active mining).

## Table 8.1 Maximum rate of baseflow reduction from surface water sources

| Surface water management zone / sub-catchments | Underlying groundwater source | Maximum rate of baseflow interception | | Time to maximum rate (years since start of mining) |
|---|---|---|---|---|
| | | ML/day | ML/year | |
| Upper Wingecarribee River | | 0.008 | 3 | 42 |
| Lower Wingecarribee River (whole zone) | NMZ1 | 0.254 | 93 | 22.5 |
| Lower Wingecarribee River excluding Black Bobs and Longacre Creeks | NMZ1,NMZ2 | 0.184 | 67 | 23 |
| Black Bobs Creek | NMZ1 | 0.063 | 23 | 26.5 |
| Longacre Creek | NMZ1 | 0.018 | 7 | 13.5 |
| Medway Rivulet (whole zone) | NMZ1 | 0.982 | 359 | 19 |
| Medway Rivulet excluding Oldbury, Belanglo, and Wells Creeks, and Wells Creek tributary | NMZ1 | 0.961 | 351 | 19 |
| Oldbury Creek | NMZ1 | 0.021 | 8 | 20.5 |
| Belanglo Creek | NMZ1 | 0 | 0 | - |
| Wells Creek | NMZ1 | 0 | 0 | - |
| Wells Creek tributary | NMZ1 | 0 | 0 | - |
| Lower Wollondilly River | NMZ1 | 0.008 | 3 | 76 |
| Nattai River | NMZ1,NMZ2 | 0* | 0* | - |
| Bundanoon Creek | SBS | 0.007 | 3 | 64 |

Notes: NMZ1 – Sydney Basin Nepean Groundwater Source Nepean Management Zone 1.
NMZ2 – Sydney Basin Nepean Groundwater Source Nepean Management Zone 2.
SBS – Sydney Basin South Groundwater Source
* - negligible

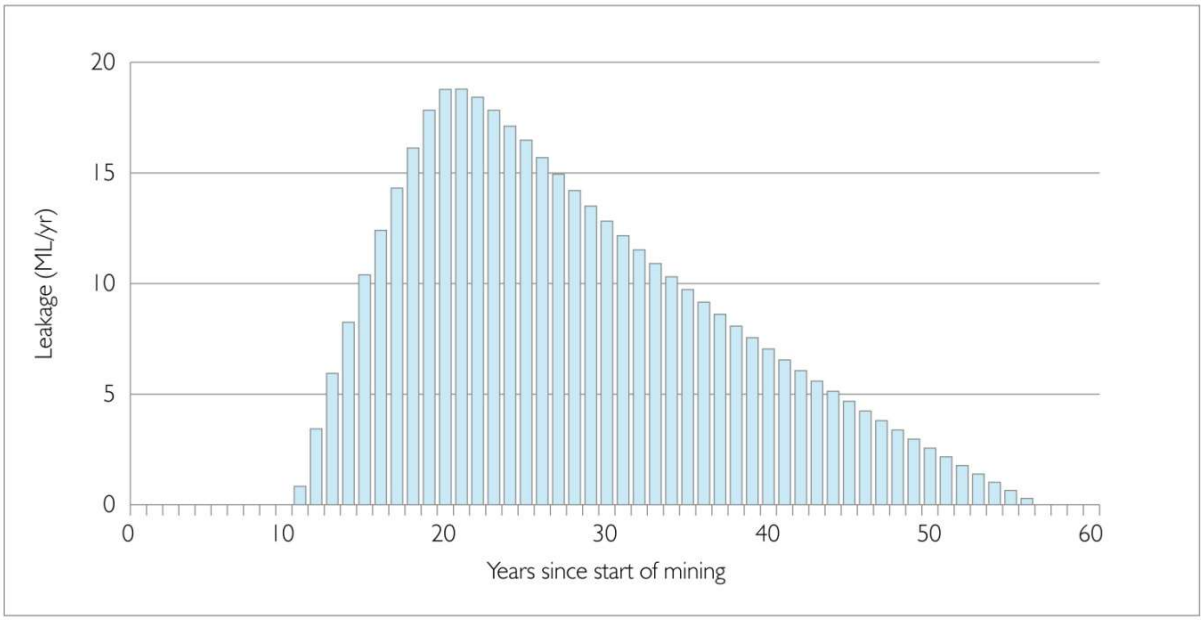



**Figure 8.1 Volume of surface water leakage over time**

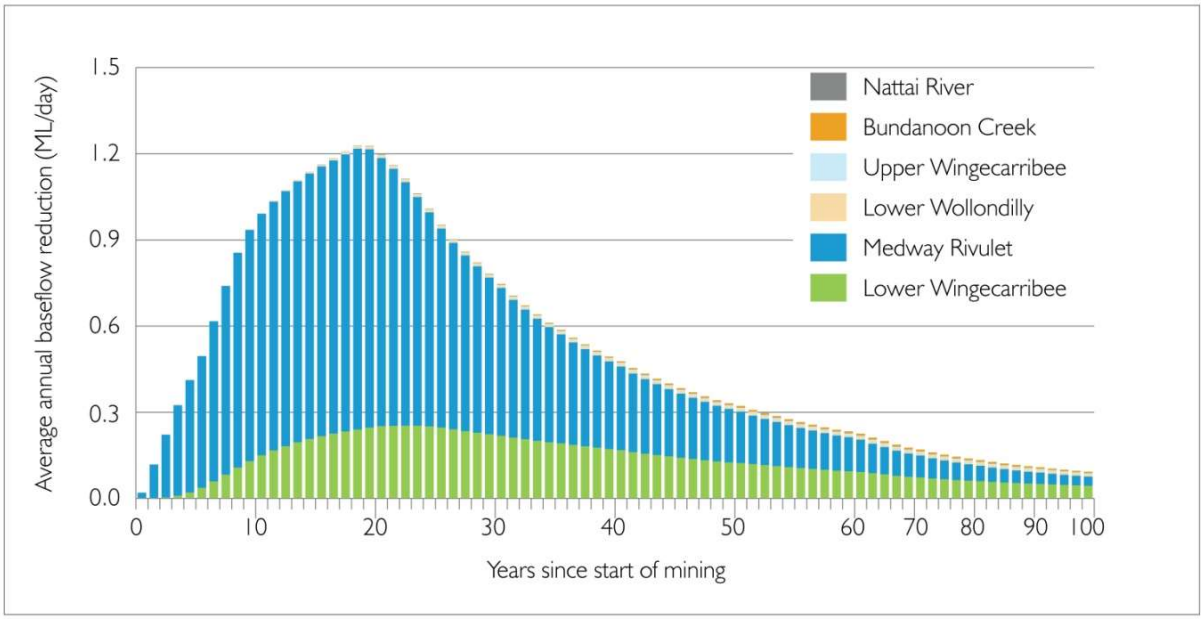



**Figure 8.2 Timing and duration of baseflow impact for each management zone**

### ii Sensitivity analyses

- The sensitivity of key model outcomes were only assessed against K, not boundary conditions, initial conditions, stresses, caving heights or mine flows.
- Revised impact predictions should be documented in a supplementary report illustrating the comparative differences between those reported in the EIS and supporting documentation and the non-average scenarios.

Comments regarding model sensitivity were addressed in the RTS main report (EMM 2018a) Section 9.3.5 (iii) with the following response.

Sensitivity analysis involves changing a model parameter by a small amount to establish how model predictions are affected by that change. In the EIS model, sensitivity analysis was applied to relaxation heights, vertical hydraulic conductivity, and drain conductance into the mine. The model audit and expert review by Middlemis (Hydrogeologic 2017) did recommend that additional sensitivity/uncertainty scenarios should be considered and this was part of the revised modelling. In the revised EIS modelling, sensitivity analysis was applied to:

- climate variability;
- specific storage;
- specific yield;
- water level recovery; and
- drain conductance.

The results of the original EIS model three parameter sensitivity analysis reported in the EIS were as follows:

- relaxation height of 2 m and 4 m. These heights were applied over an area representative of the typical extent of an actively draining area at an instant in time (about 11 $km^2$). Results indicated an increase in inflow of 4.3%; and
- Kv distributions as follows:
  - the calibrated Kv distribution; and
  - calibrated Kv of model layers 1 to 5 multiplied by 3. These layers comprise the Wianamatta Group and Hawkesbury Sandstone between the watertable and the mine workings.

The higher Kv case produces an overall 28% increase in mine inflow. Inflows are considered sensitive to the Kv distribution, in comparison to other parameters.

- Hume Coal mine drain conductance of 0.05$m^2$/d (calibrated) and 0.1 $m^2$/d. Only a comparatively small change in inflows occurs between these two cases. (Coffey 2016b).

Submissions received in response to the EIS included concerns regarding some parameters and whether these were sensitive to numerical model predictions. In response, Hume Coal committed to undertake additional sensitivity analysis and this was followed by the model audit and the independent expert review by Hugh Middlemis (Hydrogeologic 2017). Consultation with the NSW Government (DI Water) occurred in August 2017, and additional sensitivity and uncertainty modelling was discussed and agreed to at that meeting.

The sensitivity analysis in the EIS model focused on the key areas of known sensitivity and uncertainty in the data and provided efficiency to the modelling process. As part of the submissions on the Hume Coal Project and subsequent consultation with the NSW DoI Water, it was agreed to undertake some additional sensitivity runs for the model. Apart from the investigation of specific storage and specific yield values, additional sensitivity analysis has been conducted by HydroSimulations (2018) on the Modified-EIS model for:

- specific storage;
- specific yield;
- simulations with or without the **pseudo soil function**, which found that the pseudo soil function is required to be enabled in order to allow calibration convergence of the Modified-EIS model;
- simulating Hume Coal Project mining with a **drain conductance** increased by 1 order of magnitude. This indicated that the calibrated drain conductance applied in the EIS Model is considered appropriate and fit for purpose; and
- a simulation testing the efficacy of the Horizontal Flow Barrier by removing the drain cells associated with the simulation of the basalt body south of the Hume Coal Project area. The simulation found the representation of horizontal flow barriers within the EIS Model is considered appropriate and fit for purpose.

It is known that hydraulic conductivity is an important parameter in the model, so additional sensitivity on it was not required, instead it was subject to a rigorous uncertainty analysis in accordance with the draft explanatory note published by the IESC on uncertainty analysis (discussed in the RTS main report (EMM 2018a) Section 9.3.5 (iii), and presented in detail in the Revised Water Assessment (EMM 2018b), and the revised model report (HydroSimulations 2018)).

### a Specific storage

Specific storage values for the lower model layers (Layers 6 to 13) were increased by a factor of 4 while Hawkesbury Sandstone layers and above (Layers 1 to 5) were increased by a factor of 3.

The values adopted within the revised model are now much closer to the average optimised value provided by the pumping tests. Increasing the specific storage values improved the SRMS percentage error for the revised calibrated model. Due to the updated values being closer to actual field measurements, and the improved SRMS, the increased specific storage values have been formally adopted for use within the revised-EIS model.

### b Specific yield

The specific yield values used in the EIS model (Coffey 2016b) were questioned within submissions for being lower than reported within the data analysis and inconsistent with available pumping test data (Coffey 2016a).

During the process of updating the model, a sensitivity run was conducted on specific yield values that were three times greater than the values for all EIS model layers. These changes resulted in improvements to the percent SRMS error for the calibration model of 0.25%, and the values are now much closer to the field values reported within the data analysis (Coffey 2016a). The increased specific yield values have been formally adopted for use with the revised EIS model.

### c Water level recovery

The EIS Model (Coffey 2016b) was run without pseudo-soil functionality due to the version of MODFLOW used for the EIS model not supporting the pseudo soil function. The use of pseudo soil allows the rewetting of model cells once groundwater levels decline below the base of a model cell and therefore allows for a more realistic simulation of post mining recovery of water levels. The revised model (HydroSimulations 2018) adopts the use of the pseudo-soil function, which allowed for much better model convergence.

### d Drain conductance

The sensitivity analysis for the EIS groundwater model concluded that there is only a small change in inflows with realistic variations to drain cell conductance, use to simulate dewatering of the mine workings. This was considered again during the model audit and rework by HydroSimulations who then modelled additional sensitivity on drain conductance by increasing the drain conductance parameter to 0.5 $m^2/d$ (a factor of 10).

The 0.05 $m^2/d$ drain conductance value used in the EIS model was calibrated against the discharge volumes from the Berrima Mine void, and the relative area of the cell sizes between Berrima Mine and Hume Coal within the model domain (Coffey 2016b). The EIS modelling report also highlights that similar drain conductance values (0.1 $m^2/d$) were used to simulate non-collapsing development headings for proposed mining at Dendrobium Area 3B (Coffey 2012).

The 0.05 $m^2/d$ conductance value applied to the drain cells used to simulate mining of the Hume Coal Project was criticised within submissions for being too low and a parameter that was not adequately explored within the sensitivity analysis. However, HydroSimulations defended the adoption of this value at a meeting with DP&E and DI Water in August 2017 based on comparison with other sites after allowing for different cell sizes and different mining geometries.

As part of the groundwater model revision, a parameter sensitivity run that increased the drain conductance to 0.5 $m^2/d$ (a factor of 10) was completed.

Increasing the drain conductance by an order of magnitude resulted in a near doubling of the 'to sump' mine inflow, however the total inflow only increased by 33%. An approximate 10% increase in the number of bores impacted by more than 2 m also occurred – which is not significant. This demonstrates that the model is overall not particularly sensitive to small realistic changes in drain conductance.

If this increase in conductance was similarly applied to the drains simulating mining at Berrima Colliery, the modelled inflow would far exceed the observed discharge from the Berrima mine void and the conductance values would no longer be calibrated, indicating that this factor of 10 increase in drain conductance is an unrealistic value.

The drain conductance adopted in the EIS model is retained for the revised model following detailed review on drain conductance and sensitivity analysis. Due to the original drain conductance being considered correct and appropriate, and the sensitivity analysis demonstrating that increasing the value by an order of magnitude would result in unrealistic outcomes, alternative results (ie maps and predictions using unrealistic drain conductance values) has not been undertaken. Therefore, alternative drawdown maps (adopting higher drain conductance values) are considered inappropriate and not provided.

The similarities in the conductance values for two models within the Southern Coalfield, as well as knowing that the model does not calibrate with an order or magnitude change, serve to show that the conductance values used in the EIS model are suitable and appropriate. The NSW Government independent expert review (Hydrogeologic 2017) concluded that the drain conductance in the original EIS model (and therefore also the subsequent revised model) was appropriate.

### e The presence or influence of the modelled horizontal flow barrier

In the submissions on the EIS, some concerns were raised that the utilisation of the horizontal flow barriers would limit the extent of drawdown within the basalt providing unrealistic 'protection' from drawdown impacts to bores located within the basalt. However, as indicated in the data analysis, large drawdowns to the top of the Hawkesbury Sandstone would only result in small drawdown impacts in the basalt, which would be satisfied in time by decreased baseflow to streams (Coffey 2016a).

HydroSimulations has reviewed this conceptualisation and modelling and finds the method used to simulate the basalt conceptualisation to be effective (Hydrosimulations 2018).

Sensitivity runs were undertaken that demonstrate the method used to simulate the interpreted structure and associated unsaturated zone has resulted in a limited ability of drawdown to propagate through the basalt. This is consistent with the EIS (Coffey 2016a, 2016b) conceptualisation that appears to be a strong interpretation of the available evidence. The barriers in the model alone are shown not to provide the protection (ie they are not effective barriers to the overall groundwater flow) that was raised in the submissions as a concern.

## iii Uncertainty

- The rate of groundwater recovery and hence the duration of impacts on landholder bores and watercourses is based on modelling assumptions of reinjection, groundwater inflows and the site water balance. Uncertainty in these predictions may have significant implications to impact predictions and the acceptability of proposed mitigating requirements. Understanding the worst-case scenario and ensuring the model is fit for purpose is critical to assess this.
- Uncertainties are only broadly described.

Comments regarding model sensitivity were addressed in the RTS main report (EMM 2018a) Section 9.3.5 (x) with the following response.

There are different ways to categorise uncertainty, but it is often categorised into two main types (Barnett et al 2012):

- deficiency in our knowledge of the natural world (including the effects of error in measurements); and
- failure to capture the complexity of the natural world (or what we know about it).

Middlemis and Peeters (2018) propose four sources of scientific uncertainty affecting groundwater model simulations:

- structural/conceptual - geological structure and hydrogeological conceptualisation assumptions applied to derive a simplified view of a complex hydrogeological reality;
- parameterisation - hydrogeological property values and assumptions applied to represent complex reality in space and time;
- measurement error – combination of uncertainties associated with the measurement of complex system states (heads, discharges), parameters and variability (3D spatial and temporal) with those induced by upscaling or downscaling (site-specific data, climate data); and
- scenario uncertainties - guessing future stresses, dynamics and boundary condition changes (eg mining, climate variability, land and water use changes).

These are discussed in relation to the Hume Coal Project below.

### a Method for uncertainty analysis

A detailed uncertainty analysis has been completed for the revised EIS model. The EIS model was initially reworked and upgraded to a new more modern software platform and this provided benefits to the mass balance and SRMS calibration statistics. Additional sensitivity was then undertaken, as requested by the NSW Government and as recommended by the independent expert reviewer Hugh Middlemis (see Section 9.3.5 (ii) of the RTS main report (EMM 2018a) or Section 8.26 (ii) of this report). Following this model upgrade, a very detailed and considered uncertainty analysis was completed.

This uncertainty analysis was undertaken following consultation with DI Water and the independent expert reviewer Hugh Middlemis, in regard to how the uncertainty analysis should be done, what parameters should be tested and to what level the analysis needs to be undertaken. The uncertainty analysis, combined with the model rework, addresses all the concerns about the EIS model adequacy.

The method of uncertainty analysis undertaken was aligned to the recent draft guidelines on uncertainty analysis released by the IESC in March 2018 (Middlemis and Peeters 2018). The method undertaken for the Hume Project is the most complex and robust approach as suggested in the IESC guidelines. The method adopted by the Hume Coal Project is described in the guidelines as follows:

> ”An ensemble of model predictions is generated, based on a large number of model evaluations with different parameter values that are all consistent with the observations (Middlemis and Peeters 2018).“

The Hume Coal uncertainty analysis study addresses parameter uncertainty by stochastic modelling using the *Monte Carlo* method. This method operates by generating numerous alternative sets of input parameters to the deterministic groundwater flow model (realisations), executing the model independently for each realisation, and then aggregating the results for statistical analysis. HydroSimulations (2018) details this work.

Numerous numerical realisations were undertaken using cloud-based processors due to the significant computer processing power needed to undertake the work. It is a new and evolving area of groundwater modelling and computer science, and the work completed for the Hume Coal Project ensures that the modelling and predictions are as accurate and considered as possible to provide confidence and reassurance to the NSW Government, the local community and the people of NSW.

### b Uncertainty analysis results

For each of the 481 accepted model runs the realisation generated by the Monte Carlo process considered every pilot point (256 of them) and assigned a Kx value and a Kx/Kz ratio, for a total of 6,656 parameters (256 points * 13 layers * 2 parameters). Each model cell for each run was then assigned a Kx and a Kz value through interpolation from surrounding pilot point values by *kriging*.

The uncertainty analysis model results are by far the most robust and accurate assessment of the Hume Coal Project completed to date. The model results are considered to be accurate and additional modelling at this time is not warranted. The detailed uncertainty analysis demonstrates the narrow band of uncertainty in the model predictions, and renders the predictions as being sufficiently accurate. A conservative approach to use of the uncertainty analysis results is presented for the impact assessment (ie 67$^{th}$ percentile not 50$^{th}$ percentile) and, therefore, underestimation of impacts is highly unlikely and, if anything, an overestimate of impacts is presented in the Revised Water Assessment (EMM 2018b).

Although the Pells and Pan (2017) model did undertake a simple uncertainty analysis, it was not to the same extent as the recent uncertainty analysis for the revised model by HydroSimulations using cloud computing technology. The HydroSimulations uncertainty analysis was completed with the consideration of all data, in consultation with the independent expert reviewer (Hugh Middlemis) and in consultation the NSW DI Water modellers, and it also aligns to the newly developed IESC draft explanatory note on uncertainty analysis (Middlemis and Peeters 2018) and is, therefore, considered to be the most accurate estimate of impacts from the Project.

The uncertainty analysis undertaken considers the range of potential hydraulic conductivity parameters (Kz, Kx, and Ky) that may exist and completes model runs with combinations of these different input parameters. The range of hydraulic conductivity values tested in the uncertainty analysis provides a range of values that incorporates the presence or not of localised faults and fractures that could be conduits and/or barriers to groundwater flow.

The results of the uncertainty analysis demonstrate that the uncertainty falls within a relatively narrow range for both groundwater inflow (take over time), and predictions of drawdown and recovery. Therefore, the model predictions of inflow and drawdown in landholder bores can be relied upon. The original EIS model results and the revised results can be considered accurate and fit for purpose with additional confidence now the uncertainty analysis has been completed, and the results demonstrate that there is a large degree of confidence in the model predictions.

The uncertainty analysis with respect to the mine inflow predictions, drawdown in landholder bores and the watertable drawdown is taken to be the 67$^{th}$ percentile for consideration of potential inflow (ie not the 50$^{th}$ percentile which is the most likely scenario). This therefore represents a conservative approach for prediction of inflows. In accordance with the draft explanatory note from the IESC on uncertainty modelling (Middlemis and Peeters 2018), the 67$^{th}$ percentile represents the boundary where above which impacts become '*unlikely to occur in normal circumstances*'.

The updated model and uncertainty analysis provides updated predictions which are very similar to the original EIS predictions, with only very minor differences overall in the level of impact:

- mine inflow reduced by 10% (225 ML); and
- number of bores impacted increased by 1% (1 bore).

This provides a significant improvement in the level of confidence in the accuracy of the model predictions. Many of the concerns raised by both NSW Government and the community were around the perceived and demonstrated 'accuracy' of the model predictions and the reliability of these results. The detailed sensitivity analysis, uncertainty analysis and independent expert review as per recommendations from both the NSW requirements and Federal Government IESC guidelines have been adopted, considered, and actioned.

The independent expert review of the EIS model and revised model provides a high level of confidence in the results, and that they are accurate and can be relied upon to predict impacts by the Project.

### iv Volumetric take/inflow to mine

- Issues with calibration of the numerical model and application of average conditions mean the volumes predicted could be in error.
- Distribution of groundwater take throughout mining and recovery periods are presented based on model predictions that could be in error and should be reviewed following model calibration.
- The induced leakage calculated from the Upper Nepean and Upstream Warragamba Water Source is based on average conditions. Induced leakage should be calculated based on maximum leakage to ensure adequate volumetric licence can be obtained before commencement to account for the predicted take in accordance with the Aquifer Interference Policy.
- It is required that an account of model predicted annual take be prepared for the surface water sources that have predicted intercepted baseflow.

Comments regarding inflow to the mine were addressed in the RTS main report (EMM 2018a) Section 9.3.5 (xiii) with the following response.

### a Inflows

The EIS model has been revised after a detailed audit, upgraded software platforms and solvers, additional sensitivity analysis, and a detailed uncertainty analysis (HydroSimulations 2018). The model has also been subject to additional NSW Government independent expert review (Hydrogeologic 2017). The additional work and review concluded that the original EIS model prediction of inflow was accurate (in terms of both inflow and drawdown in bores). Although some minor differences have been calculated, total mine inflow has reduced by 10% (from 2,290.5 ML in the EIS to 2,066 ML in the Revised Water Assessment (Appendix 2 to the RTS main report)).

### b Alternate studies

Alternate studies commissioned by local interest groups have been published in recent years. Both the Pells and Pells (2013) and the revised model presented in Pells and Pan (2017) have been peer reviewed by Senior Principal Hydrogeologist, John Ross (EMM 2018b), Appendix 2 to the RTS main report. This specialist review was undertaken due to the numerous submissions from interest groups and the general community that relied heavily on predictions made in these two reports to support their arguments in opposition to approval of the Project. The review (EMM 2018b) considers both models and their 'fitness of purpose' for making impact predictions for an underground coal mine project. Many of the community and interest group submissions question the differences between the EIS model (Coffey 2016b) results and those presented in the Pells and Pells (2013) and the Pells and Pan (2017) model reports.

The review of the Pells and Pan (2017) model confirmed that the model and reporting did not follow the guiding principles as outlined in the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). The review revealed some major flaws with the model including:

- deficiencies in conceptualisation;
- deficiencies in boundaries assumptions;
- lack of data; and
- unrealistic hydraulic parameters.

The mine method, being non-caving, in panels (not longwall extraction as assumed in Pells and Pells (2013)), means that the roof remains intact with no fracturing of overlying strata. Following mining and filling of voids, recovery of the groundwater level commences immediately after bulkheads are installed, and occurs until pre mining levels are reached. The Pells and Pan (2017) submission suggests that changes to the mining method have little bearing on the inflow volume to the mine. This is different to what would logically be expected and different to what the HydroSimulations (2018) sensitivity analysis revealed. The primary difference is that the Pells and Pan (2017) model has:

- conductance values for mine inflow that are unrealistically high;
- hydraulic conductivity values for overlying strata that are unrealistically high; and
- specific storage/specific yield parameters that are too high.

EMM (2018b) surmises that the key concerns with the Pells and Pan (2017) model is that no conceptualisation is provided, the calibration is poor, there is limited justification for the very high horizontal hydraulic conductivity and conductance values adopted in the model, and the adopted boundary conditions are not suitable. As a result, this Class 1 model is not 'fit for the purpose' of making predictions on drawdown or mine inflow and any predictions made are considered 'unreliable' (EMM 2018b).

The Pells and Pan (2017) model is not as robust or detailed as the EIS model (Coffey 2016b), or the revised model and detailed uncertainty analysis undertaken by HydroSimulations (2018). The revised model (HydroSimulations 2018) provides the most accurate and robust assessment of the potential drawdown in landholder bores for the Hume Coal mine. This statement is agreed to and supported by the NSW Government independent expert reviewer, (Hydrogeologic 2017) in his very detailed review of the data, analysis and models by both Coffey (2016a, 2016b) and HydroSimulations (2018).

### c Comparison to Berrima Mine

The groundwater inflow to the Berrima Mine was used in the calibration of the EIS model. Although the Berrima mine is smaller in size that the proposed Hume Coal mine, the mining impacts in part of the mine are very different and the local geology is different. At Berrima, full pillar extraction occurred, which allowed roof collapse and fracturing of the overlying strata, and this in turn allows for increased groundwater inflow volume to the mine workings. The mine design is a key difference between these two mines, but as seen on Figure 8.3, two other differences that potentially affect the different inflow volume at Berrima are:

- at Berrima, almost the entire mine drains to the main headings and this water then becomes mine discharge, meaning that all of the old workings are constantly being de-watered. At the Hume Coal Project, panels have been designed to be compartmentalised and retain water once mining has been completed.; and

- greater exposed sandstone at the surface at Berrima and therefore higher rainfall recharge rates (ie there is more overlying shale and therefore less groundwater recharge at Hume).

The use of the Berrima mine inflow in calibration of the EIS model, means that this inflow volume and the above differences are incorporated and considered when estimating the potential inflow to the Hume Coal mine in the EIS model. This approach for calibration is endorsed by the NSW Government independent expert reviewer, Hugh Middlemis who states:

> "this is a good example of a best practice method that minimises non uniqueness issues and supports a model Class 2, confidence level" (Hydrogeologic 2017).

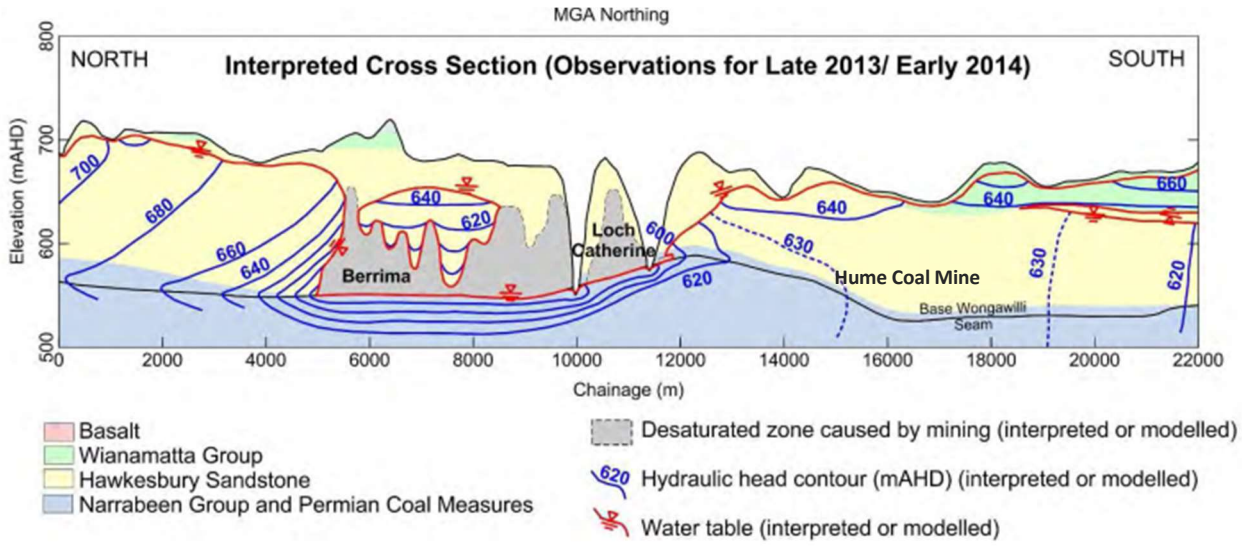



**Figure 8.3 Interpreted cross-section and piezometric levels 2013/14 (after Coffey 2016b, Figure 4.3)**

### d Model audit and peer review – inflows

The model audit and model rework by HydroSimulations (2018) used updated software solvers, and the pseudo-soil function, which proved beneficial for the model calibration, mass balance and convergence. The pseudo-soil function was therefore adopted in the final revised model.

The NSW Government independent expert review by Hydrogeologic (2017) considers the accuracy of the original EIS model and, therefore, also the reliability of the mine water inflow. The review states that the original EIS model was 'fit for mining purpose impact predictions' and the revised model and uncertainty analysis undertaken by HydroSimulations (2018) has further confirmed this. There is confidence in the inflow predictions from the revised HydroSimulations (2018) model, which is supported by data, sensitivity runs, and the detailed uncertainty analysis results.

Due to the increased confidence in the model predictions of inflow and the overall water balance, concerns around water management of a greatly increased inflow volume are no longer valid. In addition, the surface water balance has been reworked with the updated results from the revised groundwater model. The surface water balance (discussed in Chapter 8 of the RTS main report), provides additional detail on water management at the site, including consideration of climate variability.

The water inflow to the mine is required to be licensed from the source in which it is derived from, and the licensing requirements to cover the peak groundwater inflow to the mine workings are clearly discussed in Section 8.5.2 and the Revised Water Assessment (Appendix 2 to the RTS main report). The Revised Water Assessment takes a very conservative approach and adopts the licensing of all inflow to the workings irrespective of whether this inflow is removed from the mine sump.

The model audit, revised modelling (HydroSimulations 2018) and independent expert review (Hydrogeologic 2017) confirms that the EIS and revised model predictions of inflow are accurate with remodelling, resulting in a minor lowering of peak inflow volume to the mine (a reduction of 10%). The model, audit, rework and the additional detailed uncertainty analysis provides improved calibration statistics and improved mass balance errors. This further enhances confidence in the predicted model inflows.

### e NSW regulations and the AIP - licensing inflows and intercepted baseflow

The model has been designed in accordance with the NSW Aquifer Interference Policy 2012 (AIP) requirements and predicts the total inflow volume as well as the volumetric contribution and timing of that contribution from adjacent and overlying surface water and groundwater sources. These volumes are presented in the EIS (EMM 2017a) and have been reworked in Section 8.5.2 based on the revised Water Assessment (Appendix 2 to the RTS main report) and the revised groundwater model (HydroSimulations 2018). Mine inflows are 10% lower than those predicted in the EIS and intercepted baseflow volumes are similar. Losses from Medway Dam have been analysed using localised modelling and are presented on a yearly time-step (see Figure 8.1 in Section 8.2.6 (i)). The yearly timestep and maximum annual leakage is clearly presented as requested for licensing purposes as required by the AIP.

The revised Water Assessment (Chapter 11 of Appendix 2 to the RTS main report) provides more information on water take over time (including peak yearly take) from overlying sources and from Medway Dam in particular, as requested by the NSW DPI in their submission.

This volumetric contribution from each respective water source determines the water licence requirement from each source predicted to experience a volumetric impact. Ninety-three percent (93%) of the licence volume required has already been purchased and this is considered in more detail in Section 8.5.2 and the Revised Water Assessment (Chapter 12 of Appendix 2 to the RTS main report). The licence volume is required to be held prior to the volume being taken. The model predicts peak take for groundwater to occur in the latter years of mining (Years 17 and 18), and surface water peak take will occur at the conclusion of mining. Therefore, there is sufficient time for the limited volume of additional licences to be acquired. In the unlikely event that future remodelling predicts slightly higher volumes that are required, there will be sufficient time and market depth to acquire these licences as well (should they be required).

Water sharing plans set the rules for how water is shared within a water source for a ten-year period to provide security to both the environment and water users over that time. Two of the major elements of a water sharing plan are to (DI Water 2018a):

- provide water for the environment by protecting a proportion of the water available for fundamental ecosystem health....

- set annual limits on water extractions to ensure that water extractions do not increase and therefore erode the water for the environmental and also the security of supply to water users....

Specifically, for groundwater sharing plans, the environmental water provisions are aimed at protection of groundwater dependent ecosystems and "important baseflows to rivers and tidal creeks" (DI Water 2018a).

The protection of the environmental values, including baseflows, is achieved by establishing the Long Term Average Annual Extraction Limit (LTAAEL) for each groundwater source at a sustainable volume. This inherently serves to protect the storage within the system, and to reserve water for ecosystem functions, including baseflow. Together with other water sharing plan rules such as distance conditions and trading rules ensure that the water requirements of the environmental users are prioritised over extractive uses.

The *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* has established LTAAELs for each individual water source, and these limits consider environmental water requirements. For the Sydney Basin Nepean Groundwater Source, the water sharing plan has taken an additional step in this regard and has established local Management Zones to allow environmental protection to be applied at a scale smaller than the total water source.

Licences have been acquired on the open market or via an open public tender process, and are therefore within the sustainable limits of each respective water source. The physical impact of the water take for the mine on the water supply sources as a whole remains largely unchanged as the volumes are within the sustainable limits for each water source, and largely from active licences.

The NSW DPI acknowledge in their submission that the market depth for water licence is sufficient for procurement of these licences as the Project ramps up and therefore licensing of water does not represent a significant risk for the Project. The volume of water that inflows to the mine is all accounted for in licences purchased from existing licensed users as per the AIP. Therefore, there are no additional volumetric 'impacts', over and above current levels of 'impact', to WaterNSW storages and catchments, particularly those within the Sydney Catchment Authority areas.

### v Drawdown

- The groundwater model is a critical component of the EIS in regard to the potential for connection between water sources, as well as in estimating the volumes likely to be taken as a result of the mining.
- The cumulative impact is not well described, and the residual predicted water levels do not appear to be realistic.
- The water level impact contours derived from the modelling are strangely oriented and distributed. It is not clear whether the progression of mining is a factor, or if the difficulties with the numerical groundwater model have resulted in the strange distribution.
- While not assessed by the proponent, the water level / pressure impacts are considered to be Level 2, while the water quality impacts are likely to be Level 1.

Comments regarding drawdown were addressed in the RTS main report Section 9.3.5 (xiv) with the following response.

The mitigation strategies for minimising impacts to landholders includes the mine design and planned sealing of panels following mining and retaining surplus mine water in these sealed voids as mining progresses. These mitigation strategies will not prevent drawdown in landholder bores. However, compared with other potential mining techniques often used in underground coal mining, these measures are fundamentally mitigation strategies designed to minimise the overall take of groundwater and the drawdown in overlying landholder bores.

#### a Watertable drawdown contours

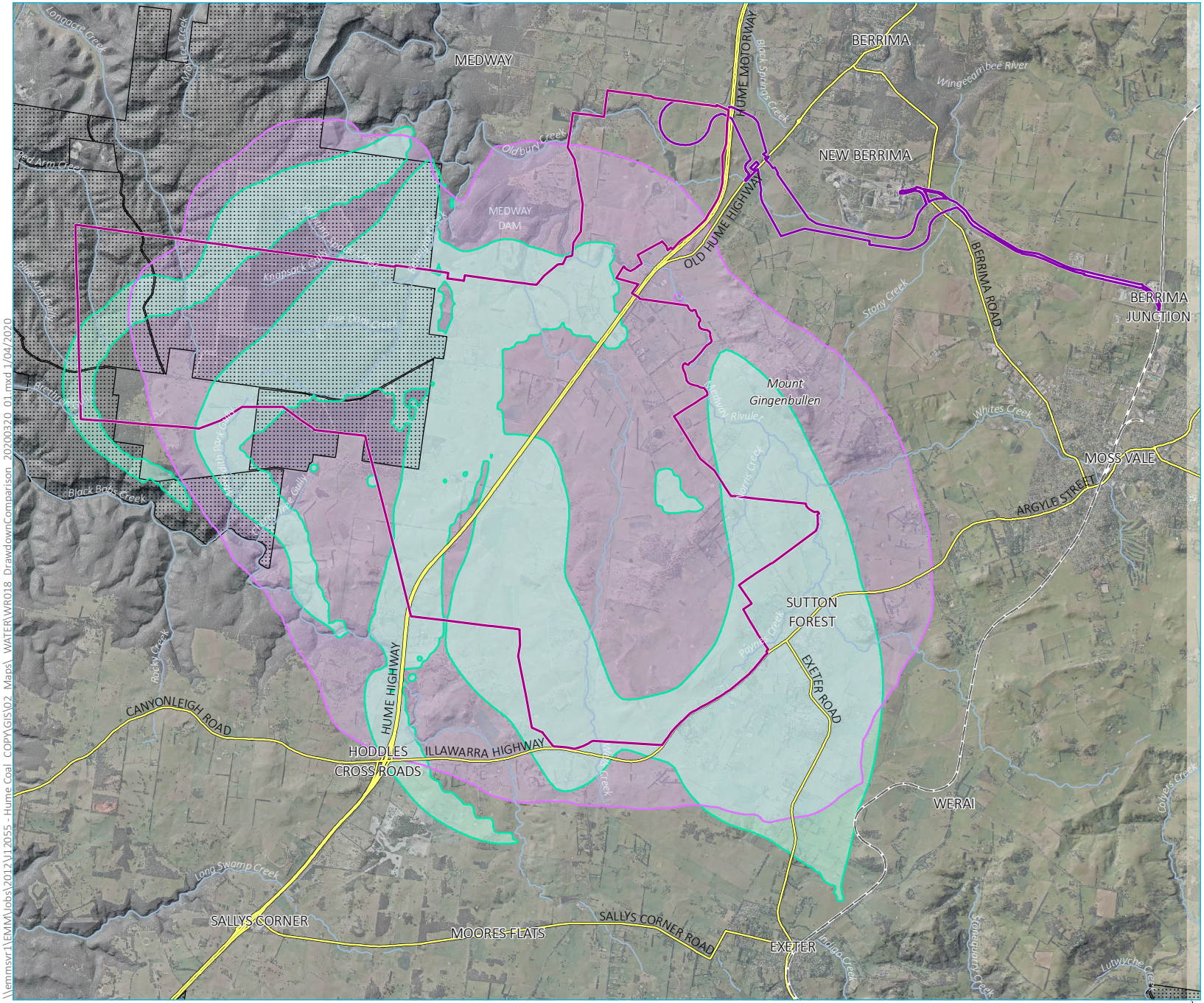
The shape of the watertable drawdown in the EIS was investigated in detail during the model audit and model rework by HydroSimulations (2018). A comparison between the maximum watertable drawdown in the EIS and the revised maximum watertable drawdown is presented in Figure 8.4 (and in Appendix 2 to the RTS main report, Revised Water Assessment Figure 11.1).

Following the update to MODFLOW-USG, and the implementation of the pseudo soil function, a change in the watertable drawdown pattern emerged and it now manifests as a concentric spatial drawdown pattern. The revised maximum drawdown together with the likely to be impacted water bores located above the mine footprint is shown in Figure 8.5.

#### b Confidence with landholder bore drawdown predictions

The main concern pertaining to drawdown model predictions in landholder bores is based primarily on the assumption that the EIS model is deficient and only classified as Class 1 confidence level. However, as demonstrated in Section 8.2.3, the original EIS model was indeed a Class 2 model and as clearly stated by Hydrogeologic (2017) in his independent expert review, the EIS model is ‘fit for impact prediction purposes’, even though the reporting of the model could have been improved. However, since that time, several refinements to the model have been made and has resulted in similar drawdown predictions in landholder bores as the original model.

Although the drawdown impact is over a slightly larger area in the revised model, much of this expanded area constitutes a more minor drawdown in bores. So, although over a larger area, the degree of drawdown in many bores is reduced. Figure 8.6 shows the extent of drawdown and the likelihood of registered water bores being impacted by 2 m or greater drawdown.




KEY

- Hume Coal Project area
- Berrima Rail Project area
- 2 m water table drawdown contour (maximum extent)
- EIS model
- Revised model

Existing environment

- Rail line
- Major road
- Named watercourse
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 1 2 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMM\Jobs\2012\J12055 - Hume Coal COPY\GIS\02 Maps\ WATER\WR018 DrawdownComparison 20200320 01.mxd 1/04/2020

Comparison between maximum watertable drawdown in the EIS and the RTS

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 8.4

HUMECOAL PROJECT

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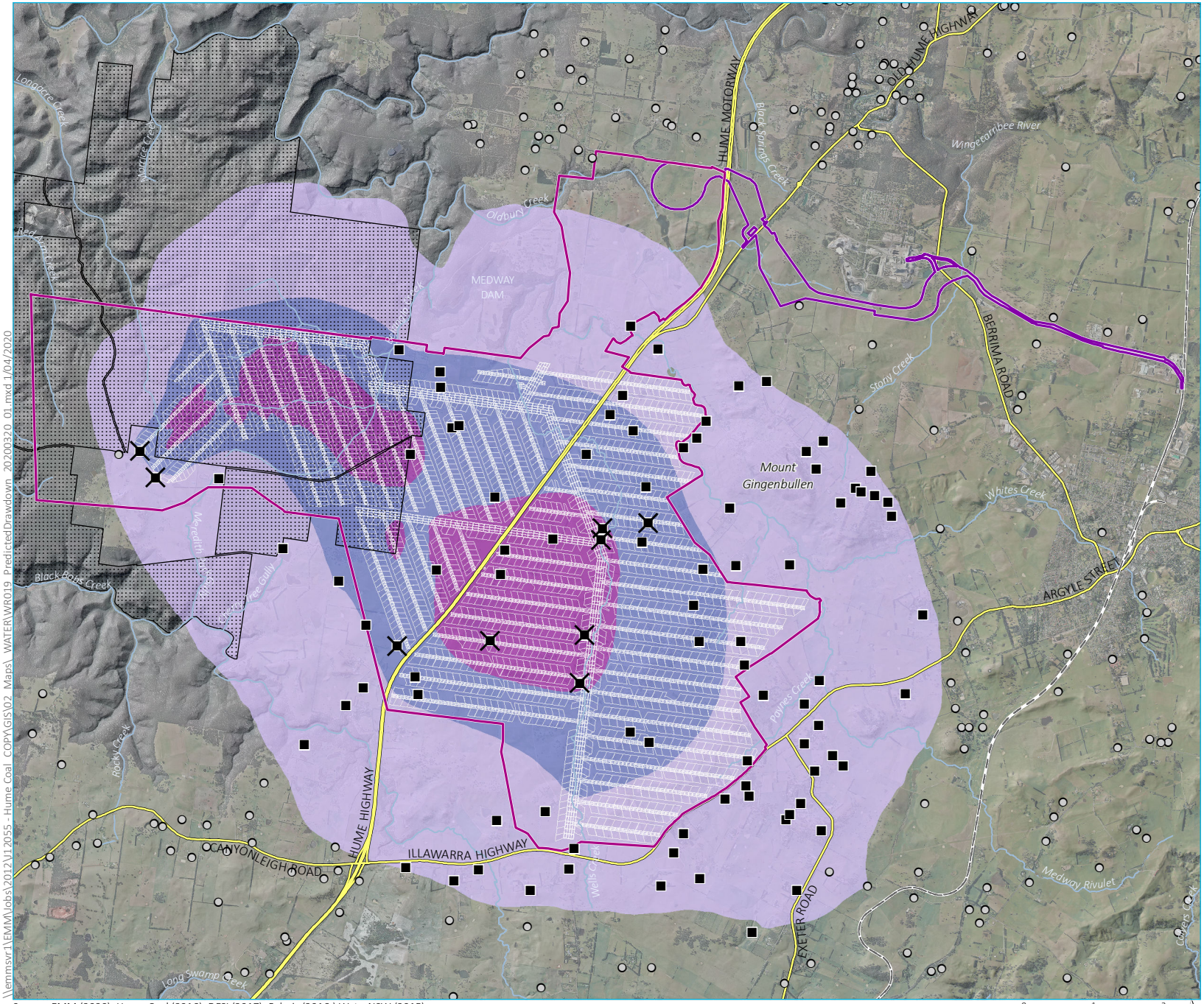
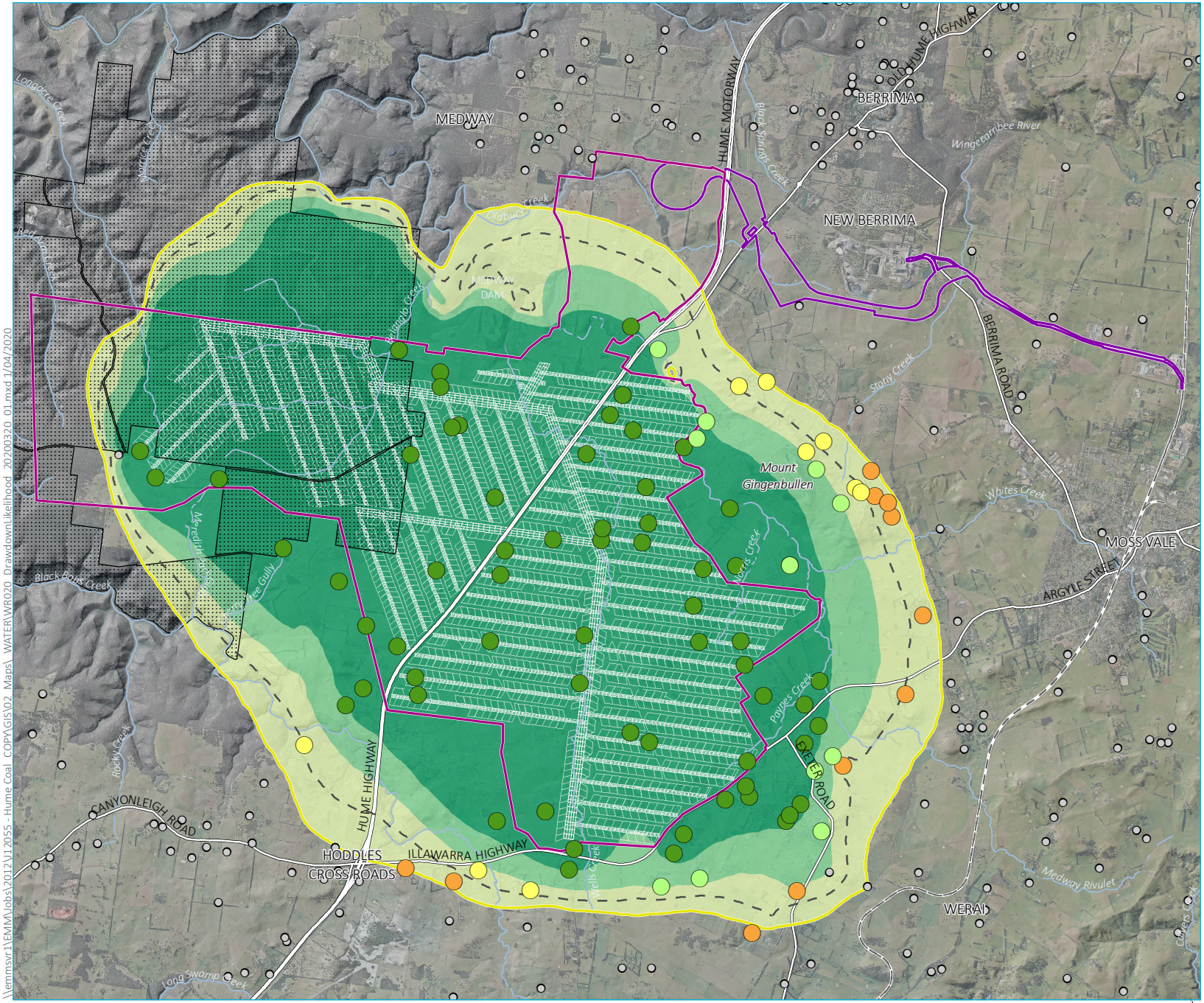

KEY
Hume Coal Project area
Berrima Rail Project area
Underground mine workings (indicative)
Bore intersected by mining
Bore impacted by 2 m drawdown or more
Non-affected bores
Maximum water table drawdown (m)
2 - 10
10 - 20
20 - 30
Existing environment
Rail line
Major road
Named watercourse
Belanglo State Forest
MEDWAY DAM
Mount Gingenbullen
HUME MOTORWAY
OLD HUME HIGHWAY
BERRIMA ROAD
ARGYLE STREET
HUME HIGHWAY
ILLAWARRA HIGHWAY
CANYONLEIGH ROAD
EXETER ROAD
Wingecarribee River
Black Bobs Creek
Longacre Creek
Oldbury Creek
Stony Creek
Whites Creek
Paynes Creek
Medway Rivulet
Rocky Creek
Long Swamp Creek
Wells Creek
Covets Creek
Predicted watertable drawdown
Hume Coal and Berrima Rail Project
DPIE Water report
Figure 8.5
0 1 2 km
GDA 1994 MGA Zone 56
N
HUMECOAL PROJECT
EMM creating opportunities
Source: EMM (2020); Hume Coal (2016); DFSI (2017); Palaris (2016;) WaterNSW (2015)
\\emmsvr1\EMM\Jobs\2012\V12055 - Hume Coal COPY\GIS\02 Maps\ WATER\WR019 PredictedDrawdown 20200320 01.mxd 1/04/2020




KEY

- Hume Coal Project area
- Berrima Rail Project area
- Underground mine workings (indicative)
- Non-affected bores

Confidence of 2 m or more drawdown in landholder bore

- Very likely
- Likely
- Median
- As likely as not

Confidence of 2 m or more watertable drawdown

- Very likely
- Likely
- As likely as not
- Median (as likely as not)
- Watertable drawdown unlikely to occur outside this contour

Existing environment

- Rail line
- Major road
- Named watercourse
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); Palaris (2016;) WaterNSW (2015)

0 1 2 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMM\Jobs\2012\V12055 - Hume Coal COPY\GIS\02 Maps\ WATER\WR020 DrawdownLikelihood 20200320 01.mxd 1/04/2020

# Likelihood of drawdowns of 2 m or greater in registered water bores

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 8.6

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Many community members and businesses raised concerns that the EIS had inaccurate drawdown predictions when compared to the Pells and Pells (2013) and Pells and Pan (2017). It is noted that both models (Pells and Pells 2013; Pells and Pan 2017) were Class 1 and therefore not suitable to make impact predictions as per the Australian Groundwater Modelling Guidelines (Barnett et al. 2012). The EMM (2018c) review of the Pells and Pells (2013) and Pells and Pan (2017) model reports highlighted other shortcomings, which is discussed in more detail in Appendix 2 to the RTS main report. The summary conclusion of the review of the Pells and Pells (2013) and Pells and Pan (2017) states that '***the model is not 'fit for the purpose' of making predictions on drawdown or mine inflow and any predictions made are considered 'unreliable'.***

The necessity for the EIS model to predict impacts to water bores and stream baseflows, and to predict inflow to the mine workings is well understood. The model has been peer and expert reviewed throughout the entire modelling process, and the post EIS audit, remodel, and detailed uncertainty analysis, which specifically considered the number of potentially impacted water bores for different uncertainty scenarios.

Hume Coal, the EIS modelling team and the NSW Government independent expert reviewer are confident that the model has been robustly conceptualised and developed, and believes that it demonstrates industry best practice, and that potential impacts are accurately predicted. The model can be relied upon to predict likely impacts in landholder bores, and the model will be verified annually, and then updated, reworked and or recalibrated as required.

The drawdown contours do not extend laterally very far from the mine footprint. This is largely due to the absence of fracturing of overlying strata and the sealing of panels as mining progresses.

### c Individual landholder bore drawdown assessment

The potential for impacts to be greater than those predicted for individual bores is low due to the conservative approach taken to modelling, and the adoption of conservative results (ie 67$^{th}$ percentile results of 94 bores rather than the more likely 50$^{th}$ percentile results of 84 bores). Consequently, the predictions from the model are considered conservative and the actual impacts are more than likely to be less than the predicted impacts.

Mitigation and management strategies for water bores includes: model verification, rework and recalibration as required, and revised make good arrangements for individuals. The model verification is the key management strategy for confirming impacts in landholder bores. The drawdown impact to water bores is predicted to occur over several decades from commencement of mining and the make good assessment will be staged to roll out over time.

Hume Coal commits to annual model verification, and then recalibration and model revisions as required. Model verification provides the most accurate information on timing and level of impact for each individual bore and appropriate mitigation options can therefore be confirmed and implemented in advance of any impacts actually occurring.

### d AIP minimal impact criteria

DI Water consider that the Project, in accordance with the AIP minimal impact criteria, triggers 'Level 2 impact' for drawdown in landholder bores and 'less than Level 1' impact for in groundwater quality. The AIP states the following in regard to minimal impact and the level of impacts:

> "There are two levels of minimal impact considerations specified in table 1. If the predicted impacts are less than the Level 1 minimal impact consideration then these impacts will be considered as acceptable.

Where an activity's predicted impacts are greater than the Level 1 minimal impact considerations specified in table 1, but these predicted impacts exceed the Level 1 thresholds by no more that the accuracy of an otherwise robust model, then the Project will be considered as having impacts that are within the range of acceptability, with extra monitoring and potential mitigation or remediation required during operation, should the Project be approved. In such circumstances, the Minister's advice will include a request that appropriate conditions be imposed to ensure the impacts of the activity are acceptable. This may include for example, adaptive management conditions requiring the proponent to monitor the actual impacts of the proposal and take action to mitigate or remediate the impacts that exceed the Level 1 thresholds.

Where the predicted impacts are greater than the Level 1 minimal impact considerations by more than the accuracy of an otherwise robust model, then the assessment will involve additional studies to fully assess these predicted impacts. If this assessment shows that the predicted impacts do not prevent the long term viability of the relevant water-dependent asset, as defined in Table 1, then the impacts will be considered to be acceptable.

The NSW Office of Water's assessment will determine the potential level of impact relative to the considerations in Table 1 and will identify where further mitigation, prevention or avoidance measures would be necessary to meet the Level 1 minimal impact considerations of, under the Level 2 minimal impact considerations, what further studies are necessary to assess whether the Project will no precent the long-term viability of a relevant dependent ecosystem or significant site. The assessment includes determining the rigour or impact predictions and the suitability of proposed mitigation, prevention or avoidance strategies.

As part of the assessment process, there may be no suitable or practical mitigation or prevention options and therefore the proponent may be asked to avoid impacts by modifying the proposed activity." (NOW 2012a).

Based on the AIP definition of minimal impact considerations and the associated 'Levels' of impact, there are two levels of impact, and three categories into which the impacts are then classified. This is summarised in Table 8.2, and provides clarity as to how the Project has been assessed under the AIP.

### Table 8.2 AIP assessment criteria and levels

| Level of impact | Definition | Action required |
|---|---|---|
| Less than Level 1<br>Less than minimal impact criteria | Impacts that are predicted to be less than the 'minimal impact criteria' | Impacts considered acceptable |
| Level 1<br>Slightly greater than minimal impact criteria | Impacts are in excess of the Level 1 minimal impact criteria but no more than the accuracy of an otherwise robust model | Impacts within the range of acceptability.<br>Additional monitoring required and potential additional mitigation and remediation during operation |
| Level 2<br>Greater than minimal impact criteria | Impacts are in excess of Level 1 by more than the accuracy of an otherwise robust model | Additional studies required.<br>Impacts then considered within the range of acceptability if the additional studies can demonstrate that the long-term viability of the resource is not compromised |

Hume Coal concurs with the classification of Level 2 impact for drawdown in landholder bores. Hume Coal has taken a conservative approach and included all bores that are impacted by 2 m or greater on the basis of the conservative 67$^{th}$ percentile model predictions – a total of 94 bores. These 94 bores are all included in the detailed make good assessment, even if the drawdown is only marginally over the 2 m threshold and the viability of the bore is unlikely to be impacted. The revised make good Assessment (Appendix 2 to the RTS main report), addresses the above 'action required' for a Level 2 impact. These additional make good studies, as required by the AIP, demonstrate that the long-term viability of the water dependent assets within the Sydney Basin Nepean Groundwater Source are not compromised.

If a project is assessed to cause a Level 2 impact it does not mean the Project cannot be approved under NSW legislation. It does mean that additional studies, conditions and mitigation measures are required for the Project before it is approved, and Hume Coal has done this and is committed to continue to do required additional studies and assessment around making good predicted impacts to landholder bores.

There is reference in many submissions with regard to triggering the 'precautionary principle' if the Project approval poses both a threat of 'irreversible damage to the environment' and 'scientific uncertainty'. This threat is not present for the Hume Coal Project. The revised EIS model predicts full recovery of groundwater pressures over a relatively short period of time (ie compared to many other mines that have recovery times in the hundreds of years), and the very detailed uncertainty analysis provides a high degree of scientific certainty. The uncertainty analysis has reduced the uncertainty of the Project's impact significantly. Detailed discussion on this is included in the revised model report (HydroSimulations 2018) in Appendix 2 to the RTS main report.

### e Commonwealth Government referral

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act 1999) and its constituent policies require a proposal to be 'referred' to the Commonwealth Government if the Project is considered to potentially have a 'more than significant impact'. A significant impact for water resources is one that is defined in the *Significant Impact Guidelines 1.3: Coal Seam Gas and large Coal Mining developments - Impact of Water Resources 2013*. These guidelines require projects to be referred if "a significant impact on a water resource is a real or not remote chance or possibility." Therefore, a conservative approach is taken with most new coal mining projects and modifications in NSW being referred to the Commonwealth Government's Department of Environment and Energy (DEE), and Independent Expert Scientific Committee (IESC) as a matter of precaution.

The Hume Coal Project was referred to the Commonwealth Government and formal notice that the Project could be assessed under the EPBC Act 1999 as a controlled action was received in December 2015. The referral under the 'water trigger' was undertaken in accordance with the Significant Impact Guidelines and the IESC guidelines for referral.

The Commonwealth Government does not mandate that projects with potential 'significant impacts' cannot be approved. They do, however, require projects to be referred and assessed by the Commonwealth Government for bi-lateral approval with the NSW Government.

The comments from the IESC were received and were considered in the modelling work after the release of the EIS (ie during the model audit, rework and uncertainty analysis). It should be noted that the detailed uncertainty analysis undertaken by Hume Coal was in accordance with the draft guidelines on uncertainty analysis released by the IESC for comment in March 2018 (Middlemis and Peeters 2018). Additional sensitivity was also undertaken in accordance with the comments received from the IESC in this regard.

### f Existing users

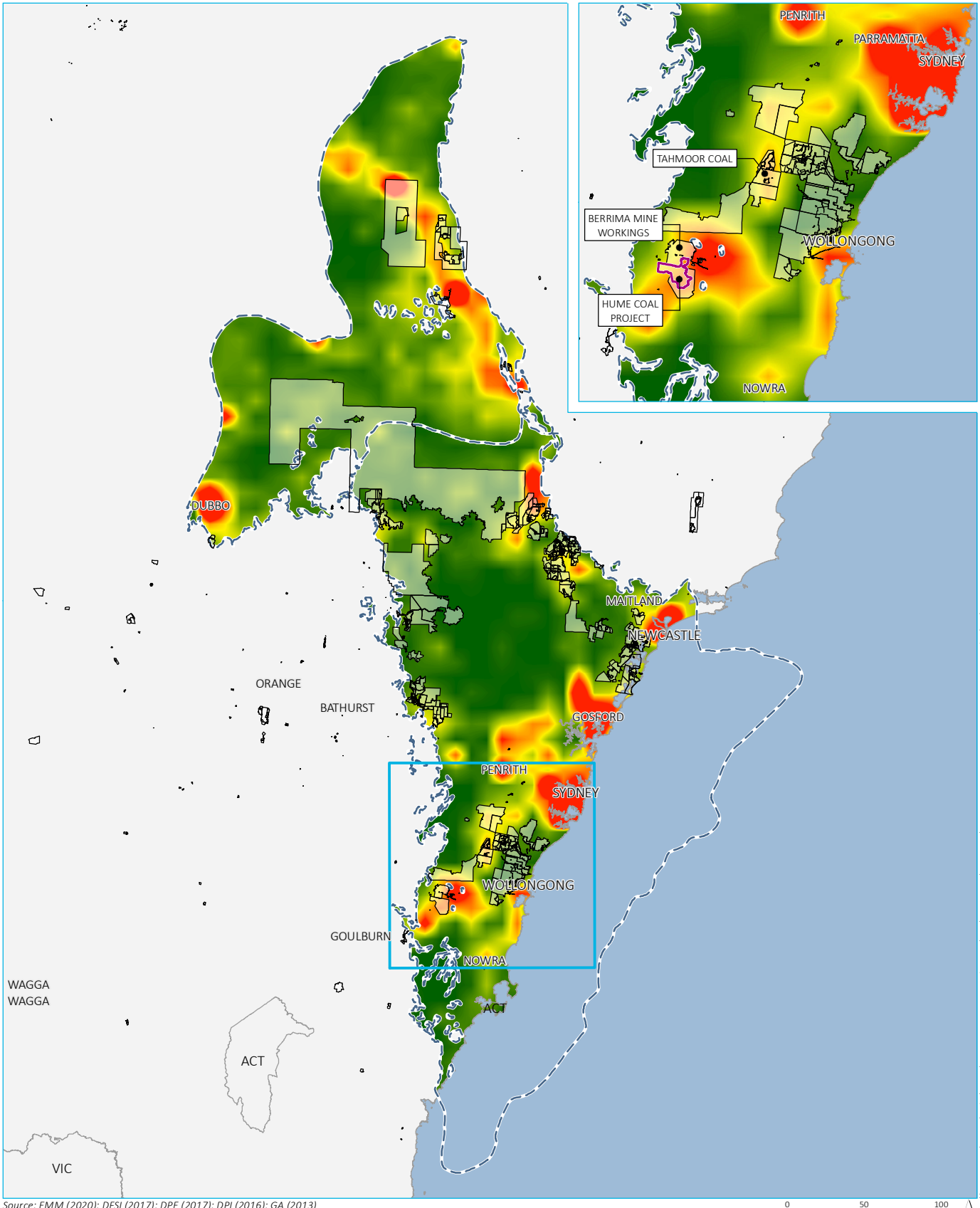
Groundwater extraction from landholder bores is not metered in this groundwater source and, therefore, no long-term usage statistics are available for inclusion in the model. This non-metering of bores is common across areas of NSW where there is no obvious stress to groundwater resources (ie such as large sedimentary basins with significant storage and unassigned water). The main groundwater sources where metering occurs is the high value inland alluvial groundwater sources of the Murray Darling Basin, where high yield bores are metered and usage is recorded regularly throughout the year.

Assumptions on groundwater use from landholder bores have therefore been made in the EIS and revised models based on some likely usage rates and model calibration. Stock and domestic bores were assumed to extract 3 ML/yr, and bores with an associated water access licence are assumed to extract 97% of their licence entitlement each year. This is a relatively standard approach taken in modelling groundwater extraction where no usage information is available, and the high percentage of 97% provides contingency for increased usage during drought times, potential over extraction from some bores, and take from unlicensed and unregistered bores.

Bore construction records were obtained from the NSW Government groundwater database for registered water bores, and this information was analysed to determine what formation and what layer/s groundwater was extracted from. This is required to predict regional drawdowns and the expected drawdown at individual bores. Where bore construction records were not available a conservative assumption was made (ie that the Hawkesbury Sandstone is fully open and extraction occurs across all layers). This conservative assumption means that the predicted drawdown at a bore will be the maximum that can be experienced at that location.

A landholder bore survey was proposed and attempted to obtain baseline data. During this process all landholders with bores likely to be impacted were contacted to measure the water level, water quality and to obtain historical records on existing bores (ie construction, pump depths, usage patterns etc). There was minimal participation in this voluntary survey and therefore only a few properties were able to be visited. Subsequent attempts to garner landholder participation throughout the EIS preparation and make good process have been made to engage directly with landholders to obtain information specific to their bores and their water needs, but with limited success. The local anti-mining activist groups have actively encouraged local landholders with bores not to engage directly with Hume Coal, and this has meant that information in the NSW Government database cannot be verified on ground at this stage. Consequently, a highly conservative approach has been adopted regarding groundwater use and the make good assessment.

The predicted groundwater drawdowns are mostly concentrated within the area overlying and immediately adjacent to the mine area. There are 94 landholder bores directly overlying and in close proximity to the mine workings predicted to experience greater than 2 m of drawdown. The number of bores may be considered large in comparison to other similar size projects but this should be considered in conjunction with the minimal number of property purchases by Hume Coal, the small landholding sizes overlying the mine area, and the moderate to high density of water bores in the area. The number of landholder bores likely to be affected is not indicative of a widespread environmental impact and or larger than average drawdown from the mine itself, but is instead an indicator of a large number of small properties, all with bores and the resulting moderately high density of water bores (Figure 8.7).




Source: EMM (2020); DFSI (2017); DPE (2017); DPI (2016); GA (2013)

0 50 100 km

GDA 1994 NSW Lambert

N

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KEY

- Hume Coal Project boundary
- Mining and exploration lease areas
- Sydney and Gunnedah basins

Number of bores per 10 km$^2$

- High : 200
- 150
- 100
- 50
- Low : 0

Bore density in the Sydney and Gunnedah basins

Hume Coal and Berrima Rail Project
DPIE Water report
Figure 8.7

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### g Cumulative impact

Climatic influences in the area continue to impact upon the local landscape. It is known that in dry periods, the water level in landholder bores can decline considerably. This rapid response is determined as a result of the increased landholder pumping (ie with limited surface water available groundwater is used as the back-up supply), as opposed to a direct effect in that year of reduced rainfall or infiltration. This is common in large groundwater sources such as the Sydney Basin, where the annual impact of reduced rainfall recharge in dry years dampened by the large storage, but groundwater pumping dominates the influence on seasonal groundwater levels.

The Hume Coal EIS states that "There are no potential future projects in the planning process that would influence the assessment of the Hume Coal Project in relation to potential groundwater impacts. Therefore, no cumulative groundwater impacts are predicted." This statement is questioned in some submissions based on the likelihood that many landholders may have plans for the future. Hume Coal has considered all consumptive groundwater users in the area, and all water access licences have been fully considered in the assessment of cumulative impacts (see Section 8.2.6). Even though new projects may emerge in the future, the water licence volume is already capped so new cumulative impacts are most unlikely. Also, it is not an expectation of the NSW Government and the planning and approval processes that future 'unknown' projects are considered.

At a recent IESC consultant roundtable discussion in Brisbane on 11 April 2018, the IESC confirmed that cumulative impact assessment needed to consider publicly available information on proposed developments, and not confidential or non-disclosed future plans. Hume Coal has done this, and does not dispute that some landholders may have future development plans for their properties and their water; however, for the purposes of the cumulative impact assessment as required by the NSW and Federal Government, the original statement in the EIS remains correct.

Cumulative impacts versus Hume Coal only impacts are presented in the EIS model. Cumulative impacts consider all water users (ie landholder pumping and ongoing outflow from the Berrima Mine) and is termed 'total drawdown' in the EIS. The project-only drawdown (ie drawdown as a result of the Hume Coal Project only) is termed 'differential drawdown' in the EIS model reports and shows the impact of the Hume Coal Project irrespective of other current stresses on the system.

Due to the effective embargo on additional licences within Management Zone 1, and the assumed extraction from water access licences of 97% of the licence volume allocated, it is not possible for new or existing users to take additional water from within this zone. New users to the area will need to purchase licences from existing users, so the overall water extraction from the area will remain stable over time and it is unlikely that there will be a greater cumulative impact than what is predicted in the revised model.

The total groundwater within the Sydney Basin Nepean Groundwater Source is illustrated in Figure 8.8. Note that in Management Zone 1, the total of all water access licences (ie not including stock and domestic users) is 12,553 ML/yr. The maximum annual extraction of water from the Hume Coal mine is 1,010 ML/yr, but the maximum volume required to be licensed per year, which includes intercepted baseflow and inflow to the mine void that is not physically removed from the groundwater source, is 2,066 ML/yr. This means that Hume will hold 16% of the available allocated volume, but will only ever remove 8% of the available allocated volume from the groundwater source, in two of the 20 years of mine operation.

Within the Management Zone 1, existing users can extract 84% of the water volume available for use each year. The physical access to this water is guaranteed via make good arrangements for existing users local to the mine area and that are predicted to experience drawdown of 2 m or more in their bore as a result of mining.

This simple analysis of licence volumes within the overall sustainable volume available within Sydney Basin, Nepean Groundwater Source - Management Zone 1 explains why regionally the mine does not represent a threat to the groundwater resource, and why the cumulative impacts of all consumptive users is significant when considering the total drawdown in landholder bores as a result of the Project.

If we consider the Hume Coal licence and take in the context of the sustainable limit of the Sydney Basin Nepean Groundwater Source (ie the LTAAEL), the volume Hume Coal will hold in licences is approximately 2% of the sustainable limit, and their physical removal of water from the water source is 1% of the greater water source sustainable yield.

In the revised groundwater modelling work undertaken by HydroSimulations (Appendix 2 to the RTS main report), the analysis undertaken addresses cumulative impacts of all existing, and future known stressors within the groundwater resources of the area. There is no new volumetric groundwater licensing being granted in Zone 1 of the Sydney Basin Nepean Groundwater Source, and therefore, any new groundwater user will need to purchase from existing users. This means that no additional extraction (ie over and above current extraction levels) will occur in the future, so cumulative impacts are inherently considered. There are no known new developments that are likely to require the movement of significant groundwater licence volume closer to the Hume Coal Mine.

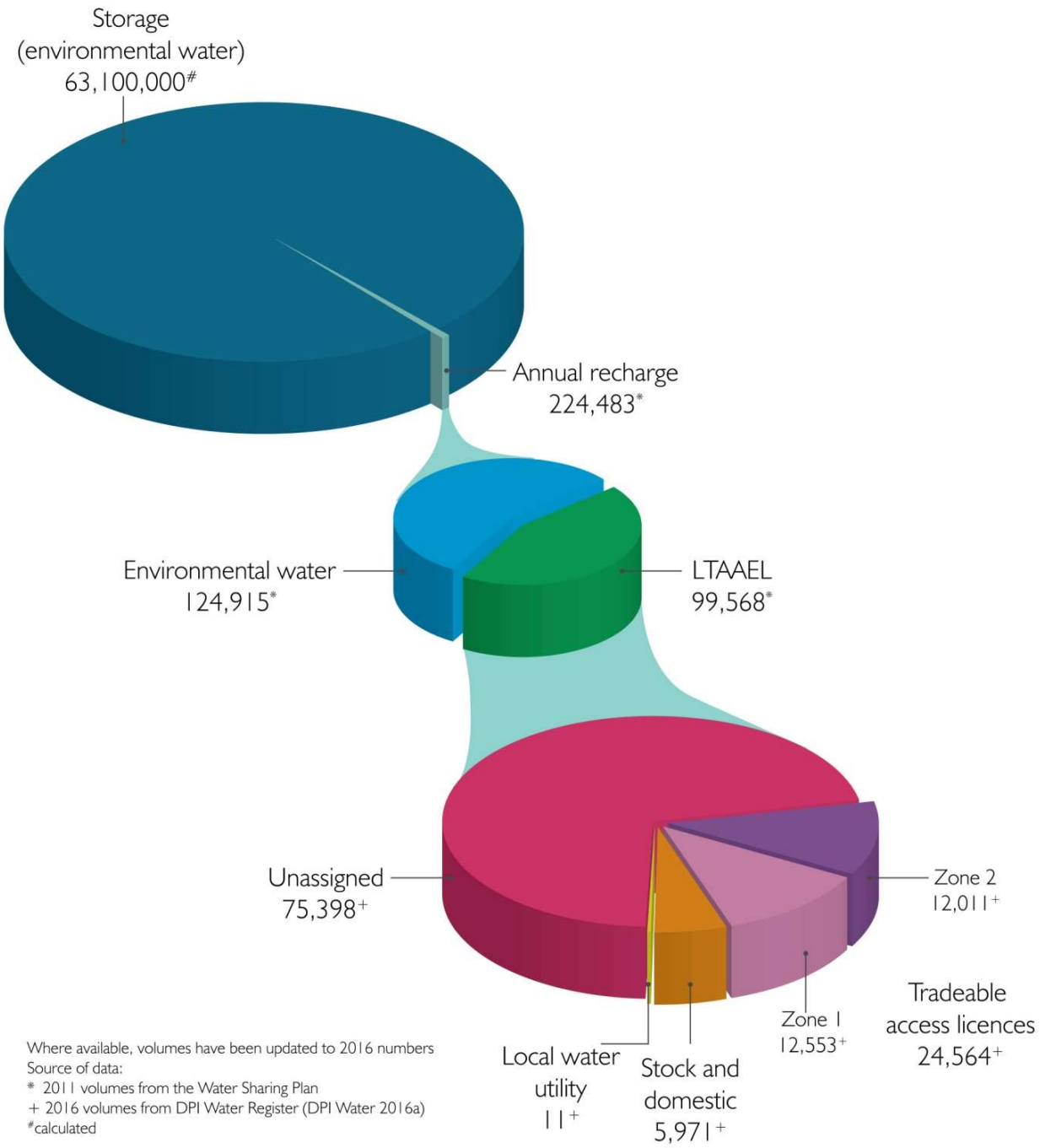


**Figure 8.8 Sydney Basin Nepean Groundwater Source available water (ML/yr)**

### 8.2.7 Calibration

- What calibration methodology was used for model calibration and does it conform to best practice?
- The calibration results have not been adequately reported.
- Modelled and observed hydrographs were not provided.
- Are the calibrated parameters plausible?
- Results from the model to predict the impacts of mining should be viewed within the context of unsatisfactory water balance errors.
- DPIW does not consider that the model is calibrated due to the following concerns:
  - very high water balance errors
  - the SRMS value is higher than that suggested by the Australian Groundwater Modelling Guidelines
  - predicted values of all four variables are outputs of the same model, in which the flow equation is inadequately solved

Comments regarding calibration were addressed in the RTS report Volume 2D Appendix F Section 4.1.3 with the following text.

The re-run of the EIS model in the updated MODFLOW SURFACT v4 software showed minimal improvements in the key calibration statistics of the Root Mean Square (RMS) magnitude and the Scaled Root Mean Square (SRMS) percentage.

The calibration model was then converted from MODFLOW SURFACT V4 software to MODFLOW USG, initially with no other changes and subsequently with specific storage values increased to more closely match field investigations.

Rerunning the EIS model with updated solver settings yielded much lower mass balance error than reported in the EIS (Coffey 2016b). Table 8.3 shows a comparison between the reported mass balance percentages from the EIS model and the re-run conducted by HydroSimulations (2018). The simulated average water balance during the calibration period and during the prediction period are presented in Table 8.4 and Table 8.5 respectively (HydroSimulations 2018).

**Table 8.3 Comparison of cumulative mass balance errors (cumulative percent discrepancy)**

| Model run | EIS model (Coffey 2016b) | Modified EIS model (HydroSimulations 2018) |
|---|---|---|
| Calibration | -3.8 | -0.15 |
| Prediction | -27.6 | -0.15 |

**Table 8.4 Simulated average water balance during the calibration period**

| Component | Groundwater inflow (recharge) ML/day | Groundwater outflow (discharge) ML/day |
|---|---|---|
| Rainfall recharge | 37.8 | - |
| Evapotranspiration | - | 20.1 |
| Rivers | 11.7 | 7.6 |
| Drains | - | 33.4 |

### Table 8.4 Simulated average water balance during the calibration period

| Component | | Groundwater inflow (recharge) ML/day | Groundwater outflow (discharge) ML/day |
|---|---|---|---|
| Constant head | | 2.4 | - |
| Wells | | - | 13.8 |
| **TOTAL** | | **51.9** | **74.9** |
| Storage | 22.9 LOSS | | |
| Discrepancy (%) | 0.01 | | |

Notes:
"Rivers" = Wingecarribee River and Medway Dam
"Drains" = Creeks, Berrima Mine, Escarpment
"Constant Head" = Wingecarribee Reservoir
"Wells" = Landholder Bores

### Table 8.5 Simulated average water balance during the calibration period

| Component | | Groundwater inflow (recharge) ML/day | Groundwater outflow (discharge) ML/day |
|---|---|---|---|
| Rainfall recharge | | 34.9 | - |
| Evapotranspiration | | - | 13.2 |
| Rivers | | 11.6 | 5.6 |
| Drains | | - | 27.1 |
| Constant head | | 2.5 | - |
| Wells | | - | 9.4 |
| **TOTAL** | | **49.0** | **55.4** |
| Storage | 6.4 LOSS | | |
| Discrepancy (%) | 0.00 | | |

Notes:
"Rivers" = Wingecarribee River and Medway Dam
"Drains" = Creeks, Berrima Mine, Escarpment
"Constant Head" = Wingecarribee Reservoir
"Wells" = Landholder Bores

The re-run of the EIS model in the updated software showed some improvements in the key calibration statistics of the Root Mean Square (RMS) magnitude and the SRMS percentage. The revised calibration statistics have been conducted on all available, time-series calibration data as opposed to the 'last available observed water levels' presented for the EIS model (Coffey 2016b).

Table 8.6 shows a comparison between the reported calibration statistics from the EIS model and the re-run conducted by HydroSimulations (2018).

### Table 8.6 Comparison of key calibration statistics

| Key statistic | EIS Model (Coffey 2016b) | EIS model Re-Run (HydroSimulations 2018) |
|---|---|---|
| **Number of Data Points** | **49** | **2502** |
| Residual Mean (m) | 3.11 | 3.7 |
| Absolute Residual Mean (m) | 12.14 | 12.19 |
| **Root Mean Square (m)** | **17.06** | **15.41** |
| **Scale Root Mean Square (%)** | **11.9** | **10.76** |
| Correlation Coefficient | 0.795 | 0.77 |

Additional model hydrographs are presented in the revised model report (Appendix 2 to the RTS main report, Volume 2D – Appendix F, Figures 5 to 15) and are included in Attachment C. DI Water required more demonstrated evidence of calibration, but their submission agreed with the EIS model results as they stated that the calibration parameters, of hydraulic conductivity, stream flows and discharge to voids are all within the plausible range.

The DI Water comment that the calibration to four variables is commendable, but they also state that the calibration is 'inadvertently solved' due to the water balance errors. This is strongly refuted by Hume Coal and the modelling team. The calibration for the EIS was undertaken with great care and in accordance with industry best practice. The updated solver settings in the revised model yield significantly improved mass balance errors and demonstrate clearly that the EIS model is very well calibrated. The NSW Government independent expert reviewer, Hugh Middlemis, agrees that the calibration is satisfactory (Hydrogeologic 2017):

> "Is the model calibration satisfactory? Yes Acceptable model calibration performance and good time series matches at most bores (except 2 of 6 VWP's which is not unreasonable). EIS report states 11.9% SRMS, exceeding 10% criterion, but refinements have reduced the SRMS to <10%, and water balance error terms to <0.5% (see Section 2 and Appendix A), which is satisfactory.
>
> Calibration of aquifer property values (Kh, Kv, S, Sy) has been well constrained by pumping test estimates of property values, and by simultaneously honouring observed groundwater levels, along with the measured Berrima mine inflow (deep system) and inferred stream baseflows (shallow system).
>
> This is a best practice approach that reduces model non-uniqueness problems (that many different sets of model inputs can produce nearly identical aquifer head distributions).... "(Hydrogeologic 2017).

## 8.3 Management and mitigation measures

### 8.3.1 Landholder bores

- The results of the bore assessments are requested, along with proposed make good measures (based on bore assessment results) for each bore predicted to exceed Level 1 minimal impact considerations of the AIP. It is noted that make good measured may be required for many decades post mine closure.
- Further consideration is required for the ability to implement the proposed make good provisions due to the high number of impacted bores and the scale of works and monitoring required. The proponent should provide detailed information regarding its strategy for dispute resolution in the case affected landholders elect not to engage in negotiations.
- Additional clarification of the timing of the make good arrangements is needed to fully understand the suitability of the proposed measures.
- The following points should be clarified in regard to the make good strategies:
  - Increased pumping costs for all bores subject to make good
  - Pump lowering is not always practical (bore age, construction and siltation need to be considered)
  - Pump lowering may lead to less efficient water distribution, as well as more frequent maintenance and cleaning
  - Deepening bores may produce different yields and different water quality
  - Potential damage to bore or pumping equipment during pump removal
  - Pumping against greater hydraulic head may generate iron-related encrustation problems within the bore under cyclic operating scenarios
- Consideration for surface infrastructure locations and decommissioning of old bores if replacement bores are relocated to another area of the property.
- Damaged casing or non-vertical bores may prevent the use of drilling equipment.

Comments regarding landholder bores were addressed in the RTS main report (EMM 2018a) Section 9.4.2 with the following response.

#### i Overview

In NSW, a project can have impacts on other users that are deemed 'greater than minimal impact', but these impacts must be managed and mitigated via 'make good provisions'. Hume Coal acknowledge that there will be changes to groundwater levels in excess of the 'minimal impact criteria' proposed by the AIP, and therefore Hume Coal commits to negotiate make good arrangements with these users, in accordance with any relevant conditions of consent. The presence of the mine will not threaten local businesses ability to access water for their operations, and will therefore not influence the property market. Hume Coal is committed to the principle of maintaining existing users' access to water and making good any impacts deemed to be greater than minimal impact.

Partial depressurisation of the Hawkesbury Sandstone aquifer overlying the mine will occur as mining progresses, with some dewatering near the watertable. Shallow bores in the sandstone that are not fully penetrating will be the most impacted as drawdown occurs (they may not experience the greatest drawdown but because of their shallow depth they may go dry). Greater water level drawdowns will occur in the deeper sandstone, but groundwater will still occur in these rocks (ie they will remain saturated). The majority of the Hawkesbury Sandstone will remain saturated throughout mining. The Hawkesbury Sandstone aquifer will not be 'drained', 'cracked through' or 'destroyed'. It is depressurised, and as a result the watertable will experience some drawdown, but not total dewatering. The integrity of the Hawkesbury Sandstone is not compromised and will not be 'damaged', as the mine is designed to result in minimal levels of overburden deformation. There is no irreversible damage to the Hawkesbury Sandstone, as groundwater levels will fully recover in time.

The make good analysis considers both the depressurisation and drawdown/dewatering impacts of the Project on individual landholder bores (ie reduced yields and water levels) and has used the detailed uncertainty analysis to provide greater confidence in the predictions for each individual landholder bore.

The conclusion of the NSW DPI in respect to impacts on landholder bores is that the proposed strategies were ”reasonable considering the circumstances”. The detailed uncertainty analysis undertaken in the model rework estimates that 94 bores will experience drawdown of 2 m or greater as a result of the Hume Coal Project. This number (94), is based on the conservative 67$^{th}$ percentile which is the boundary between 90-67$^{th}$ percentile (ie unlikely to occur under normal conditions), and the 33-67$^{th}$ percentile (about an equal chance of occurring as not). Hume Coal has taken a conservative approach in adopting the 67$^{th}$ percentile for make good arrangements, rather than the 50$^{th}$ percentile which would have reduced the number of affected bores significantly.

Should the property ownership change prior to the negotiation and implementation of a make good agreement, the requirement for make good, in accordance with the conditions of consent, will remain in place for that individual bore.

The make good strategy contains a number of options for maintaining water supply for landholders. The initial assessment has identified some key overriding principles to categorise bores into groups based on their level of impact and bore construction (ie depth). Field inspection, agreement with landholders and the practicalities of the make good options need to remain flexible to ensure the most appropriate make good arrangements are made for each individual bore and each individual landholder.

Ongoing monitoring of the actual drawdown in landholder bores and across the groundwater monitoring network is required to verify model predictions and the timing of impacts. This information will be critical to ensure the make good arrangements are coordinated efficiently with landholders. It is also recognised that different strategies may need to be adopted for an individual bore over time. The consultation with individual landholders will be ongoing. Make good agreements will be legal commitments to ensure that agreed and acceptable outcomes can be obtained. The method for achieving these outcomes and the timing of implementation of make good arrangements will be supported by verifiable data from affected bores and the monitoring network, and clearly stated in agreements.

The revised make good assessment (Appendix 2 to the RTS main report) further considers the scale and number of bores potentially requiring make good works, and provides significantly more detail on individual bores and the logistics of implementing such a program. Timing of this is important, as not all bores will experience drawdown at the same time.

The Hume Coal Project drawdown impacts need to be considered in relation to the cumulative impacts generated by other users, and as outlined in Section 8.2.6v. In areas distant from the mine, perceived impacts to individual bores are more likely to be the result of seasonal conditions, bore or pump problems, and/or usage by others users, and this will be considered when addressing make good strategies for these areas.

The effect of drought has been considered with respect to drought sequences, and climatic patterns such as ENSO (El Niño Southern Oscillation).This climatic variability is included in the groundwater modelling and uncertainty analysis discussed in Section 8.2.6iii.

### ii Impacts to agriculture and other consumptive users

The groundwater drawdown predictions on landholder bores is subject to the provisions of the AIP, with bores experiencing drawdown of 2 m or greater requiring make good provisions. This assessment has been undertaken in great detail, using available information. Consultation with potentially impacted landholders has occurred on several occasions via letters, advertisements in the local paper and phone calls (details on consultation outlined in Appendix 2 of the RTS report).

The NSW DI Water provided Hume Coal with a comprehensive listing of all existing water bores late 2015 for use in the EIS (this list was then updated by WaterNSW on of 27 April 2018), for an area well in excess of the predicted area of influence of the mine (ie a distance in excess of 5 km from the mine boundary). This list identifies the location of all known bores and their associated licence/approval. Individual bores can then be linked to the groundwater database and their construction details and associated information at the time of construction can be extracted. The location of each bore (and their associated screened interval) was then reviewed against the RTS model and the model run to predict drawdown at every location. Hume Coal are therefore confident that all known bores that are in the area have been included in the assessment, and is using the 67$^{th}$ percentile results to conservatively predict potential drawdown impacts for each of these bores.

As stated, the predicted drawdown impacts at individual bores has been modelled using the regional model developed to predict mine inflow and regional depressurisation and drawdown. The model predicts results for bores with reference to the nearest model cell for the location of the bore, and the bore screened depth is attributed to one or more model layers. The model is very accurate at the regional scale, but there will be differences between model predictions and reality at a local scale (ie at a bore level). This does not mean that the groundwater model cannot be used to assess impacts. The groundwater model is consistent with industry standard.

Movement of water from the agriculture sector to mining has occurred via the purchase of Water Access Licences on the open transfer market. No distinction or priority of access exists in the WMA2000 for uses other than basic rights or town water supply, so both mining and agriculture uses have the same priority for access.

The revised water assessment for the Project comprises a water monitoring plan, which outlines the ongoing monitoring proposed for the Project (EMM 2018b). This plan outlines how the monitoring network will be sufficient to monitor the Project impacts and provide information for model verification over time. This plan will be revised and updated to include requirements from the NSW Government as outlined in the conditions of approval for the Project. The onus will be on Hume Coal to monitor the drawdown impacts in their monitoring network, other nominated sites, and work with the community as make good arrangements need to be implemented.

### iii Consultation on make good

Consultation on make good commenced in 2016 with several avenues pursued to encourage landholder participation with water bore assessments and make good requirements. The communication strategy included letters, advertising on the local radio and in the newspaper, and phone calls to individuals.

The specific details of likely impacts to individual bores were not known until the EIS model was developed. Prior to this, general information and communication of the Project and potential impacts were ongoing. Consultation with individuals on likely impacts to water bores occurred promptly once the model was developed and predictive results were available. This occurred with the exhibition of the EIS. It appears that some in the community are frustrated with insufficient specific consultation occurring on impacts to bores. However, Hume Coal maintains that a considered approach using quality data and peer reviewed results were required before communicating likely impacts to individuals. Only those landholders with bores predicted to experience drawdown of in excess of 2 m were consulted directly with regarding the details of their individual bores. Communication with landholders and the community in areas beyond where 2 m drawdown in bores is predicted has been undertaken but has been more general in nature and not targeted specifically at individual bore owners.

There is an ongoing conversation about the AIP and the requirements for make good arrangements for those bores overlying the mine that are likely to experience drawdown. This conversation to date has been undertaken publicly, and also via the Hume Coal Water Advisory Group members.

All landholders with bores that were expected to experience a drawdown in excess of 2 m as predicted by the EIS groundwater model were contacted in January 2017 and in May 2017 via individual letters. Individuals were encouraged to provide information to Hume Coal on their bore, and also have their bore surveyed. This field inspection is important to verify the latest information about the bore against the DI Water groundwater database

which only archives the 'as constructed' bore data. Limited responses from landholders have been received, and therefore field verification and detailed one-on-one consultation with landholders has been difficult.

In summary the make good consultation has comprised:

- 148 letters - two rounds of individual letters to all individuals identified as being impacted by more than 2 m (January 2017 and May 2017), and additional ad hoc letters;
- 43 emails for various enquiries;
- 75 phone calls;
- 9 meetings;
- 2 media releases;
- summary project document releases;
- fact sheet releases;
- updates to the Hume Coal website; and
- use of social media (ie Hume Coal Facebook page).

The Water Advisory Group provided a valuable community engagement platform during the development of the EIS. Ongoing consultation with landholders within a formal committee manner will be subject to discussions with both the NSW Government and the local community in the future.

#### iv Make good detail for individuals

The revised version of the make good assessment (Appendix 2 of the RTS report) provides a greater level of detail for each individual bore predicted to experience a drawdown of 2 m or more as a result of the Project. Individual bores have been reviewed in great detail, with individual make good options and their applicability over time being explored. Consultation with individual landholders is ongoing, with many landholders preferring not to engage with Hume Coal on this issue at this time due to general concerns about the Project and on advice from local interest and activist groups.

The age, construction details and status of individual bores is currently based on the NSW Government bore construction records. Advice from the local community is that regardless of age, bores in the area continue to perform over time, so at this stage no discount for bore age has been applied to the make good assessment. However, field verification of the bore status, condition and current use is required as part of the necessary process for make good arrangements for individual bores. Reluctance for some landholders to engage directly with Hume Coal means that limited direct consultation and field inspection of bores has been undertaken to date.

Field inspection of each location and possible downhole inspection (ie using cameras or logging equipment) is proposed prior to finalising individual make good agreements for bores. Individual bore assessments have not been undertaken due to numerous access restrictions. This has hindered Hume Coal's desire to consult with landholders and to progress individual make good bore arrangements.

Agreements with landholders on the strategy that meets their specific requirements will be negotiated. The most suitable 'make good' arrangement for individual properties may vary and, therefore, flexibility with the exact details as to how water will be supplied is required.

Make good arrangements will remain in place up until groundwater levels have recovered to within 2 m of the original water level prior to mining. Make good arrangements are not required for water quality, as water quality impacts are not predicted to change the beneficial use category of the groundwater source and are therefore within minimal impact criteria.

### v Additional strategies for make good

It is acknowledged that the pre-mining pumping rates in bores that will experience significant drawdown may reduce during the period when water levels overlying the mine are lowered. This has been considered in the make good assessment, and should this occur, options such as an increased capacity pump, lowering of pumps, a second bore and/or increased water storage facilities at the surface will be incorporated into the make good agreement so that the water supply can be maintained at the level required and previously delivered. The updated make good assessment report (Appendix 2 to the RTS main report) contains additional detail on this and details for a staged approach for individual make good assessments.

It is also acknowledged that due to the very high iron levels in the natural groundwater system that iron encrustation of bores may also occur at a higher rate than occurs currently. Provisions for managing iron encrustation in bores that are drawn down significantly can form part of the revised make good arrangements.

The combination of potential temporary yield loss and encrustation of bores and pipes may lead to less efficient water distribution networks for some landholders; this is acknowledged and can be incorporated in the revised make good arrangements.

Provision of water to properties via tankers is not proposed as a key strategy (particularly for large licence holdings); there are alternative options available that are articulated in more detail in the revised make good assessment report.

### vi Provision for increased pumping costs

Provision for paying increased pumping costs or other compensatory measures are to apply to all bores that experience a water level decline that is in excess of 2 m from the baseline assessment. The lowering of pumps in the borehole has a capital cost (see below), but the lowered water level (not increased pump depth), determines the increased operating costs. Acknowledgement of these costs is incorporated in both the EIS and Revised Water Assessment versions of the make good assessment reports.

### vii Provision for lowering of pumps

The lowering of pumps is proposed to maintain supply to overcome the predicted impact to individual bores. The considerations for lowering pumps include:

- the capital cost (ie pump column and electrics);
- potential additional capital costs (ie should pumps need servicing due to disturbance of the pump during its removal and reinstallation); and
- labour costs (costs associated with the removal and lowering of the pump, and potential additional maintenance costs associated with siltation and sedimentation at the base of the bore should removal be required).

Hume Coal acknowledges that lowering of pumps will not be practical in all bores. Technical limitations for lowering pumps may occur and this has been incorporated into the strategy of the make good assessment. The plan for make good at each individual bore is subject to technical feasibility, and in the process of lowering a pump in a bore it

may become apparent that the pump cannot be lowered, or that lowering the pump will not resolve the potential reduction in water supply. Alternative solutions will be negotiated at that time with each landholder. This flexibility of approach is required so that the delivery of make good (ie ongoing water supply for all landholders) can be achieved.

The make good strategies that apply to each bore currently are based on the information, knowledge and understanding of publicly held records. Prior to field assessments to confirm the current status of individual bores, the strategy for an individual bore (ie the logical options based on information at hand) will remain in place.

### viii Provisions for deepening of bores

For some shallow bores that experience mine-induced drawdown and are not fully penetrating in the sandstone aquifer, deepening of the bore may be an option. It is acknowledged that in attempting to deepen some bores it may become apparent that it is not physically possible for various reasons such as: the original hole is not straight, partial or full collapse of bore and/or casing at depth, risk of losing drill equipment to rusted casing at the surface etc. Therefore, for bores identified as being suitable for deepening, the best proposition may be the provision of a new, deeper bore immediately adjacent to the existing bore. This is sometimes the simplest, quickest and most cost-effective solution to deepening an existing bore.

### ix Replacement bores

It is acknowledged and outlined in greater detail in the revised make good assessment report (EMM 2018b) that the decommissioning of old bores may need to occur (ie if the landholder consents to this) in accordance with *Minimum Construction Requirements for Water Bores in Australia* (NUDLC 2012). Individual landholders may also choose to retain the original bore and this will be part of the individual negotiations and agreements for each landholder.

Redrilling of bores will be in accordance with industry best practice and utilise local knowledge of drilling and geological conditions to ensure successful outcomes for replacement bores.

Should a replacement bore need to be moved to a new site distant from an existing site, then consideration of the existing distribution network/power supply and provision for upgrading is included (and this is outlined in the revised make good assessment report). In relocating a bore there may be some changes to individual bore yield and this will be measured and considered upon drilling (strategies may be to construct a larger diameter bore, or to construct two bores in place of one).

Groundwater quality is typically very uniform within the Hawkesbury Sandstone and the Wongawilli Coal seam within the Project area, and therefore changes to groundwater quality are not envisaged. Should a bore be constructed into the deeper underlying Illawarra Coal Measures, then the groundwater quality will be tested and if the beneficial use class is no longer maintained then options to rectify this will be investigated (and may include dilution with other water supplies). Water quality differences are considered to be very low risk but are nonetheless considered.

### x Dispute resolution

The AIP provides the framework for how impacts on bores as a result of a project approval are to be managed, and the AIP assumes that an outcome can be reached as it does not discuss dispute resolution mechanisms. The process for resolution of disputes is outlined in the make good assessment (EMM 2018b) and discussed further in the updated water assessment in response to IPC recommendations R4, R5, R6, R7 and part of R8 (EMM 2020). Processes such as mediation, arbitration then legal proceedings may be required in some circumstances.

### 8.3.2 Subsidence

- It is not clear that saturated conditions within the mined panels will be sufficient (with a small proportion of incorporated reject material) to provide long-term support to the remnant pillars holding up the roof.

This comment regarding subsidence was addressed in the RTS main report (EMM 2018a) Section 9.4.5 with the following response.

Based on the geotechnical modelling described in Chapter 16 of the RTS main report (EMM 2018a), the potential for wide-scale geotechnical instability in the mine resulting in material levels of overburden deformation is extremely low. This effectively translates to the potential for impacts the overlying Hawkesbury Sandstone being very low, and therefore additional drawdown, depressurisation or inflow as a result of this occurring are also very low.

In addition, Volume 2 of the RTS has stated that extensive technical investigations have taken place over several years to develop and refine the Project, and arrive at the proposed design. The key leading practices adopted to minimise impacts to water resources and related assets are:

- innovative and tailored non-caving mine design (resulting in imperceptible levels of subsidence or damage to the overlying Hawkesbury Sandstone);
- underground emplacement of reject (which removes the need for permanent surface stockpiles); and
- sealing mined panels, and filling with water (which allows groundwater to recover more rapidly).

The proposed method is low impact and will have negligible surface and subsurface subsidence, and minimal overburden fracturing. Worst case estimates of subsidence associated with the proposed non-caving mining method predict 'imperceptible' surface disturbance due to mining, with predicted settlement of less than 20 mm (EMM 2017e; Mine Advice 2016). Further information can be found in Appendix L of the main EIS report is a subsidence assessment by Mine Advice.

### 8.3.3 Salt changes in Hawkesbury Sandstone

- Geochemical modelling conducted and presented in the Hydrogeochemical Assessment Report indicates that due to mine dewatering altering local flow regime there is potential for a net increase in salt flux from the Wianamatta Group shale to the Hawkesbury Sandstone of 1.3 % above baseline conditions.

This comment regarding salt concentrations within the Hawkesbury Sandstone was addressed in the RTS main report Section 9.4.7 with the following response.

Wianamatta Group (WG) shales only outcrop in the eastern half of the Project area with Hawkesbury Sandstone exposed in the western half. The shale sequence thickens to the east and north. Where the shale is weathered and thin there is unlikely to be any groundwater present. Where it thickens, a variable depth watertable forms depending on recharge rates and the permeability of the shale. There are rarely any water bearing zones of note that are accessed for water supply purposes. There is limited natural vertical connectivity with the underlying Hawkesbury Sandstone aquifer as evidenced by lower water levels in the sandstone. At most sites (such as at the H35A and B site) the groundwater in the shale is perched above the regional watertable in the sandstone (ie there is no hydraulic connection as there is an unsaturated zone in between these systems). At other sites where there is hydraulic connection between units, saline groundwater is usually evident at shallow depth in the sandstone.

It is acknowledged that the water quality monitoring data for the Wianamatta Group shales within the Project area is limited to one monitoring bore (H35B), due to the difficulty and scarce interception of water bearing zones within the shale geology. However, as a result of this, the potential spatial variability of groundwater salinity in the

Wianamatta Group shale is uncertain. The value used (1,700 mg/L) lies within the range recorded for the Wianamatta Group shales elsewhere in the Sydney Basin, and that the groundwater salinity in the Wianamatta Group shales is variable and can be higher. However, given the upland location of the Hume Coal Project, this groundwater salinity is considered acceptable and a likely representation of the groundwater quality of the shales in this area.

### i Groundwater Salinity Information

A review of publicly available groundwater quality information for the Wianamatta Group shales in the vicinity of the Project area identified that the published proceedings of the 2009 *Groundwater in the Sydney Basin Symposium* includes a paper providing commentary on groundwater salinity in the Wianamatta Group shales of the Southern Highlands (Russell et al 2009). The following observation was made in the cited paper regarding groundwater salinity in the shale formations:

> Notable differences exist between groundwater salinity distributions for the Wianamatta Group strata in the western Sydney area and in the Southern Highlands (Fig. 8). In particular, the salinity of groundwater in the Southern Highlands is generally considerably less (typically <3,000 mg/L) than that in the western Sydney area (mainly >5,000 mg/L). This is presumed to be related to the topographic elevation of the former due to regional and intermediate deformation and uplift leading to the subsequent flushing of accumulated salts from the rock matrix.

This is consistent with the monitoring results from H35B, for which the laboratory-reported total dissolved solids (TDS) ranged from 1,480 mg/L to 1,750 mg/L.

A search of the groundwater databases administered by the DI Water identified very little information regarding groundwater salinity in the shale formations in the vicinity of the Project area. The following based salinity information was identified:

- GW057943 (south of Sutton Forest) – a salinity category of 1,001 – 3,000 mg/L recorded for inflows during drilling through shale formations;
- GW102777 (south of Sutton Forest) – a salinity of 380 mg/L recorded for inflows during drilling through shale formations;
- GW104423 (west of Moss Vale) – a groundwater salinity of 540 mg/L was recorded for inflows during drilling through shale formations;
- GW105744 (south of Sutton Forest) – a groundwater salinity of 800 mg/L was recorded for inflows during drilling through shale formations; and
- GW106517 (south of Sutton Forest) – a groundwater salinity of 1,300 to 1,700 mg/L was recorded for inflows during drilling through shale formations.

While the salinity information is limited, it is consistent with the values measured in H35B.

### ii Hume Coal Bore Installation Logs

The following groundwater salinity information was recorded for inflows from shale horizons encountered during installation of the Hume Coal monitoring bore network. It is noted that because the bores were installed using an air hammer rig with water introduced as a drilling fluid, the values are considered to be of low reliability for characterisation of formation water quality (i.e. likely to be a mix of drilling and formation water). However, the data are provided for completeness:

- HU0129PZB: 346 to 619 µS/cm (no information on inflow rate recorded);

- HU0136PZA: 506 to 557 µS/cm, with inflow rates of 5 to >10 L/s recorded;
- HU0136PZB: 530 to 557 µS/cm, with inflow rates of 3.3 to 5 L/s recorded; and
- HU0088PZA: 988 µS/cm, with an inflow rate of 0.1 L/s recorded (at base of shale).

In summary, the groundwater salinity values for shale formations in the vicinity of the Project area are generally consistent with those reported at H35B, and are characteristic of the lower salinity groundwater of the WG Wianamatta Group Shale in the Southern Highlands, rather than the higher salinities reported in the Cumberland Basin of Western Sydney to the north.

### iii Potential Increase in Downward Groundwater Flux from the Shale

At most sites where the groundwater in the shale is perched above the regional watertable in the sandstone, groundwater migration cannot occur unless the unsaturated zone between the units becomes saturated or there is a conduit (such as water bore) that connects the two formations.

At other sites where there is full saturation, there is a natural downward hydraulic gradient between the shale and the underlying Hawkesbury Sandstone. At these sites the magnitude of groundwater flux between the shale formation and the underlying sandstone is a function of:

- the hydraulic conductivity of the shale (which can reasonably be assumed to remain constant over time); and
- the height of the saturated water column in the shale in excess of the "pressure head" at the top of the sandstone formation.

The greater the pressure head in the upper Hawkesbury Sandstone formations, the smaller the downward flux of groundwater from the shale formations and vice versa.

The temporary loss of this pressure head due to depressurisation may result in a marginal increase in the downward gradient in the affected area (where connection occurs). However the absolute change in the downward groundwater flux would be relatively small and the maximum mining-induced depressurisation at the top of the sandstone can only ever result in a small incremental increase in the downward flux of groundwater from the Wianamatta Group shales, as indicated by the modelled flux results during the life of mining.

In summary, the groundwater connectivity and salinity migration between Wianamatta Group shales and the underlying Hawkesbury Sandstone will be one of three scenarios:

- (Most likely) where the shale watertable is perched above the sandstone watertable there is negligible migration of saline water into the sandstone and this will remain unchanged with mining that induces a fall in sandstone water levels.
- (Likely) where the shale watertable is higher than the sandstone watertable which is within or at the base of the shale then there is limited migration of saline water into the sandstone and fluxes are likely to remain unchanged or reduce with mining that induces a fall in sandstone water levels.
- (Unlikely) where the sandstone watertable is higher that the shale watertable and currently there is no migration of saline water into the sandstone, a reversal in the hydraulic gradient caused by mining that induces a fall in sandstone water levels may induce a small flux of saline water into the sandstone.

Therefore, the influence of the groundwater salinity in the shale on the groundwater salinity in the upper Hawkesbury Sandstone is at its maximum during the current pre-mining conditions. Irrespective of any spatial variability of salinity in the shale, a potential increase in groundwater flux between the geological units attributable to mining-induced depressurisation is considered negligible.

### 8.3.4 Ongoing monitoring plan

- The Environmental Impact Statement identifies that a Subsidence Management Plan (SMP) will detail how subsidence monitoring will be conducted. It is recommended that DPI Water review the SMP once drafted, and that the plan includes specific long-term pillar stability and bulkhead integrity monitoring.
- A more comprehensive monitoring strategy is required to ensure impacts to ecosystems and water users can be readily identified and addressed. It is recommended that DPI Water review the Water Management Plan once drafted.
- It is not clear that the post-closure monitoring period of 5 years after the completion of mining is sufficient to define the management of ongoing impacts.
- Repeated groundwater model validation (at undefined schedules) based on ongoing monitoring and annual reporting is proposed.
- In order to confirm the extent of the model predicted zone of impact calculated by the model to exceed two metres it is also recommended the proponent install a minimum of three monitoring bores with screened intervals in Hawkesbury Sandstone west of GW075036, and west/northwest of HU0088 A/B.
- The Department does not support the restriction placed on monitoring only within 'periods of extended drought'.

These comments regarding ongoing monitoring were addressed in the RTS main report (EMM 2018a) Section 9.4.8 (ii) with the following response.

In accordance with the Groundwater Monitoring and Modelling Plan (GMMP) a detailed water monitoring program is currently being undertaken. The GMMP is periodically reviewed by DI Water and any required changes are incorporated. This process will be ongoing for the life of the mine and the details of the GMMP are incorporated into the overall water management and monitoring strategy for the Project.

In summary, all existing monitoring bores will continue to be monitored (with automatic data loggers installed in all bores and dedicated low flow pumps installed) to provide for regular water quality sampling to be undertaken.

The monitoring network will be expanded with extra monitoring bores strategically placed (subject to land access) to ensure that model verification can occur (ie allow comparison of model results to actual water levels as mining progresses), and to provide early indications of any likely impacts to landholder bores. Consultation with DI Water on placement of additional monitoring bores will be undertaken, with a view to providing more at a distance from the mine to confirm the lateral extent of drawdown. Monitoring of shallow groundwater near terrestrial ecosystems that may be partially groundwater dependent is also being considered. Monitoring (both level and quality) of selected landholder bores in and around the Project area (particularly those predicted to experience drawdown in excess of 2 m).

The post mining monitoring will be in excess of 5 years post mining, and Hume Coal will monitor post closure in accordance with the relevant approval and licence conditions. Monitoring of groundwater will occur post mining, regardless of whether there is a drought or not. Consultation with DI Water will occur during the post mining monitoring period and an agreement on the timeframe of recovery monitoring will be determined collectively. The timeframe required is likely to be subject to the level and speed of groundwater recovery, and will be reviewed and revised annually. It is likely during this period that a gradual scaling back of the monitoring network will occur (both in terms of number of bores and frequency of measurements/sampling).

The trigger levels for responses based on monitoring of water levels and quality during mining are yet to be developed and will be completed as part of the secondary approval process that involves monitoring plans and environmental protection licences. The principles for beneficial use will be considered for groundwater monitoring, and alignment with predicted water level drawdown from the revised EIS model.

Model verification (ie using actual data collected as mining progresses) and reporting is proposed at 12 monthly intervals for the first 10 years of operation, with model recalibration as/when required. Following the first 10 years of operation, model verification is proposed to occur at 2 yearly intervals until mining ceases, with recalibration as/when required. Model verification is the process by which the model predictions are measured against observed monitoring data. Recalibration is only required if the predictions of impact in the model vary significantly from the observed water level drawdowns and mine water inflow volumes, or stream flow is responding to baseflow losses. If model recalibration is required, then updated predictions of drawdown in landholder bores will also be reforecast at that time Ongoing monitoring will inform the drawdown predictions (and any revised prediction in terms of degree of impact and the timing of the impact). It is envisaged that where an accurate understanding of groundwater take volume is required for landholder bores, that meters will be installed. It is a mandatory condition for bores that are linked to a Water Access Licence to have a metre installed, but not for stock and domestic bores – however, they can be applied to stock and domestic bores as required.

A subsidence monitoring plan will be prepared by Hume Coal and DI Water will have an opportunity to review and provide comments on this plan once it is available. Any recommendations for additional groundwater monitoring as a result of this plan will be incorporated into the groundwater monitoring program.

Hume Coal's analysis of drawdown in landholder bores via the uncertainty analysis and detailed work provides confidence in the accuracy of the predictions. The uncertainty analysis undertaken provides confidence that the range of potential changes (ie moving towards to boundaries of the uncertainty analysis results), that impacts (ie drawdown and inflow) at these more conservative ranges can be managed. It is not anticipated that drawdown in landholder bores will be greater than predicted. However, if it is, then it will be managed using the same make good strategies that are being applied all impacted bores, ie funding for increased pumping costs, lowering pumps, providing a new bore and associated headworks, etc.

### 8.3.5 AIP Assessment

- NSW DPI raised Comments regarding the AIP assessment. They stated the need to ensure all AIP criteria adequately addressed various aspects not adequately addressed in the EIS, particularly the validity of numerical modelling to define impacts and the flow on mitigation and management of those impacts.
- The ability to obtain the entitlement in the Nepean Management Zone 1 is the key concern, as although entitlement is available the ability to acquire this is yet to be confirmed.
- The dispute resolution approach requires additional information to address the potential that landholders will not willingly agree to enter into make good agreements with Hume Coal.
- The make good strategies are confirmed to be reasonable, but more information is required in the timing of implementation of these strategies for individual bores.
- The assessment against the Aquifer Interference Policy by the proponent has not addressed the requirements of the policy, rather it has referred to sections of the EIS, complicating the review.

These comments regarding the AIP assessment were addressed in the RTS main report Section 9.5 with the following response.

The AIP assessment has been undertaken in detail in the Revised Water Assessment (EMM 2018b). This revised assessment addresses each of the requirements in detail in the checklist table and does not refer back to sections of the EIS.

The revised groundwater modelling work and detailed uncertainty analysis (Section 8.2.6iii) provides more confidence in the modelling results and hence the attributed mitigation and management strategies. A detailed discussion on the make good arrangements is provided in Section 8.3.1.

The Water Management Act 2000 (WMA2000) (under Section 91) defines an 'aquifer interference activity' as an activity involving any of the following:

a) penetration of an aquifer;

b) interference with water in an aquifer;

c) obstruction of the flow of water in an aquifer;

d) taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations; and

e) disposal of water taken from an aquifer as referred to in paragraph

The WMA2000 Section 91 provisions require a separate 'Aquifer Interference Approval', but the Section 91 provisions are not currently active. They will come into force when the Aquifer Interference Regulation is made under the WMA2000. In the meantime, the NSW Aquifer Interference Policy 2012 (the AIP) sets out the policy around subclause (d) with respect to interference to water levels, water pressures and water quality.

Although an Aquifer Interference Approval is not required, the volumetric take of water does require licensing. Water access licences are able to be traded on the open market, and additional groundwater entitlement is not 'issued' by the NSW Government in this area. Hume Coal currently holds 93% of the required licensed entitlement from the Sydney Basin Nepean Management Zone 1 Groundwater Source (see Table 8.7).

**Table 8.7 Summary of WALs held by Hume Coal**

| Water source | WAL required (ML) | Amount acquired by Hume Coal (ML) | % held by Hume Coal |
|---|---|---|---|
| Nepean Management Zone 1<br>Sydney Basin Nepean Groundwater Source | 2,059 | 1,909 | 93% |
| Nepean Management Zone 2<br>Sydney Basin Nepean Groundwater Source | 8 | 5 | 63% |
| Sydney Basin South Groundwater Source | 7 | 25 | 100% |
| Medway Rivulet Zone of the Upstream Warragamba and Upper Nepean Unregulated River Water Source | 19 | 31 | 100% |
| Total | 2,093 | 1,970 | 93% |

Hume Coal concurs with the classification of Level 2 impact for drawdown in landholder bores, and a less than Level 1 minimal impact for groundwater quality (Section 8.2.3).

The AIP requires Level 2 impacts to be further investigated, and then mitigated or avoided, and/or to enter into make good arrangements. The policy therefore provides a mechanism for 'greater than minimal impact' to be approved, but requires that any impacts that are considered 'greater than minimal impact' are adequately studied, and then either avoided, mitigated or that impacts are subject to made good.

## 8.4 Surface water

### 8.4.1 Baseline data

- Identified gaps in the background monitoring could be resolved if the proponent adequately describes the reasons behind the sampling events not being reported.
- DPI Water River Styles® mapping has identified highly fragile river reaches within the Project area which were not identified in the environmental assessment. Ensuring an adequate understanding of impacts to these reaches and developing adequate monitoring and management options is recommended.
- Further surveys should be undertaken of the unconfined River Styles® identified in the EIS and consistent with the NSW DPI Water 2012 River Styles® mapping. The surveys should include identifying remnant ponds features, extent and stand pond level and depth.

These comments regarding baseline data were addressed in the RTS main report (EMM 2018a) Section 8.1.1 with the following response.

#### i Data gaps

The surface water baseline dataset is extensive for the Project. The monitoring network design was undertaken in consultation with the then NSW Office of Water (now WaterNSW/DI Water). It was designed specifically to provide data to inform a robust assessment of the baseline conditions and to allow the impacts of the Project to be calculated. The design of any monitoring network needs to consider the practical aspects such as site accessibility for installing gauges and loggers, and access for ongoing sampling programs. As with any monitoring network in a rural environment, site access was a factor that contributed to the final monitoring network design.

It is acknowledged that the surface water quality data collected for the Project has gaps in the period of record. The reasons for this are mainly due to access restrictions and the ephemeral nature of the streams in the area and site details summarised below:

- SW02 – Very difficult access. Only sampled when installing the stream gauge and taking manual flow readings. Not a key monitoring site within the network as there is an upstream location (SWQ01) and a downstream location (SWQ02) on Black Bob's Creek.
- SWQ09 – Physical access was restricted, no samples collected.
- SWQ08 – Regularly dry, samples were able to be collected in 12 out of 24 site visits. This location is considered unlikely to be impacted by mining.
- SWQ13 – Predominantly dry, samples were able to be collected in 2 out of 25 site visits. This location is considered unlikely to be impacted by mining.
- SWQ07 – Predominantly dry, samples were able to be collected in 5 out of 26 site visits. This location is considered unlikely to be impacted by mining.

The surface water quality monitoring program aligns with the recommendations in the ANZECC (ANZECC and ARMCANZ 2000) Guidelines. The NSW Government, as the ultimate regulator, will determine final requirements.

Raw data for all monitoring programs is available in a detailed field report for the Project, including original copies of the laboratory analysis sheets. This field report did not form part of the EIS, mainly due to its very large size, but can be made available to the NSW Government if requested.

### ii River Styles®

With respect to the NSW DPI comments on the NSW DPI Water 2012 River Styles® mapping, it is noted that this dataset was developed by consultants using remote GIS techniques with no field verification. The geomorphic assessment undertaken for the EIS was developed using the River Styles Framework (Brierly and Fryirs 2005) and were verified by a geomorphological field survey. Although the terminology of "highly fragile river reaches" was not used, the reaches of Medway Rivulet, Wells Creek and Oldbury Creek identified as "high fragility" in the NSW DPI 2012 River Styles® spatial data have generally been identified in the EIS assessment as "stream reaches at risk of erosion due to changes in flow regime", which is comparable. In terms of geomorphological impacts, the main potential impact to the "high fragility" reaches is erosion associated with increased flows. However, the potential for erosion is low considering the minimal change in flow predicted.

Further geomorphic field surveys will be undertaken for unconfined River Styles® identified in the EIS and consistent with the NSW DPI Water 2012 River Styles® assessment during the detailed design phase of the Project. Surveys will focus on reaches identified as possessing high fragility in the NSW DPI Water 2012 River Styles® assessment, subject to land access. Surveys will include identifying remnant pond features, extent and standing pond level and depth. The characterisation of streams in the Project area will be confirmed at the detailed design phase using additional stream gauging data collected as part of the ongoing baseline monitoring program. A detailed geomorphic assessment report will be prepared at the detailed design phase to outline the current geomorphic condition and projected recovery trajectories under current management regimes, potential subsidence conditions and with rehabilitation actions in place. The additional geomorphic assessment will include review of the categories assigned to Black Bobs Creek and Medway Rivulet as raised in the above submissions.

Post-mining geomorphic field surveys will be undertaken for areas likely to have differential settlement, subject to land access. There are no areas predicted to have material levels of differential settlement, with vertical subsidence movements predicted to be less than 20 mm. As stated above, no mining is proposed to be undertaken directly beneath Medway Rivulet. Post-mining surveys will focus on identifying likely or potential disturbance and channelisation within, or downstream of, remnant ponds and valley fills. Where areas are classed as swampy meadows, the surveys will incorporate catenary survey lines to detect drawdown within the fill sediments, subject to land access.

Where channelisation impacts resulting from mining are identified, specific remediation programs will be developed to identify controls to prevent further channelisation within and between chain of ponds. Remediation programs will be developed in accordance with existing rehabilitation standards (eg Rutherford et al 2000) and recent research on processes related to geomorphic recovery in high fragility river channels (eg MacTaggart et al. 2006, Mould and Fryirs 2017).

### 8.4.2 Site water management

#### i Buffer distances

- Confirm the buffer distances between proposed works and the high bank of watercourses. DPI Water recommends buffers to be implemented consistent with the "Guidelines for Controlled Activities on Waterfront Land (DPI Water 2012)".

This comment regarding buffer distances was addressed in the RTS main report (EMM 2018a) Section 8.3 with the following response.

Where relevant, Hume Coal commit to complying with buffers consistent with the "Guidelines for Controlled Activities on Waterfront Land (NOW 2012b)".

The project proposes to construct a conveyor, power line and widen an existing roadway over Oldbury Creek, and construct a conveyor and upgrade an existing farm road over Medway Rivulet. These activities are proposed on waterfront land and meet the criteria for requiring a controlled activity approval. However, as the Project is a State Significant Development under Section 89J (1) (g) of the EP&A Act 1979, (once development consent is granted) it will be exempt from requiring an approval to undertake work on waterfront land. Despite that, the assessment of these activities has been considered in accordance with the policies and guidelines in respect of waterfront land and riparian corridors.

#### ii Site water storages

- Consideration of dam safety matters in accordance with the Dams Safety Act is required.
- Consideration is recommended of the ability to install culverts to maintain the current flow regime from the dam (on Oldbury Creek).
- Complete an assessment of impacts on downstream users and the environment due to the proposed raising of the dam wall on an existing dam on Oldbury Creek.
- Increasing the dam wall (existing dam on Oldbury Creek) has the potential to increase the dam capacity and hence may require the purchase of additional water entitlement.

These comments regarding site water storages were addressed in the RTS main report (EMM 2018a) Section 8.3.2 with the following response.

#### a Dam Safety

Where appropriate, Hume Coal Project dams will be designed, constructed, operated and maintained to meet the requirements of the NSW Dams Safety Committee (DSC) under the Dams Safety Act 1978.

The NSW DSC is the State's regulator for dam safety and is responsible for ensuring the safety of dams whose failure would cause serious community consequence, including environmental effects. The NSW DSC prescribes these dams under the provisions of the Dams Safety Act 1978 and uses a consequence category system to determine the need to prescribe a dam. All 'Extreme', 'High' and 'Significant' consequence category dams, along with 'Low' consequence category dams over 15 m high, are prescribed under the Dams Safety Act 1978 on the recommendation of the NSW DSC. However, all dams over 15 m high, or with populations downstream, or containing toxic materials should be referred for DSC consideration regardless of potential failure consequences.

The NSW DSC requires that new dams are designed and constructed according to appropriate engineering standards and safety criteria. After construction, dam safety is monitored by requiring prescribed dam owners to arrange for:

- proper operation and maintenance using trained personnel;
- regular surveillance using trained personnel;

- appropriate dam safety emergency plans to be in place for dams whose failure could cause loss of non-itinerant life;
- ongoing assessment of dam behaviour on the basis of surveillance information;
- periodic review of compliance with current DSC requirements;
- review of all dam information and assessments by experienced personnel; and
- actions, in response to dam assessments, to ensure that dams are maintained in a safe condition.

### b Oldbury Creek

Hume Coal does not intend to raise the wall on the existing dam on Oldbury Creek, but may consider upgrading the existing access track by widening the embankment, if necessary. Widening of the embankment will be designed so to not affect how the dam spills during normal rainfall events or downstream users and the environment. The existing spillway through the embankment will be maintained at the current level so that the water stored within the storage will not increase in volume.

It is noted that Section 6.1.3 of the *Hume Coal Project Flooding Assessment* (WSP PB 2016d) references that the embankment across Oldbury Creek will be raised and that it will also have poles for electricity lines installed. This statement is incorrect. As mentioned above, the embankment will not be raised but may be widened; this work will not affect the storage capacity of the existing dam. The electricity lines will be constructed at the other, upstream crossing of this dam.

As stated above, all Hume Coal Project dams will be designed, constructed, operated and maintained to meet the requirements of the *NSW Dams Safety Committee* (DSC) under the *Dams Safety Act 1978*.

## iii Water demand and supply

- The timing and nature of operational water demand is not well described within the EIS and supporting documentation, which means the amount of water likely to be reinstated to sealed mined panels is not clearly defined.

This comment regarding operational water demand was addressed in the Revised Water Assessment Section 2.3.1 with the following response.

During construction, the Project's water needs will be sourced via licensed groundwater bores, located on land owned by Hume Coal. Potable water will also be sourced from water supply bores and/or trucked to site and stored in tanks, both at construction sites and the accommodation village.

During operation the Project will require water for a range of uses including:

- coal preparation plant (CPP) process water;
- co-disposed reject make-up water;
- ROM stockpile water;
- underground operations water;
- administration and workshop area water; and
- accommodation village consumption and cleaning.

The water volumes for various demands over the mine's 19-year life are presented in Figure 8.9. These volumes were inputs to the water balance model.

Potable water will continue to be sourced from bores and/or trucked to site and stored in tanks during mine operation. Water for us in amenities (non-potable) will be sourced from bores. This volume is negligible and so is not included in the water balance model shown in Figure 8.9.

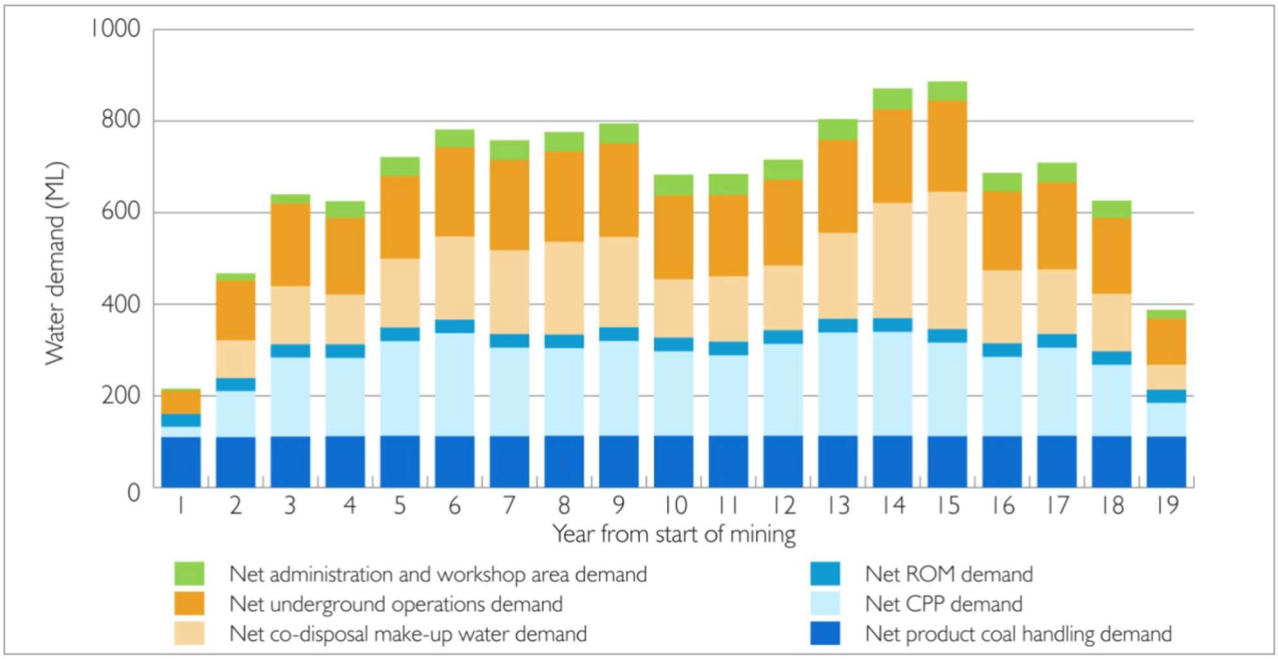


**Figure 8.9 Project water demands**

### 8.4.3 Surface water impacts

#### i Surface water take and compensation

- Quantify the annual maximum volumetric losses to the surface water systems over the life of the Projects impacts during dry and wet periods. Yield impacts identified in the EIS are currently expressed as a percentage. A concept compensatory flow regime should be developed to mitigate impacts to the surface water system in regard to losses to Town Water Supply and low flow impacts on Basic Landholder Rights users and the environment.
- Implementation of compensatory flows to the surface water system would alter the water balance and the associated availability of water for mine use and aquifer recovery. Detailed review of the potential changes to water supply and drawdown impacts will be required.
- The assessment provided doesn't clearly quantify the volumetric impacts for maximum or worse case scenarios, and advise whether this has been considered by Wingecarribee Council in future water supply planning.

These comments regarding surface water take and compensation were addressed in the RTS main report (EMM 2018a) Section 8.4.3 with the following response.

The flow impact assessment undertaken for the Hume Coal Project EIS (WSP PB 2016c) has been revised to include the revised baseflow reduction estimates from post-EIS numerical groundwater modelling, including robust uncertainty analysis and climate sensitivity analysis, undertaken by HydroSimulations (2018). The flow impact assessment has also been revised to include the revised estimates of releases from SB03 and SB04 to Oldbury Creek as predicted by the revised water balance model. The assessment methodology (where the methodology differs from the EIS) and results are outlined in Section 10.1 of Appendix 2 to the RTS main report and Section 4 of the *Hume Coal Project Revised Surface Water Assessment* (WSP 2018).

The revised base case flow impact assessment adopts baseflow reduction estimates from the revised numerical groundwater model. The results of the base case flow impact assessment are provided in Section 10.1 of Appendix 2 to the RTS main report. A flow assessment climate sensitivity analysis has also been undertaken adopting baseflow reduction estimates using an average climate, as well as extreme wet climate scenario and extreme dry climate scenario from groundwater modelling climate sensitivity analysis. The results of the flow assessment climate sensitivity analysis are provided in Section 10.1.5 of Appendix 2 to the RTS main report. Flow impacts results are provided as a percentage change in yield and as an annual mean and annual maximum volumetric loss over the 19-year mining period.

The revised base case flow impact assessment predicts that local impacts on yield in the Oldbury Creek sub-catchment will be 4.3% (mean of 159.1 ML/yr) for wet conditions and 4.5% (mean of 71.9 ML/yr) for dry conditions. However, there are no known or probable stream water users in this sub-catchment except for the farming operation affiliated with Hume Coal. The predicted yield impact for the wider Medway Rivulet Management Zone (which includes the Oldbury Creek catchment) is 0.9% (mean of 433.9 ML/yr) under wet conditions and 1.6% (mean of 239.1 ML/yr) under dry conditions. Less than a 0.05% reduction in yield, ie negligible reduction, is predicted for the Lower Wingecarribee River, Upper Wingecarribee River, Lower Wollondilly River, Bundanoon Creek and Nattai River management zones under wet and dry conditions. With continued constant discharges from Moss Vale and Berrima sewage treatment plants, there are zero no flow days predicted for the Medway Rivulet sub-catchment and the Oldbury Creek sub-catchment. Given the low yield impacts predicted, compensatory flows are not considered necessary.

Given the low yield impact predictions, there will be minor to imperceptible impacts on downstream users, including impacts to productive land, and inter-dam transfers. The Council currently does not use the Medway Dam for water supply purposes.

Hume Coal holds sufficient licences to account for the volumetric take from the surface water system (as well as the groundwater system) and, as such, make good provisions are not required. Due to impacts being negligible, make good for surface water users is also not required. Refer to Section 8.5 for responses to submissions relating to water licensing. Harvestable Rights have been calculated and Hume Coal can manage and offset their baseflow impacts by removal or construction of existing farm dams as turkey nests (ie so they do not intercept overland flow).

Spring fed dams are unlikely to be impacted by the Project, due to the likely water source for the spring being perched or shallow groundwater and is likely disconnected to the regional groundwater systems. However, local assessments will be required for each dam to confirm this. Landholders with existing spring-fed dams are invited to consult with Hume Coal in order to obtain baseline measurements and potentially negotiate make good agreements if located in an area where watertable drawdown as a result of the mine is predicted to compromise the water supply within a spring-fed dam by more than normal seasonal variation.

Matters regarding compensation for declines in groundwater levels in existing landholder bores are addressed in Section 8.3.1 and in the Revised Water Assessment (Appendix 2 to the RTS main report, Chapter 13).

As described in Section 12.2.3 of the Revised Water Assessment (Appendix 2 to the RTS main report), for the Hume Coal Project, most streams are classified as gaining streams which continue to be gaining streams throughout the Project (ie even after the regional watertable is lowered). This is due to many streams overlying perched shallow groundwater systems that are not affected by the regional watertable. As shown above, reduction in baseflow to streams results in minor to imperceptible impact to the flow regime as a result of drawdown in the watertable. The main exception is Medway Dam, which transitions from a gaining to a losing system during mining (likely due to the artificial elevation of the water surface).

The numerical groundwater model has been revised following the EIS to account for matters raised during the exhibition process (HydroSimulations 2018). Along with robust uncertainty analysis, localised modelling for the Medway Dam has enabled more accurate predictions of surface water leakage from the dam as a result of the Project. The volume of induced leakage from Medway Dam (a maximum of 19 ML/yr) will be accounted for with surface water licences already held by Hume Coal. This transition from a gaining to a losing system is temporary; Medway Dam is predicted to revert back to a gaining system approximately 25 years following cessation of mining and void filling. Refer to Section 12.2.3 of the Revised Water Assessment (Appendix 2 to the RTS main report) for further detail.

### ii Baseflow reduction

- Detailed assessment is required of the potential impact to aquatic ecosystems posed by aluminium concentrations exceeding guideline values for aquatic ecosystems, with respect to baseflow reduction potential impacts on water quality.

This comment regarding baseflow reduction was addressed in the RTS main report (EMM 2018a) Section 8.4.9 with the following response.

Baseflow reduction predictions for surface water sources, management zones and sub-catchments within those zones have been revised following additional post-EIS numerical groundwater modelling, including robust uncertainty analysis (HydroSimulations 2018).

An additional mass balance analysis has been undertaken as part of the *Hume Coal Project Revised Surface Water Assessment* (WSP 2018, Section 5.5) to assess potential water quality impacts associated with reduced dilution from baseflow reduction. GoldSim mass balance modelling was undertaken for the Medway Rivulet Management Zone for parameters that have higher baseline concentrations in surface water than groundwater, as there is the potential for streamflow concentrations to increase for these parameters due to reduced dilution from baseflow. GoldSim mass balance modelling demonstrated that the cumulative frequency graphs of nitrate, nitrite, calcium, sodium, sulfate and aluminium concentrations in streamflow are very similar for the existing and operational scenarios. The change in concentration between the existing and operational scenarios is almost undetectable up to the 99$^{th}$ percentile of the model's results. There is a slight increase (<3%) in concentrations between the 99$^{th}$ and 100$^{th}$ percentile. For example, for aluminium, the predicted change in concentration as a result of the Project is 2.9% or 0.004 mg/L higher than baseline values (ie 0.142 mg/L compared with 0.138 mg/L). Comparison to guideline values for aquatic ecosystems, drinking water, irrigation and livestock suggest that changes in surface water concentrations as a result of baseflow reduction will have a neutral effect on the beneficial use of surface water in the Project area. Given the results of this quantitative assessment, further assessment of the potential impacts to aquatic ecosystems posed by aluminium is not considered to be necessary.

### 8.4.4 Monitoring and management

- Preparation of an operational Water Management Plan will be required to detail the water balance, monitoring and mitigating measures for the Project. This will be required to include a comprehensive surface water and groundwater monitoring program and a contingency response plan which would need to include accepted trigger levels and viable mitigating measures. Detailed make good provisions would be a key element to this plan.
- The monitoring regime should include both regular and event-based monitoring across both up and down-stream locations.
- The monitoring and management program should be designed to test predictions made in the proposal, specifically that (due to their facultative dependence on groundwater) - no impacts are expected to terrestrial vegetation as a result of groundwater reductions, except in periods of drought.
- Annual monitoring should be undertaken where riparian vegetation is deemed to be at moderate or high risk to enable early detection and management of impacts.
- The proponent should clearly define how determination will be made of whether impacts to riparian and aquatic ecosystems are a result of mine activity.
- The proponent should prepare and implement management plans to manage and mitigate water related impacts during construction, operation and rehabilitation.
- A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts is required.
- The site water balance should be updated yearly and made available via annual reporting.

These comments regarding monitoring and management were addressed in the RTS main report Section 8.5 with the following response.

#### i Water management plans

As stated in the EIS Water Assessment, two main water management plans (WMPs) will be developed for the Project, one for the construction phase (CWMP) and one for the operational phase (OWMP). The CWMP will be developed prior to the construction phase. A rehabilitation WMP will also be considered. The WMPs will be a sub-plan of the environmental management system. The WMPs will document the proposed mitigation and management measures for the approved project, and will include the surface and groundwater monitoring program, reporting requirements, spill management and response, water quality trigger levels, corrective actions, contingencies, make good measures, and responsibilities for all management measures.

The WMPs will be prepared in consultation with DPI Water, EPA, WaterNSW, and the local council, and will consider concerns raised during the submissions and approvals process for the Project. With regard to the Water Management Plans, this will include consultation regarding the design (location, frequency and monitored parameters) of the monitoring network. The construction and operation water monitoring network will be designed with the purpose of enabling early detection of impacts (predicted or otherwise) to sensitive receptors (including, but not limited to, aquatic ecosystems, drainage lines, riparian land, groundwater dependant ecosystems, and surface water and groundwater users).

The WMPs will include details of the surface water and groundwater monitoring program, which will incorporate and update the existing monitoring network, monitoring frequencies and water quality constituents, and physical water take and pumping volumes between water storage structures (including the void, the sump, mine water dams and stormwater basins). Reporting frameworks for the above will be prepared in accordance with licensing and agency requirements. Contingency response plan including accepted trigger levels for water quality parameters will be developed as part of the WMPs to assist in early identification of water quality trends and to assist in providing confirmation (or otherwise) of the NorBE predictions. The monitoring program will be prepared in accordance with the approved project's environment protection licence (EPL), once enacted. Further details regarding the Water Management Plans and ongoing monitoring are included in Chapter 13 of Appendix 2 to the RTS main report.

In relation to 'recycled toilet water', sewage from the administration and workshop areas will be treated and reused on site. Black water will be subject to tertiary treatment and harvested for reuse in the CPP; therefore, no runoff of this treated wastewater stream will occur. Grey water will be subject to primary treatment and used for drip irrigation of landscaped areas. The drip irrigation system will be designed and operated in accordance with the relevant guidelines at the time, such as the document *Environment Guidelines – Use of effluent by irrigation* (NSW Department of Environment and Conservation 2003), so that there is no offsite impacts associated with the sewage treatment system.

### ii Monitoring plan

As stated in the *Hume Coal Project Water Impact Assessment* (EMM 2017c) and the Revised Water Assessment (Appendix 2 to the RTS main report, Chapter 13), baseline data will continue to be collected from the water monitoring network throughout the life of the mine. Expansion of the network may be considered once the Project starts construction and then operation. The ongoing development and expansion of the monitoring network will occur in consultation with WaterNSW and DPI Water, and as per the guidelines for the GMMP, which will evolve as the Project progresses. Consultation will include details regarding the monitoring site location, frequency of monitoring and monitored parameters.

Monitoring each component of the water management system will form the basis of how and when management responses are required. The monitoring network is fundamental to achieving effective management and early detection of project impacts and as such has been designed (and will continue to be designed) with this objective.

To help analyse monitoring data, triggers and thresholds will be developed to provide context when and what management measures are to be implemented. Water quality monitoring will be undertaken both within and outside of the mine water management system, including in upstream and downstream environments to account for impacts observed at sensitive receptors. Triggers will be designed with respect to cumulative impacts on sensitive receptors.

The baseline stream gauging program is ongoing with the purpose of better establishing baseline flow conditions prior to mining. Additional data will be available in the future. Appropriate trigger levels and response actions to address measured flow impacts will be developed using the additional baseline stream gauging data, prior to construction of the Project. Triggers and response actions will be developed in consultation with the relevant regulatory agencies.

A surface water flow monitoring program will be implemented in local catchments during construction, operation and rehabilitation stages of the Project. The surface water flow monitoring program will involve monitoring of stream gauges on Medway Rivulet and Oldbury Creek upstream and downstream of surface infrastructure areas and monitoring of the volume of water released from SB03 and SB04 to Oldbury Creek, subject to site access. The results of the monitoring program will be compared to the pre-mining baseline flow statistics. The objective of the program will be to confirm the predicted flow impacts.

As part of the groundwater monitoring program, it is intended that additional shallow monitoring bores will be installed in areas identified as having shallow groundwater and known terrestrial ecosystems with possibly affected species (subject to site access), and to also monitor groundwater-surface water connectivity and any changes that may occur. These additional monitoring sites will be determined based on site access and through discussions with DPIE-Water on their specific requirements. Monitoring of terrestrial vegetation, both native vegetation and significant private gardens, can be incorporated into this monitoring regime.

The Hume Coal Project water balance model (Appendix 2 to the RTS main report, Section 8.2) will continue to be refined over the life of the Project and will be used as an operational tool for site water management and to verify predicted stream flow impacts. The operational water balance model will incorporate the AWBM rainfall-runoff model that was developed for the Hume Coal Project EIS. The AWBM model calibration will be refined prior to construction of the Project using the additional baseline stream gauging data. The operational water balance model will utilise site monitoring data (such as rainfall data, demand data, groundwater inflow data, surplus water pumping in to void data etc). The operational water balance model will also include a pre-mining scenario to allow for comparison between simulated flows from the SW04 and SW08 catchments for the mining and pre-mining scenarios.

### 8.4.5 Conditions of approval

#### i Secure yield analysis

- To further assess the impact on town water supply the proponent is recommended to undertake a secure yield analysis in consultation with Wingecarribee Council. This would need to be in accordance with the draft NSW Guidelines on Assuring Future Urban Water Security – Assessment and Adaption Guidelines for NSW Local Water Utilities.

This comment regarding undertaking a secure yield analysis was addressed in the RTS main report Section 8.6 with the following response.

Medway Dam is a third-tier water supply and receives treated effluent from the Moss Vale sewage treatment plant via Medway Rivulet. It does not currently supply water into the Wingecarribee Shire Council's (WSC) drinking water system.

A secure yield analysis will be undertaken in consultation with WSC at the detailed design phase to further assess the impact on town water supply subject to cooperation by WSC. The analysis would be in accordance with the draft guidelines Assuring Future Urban Water Security – Assessment and Adaption Guidelines for NSW Local Water Utilities (NSW DPI 2013).

### ii Geomorphology

- Areas likely to have differential settlement should have post-mining surveys conducted. These should focus on identifying likely or potential disturbance and channelisation within or downstream of remnant ponds and valley fills. Where these may be classed as swampy meadows, surveys should incorporate catenary survey lines to detect drawdown within the fill sediments.
- Reporting of current geomorphic condition and projected recovery trajectories under current management regimes, potential subsidence conditions and with rehabilitation actions in place is recommended. These should be compared to ongoing management where management intervention is deemed necessary.
- Specific remediation programs should be developed to identify likely controls and where constructed controls may be required to prevent further channelization within and between chain of ponds (see Attachment D). These are to be consistent with existing rehabilitation standards (e.g. Rutherford et al 2000) and recent research on processes related to geomorphic recovery in high fragility river channels (e.g. MacTaggart et al 2006, Mould and Fryirs 2017).

These comments regarding geomorphology were addressed in the RTS main report Sections 8.1.1 and 8.6 with the following response.

Further geomorphic field surveys will be undertaken for unconfined River Styles® identified in the EIS and consistent with the NSW DPI Water 2012 River Styles® assessment during the detailed design phase of the Project. Surveys will focus on reaches identified as possessing high fragility in the NSW DPI Water 2012 River Styles® assessment, subject to land access. Surveys will include identifying remnant pond features, extent and standing pond level and depth. The characterisation of streams in the Project area will be confirmed at the detailed design phase using additional stream gauging data collected as part of the ongoing baseline monitoring program. A detailed geomorphic assessment report will be prepared at the detailed design phase to outline the current geomorphic condition and projected recovery trajectories under current management regimes, potential subsidence conditions and with rehabilitation actions in place. The additional geomorphic assessment will include review of the categories assigned to Black Bobs Creek and Medway Rivulet as raised in the above submissions.

Post-mining geomorphic field surveys will be undertaken for areas likely to have differential settlement, subject to land access. There are no areas predicted to have material levels of differential settlement, with vertical subsidence movements predicted to be less than 20 mm. As stated above, no mining is proposed to be undertaken directly beneath Medway Rivulet. Post-mining surveys will focus on identifying likely or potential disturbance and channelisation within, or downstream of, remnant ponds and valley fills. Where areas are classed as swampy meadows, the surveys will incorporate catenary survey lines to detect drawdown within the fill sediments, subject to land access.

Where channelisation impacts resulting from mining are identified, specific remediation programs will be developed to identify controls to prevent further channelisation within and between chain of ponds. Remediation programs will be developed in accordance with existing rehabilitation standards (eg Rutherford et al 2000) and recent research on processes related to geomorphic recovery in high fragility river channels (eg MacTaggart et al. 2006, Mould and Fryirs 2017).

### iii Flood criteria

- The flood assessment for a 1 in 100 year ARI event has identified afflux impacts to be primarily on Hume Coal or Boral owned land. A minor increase in flood extent is predicted upstream of the Hume Highway on private property. It is recommended confirmation be obtained from the private landholders that the afflux impacts are acceptable, or appropriate mitigation or compensation arrangements be developed.

This comment regarding flood criteria was addressed in the RTS main report Sections 8.4.6 and 8.6 with the following response.

Although flood modelling was not undertaken for the 10-year ARI event, modelling was undertaken for the 5-, 20- and 100-year average recurrence interval (ARI) events and the probable maximum flood (PMF).

The flooding and drainage assessment found that the impacts on flooding for the operation and rehabilitation scenarios are within proposed acceptability criteria, with the exception of five discrete locations for the operational phase. At all five locations the impacts are confined to land owned by either Hume Coal or Boral and generally are removed for the rehabilitation phase, with the exception of an impact east of the Berrima Cement works where the rail infrastructure is to be retained under the preferred option.

Predicted afflux at private properties is less than the proposed acceptability criteria of 250 mm for flooding events up to the 100-year ARI. Flood impacts at private properties are minor and short-lived and unlikely to affect stocking capacity. Nonetheless, consultation will be undertaken with affected private landowners where flood impacts, although minor, are predicted.

### iv Scour protection

- Scour protection measures are proposed which will be critical to the design and ongoing management. DPI Water recommends all works associated with watercourse crossings to be in accordance with the DPI Water "Guidelines for Controlled Activities on Waterfront Land (2012)".

This comment regarding scour protection was addressed in the RTS main report (EMM 2018a) Section 8.6 with the following response.

The NSW DPI will be consulted during the design phase of the waterway crossings and associated scour protection at location FG / GEO01 – Stony Creek and at location FG21 / GEO04 – Oldbury Creek. The NSW DPI will be provided with the detailed design for these crossings for review and comment prior to construction.

### v Erosion and sediment control measures

- The proponent must prepare an Erosion and Sedimentation Control Plan in consultation with DPI Water prior to the commencement of activities.
- A series of watercourse crossings are proposed on watercourses, including the replacement of a bridge on Stony Creek (5th order stream) with a series of culverts. The associated road embankments are predicted to concentrate flows and increase the risk of erosion and scouring at all crossings.

These comments regarding erosion and sediment control measures were addressed in the RTS main report (EMM 2018a) Section 8.6 with the following response.

Mitigation and management measures to be implemented for the Berrima Rail Project to avoid impacts on surface water quality are outlined in Section 13.5.7 of the Berrima Rail Project EIS and in Section 5.4 of the Revised Surface Water Assessment (WSP 2018). These measures will be implemented during construction and rehabilitation as well as during operation of the rail line. An Erosion and Sedimentation Control Plan, in consultation with DPI Water and WaterNSW, will be prepared prior to the commencement of activities.

The NSW DPI will be consulted during the design phase of the waterway crossings and associated scour protection at location FG / GEO01 – Stony Creek and at location FG21 / GEO04 – Oldbury Creek. The NSW DPI will be provided with the detailed design for these crossings for review and comment prior to construction.

### vi Post project approval

- Specialist monitoring of the bulkhead integrity and pillar stability to be included as part of the water management plan and subsidence management plan to identify whether future irregular and unpredictable subsidence (resulting from periodic support failure) will have an impact on groundwater availability for licensed users and the potential for aquifer damage (see Attachment A).
- ongoing verification of impacts on surface water and groundwater sources should be completed. This will include regular updates of the surface water and groundwater models, and discussion with relevant agencies where impacts are diverging from original impact and water take predictions. Where variations in predictions occur, consideration would need to be given as to the consistency of the approved project in consultation with Department of Planning and Environment and relevant agencies.
- Management of flows where baseflows are affected to consider replacement or replenishment options. These could include geomorphic rehabilitation to replace and/or improve channel and pool condition.
- It is recommended that a subsidence expert considers the long-term stability of the pillars, potential for failure to occur and impact on groundwater resources.

These comments regarding post project approval were addressed in the RTS main report (EMM 2018a) Section 8.6 with the following response.

In response to the above submissions by NSW DPI, post-project approval Hume Coal will commit to the following:

- Ongoing verification of the prediction groundwater and surface water models with respect to monitoring data. Results will be discussed with the relevant agencies where impacts and/or water take significantly diverge from original predictions.

- Consultation with DI Water regarding Water Access Licences planned to be associated with the Project to confirm licensing amendment requirements, if necessary.

- In drainage lines where baseflows are shown to be affected significantly by the Project, Hume Coal will consider management measures in consultation with the relevant agencies.

The issue of pillar stability has been comprehensively addressed in the Hume Coal Project EIS in the subsidence assessment undertaken by MineAdvice (Volume 7, Appendix L to the RTS main report) which included a report on pillar stability as an appendix. Hume Coal utilised an established and appropriate empirical design methodology called ARMPS-HWM (Analysis of Retreat Mining Pillar Stability software for Highwall Mining) to undertake the initial design for the EIS. ARMPS-HWM was developed by NIOSH in the US, and is based on a database incorporating over 3000 individual web pillars, including many of similar geometries to those proposed by Hume Coal.

Empirical design methodologies are directly tied to real-world observations and hence they can be incredibly powerful when correctly applied with skill and diligence within the limitations of their relevant database. The use of empirical design methods is supported by Gale and Hebblewhite (2005), which is mirrored in the NSW Trade & Investment (Mine Safety) Code of Practice *Strata Control in Underground Coal Mines* (2015), whereby "experiential, numerical, empirical-mechanistic and hybrid" are listed as being "applicable methodologies" for the design of similar types of pillars.

ARMPS-HWM is judged by MineAdvice to be "mechanistic" given that it incorporates more than simply the loading and stability state of the web pillar in formulating suitable layout designs.

## 8.5 Water licensing

### 8.5.1 Harvestable rights and exemptions

- No discussion of licence exemptions was included.
- Confirm whether the Primary Water Dam is a turkeys nest dam and whether all dams meet the exclusion requirements of the Harvestable Rights Dam Order.

These comments regarding harvestable rights and exemptions were addressed in the RTS main report Section 11.3 with the following response.

Hume Coal are not seeking licence exemptions or water licences from the NSW Government over and above standard exemptions that apply for all major projects in NSW. Hume Coal have applied the current regulation and policies as they stand to ensure that they are compliant and they hold water licences (purchased from the open market) for water inflows and take in accordance with the WM Act, Aquifer Interference Policy and relevant Water Sharing Plans.

The Primary Water Dam (PWD) is constructed as a turkey nest dam and does not receive any runoff from the surrounding catchment. It only receives water via direct rainfall on the surface of the dam, and water that is pumped from stormwater basins and mine water dams during high rainfall events. The main function of the primary water dam is flood mitigation and water management in wet periods to avoid discharges to local creeks (hence its large size). Its secondary purpose is a water supply holding dam for the Project water requirements. Turkeys nest dams are exempt pursuant to item 5 of Schedule 2 of the Harvestable Rights WMA s 54 order made in Gazette Number 40 on 31 March 2006 at page 1,628.

### 8.5.2 Licensing requirements

- The proponent should re-evaluate volumes required to be licenced based on maximum or worst-case conditions, not average conditions. The proponent should provide detailed confirmation of access to entitlement. Modelling only considers average conditions, what happens during drought to required licenses.
- DPI Water advises that the maximum annual volumes of surface water and groundwater predicted to be taken by the proposed mine during operation and in the recovery phase (in case of ongoing residual take) is required to be licensed from the commencement of the mine.
- Works associated with the dam wall on Oldbury Creek may lead to additional water being harvested and that additional licence volume may be required.

These comments regarding licensing requirements were addressed in the RTS main report Section 11.4 with the following response.

#### i Worst case taken into consideration

The effect of climatic variability (ie wet and dry periods) was considered in the revised groundwater modelling and analysed in detail within the sensitivity analysis and compared to the results of using the average climate. The modelling showed that climate variability had limited effect on required water licence volumes (for both groundwater and surface water). There was minimal change in licence requirement between the average climate, the wet climate, and the dry climate cases. The technical aspect of this climate scenario modelling is discussed in detail in Section 8.2.5 and in the revised Water Assessment (EMM 2018b).

### ii Groundwater model accuracy

The groundwater model for the project has been through rigorous review, audit, upgrade and revision and detailed uncertainty analysis. The NSW Government appointed independent expert reviewer, Hugh Middlemis has also undertaken a thorough review of the model. The model is deemed 'fit for the purpose of predicting inflows from mining' and as such stakeholders can have confidence that the numbers presented for water licensing are accurate, and are unlikely to change significantly as mining progresses.

The effect of climatic variability was considered in the revised groundwater modelling, the sensitivity analysis and the detailed uncertainty analysis. The climate variability had limited effect on required water licence volumes (for both groundwater and surface water). The technical aspect of this climate scenario modelling is discussed in detail in Section 8.2.5 and in Appendix 2 to the RTS main report. The conservative approach of the 67$^{th}$ percentile is adopted for the predicted licensable volume which is conservative in that the most likely scenario is 50$^{th}$ percentile and Hume Coal are therefore licensing more than the most likely scenario to provide existing water users and the NSW Government with enhanced confidence that the likely water requirements for the Project are more than fully covered.

The detailed uncertainty analysis has provided robust and defendable results in terms of water requirements. Hume Coal has taken a conservative approach to licensing requirements, and is using the 67$^{th}$ percentile (and not the average 50$^{th}$ percentile which is the most likely scenario). The revised modelling and uncertainty analysis provides revised forecasts of required licence volume, which are very similar to the original Coffey EIS results – but are considered more robust due to the very detailed uncertainty analysis upon which they are based (this is in accordance with the new draft IESC guidelines for modelling uncertainty).

The project's mining method progressively seals off the mine void from the active mine workings with bulkheads, so that most groundwater that would have otherwise flowed into the mine is not extracted and pumped to the surface, but physically remains in the groundwater source. The volume of water proposed to be licensed by Hume Coal is in strict accordance with a literal reading of the Aquifer Interference Policy. It is taken to be intercepted baseflow, plus the groundwater inflow to the sump that is physically handled (taken) by the mine's water management system, plus the groundwater inflow to the void (both behind bulkheads and into down dip areas), even though this water in the void is not physically removed, and remains within the groundwater source.

Based on the results of the 67$^{th}$ percentile uncertainty analysis revised numerical groundwater model (HydroSimulations 2018) and the revised water balance model (WSP 2018), the maximum physical extraction of water from within the mine workings in one year is 1,010 ML/yr in Year 17 (Figure 8.10). However, because Hume Coal is adhering strictly to the literal reading of the AIP, the total volume that will be licensed is 2,066 ML/yr in Year 17 which represents the water physically taken (sump), plus water that moves into the sealed and down-dip void areas but remains in the mine workings (void).

It should be noted that Figure 8.11 shows that volumetric inflow to the void (which mostly remains in the groundwater source) is greater than the volume of water that inflows to the sump (and physically taken) That is, Hume Coal's water licensing approach is conservative, having more licence than physically taken or used from within the greater groundwater source.

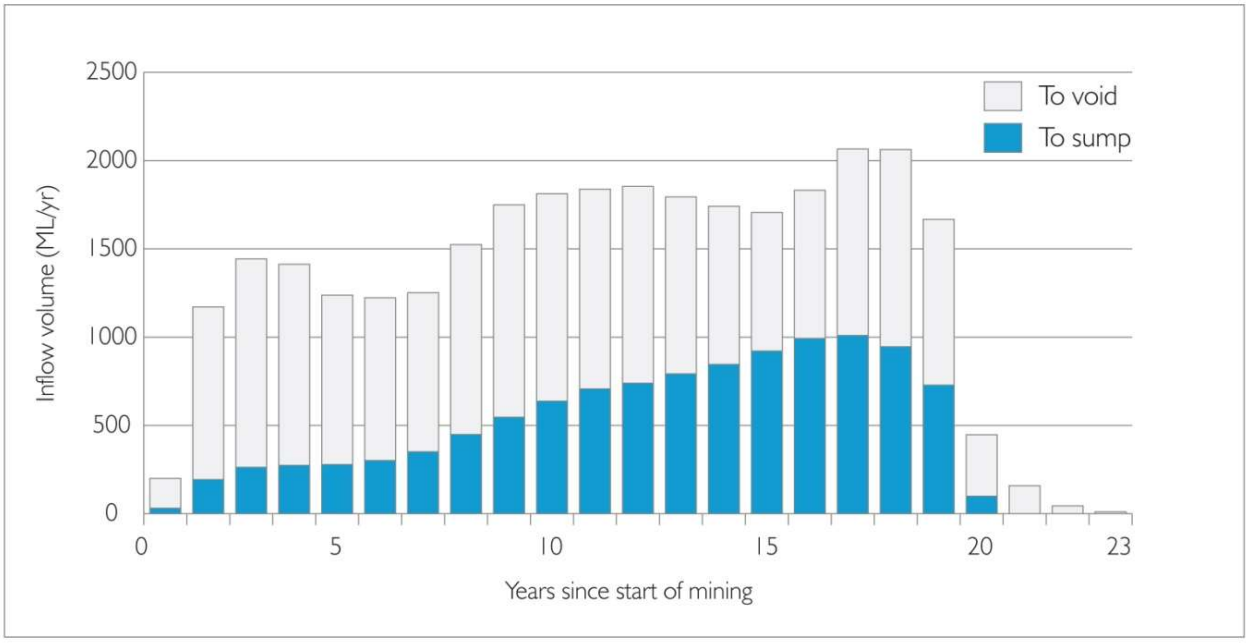


**Figure 8.12 Annual water inflow volumes to the mine**

As per the AIP, the total mine inflows must be licensed from within the source from which it derives. Therefore, based on the latest predictive modelling estimates, the maximum volume required for licensing from each individual water source is:

- Nepean Management Zone 1 Sydney Basin Nepean Groundwater Source 2,059 ML/yr in year 17;
- Nepean Management Zone 2 Sydney Basin Nepean Groundwater Source 7.1 ML/yr in year 25;
- Sydney Basin South Groundwater Source 6.5 ML/yr in year 74; and
- Medway Rivulet Management Zone of the Upper Nepean and Upstream Warragamba Water Source, 19 ML/yr in year 21.

Maps showing the locations of these water sources/management zones are included in Figures 3.1 and 3.2 of Appendix 2 of the RTS report.

The relative volumetric contributions from the Greater Metropolitan WSP groundwater sources are illustrated in Figure 8.13 (Sydney Basin Nepean Groundwater Source Management Zone 1) and Figure 8.14 (Sydney Basin Nepean Groundwater Source Management Zone 2, Sydney Basin South Groundwater Source, Medway Rivulet Management Zone).

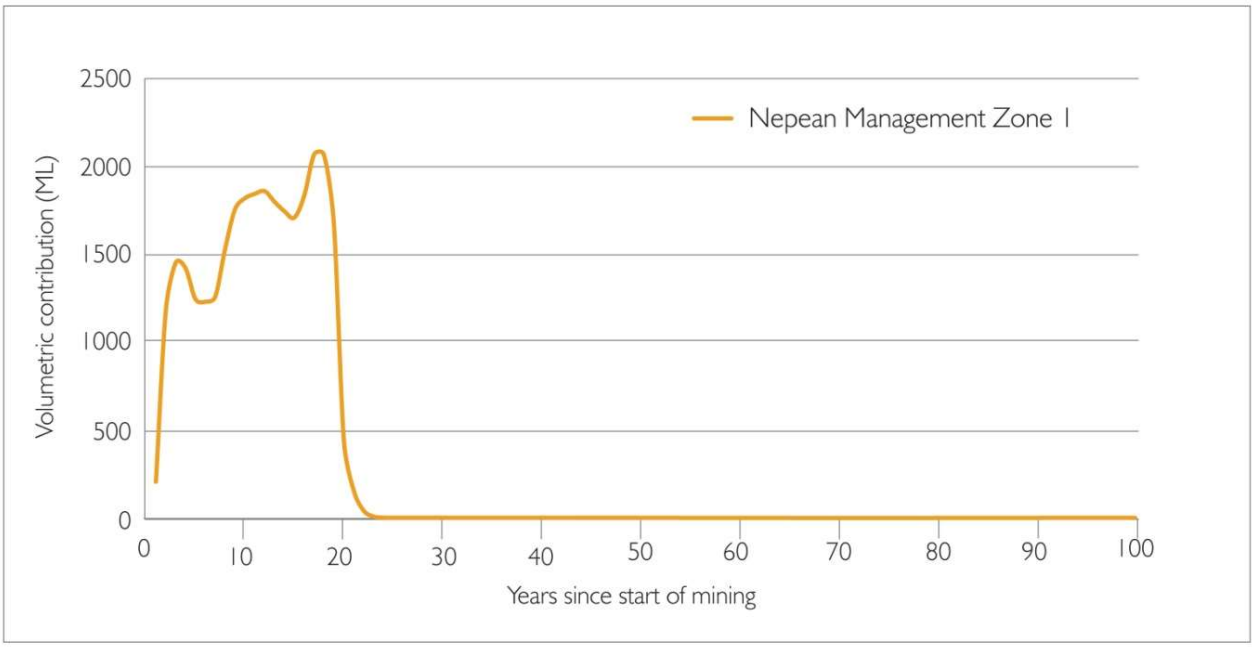


**Figure 8.15** **Groundwater take: Nepean Management Zone 1**

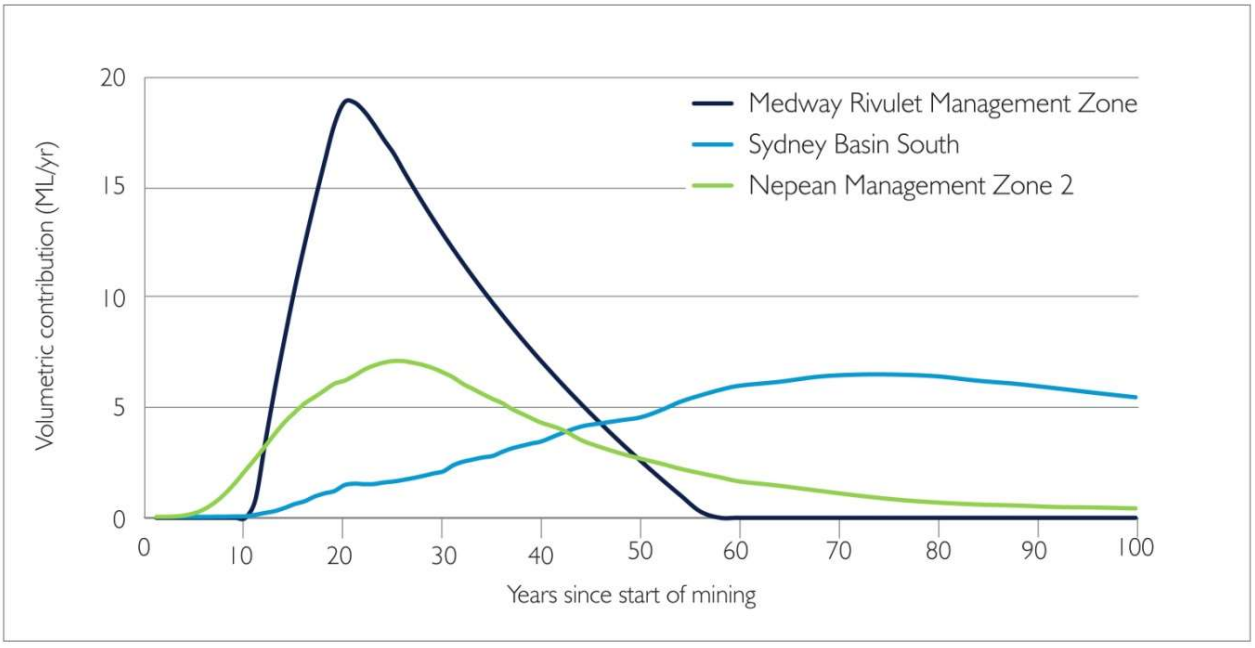


**Figure 8.16** **Groundwater and surface water take: Medway Rivulet Management Zone, Sydney Basin South, Nepean Management Zone 2**

### iii Timing of licence acquisition

There is no legal requirement to hold licences to cover the peak volumetric take from the commencement of the mine (or even from Project Approval or the lodging of the EIS). Nevertheless, Hume Coal has already acquired 93% of the required licences on the market over the last few years. Hume Coal will be able to acquire the remaining 7% of licence requirements before the commencement of the mine via the open market, and from controlled allocation releases. There are sufficient licences remaining in the market to purchase the remaining water licence requirements.

### iv Surface water

The revised modelling and uncertainty analysis fully explore the conceptualisation of the surface and groundwater connectivity across the Project area. Watertable elevations have been considered in detail throughout this process and a more probable surface has been derived through the uncertainty analysis work. There are baseflow contributions to permanent streams in both the upper and lower catchment areas. In the upper catchment areas, most baseflow is derived from perched aquifers in the basalt areas. These springs are disconnected from the regional aquifer in the Hawkesbury Sandstone and will be unaffected by mining. In the lower catchment, rivers are incised into the regional Hawkesbury Sandstone aquifer and are commonly referred to as 'connected-gaining' streams.

### v Oldbury Creek embankment

The works on the existing dam wall (embankment) across Oldbury Creek will not increase the storage capacity of the existing dam and, as such, there is no requirement for additional water licences. Hume Coal does not intend to raise the dam wall but may consider upgrading the existing access track by widening the embankment, if necessary. Widening of the embankment will not affect how the dam spills during normal rainfall events. The existing spillway through the embankment will be maintained at the current level so that the water stored within the storage will not increase in volume.

It is noted that Section 6.1.3 of the Hume Coal Project Flooding Assessment (WSP PB 2016d) references that the embankment across Oldbury Creek will be raised and that it will also have poles for electricity lines installed. This statement is incorrect. As mentioned above, the embankment will not be raised but may be widened; this work will not affect the storage capacity of the existing dam. The electricity lines will be constructed at the other, upstream crossing of this dam.

### 8.5.3 Licence activation and impacts

- The impacts (reduced yield to and increased leakage from Medway Dam) raise concern in regards to town water supply security and the ability to adequately mitigate this impact such as through compensatory flows.
- Where the Project proposes the use of WALs currently linked to water supply works not associated with this project, consultation with DPI Water will be required to confirm licensing amendment requirements.

These comments regarding licence activation and impacts were addressed in the RTS main report Section 11.5 with the following response.

#### i Medway Dam

Impacts to surface water users are minimal and the revised modelling predicts a maximum annual loss of 19 ML from the water stored in Medway Dam. Hume Coal already holds sufficient licences to account for this surface water take. For comparison, this volume is 5 times smaller than the annual volume of water lost due to evaporation from the Medway Dam surface (approximately 100 ML per year). The reliability of Medway Dam will not be changed as a result of the Project and its role as a potential back-up town water supply is not impacted. Medway Dam is currently not used (and has not been used in recent years) for the purpose of town water supply, so there are no impacts predicted to town water supply reliability.

#### ii Licensing amendments

The Hume Coal Project has purchased access licences and will consult with DI Water with regard to work and use approval requirements after development consent. The requirement to hold work and use approvals under the WMA is exempt for major projects, however it is understood that miscellaneous work approvals can be issued with conditions and/or relevant conditions can be applied to the consent conditions.

### 8.5.4 Licence status

#### i Modelling accuracy

- Acquiring additional licences (contingency) could be considered if modelling predictions are thought to be inaccurate and additional water may be required.

This comment regarding modelling accuracy was addressed in the RTS main report Section 11.6.1 with the following response.

The potential uncertainty or inaccuracy of the modelling predictions is thoroughly discussed in Section 8.2.6iii. A detailed uncertainty analysis has been completed for the revised EIS model, following consultation with DI Water and the NSW Government independent expert reviewer Hugh Middlemis.

The results of the uncertainty analysis demonstrate that the uncertainty falls within a relatively narrow range for both groundwater inflow (take over time), and predictions of drawdown and recovery. Therefore, the model predictions of inflow and drawdown in landholder bores can be relied upon. The original EIS model results and the revised results can be considered accurate and fit for purpose with additional confidence now the uncertainty analysis has been completed, and results demonstrate that there is a large degree of confidence in the model predictions.

The uncertainty analysis with respect to the mine inflow predictions, drawdown in landholder bores and the watertable drawdown is taken to be the 67th percentile for consideration of potential inflow (ie not the 50th percentile which is the average scenario). This therefore represents a conservative approach for prediction of inflows. In accordance with the draft explanatory note from the IESC on uncertainty modelling (Middlemis and Peeters 2018), the 67th percentile represents the boundary between *'as likely to occur as not'* and '*unlikely to occur in normal circumstances'*.

The revised numerical model and 67th percentile results for inflows/losses have been accepted by the independent expert reviewer and are being used to determine final water requirements. There is only a small change in the predicted mine inflow volumes, with the modelling suggesting a small reduction in required licence volume.

Regarding the amount of water access licences required in Nepean Management Zone 2 and Sydney Basin South groundwater source, some licences were obtained via the controlled allocation process during May 2017. An additional volume (3 ML) is still required for Nepean Management Zone 2 to account for the migration of water from those water sources whilst all required licences for Sydney Basin South groundwater source have been acquired.

The revised and updated model indicates that there are minimal volumetric impacts to permanent streams within the overlying Upper Nepean and Warragamba unregulated surface water source and therefore no additional surface water licences are required to account for impacts.

Hume Coal is confident with the peak inflow predictions and these are calculated as a conservative number. Hume Coal does not envisage that their project water requirements will be in excess of their current share of the available water, provided the extra 150 ML is secured in Nepean Management Zone 1, predominantly for Years 17 and 18. Within this time period, model verification and recalibration will occur as necessary. This verification and recalibration will allow the model to be refined to even more accurately predict inflow volumes and the timing of peak flows. Should the licence requirement increase, then either additional entitlement will be purchased prior to these inflows occurring, or the mine plan will be altered to ensure that the volumetric take does not exceed the available licensed volumes.

### ii Ability to acquire licenses

- A discussion of licences held and identification of possible means to obtain additional authorisations should be included.
- Consideration should be given to potential future reductions via available water determinations, or other licence restrictions.
- Groundwater licencing requirements will need to be reassessed following review of the groundwater model.

These comments regarding the ability of Hume Coal to acquire additional water licences were addressed in the RTS main report Section 11.6.2 with the following response.

The current licence holdings (ie updated Table 12.2 from the EIS) are presented in Table 8.8. Hume Coal have secured most of the required licence volume over the past few years, and can adequately account for all inflows in all years up to and including Year 16. There is a small deficient for Years 17 to 21. All water reporting to the sump and extracted for reuse is licensed in all years with the existing licences held by Hume Coal. Hume Coal believes that the required additional licences can be purchased on the open market in advance of project commencement. The water market is clearly functioning as intended as this new industry has enabled Hume Coal to acquire 93% of the licences required for the Project.

At the time of submitting the EIS in 2017, Hume Coal held 60% of the required water licence shares in Sydney Basin Nepean Groundwater Source – Management Zone 1. Since that time the revised groundwater modelling and detailed uncertainty analysis has determined the predicted inflows and additional 508 ML of groundwater licence shares has been acquired. For the 67$^{th}$ percentile uncertainty analysis (ie more conservative that the most likely 50% case), Hume Coal currently hold 93% of the peak inflow predictions for the Sydney Basin Nepean Groundwater Source – Management Zone 1 (requiring an additional 150ML). Current licence volumes and required volumes are outlined in Table 8.9.

The EIS model assessment of surface water losses predicted the average annual licence requirement from Upstream Warragamba and Upper Nepean Unregulated River Water Source - Medway Rivulet Zone was 36.5 ML. The revised modelling, including localised Medway Dam model, and uncertainty analysis suggests a peak take of 19 ML in year 21 of surface water leakage from Medway Dam in the Medway Rivulet Management Zone and no additional baseflow loss from adjacent surface water sources. Hume currently hold 31 ML of entitlement in the Medway Rivulet Management Zone and plan to retain this licence for the medium term as contingency if surface water licences are required in the future.

**Table 8.10 WAL requirements and Hume Coal owned licensed volumes**

| Water Source | WAL required (ML) | Volume of Hume Coal owned licence (ML) | Required additional volume (ML) |
|---|---|---|---|
| Sydney Basin Nepean Groundwater Source - Management Zone 1 | 2,059 | 1,909 | 150 |
| Sydney Basin Nepean Groundwater Source - Management Zone 2 | 8 | 5 | 3 |
| Sydney Basin South Groundwater Source | 7 | 25 | - |
| Upper Nepean and Upstream Warragamba Unregulated River Water Source - Medway Rivulet Zone | 19 | 31 | - |
| **Total** | **2,093** | **1,970** | **153** |

Hume Coal currently hold sufficient licence volume in the Sydney Basin Nepean Groundwater Source Management Zone 1 to account for mine inflows in all years of mining, except for two years of operation (Year 17 and Year 18). For Sydney Basin Nepean Groundwater Source Management Zone 2, an additional 3 ML is required to be purchased from existing users or via controlled allocation release.

The acquisition of access licences for Hume Coal is continuing, and new opportunities to purchase the final water volumes are expected in the coming years. Landholder circumstances change over time, properties change hands, and Hume Coal is a willing buyer. Based on the recent sales history, Hume Coal sees no impediment in gaining these additional licences.

### iii Water share prices

- A description should be given of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo.
- Confirm the location and license numbers of the potential licensed bores to be used to supplement water supply for the Project and the maximum volume to be extracted.

These comments regarding water share prices were addressed in the RTS main report Section 11.6.3 with the following response.

As the Sydney Basin Nepean Management Zone 1 Groundwater Source was one water source that was previously embargoed and supply was capped for some time, prices were accordingly relatively high prior to Hume Coal entering the market. This situation is relatively unchanged. Given that Hume Coal has secured 93% of licences required for the Project already, it is extremely unlikely that Hume Coal's attempts to secure the remaining small volume (150 ML) will drive up the licence share prices substantially enough for them to become financially unaffordable for the Project.

In addition, given that Hume Coal already have the majority of required licence shares, and obtained them in recent years when annual rainfall was average or below average (refer to Figure 2.3 of Appendix 2 to the RTS main report), Hume Coal is confident that the remaining 150 ML of licence shares required for Sydney Basin Nepean Management Zone 1 will be able to be obtained via market trading regardless of whether dry periods persist.

The operational water supply source for the Project in its early years may be taken directly from the Hawkesbury Sandstone aquifer rather than from the mining void and sump. The water will be sourced by using existing access licences in the early phases of the Project (ie in those years where minimal groundwater will be intercepted by mining). The final bore location/s (for water supply) have not been selected and once this occurs Hume Coal will discuss the location and volumes with DI Water and provide relevant details ahead of drilling.

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Attachment A

# Hume Coal and Berrima Mine comparison

# Hume Coal and Berrima Mine comparison

Attachment A to the DPIE Water report

Prepared for Hume Coal Pty Ltd
March 2020

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# Hume Coal and Berrima Mine comparison

Attachment A to the DPIE Water report

**Report Number**

J12055 IPC Water RP 3

**Client**

Hume Coal Pty Ltd

**Date**

31 March 2020

**Version**

v2 Final


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31 March 2020

**Approved by**

**Liz Webb**
Director
31 March 2020



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# 1 Introduction

Hume Coal Pty Limited (Hume Coal) proposes to construct and operate an underground coal mine and associated mine infrastructure in the Southern Coalfield of New South Wales (NSW) (the Hume Coal Project). The mine will produce metallurgical coal with a secondary thermal coal product. Around 50 million tonnes (Mt) of run-of-mine coal will be extracted from the Wongawilli Seam via a non-caving mining system, resulting in approximately 39 Mt of saleable coal over a project life of about 23 years, including construction and rehabilitation.

This report presents an enhanced discussion of the similarities and differences between the Berrima Colliery (existing situation and closure situation) and the proposed Hume Coal Project. A comparison between the Berrima Colliery and the Hume Coal Project has been provided in the various reports submitted to the NSW Department of Planning and Environment (DPE, now the Department of Planning, Infrastructure and Environment (DPIE)) as part of the environmental impact statements (EIS) and response to submissions (RTS) report. Information previously presented in the EIS (EMM 2017) and RTS (EMM 2018a and 2018b) is represented in this report, whilst making use of available historical reports relating to the Berrima Colliery.

Numerous historical mines/collieries have operated in the Project area, however for ease of comparison the Berrima Colliery was selected as it had been in operation until 2013 and it is one of the closest to the Hume Coal Project.

This comparison report describes the main differences and similarities between the two projects (historical and proposed), assessing the landscape location, geological environment, hydrogeological setting, mining methods and mine closure.

# 2 Landscape location

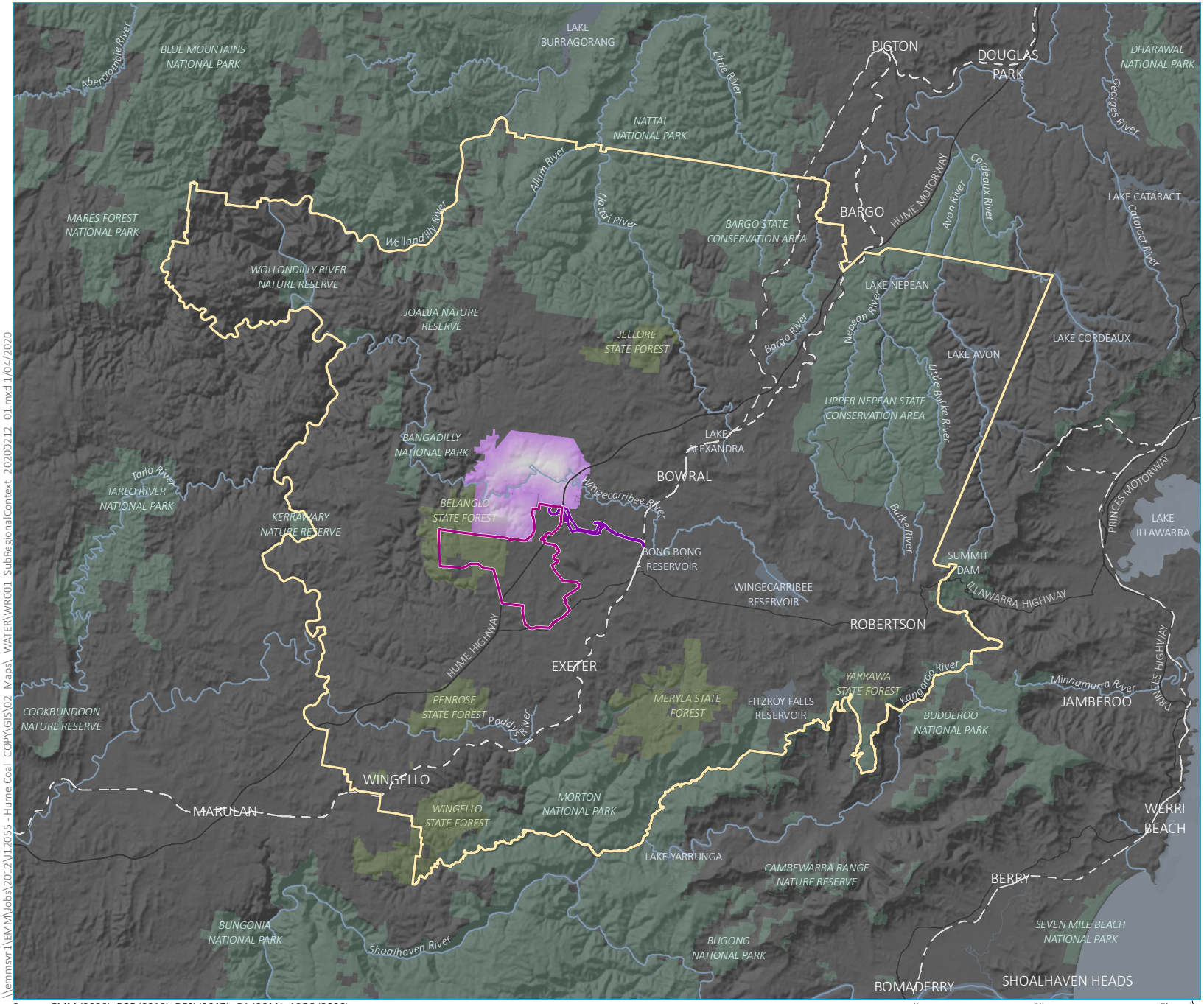
## 2.1 Hume Coal Project

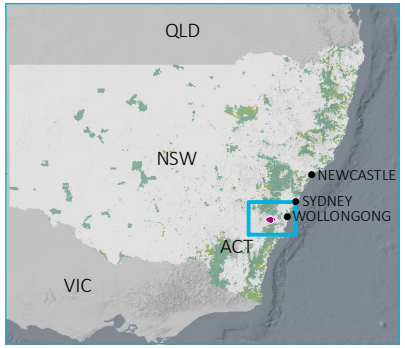
The Hume Coal Project area (herein referred to as the Project area) is around 100 kilometres (km) south-west of Sydney and 4.5 km west of Moss Vale town centre in the Wingecarribee LGA (refer to Figure 2.1 and Figure 2.2). It is in the Southern Highlands region of NSW and the Sydney Basin Biogeographic Region. The proposed surface infrastructure area is 7.2 km north-west of Moss Vale town centre.

Hume Coal holds exploration Authorisation 349 (A349) located to the west of Moss Vale, covering approximately 8,900 hectares (ha), although mining is not proposed across its full extent. The proposed underground mining area is approximately 3,474 ha.

A low impact first-workings mining system will be used which leaves many pillars of coal in place so that the overlying strata is supported, and therefore surface subsidence impacts will be negligible. Mine and surface infrastructure layout is provided in Figure 2.3.

Further discussion on the proposed mining method is provided in Section 5 of this report.




KEY

- Hume Coal Project area
- Berrima Rail Project area
- Berrima Colliery lease bounday (CCL 748)
- Wingecarribee Shire local government area
- Rail line
- Motorways and primary roads
- River
- Named waterbody
- NPWS reserve
- State forest

Source: EMM (2020); DPE (2019); DFSI (2017); GA (2011); ASGC (2006)

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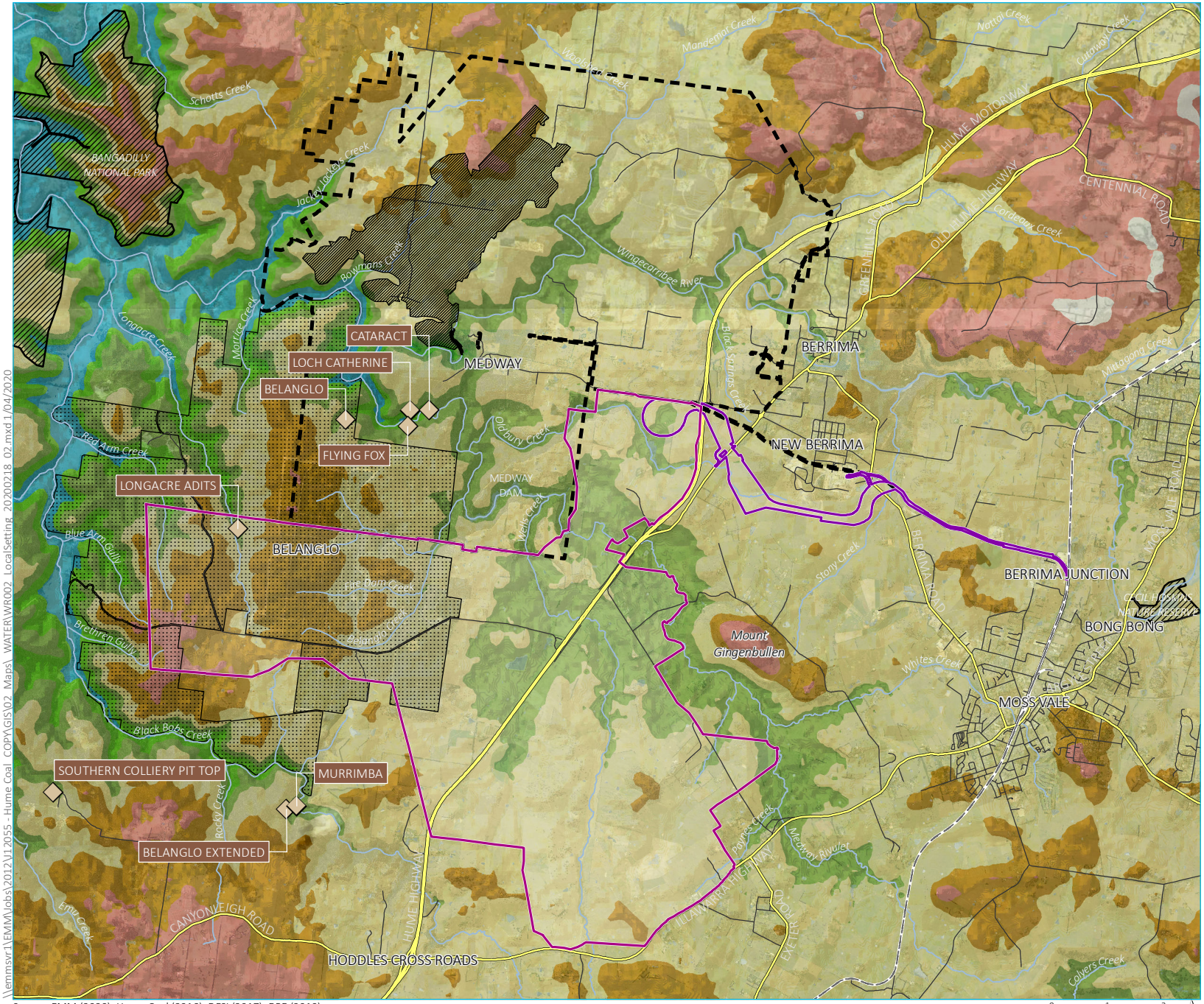
# Regional setting

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 2.1

HUMECOAL PROJECT

EMM creating opportunities




KEY

- Hume Coal Project area
- Berrima Rail Project area
- Berrima Colliery lease bounday (CCL 748)
- Berrima Colliery mine workings (indicative)
- Historical coal mine

Existing environment

- Rail line
- Major road
- Minor road
- Named watercourse
- Waterbody
- NPWS reserve
- Belanglo State Forest

Elevation (m AHD)

- 500-550
- 550-600
- 600-650
- 650-700
- 700-750
- 750-800
- 800-850

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 1 2 km

GDA 1994 MGA Zone 56

N

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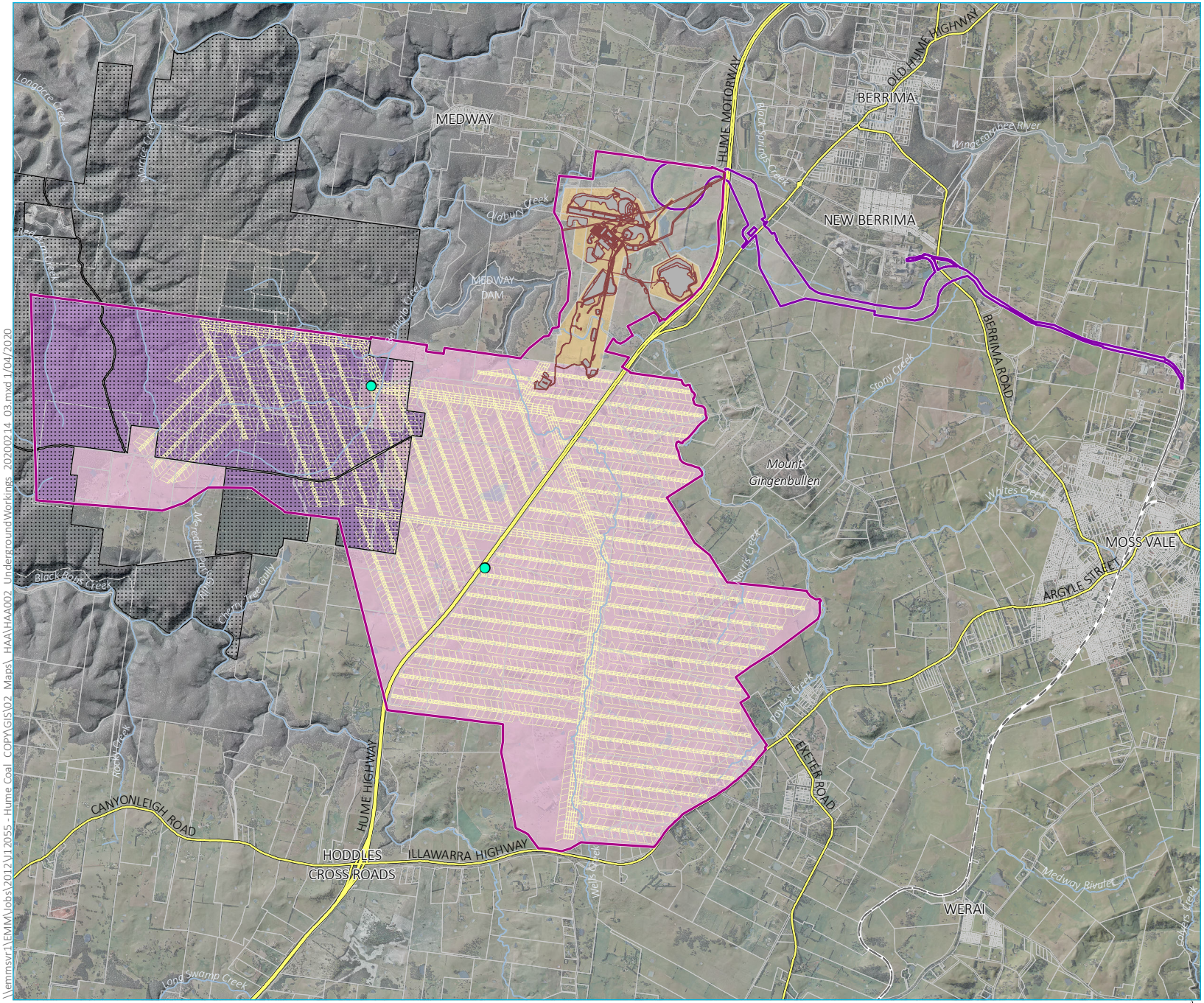
# Local setting

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 2.2

HUMECOAL PROJECT

EMM creating opportunities




KEY

- Hume Coal Project area
- Berrima Rail Project area
- Downcast ventilation shaft (3 m diameter, not shown to scale)
- Indicative surface infrastructure footprint
- Underground mine workings (indicative)

Mining lease application area

- MLA 527
- MLA 528
- MLA 529

Existing environment

- Rail line
- Major road
- Named watercourse
- Waterbody
- Cadastral boundary
- Belanglo State Forest

Source: EMM (2020); Hume Coal (2016); Palaris (2016); DFSI (2017); DPE (2019)

0 1 2 km

GDA 1994 MGA Zone 56

N

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# Mine and surface infrastructure layout

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 2.3

HUMECOAL PROJECT

EMM creating opportunities

### 2.1.1 Topography

The Project area is situated on the elevated but relatively flat Nattai Plateau. Elevations typically range from around 550 to 735 metres above Australian Height Datum (mAHD). Most of the central and eastern parts of the Project area have very low rolling hills with occasional elevated ridge lines. Steeper slopes and deep gorges are located to the immediate west, north-west, and south of the Project area and are products of incision from watercourse flow (eg Black Bobs Creek and Longacre Creek).

The Southern Highlands has some peaks of igneous origin, including Mount Gingenbullen (800 mAHD) to the north-east of the Project area.

### 2.1.2 Hydrology

The Project area and most of A349 are within the Wingecarribee River catchment, a sub-catchment of the Hawkesbury-Nepean River catchment. A small portion of the south-eastern corner of A349 is within the Bundanoon Creek catchment, a sub-catchment of the Shoalhaven River catchment.

The proposed surface facilities will be within the Medway Rivulet and Oldbury Creek catchment areas, which form part of the Medway Rivulet Management Zone, flowing into the Wingecarribee River. The Project area is traversed by several drainage lines (including creeks) generally flowing north to north-westerly, all of which discharge to the Wingecarribee River, at least 5 km downstream (north-west) of the Project area boundary. Surface water features in and surrounding the Project area are shown in Figure 2.1.

The Wingecarribee River flows east to west, north of the Project area. The median flow in Medway Rivulet and Oldbury Creek are 5 megalitres per day (ML/day) and 0.014 ML/day respectively, compared with a median flow in the Wingecarribee River, into which they eventually flow, of 30.1 ML/day (WSP PB 2016).

Medway Rivulet is the main drainage line in the Project area. Its primary tributaries include Oldbury Creek, Paynes Creek, Wells Creek, Wells Creek tributary and Whites Creek. The headwaters of Medway Rivulet start near Moss Vale. Surface water flow is influenced by several in-stream storages that impede continuous flow within the upper catchment. Near the proposed surface infrastructure area, Medway Rivulet is confined by steep gullies (WSP PB 2016). Downstream of the Project area, Medway Rivulet has been dammed to create Medway Dam, a relatively small (1,350 ML) reservoir that is part of Wingecarribee Shire Council's (WSC) water supply system. Medway Dam is a prescribed dam under Schedule 1 of the NSW *Dams Safety Act 1978*. This dam is outside the Project area and no mining will occur beneath it or its Notification Zone.

Oldbury Creek begins near New Berrima and joins Medway Rivulet 1.5 km downstream from Medway Dam. Similarly to Medway Rivulet, the creek is characterised by several in-stream storages that impede continuous flow within the upper catchment. A large agricultural in-stream storage dam is near the northern part the surface infrastructure area.

There are some water treatment plants (WTPs) and sewage treatment plants (STPs) within the catchment of the Wingecarribee River.

Medway Dam supplies an 8 ML/day capacity WTP that can provide water to Berrima and back-up supply to parts of Bowral and Mittagong and the Wingecarribee local government area (LGA) system, but has not been operational since June 2013. The main water supply for these communities and the locality more broadly is from Wingecarribee Reservoir, around 14 km east of the Project area, which has a 40 ML/day capacity WTP. Additional back-up or supplementary supply is from Bundanoon Creek Dam.

The Moss Vale STP is located at on the western side of Moss Vale. Treated sewage from the STP discharges into Whites Creek, which is a tributary of Medway Rivulet upstream of Medway Dam. The Berrima STP is located to the west of New Berrima. Treated sewage from this STP discharges directly into Oldbury Creek.

## 2.2 Summary of historical mining in the area

As reported in the Hume Coal EIS (EMM 2017), there is a long history of mining in the Southern Highlands, with coal exploration and mining activities occurring since the 19th century.

Historical mines within and in close proximity to the Project area are summarised below and illustrated in Figure 2.2:

- Berrima Colliery (no longer operating) is located to the north of Wingecarribee River (Figure 2.2). The Berrima Colliery mining lease (CCL 748) adjoins Hume Coal's northern boundary. The colliery is currently undergoing closure having ceased operations in 2013. The workings are the most extensive of any mine in the area and comprise first workings and full pillar extraction in the Wongawilli Coal Seam. Production varied between 0.13 and 0.46 Mt/year. Further discussion on the history of the Berrima Colliery is provided in Section 2.3.

- The Loch Catherine Mine (abandoned), opened in 1924 with an anticipated maximum possible production of 73,000 tonnes per year (t/year) (equivalent to 200 t/day). It is located underneath the Berrima Colliery stockpile bounded by Medway Rivulet and the Wingecarribee River. The mine worked the Wongawilli Coal Seam and ceased mining in the 1960s. The mine access adits within the Medway Rivulet escarpment are still open, and iron staining is evident in the water pooled at the mine entries. It included some mechanised workings utilising shuttle cars. Coffey (2016a) reported that full extraction is thought to have occurred, based on the shape of the mine footprint, and its presence in the NSW *Coal Mine Subsidence Compensation Act 2017* on the list of compulsory contributors to the compensation fund.

- Southern Colliery (abandoned), located on Foxgrove Road approximately 5 km south-west from the Project area. Mining is thought to have occurred in the Tongarra Seam. This was a small scale mine which ceased operations many years ago (EMM 2017).

- Numerous adits at coal seam outcrops are present along local escarpments (see Figure 2.2) and represent pre-mechanisation (manual) abandoned workings. Examples are Black Bobs, Belanglo (abandoned in the 1950s), Belanglo Extended, and Flying Fox collieries to the west of the Project area, and Erith Colliery near Bundanoon. These were likely to be very small operations, probably mining less than 100,000 t in total. Most are not sealed and drain into local watercourses. They typically consist of two headings extending in from outcrop by a few hundred metres. Belanglo was a small operation along Black Bobs Creek, presumed to be on the southern side of the creek, to the west of the Hume Highway. Murrimba Colliery was on the eastern side of Black Bobs Creek in approximately the same location and was abandoned after hitting a full face of stone a few hundred metres from the creek (coincident with a high magnetic anomaly). Belanglo Colliery is in the Berrima Colliery lease in a tributary of Medway Rivulet (EMM 2017 and Coffey 2016a).

- Two adits have also been discovered along Longacre Creek, to the north-west of the Project area. The workings are of unknown length and are situated above one another (in the Tongarra and Wongawilli Coal seams). Historical literature discusses a number of old mines in the area around the Loch Catherine mine, and it is likely that other small scale abandoned mine workings are present along the coal seam outcrop in this area (EMM 2017).

These historical adits are generally open to the atmosphere and the old workings are potentially in direct connection to the environment (eg water discharging from the adit to watercourses). The historical mine adits are generally south and west of the Berrima Colliery and along river edges at coal outcrop locations, which facilitated extraction (refer to Figure 2.2).

Coal mining continues in the Wingecarribee LGA today as mentioned in Section 1.1 of the Hume Coal EIS (EMM 2017), including Tahmoor Colliery at CCL 747, an underground longwall mine operating in the Bulli Seam, extending into the northern end of the LGA. The mining leases associated with Dendrobium and Wongawilli Collieries also extend into the north-west of the LGA.

## 2.3 Berrima Colliery

The Berrima Colliery was an underground coal mine located approximately 7 km west of Berrima village and north of the proposed Hume Coal Project (refer to Figure 2.2). Principally it provided coal for use in the kiln(s) at the Berrima Cement Plant, located approximately 7.5 km east-south-east of the colliery at New Berrima.

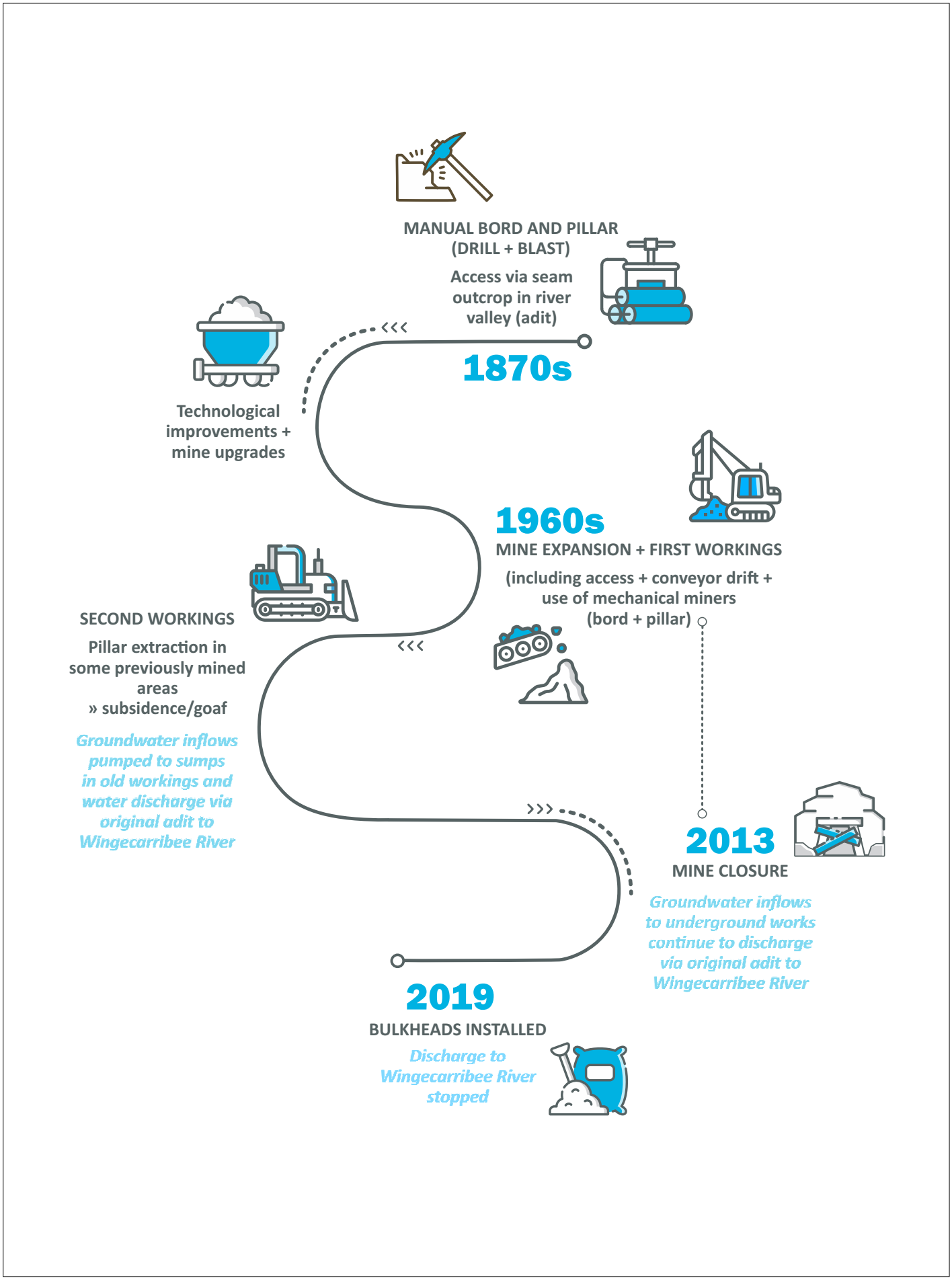
Mining was conducted by a bord and pillar operation which removed the bottom 2 to 3 m of the 10 m thick Wongawilli Coal seam (Cook 2008). Mining began in 1872 at the colliery and had been in continuous operations from 1924 to its closure in November 2013. The colliery was placed under care and maintenance after a protracted legal challenge to the owner's application for planning approval under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for continued operations. A summary schematic of the Berrima Colliery mine evolution is summarised in Figure 2.4.

Berrima Colliery had a single-entry point (or portal) located at the pit top facilities in Medway. However, initially, the entry point was from an adit, which is a horizontal passage leading into the mine. Coal was transported from underground by conveyor to an onsite crusher and loaded on to trucks to be transported to customers (including predominantly the Berrima Cement Works) or stockpiled at Loch Catherine, approximately 1 km south of the pit top facilities at Medway. The colliery had one continuous miner, two shuttle cars, a feeder breaker and three breaker line supports. Surface equipment included mine support facilities such as an administration building and bathhouse, ventilation fan, conveyors, coal handling systems and mobile plant. There was also a truck fleet, water cart and front-end loader for the transportation of coal.

Berrima Colliery did not process the coal mined. As such, product coal was un-beneficiated and supplied run of mine (ROM).

Production rates at Berrima Colliery varied over time between 125,000 and 460,000 t/year of ROM coal with capacity to produce up to 500,000 t/year (Mitchell McLennan 2009). Coal was trucked six days per week either directly to Berrima Cement Works and other customers (including overseas) or stockpiled at Loch Catherine (up to 100,000 t/year).

Berrima Colliery operated under CCL 748, with a lease holding area of 6,157 ha. The Hume Highway intersects the lease in the east, while the Wingecarribee River, the dominant geomorphologic feature in the area, intersects the middle of the lease boundary, running generally east to west. The Berrima Colliery workings are in the north-western portion of the lease. The extent of past mining within the colliery can be seen in Figure 2.2.




Berrima Colliery Mine Summary

Hume Coal Pty Ltd

Hume Coal and Berrima Mine Comparison

Figure 2.4

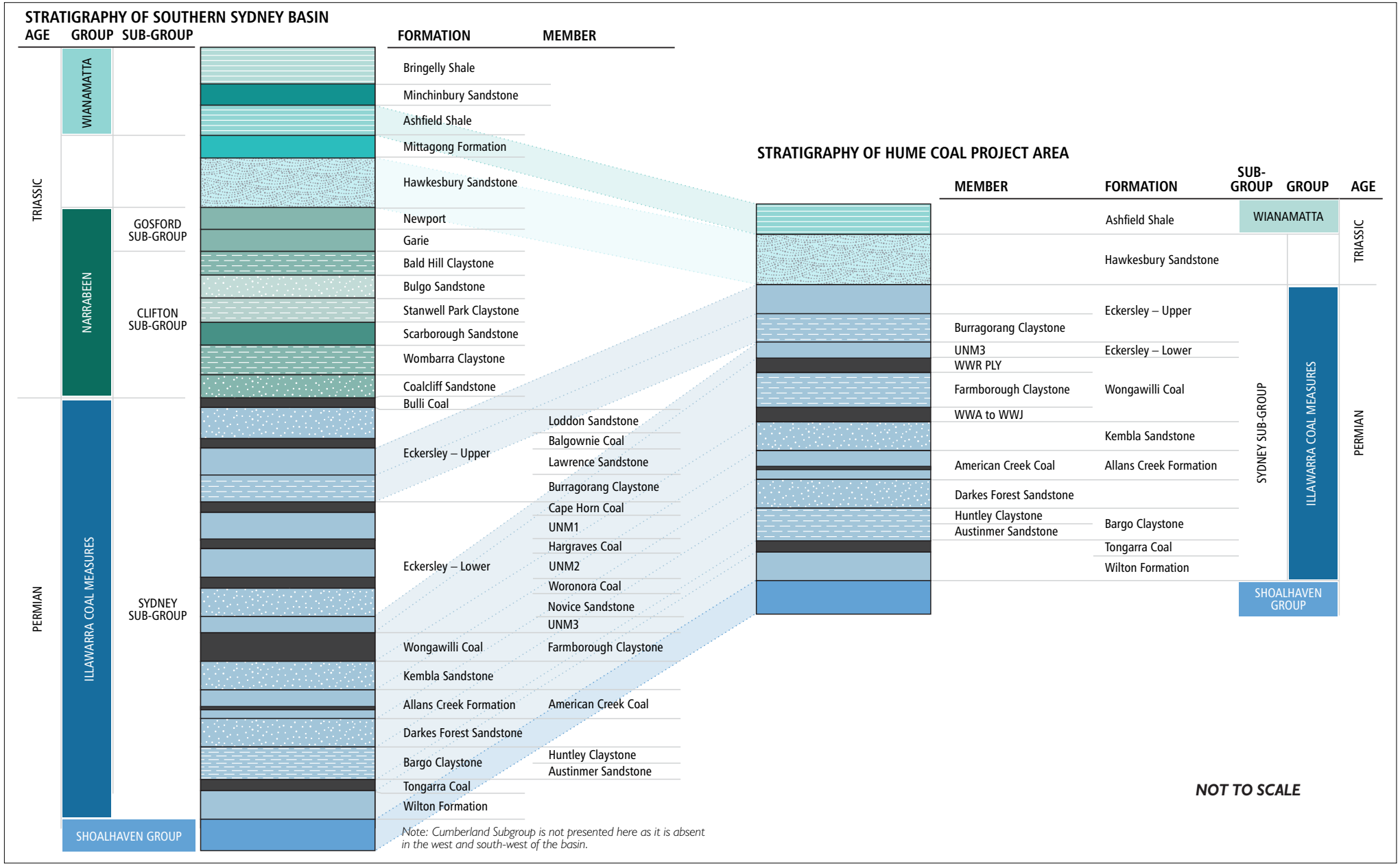
# 3 Geology

## 3.1 Regional geology

The regional geological setting has been described in the revised water assessment submitted as part of the RTS (EMM 2018) as the Permo-Triassic sedimentary Sydney Basin extending north to south along some 350 km of central NSW coastline (from Newcastle to just north of Batemans Bay), and to the Great Dividing Range in the west. About one quarter of the basin is offshore to the east of the shoreline (Brunker and Rose 1967). The onshore sedimentary units are thickest (up to 4.5 km) in the northern part of the basin (Geoscience Australia 2016). The Sydney Basin is interpreted as a bowl-shaped structure, and in many places in the basin, the sedimentary sequence has been subjected to tectonic forces creating a series of extensive fault lines.

During the early stages of basin development, marine volcanic sediments and the Permian Shoalhaven group were deposited (Blevin et al. 2007). Swamp environments during a colder climate in the late Permian allowed for deposition of the Illawarra Coal Measures (ICM), which contain the coal seam proposed to be mined: the Wongawilli Coal seam. Subsequently, very large rivers deposited the Triassic Hawkesbury Sandstone (Moffit 1999; Rust and Jones 1987). Shallow marine sediments, and later more river sediments, continued to accumulate in the basin during the Jurassic period, although the majority of these younger rocks have since been eroded (Blevin et al. 2007). Although significantly eroded in places, the Wianamatta Group is present in the east of the Southern Coalfield of the Sydney Basin. Post-Triassic volcanism emplaced Jurassic intrusions and Tertiary basalts (McLean and David 2006) above the Wianamatta Group sediments.

The stratigraphy of the Southern Sydney Basin is presented with a comparison to the stratigraphy of the Project area in Figure 3.1. The surface geology of area is presented in Figure 3.2.




South Sydney Basin vs Project area stratigraphy

Hume Coal Pty Ltd

Hume Coal and Berrima Mine Comparison

Figure 3.1

### 3.1.1 Geological units

#### i Permian Shoalhaven Group

The Shoalhaven Group's Berry Siltstone comprises sandy grey mudstone, claystone, siltstone and sandstones deposited under shallow marine conditions (McLean and David 2006). This unit is more than 100 m thick and unconformably overlies the strongly folded Palaeozoic basement (Moffit 1999).

#### ii Permian – Illawarra Coal Measures

The ICM is a sequence of interbedded sandstone, siltstone, claystone and coal with minor tuff, conglomerate and intrusions (McLean and David 2006). It ranges in thickness from greater than 500 m in the depositional centre of the Southern Coalfield, to less than a few metres along the western edge of the basin. The ICM consists of two subgroups: the basal Cumberland Subgroup; and the Sydney Subgroup, which contains all of the economic coal seams including the Wongawilli Coal seam.

The geological units of the ICM, from oldest to youngest, are described by Moffitt (1999) and summarised below:

- The basal formation of the Sydney Subgroup is the Marrangoo Conglomerate which is widespread across the Sydney Basin and has been observed as far south as Sutton Forrest. In the south-west of the Basin, the Marrangoo Conglomerate consists of pebble to cobble conglomerate that fines upward to coarse-grained sandstone that are derived from the Lachlan Fold Belt.

- The Wilton Formation is dominated by dark claystone and siltstone, interbedded with sandstone. It extends over most of the northern half of the Southern Sydney Basin and thickens to the north and north-east.

- The Tongarra Coal seam conformably overlies the Wilton Formation where present in the northern and central areas of the Southern Coalfield. The unit consists of coal, carbonaceous siltstone and claystone and tuffaceous claystone.

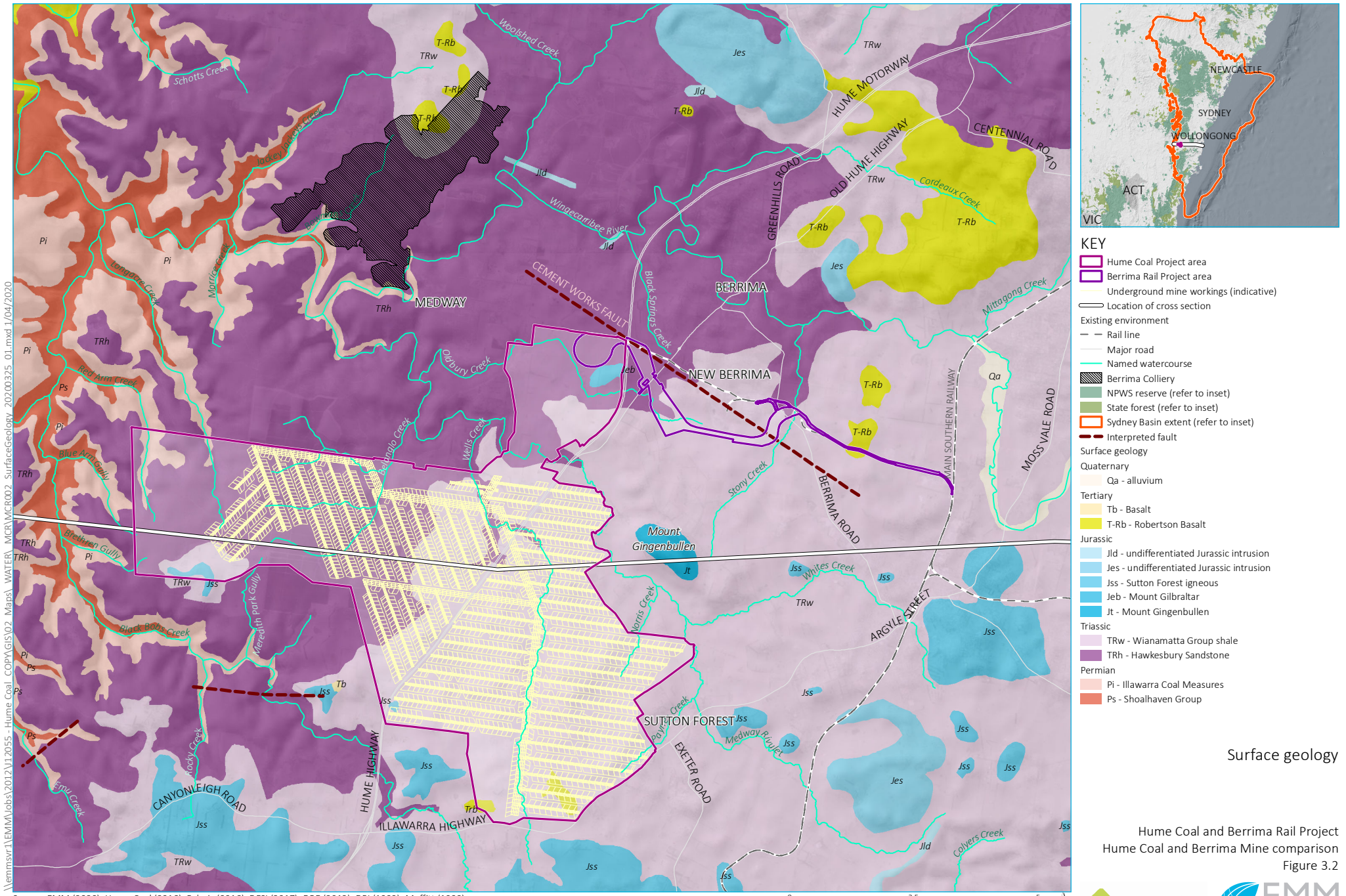
- The Bargo Claystone conformably overlies the Tongarra Coal seam and consists of dark, interlaminated claystone, siltstone and minor thin tuffaceous beds. It ranges in thickness from a few centimetres in the south-west to greater than 50 m in the north-east.

- Darkes Forest Sandstone is present over most of the central, north-western and north-eastern parts of the Southern Coalfield. It is absent in the western margin and south-west of Mittagong. The unit consists of medium to fine-grained lithic sandstone with minor interbeds of siltstone and claystone.

- Allans Creek Formation commonly overlies the Darkes Forest Sandstone, however it is absent in the south-west and is around 1 m thick in the Berrima, Mittagong and Robertson area where it consists of coal and carbonaceous claystone. The unit thickens up to 45 m to the north-east.

- The Kembla Sandstone overlies the Allans Creek Formation with an erosive contact. It is comprised of distinct coarse to medium-grained lithic sandstone with interbeds of claystone and siltstone. This unit is regionally extensive and is referred to by Bamberry (1991) as being the most extensively developed fluvial unit in the Sydney Subgroup.

- The Wongawilli Coal seam is the thickest and most widespread coal interval in the Southern Coalfield and has been correlated with the Middle River Coal Member in the Western Coalfield. The unit contains coal, siltstone, tuffaceous claystone and kaolinitic claystone. The Farmborough Claystone member of the Wongawilli Coal seam is a tuffaceous claystone that is typically up to 2 m thick.

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Source: EMM (2020); Hume Coal (2016); Palaris (2016); DFSI (2017); DRE (2013); DPI (1999); Moffitt (1999)

Surface geology

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 3.2

HUMECOAL PROJECT

EMM creating opportunities

- The Eckersley Formation overlies the Wongawilli Coal seam and consists of coarsening upward sequences of interbedded claystone, siltstone, coal, carbonaceous and tuffaceous claystone and minor, medium-grained lithic sandstone. The Formation contains the following members: Novice Sandstone, Woronora Coal, Hargraves Coal, Cape Horn Coal, Burragorang Claystone, Lawrence Sandstone, Balgownie Coal and Loddon Sandstone. The Formation has been eroded during deposition of the Hawkesbury Sandstone in places in the south-west of the Southern Coalfield.

### iii Narrabeen Group

The Narrabeen Group consists of two main subgroups, the basal Clifton Subgroup and the Gosford Subgroup (Moffitt 1999). The Clifton Subgroup includes the Coal Cliff Sandstone, Wombarra Claystone, Scarborough Sandstone, Stanwell Park Claystone, Bulgo Sandstone and Bald Hill Claystone. The Gosford Subgroup includes the Garie and Newport Formations.

Consistent with other units of the Sydney Subgroup, the units within the Narrabeen Group are thin or absent in the south-west of the Southern Coalfield, with thicknesses increasing to the north-east.

### iv Triassic – Hawkesbury Sandstone

The Triassic Hawkesbury Formation outcrops over much of the region and forms cliffs along the Illawarra escarpment and around Kangaroo Valley (Moffitt 1999). This unit is regionally extensive and varies in thickness from 100 m to 250 m, increasing in thickness to the north-east. Two major facies of the Hawkesbury Sandstone are described by Moffitt (1999):

- sheet facies: characterised by small to large scale planar to trough crossbeds that range from a few centimetres to 5 m or more;

- massive facies: characterised by massive bedding, mostly structureless poorly sorted sandstone, containing higher portions of clay and less chemical cements and quartz overgrowth than the sheet facies.

The Hawkesbury Sandstone is a medium to coarse grained quartz arenite (sedimentary rock with more than 90% detrital quartz) with minor siltstone, shale, mudstone and laminate lenses (McLean and David 2006; Scheibner and Basden 1998).

The sandstone is largely medium grained, rounded quartz and rare lithic pebbles. The interbeds are lensoid from a few metres up to 10 m in thickness and are commonly several kilometres in length. The Hawkesbury Sandstone outcrops over much of the Berrima Colliery lease and the Project area (see Figure 3.2).

The Hawkesbury Sandstone was deposited in an active fluvial system and, in some locations, deposition has eroded the entire Narrabeen sequence and portions of the underlying ICM (O'Neill and Danis 2013). Due to the large-scale nature of the fluvial depositional environment, the facies of the Hawkesbury Sandstone ranges from fine grained overbank / flood sediments and coarser grained channel deposits (Jones B 1983, 2020).

### v Triassic – Mittagong Formation

The Mittagong Formation is a transitional unit of about 6 to 15 m in thickness (Herbert and Helby 1980) between the Ashfield Shale and the Hawkesbury Sandstone. The unit is derived from floodplain sediments deposited at the end of the Hawkesbury depositional episode.

The Mittagong Formation is difficult to identify in borehole logs due to its similarity in appearance to both the Hawkesbury Sandstone and Ashfield Shale. It is generally not mapped as surface outcrop, likely due to the difficult identification in situ.

#### vi Triassic – Wianamatta Group

The Wianamatta Group represents the last phase of the sedimentation directly related to development of the Sydney Basin (Moffitt 1999).

The basal formation of the Wianamatta Group is the Ashfield Shale, which comprises dark grey to black shale and siltstone interbedded with lithic sandstones and siltstone, and very minor coal bands.

The Minchinbury Sandstone is a quartz-lithic sandstone unit and forms a mappable unit that separates the underlying Ashfield Shale from the overlying Bringelly Shale. The Bringelly Shale consists of claystone and siltstone, laminate and sandstone (Moffitt 1999).

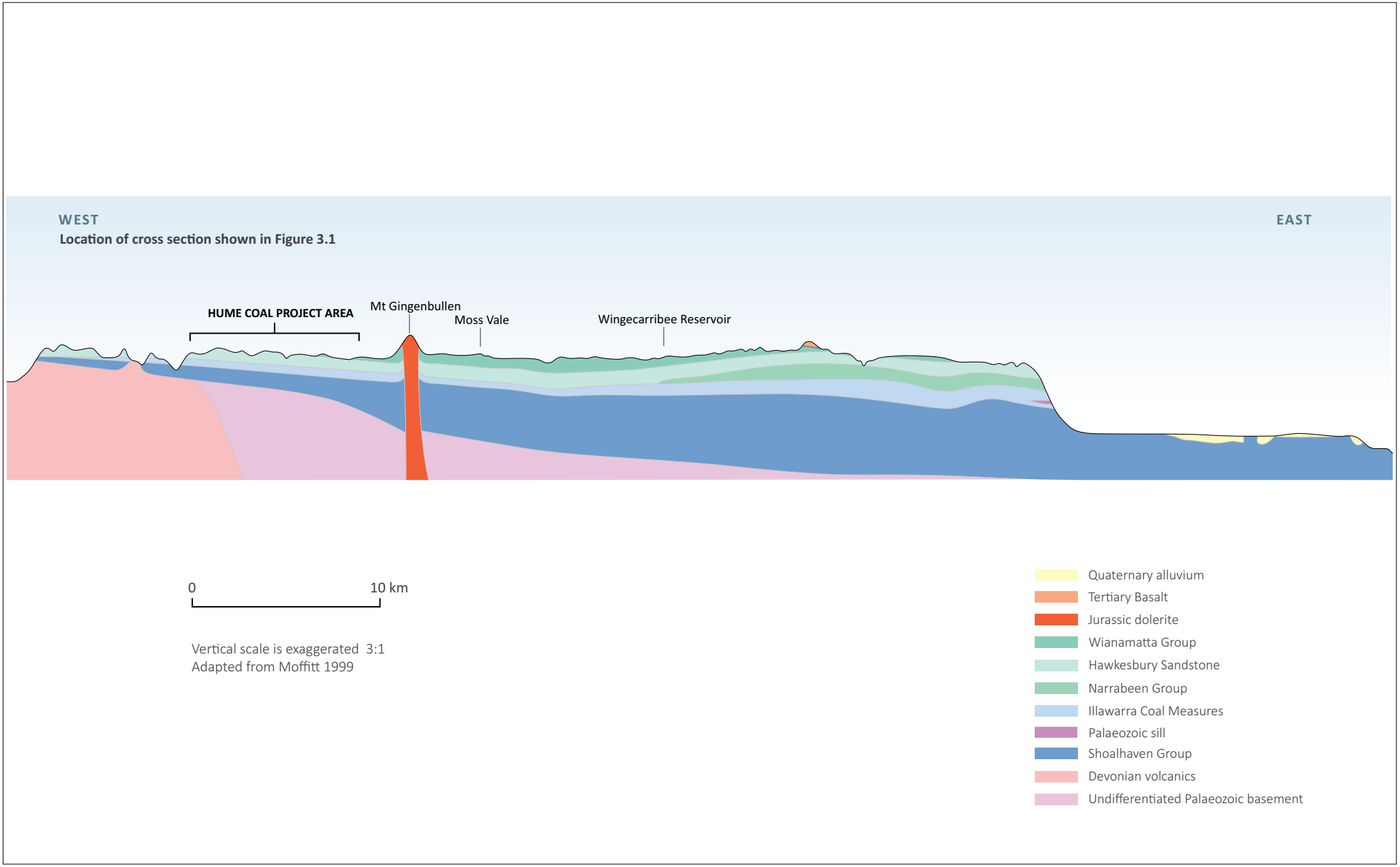
The Ashfield Shale outcrops over much of the eastern part of area, while the Hawkesbury Sandstone is exposed over much of the western part.

#### vii Tertiary and Jurassic

The hills in the southern part of the Project area and immediately outside are capped with remnant, isolated Tertiary Robertson Basalt flows (Moffit 1999). Some 15% of the Project area has outcropping basalt (Coffey 2016a). There is also a notable igneous Jurassic intrusion, the Mount Gingenbullen dolerite sill, that has formed a steep hill immediately east of the Project area (Thomas, Biggin and Schmidt 2000). Smaller igneous intrusions have been observed during drilling programs and as lineaments in aerial photography (R Doyle 2015, pers. comm., September). The Tertiary basalt outcrops are unrelated to the Mount Gingenbullen intrusion.

### 3.1.2 Geological structure

Stratigraphy across the Project area is regionally continuous and gently dipping to the east as shown in Figure 3.3. Moffit (1999) has mapped few structural features within the Project area; however, immediately north of the Project area, a north-west to south-east oriented structure 8 km long is identified as the Cement Works Fault (see Figure 3.2). This fault is interpreted as a major fault extending to basement, with a maximum displacement of between 50 m and 65 m (R Doyle 2016, pers. comm., 27 July; Coffey 2016a). The Sydney Basin is unconformably bound by the Lachlan Fold Belt, which outcrops some 5 km to the west of the Project area.




Regional geological cross section

Hume Coal Pty Ltd
Hume Coal and Berrima Mine Comparison
Figure 3.3

## 3.2 Berrima Colliery

In 2015, David completed a hydrogeological assessment for the closure of the Berrima Colliery for Boral Cement Limited. David (2015) reported that:

> The basement comprises mudstones, shales and siltstones of the Permian Shoalhaven group. This is overlain by Permian ICM which comprise siltstone and claystone and amongst other seams the Wongawilli Seam which was extracted at Berrima Colliery. The Hawkesbury Sandstone sequence overlays the ICM and is around 120 m in thickness. The sandstone is divided into two zones separated by a siltstone/claystone interlayer.
>
> The Shoalhaven Group outcrops to the west of Berrima Colliery, while the ICM outcrop along a very thin strip less than 200 m wide at the boundary between the Shoalhaven Group and the Hawkesbury Sandstone. Hawkesbury Sandstone outcrops over most of the area in a 5 km radius from the colliery, where it is not covered by a relatively thin layer (up to 40 m) of Wianamatta Group sediments (typically shale) and/or the Robertson basalt.
>
> Dykes have been mapped underground in the Berrima Colliery with up to 10 m in thickness.

It should be noted that Berrima Colliery's mining area is located mostly on exposed Hawkesbury Sandstone, with very little Ashfield Shale / Wianamatta Group sediments present in the mining area. The depth of mining ranged from 110 m to 190 m and the overlying strata was primarily the Hawkesbury Sandstone unit.

In 2010, Australasian Groundwater and Environmental Consultants (AGE) undertook a groundwater assessment for the continued operations at the Berrima Colliery and presented the major stratigraphic units for the lease area (see Table 3.1).

**Table 3.1 Summary of stratigraphic sequence at Berrima Colliery**

| Group/ Formation | Berrima Colliery thickness | Notes |
|---|---|---|
| Robertson basalt | unknown | |
| Unnamed dykes | 3 to 10 m | |
| Ashfield Shale (Wianamatta Group) | Approx 20 m | This unit is not present over the Berrima Colliery mine area. The Wianamatta Group is exposed at the surface in the northern area of the colliery (refer to Figure 3.1). |
| Hawkesbury Sandstone | Approx 110 m | The unit typically outcrops in the area especially along the edges of escarpments. Accounts for 20% of the outcrops in the Wingecarribee Shire. |
| Narrabeen Group | 0-6 m<br>Variable | |
| Illawarra Coal Measures | Approx 10 m | Wongawilli Coal ranges from 6-10 m thick |
| Shoalhaven Group | - | |

Note: Adapted from AGE 2010, and SKP 1983.

Figure 3.2 shows the surface geology over the area including Berrima Colliery and shows the workings and the outcropping of coal measures along the Wingecarribee River. Of note is the absence of the Wianamatta Group over the majority of the Berrima Colliery mining area. At the Berrima Colliery, the Wongawilli Coal seam varies in thickness between 6 m to 10 m with the bottom 2 m to 3 m as the extractable coal seam, which is bright coal with thin tuff and mudstone interbeds (AGE 2010). Below the Wongawilli seam is the thinner Tongarra Coal seam that was not targeted for extraction at the Berrima Colliery.

Further description of the igneous extrusives and intrusions was provided by AGE (2010) as follows:

> A large number of dykes occur in the Southern Coalfield, either separately or in swarms. Some are up to 5 km in length and generally less than 3 m in width. In the area of the Berrima Colliery, the dykes have approximately the same strike direction as most of the faults and are along the most dominant joint directions – that is, west north-west to north north-west. Several zones of dykes and dyke swarms have been intersected during mining at Berrima Colliery and can be up to 10 m thick. The dykes are highly weathered and are therefore relatively weak, but can have a hard cindered crust.

AGE (2010) reviewed the Berrima Colliery area for geological structures and faults. The Cement Works Fault is the largest known fault in the area and is interpreted to be located to the south of the township of Berrima (Figure 3.2), striking north-west with a measured displacement of 65 m. However, the fault was not observed at the Berrima Colliery and it has not been mapped west of the Wingecarribee River, although several stretches of the river run parallel to the fault suggesting that the surface water feature may be influenced geological structures. In the Berrima Colliery EIS (SKP 1983), the fault was inferred to continue westward from the Berrima Cement Works towards the colliery. Based on the coal seam structure contours presented in the EIS, the fault appears to continue towards the Wingecarribee River but the displacement diminishes in that direction.

In the 1983 EIS, a Wongawilli Coal seam structure map was presented and is included here as Figure 3.4. The Wongawilli Coal seam floor dips from west to east across the Berrima Colliery. The low area of the seam coincides with the initial colliery entry points and the historical pit water discharge point at the drainage adit.

## 3.3 Hume Coal

The local geological setting for the Hume Coal Project is presented in the revised water assessment (EMM 2018b) and the water technical report (EMM 2020). Figure 3.1 shows the stratigraphy at the Project area.

Hume Coal engaged Professor Brian Jones of University of Wollongong to conduct a review of geological information for the Hume Coal Project (including investigation of core photographs and examination of geological outcrops in the area). The objective of the review was to specifically describe and investigate the characteristics of the lithology between the Wongawilli Coal seam and the lower Hawkesbury Sandstone in the Project area (Jones 2020). This additional work was commissioned primarily to address the ongoing questions raised by the community in regard to the geological interpretation of the layers immediately above the Wongawilli Coal seam. The information presented below is a summary of the work completed by Jones (2020). The full report by Professor Brian Jones is provided in Annexure B to Appendix B of the IPC response report.

The stratigraphic succession of the Wongawilli Coal seam in the south-western Sydney Basin is poorly documented in public literature. In the area near and east of Bundanoon, typical medium to coarse-grained Hawkesbury Sandstone lies disconformably above the Wongawilli Coal seam as seen at the Erith Coal Mine and at Meryla Pass. However, in the Project area in the Belanglo State Forest and to the west of Sutton Forest, the stratigraphy has not been described in detail.

The Wongawilli Coal seam, below the Farmborough Claystone, consists of Plys A to J, with Ply E to I being the mining section at the Hume Coal Project. The R Ply is located above the Farmborough Claystone.

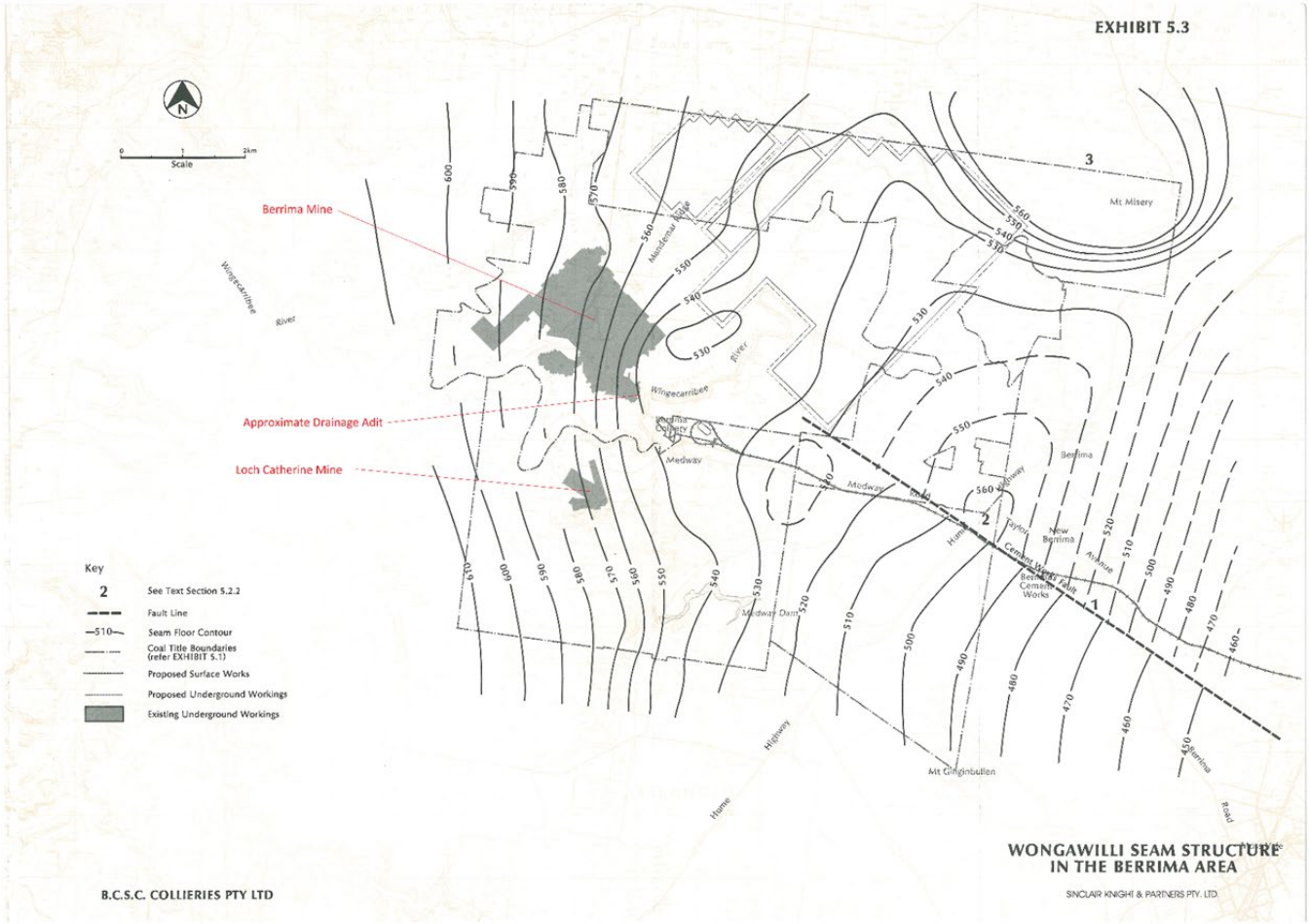



**Figure 3.4 Wongawilli seam structure in the Berrima area (after SKP 1983)**

The elevation of the workable section of the Wongawilli Coal seam (below the Farmborough Claystone, if present) rises from 480 mAHD in the eastern area of the Project area to 630 mAHD in the west (Jones 2020). A 2-4 km wide north-south zone in the central part of the Project area shows a much lower gradient probably due to faulting and diapiric intrusions. Hume Coal have also interpreted the presence of faulting through this zone based on a variety of exploration techniques. The preserved thickness of the Wongawilli Coal seam (including the Farmborough Claystone and the roof plies) shows a general increase from the south-west to the north-east. This decrease in thickness in the west and south-west may be partly attributed to depositional thinning towards the margin of the basin, however Jones (2020) advises it is probably mainly due to post-depositional erosion of the upper plies in the coal seam. Over most of the Project area, the Wongawilli Coal seam shows local variations of several metres in seam thickness, but shows no clear evidence of broad river channel incision beneath the Hawkesbury Sandstone (Jones 2020). Evidence for erosion in the western and south-western parts of the Project area is also provided by the low number of coal plies preserved in this area. In this area of thin Wongawilli Coal seam, only the lowest 2 or 3 plies are preserved. The number of coal plies preserved increases both to the north and to the east where moderately extensive areas have the Farmborough Claystone preserved above the workable coal seam (Jones 2020).

The contact between the Hawkesbury Sandstone and the ICM has been described as erosional by Bos (1988) with the amount of erosion increasing towards the south-west. This has resulted in the Hawkesbury Sandstone directly overlying the Wongawilli Coal seam along the escarpment to the south of Moss Vale. Various literature (see Jones 2020) report units of the Eckersley Formation (including the Burragorang Claystone) being present beneath the Hawkesbury Sandstone and the upper Wongawilli Coal seam and, in places, the Burragorang Claystone directly overlying the Wongawilli Coal seam.

The Unnamed Member 3 (UNM3) represents the basal unit of the lower Eckersley Formation and is observed in the Project area (Jones 2020). This unit consists predominantly of carbonaceous mudstone or shale, ranging from structureless to weakly or well laminated. It is very similar in character to the shales in the underlying Wongawilli Coal seam. However, in places it contains thin sandstone interbeds at the base or within the unit representing higher energy pulses of deposition. The unit commonly ranges in thickness from 1 to 3 m but ranges up to 7.7 m locally (Jones 2020).

The findings of Jones' work (2020) are summarised below:

- Along the south-western margin of the Project area, the top of the Wongawilli Coal seam has been removed by erosion that progressively decreases to the north-east. This erosion started in the lower Eckersley Formation prior to the emplacement of the Burragorang Claystone. In the central part of the Project area, the Hawkesbury Sandstone has also eroded down onto the Wongawilli Coal seam.

- In the Project area, the Wongawilli Coal seam is separated from the Hawkesbury Sandstone by a fine-grained succession including some or all of the Farmborough Claystone, UNM3, lower Eckersley Formation, Burragorang Claystone and upper Eckersley Formation (and possibly some Narrabeen Group equivalent) that ranges in thickness from 0 to 7.7 m.

- The Eckersley Formation (and possibly Narrabeen Group equivalents) in this part of the Sydney Basin have also been derived from the Lachlan Fold Belt to the south-west and are lithologically similar to, but finer grained than, the Hawkesbury Sandstone.

- A north-northeast trending zone about 2 to 2.5 km wide extends through the middle of the Project area and represents a major river axis of the Hawkesbury Sandstone. A tripartite subdivision (as described by Lee (2009)) of the Hawkesbury Sandstone may be apparent in this area.

- The north-western and south-eastern portions of the Project area are characterised by deposition by smaller river systems and contain numerous low permeability fine-grained floodplain deposits that provide at least local vertical permeability barriers to groundwater movement.

- The irregular distribution of oxidised zones within the Hawkesbury Sandstone suggests that most oxidised groundwater ingress into the Hawkesbury Sandstone occurs through joints and faults rather than vertical percolation through the unit because of the presence of numerous thin vertical permeability barriers in the form of overbank deposits.

The observations from the assessments, including the work completed by Jones (2020) and the conceptual understanding of the local geology is illustrated in Figure 3.5.

Wongawilli Coal seam structure map is presented in Figure 3.6. The Wongawilli Coal seam floor dips towards the north-east, consistent with the regional trend. The top of the Wongawilli Coal seam is about 70 to 180 m below ground level. The Hawkesbury Sandstone is between 50 m and 120 m thick within the Project area (Coffey 2016a; Rust and Jones 1987). Surface geology is shown in Figure 3.2 and is an important consideration for the conceptualisation of the groundwater recharge mechanisms at the site.

Sedimentary units of the Wianamatta Group outcrop over much of the eastern part of Project area while the Hawkesbury Sandstone is exposed over much of the western part. The Hawkesbury Sandstone has been incised by creek channels and, as a result, Permian coal outcrops next to drainage lines in the west. The hills to the immediate south of the Project area comprise remnants of thick Tertiary Robertson Basalt flows that overly the Wianamatta Group sediments (Moffit 1999).

The Project area also contains some late Jurassic igneous intrusive activity. Tertiary igneous extrusive activity was significant in the region and resulted in numerous volcanic breccia necks and sills, basalt flows and dykes (McLean and David 2006).

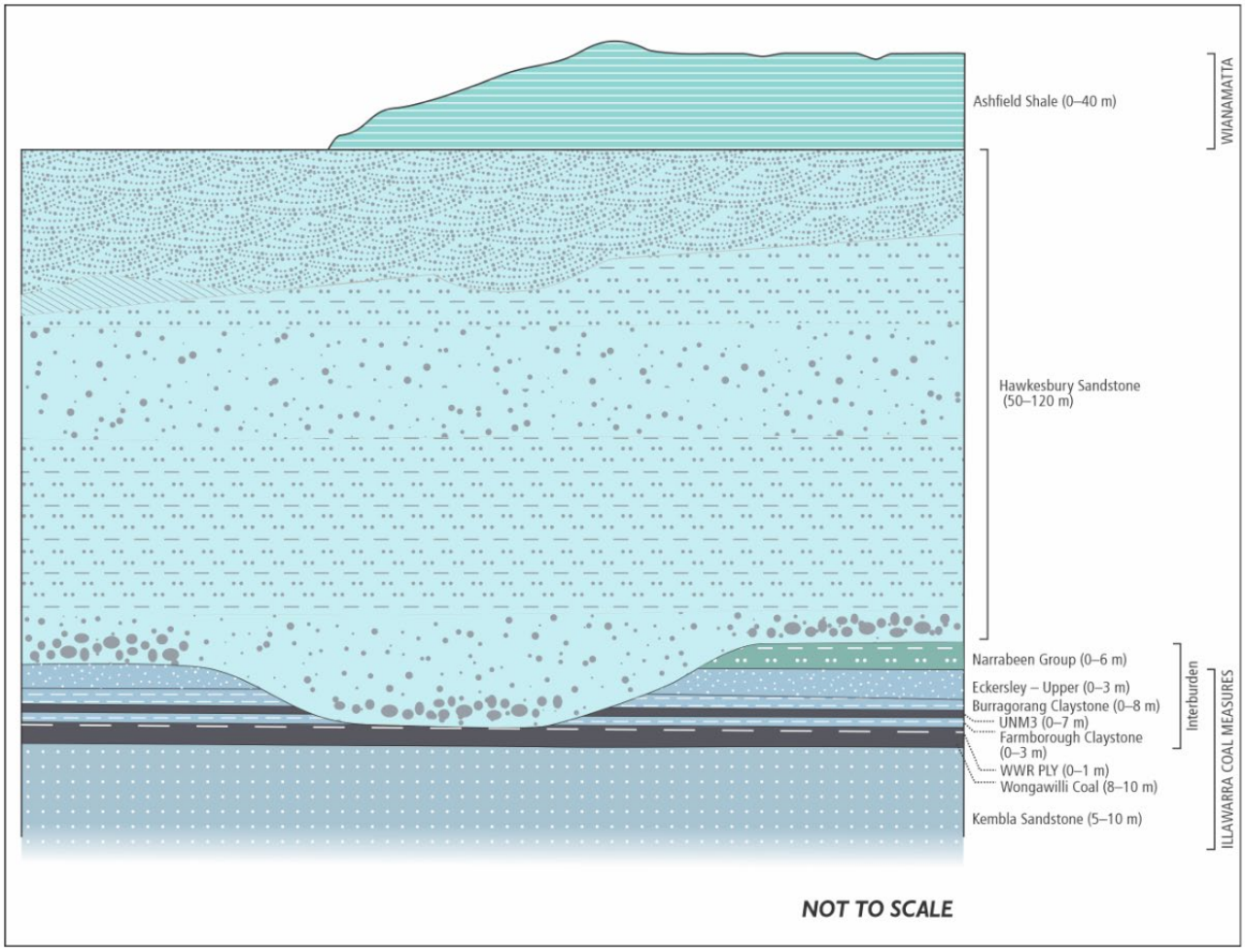
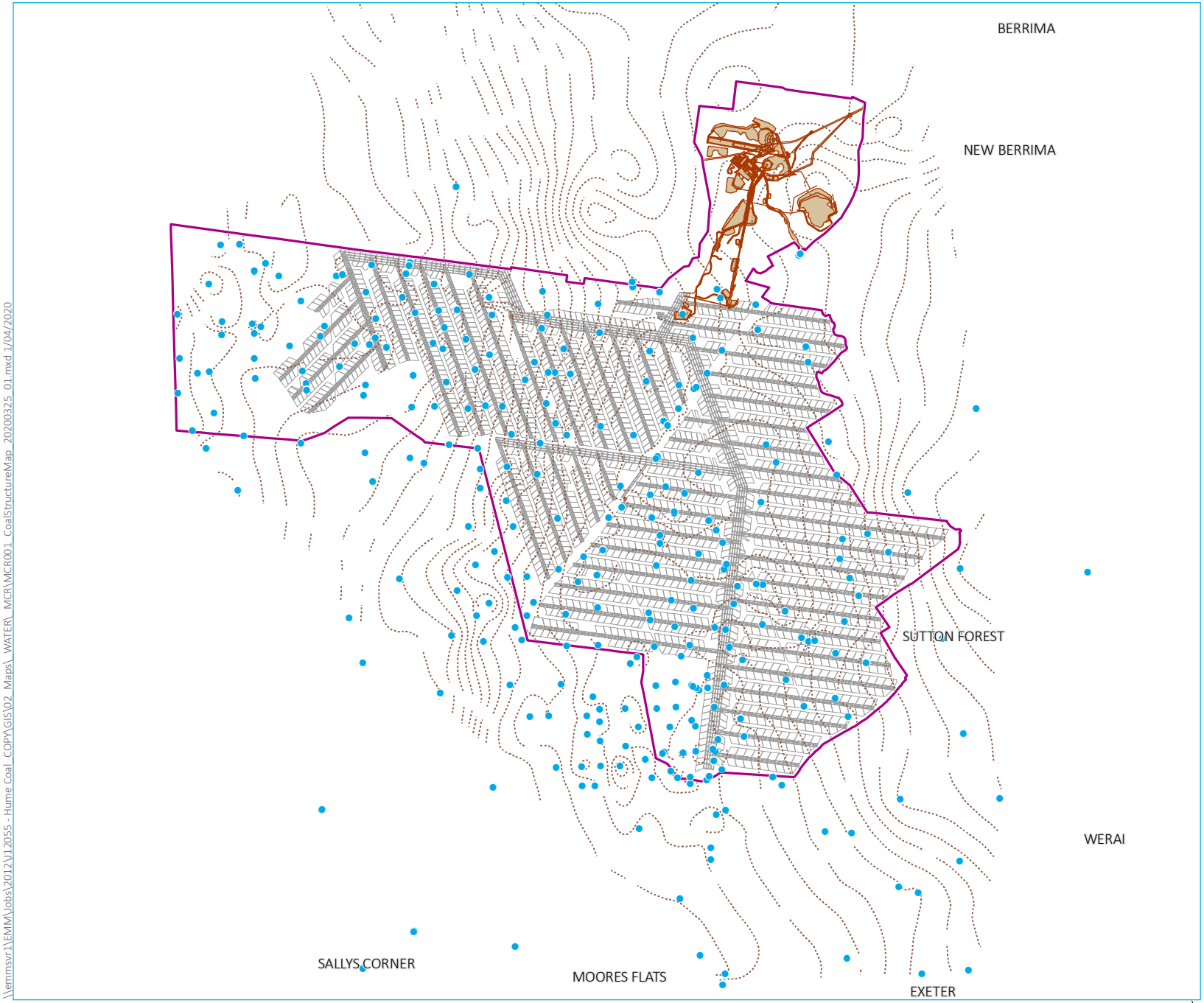



**Figure 3.5 Conceptual diagram of the geological units in the Project area**




Source: EMM (2020); Hume Coal (2016, 2019); Polaris (2016)

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# Hume Coal Project Wongawilli Coal structure map

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 3.6

HUMECOAL PROJECT

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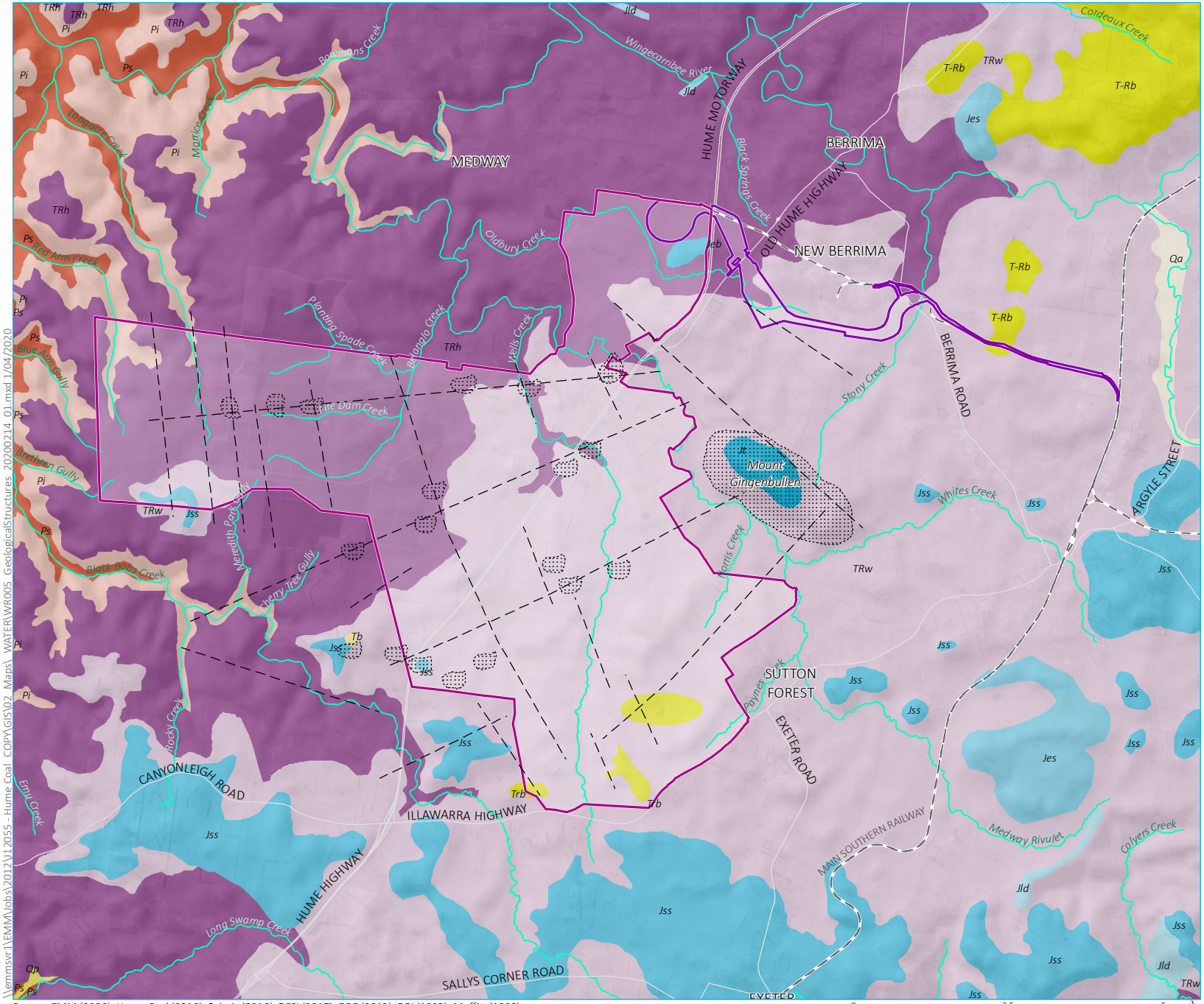
### 3.3.1 Geological structure

On a local scale, Hume Coal has interpreted probable minor faults and structural features that intersect the coal seam within the Project area based on results from exploration drilling, geophysics, and previous work in the area (Figure 3.7). The dominant alignment is north-north-west to south-south-east, while a secondary faulting direction is shown as east-south-east to west-north-west (R Doyle 2015, pers. comm., September). Most of these probable features are likely to have small offsets and are unlikely to extend to the basement or higher up into the overlying stratigraphy (R Doyle 2016, pers. comm., 12 September).

The Southern Highlands region has a higher density of igneous intrusions than elsewhere in the Sydney Basin (Coffey 2016a). There are numerous diatremes spatially associated with the faults within the Project area; Hume Coal interprets the diatremes to have intruded into the existing structures rather than to be synchronous (R Doyle 2016, pers. comm., 27 July).

A Tertiary major sub-vertical structural feature underlying the main Robertson Basalt outcrop around Exeter, south-east of the Project area, is interpreted from hydraulic head data, regional lineaments and structural contour surfaces (Coffey 2016a). This feature runs about east-north-east to west-south-west, below the basalt body and is inferred to be a pathway for the basalt extrusion (Coffey 2016a).




KEY

- Hume Coal Project area
- Berrima Rail Project area

Existing environment

- Rail line
- Major road
- Named watercourse

Geological structure

- Hume Coal interpreted faults
- Diatremes (probable)

Surface geology

Quaternary

- Qa - alluvium
- Qp - peat

Tertiary

- Tb - Basalt
- T-Rb - Robertson Basalt

Jurassic

- Jld - undifferentiated Jurassic intrusion
- Jes - undifferentiated Jurassic intrusion
- Jss - Sutton Forest igneous
- Jeb - Mount Gilbraltar
- Jt - Mount Gingenbullen

Triassic

- TRw - Wianamatta Group shale
- TRh - Hawkesbury Sandstone

Permian

- Pi - Illawarra Coal Measures
- Ps - Shoalhaven Group

Source: EMM (2020); Hume Coal (2016); Palaris (2016); DFSI (2017); DRE (2013); DPI (1999); Moffitt (1999)

0 2.5 5 km

GDA 1994 MGA Zone 56

N

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# Geological structures for the Hume Coal Project area

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 3.7

HUMECOAL PROJECT

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# 4 Hydrogeology

## 4.1 Overview

The groundwater resources of the Project area are within Nepean Management Zone 1 of the Sydney Basin Nepean Groundwater Source, which is managed under the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*.

The groundwater units within the Project area are defined as:

- localised low permeability groundwater systems associated with the Robertson Basalt and Wianamatta Group shales;
- regional porous fractured rock groundwater system located in the Hawkesbury Sandstone; and
- localised water bearing zones associated with the ICM and the Shoalhaven Group.

The Hawkesbury Sandstone is the main groundwater bearing unit used for water resources in the region. Groundwater within the Hawkesbury Sandstone is generally fresh with varying bore yields (the median bore yield of registered bores in the area is 2 litres per second (L/sec)).

Michael et al in 2009 described the conceptual hydrogeological model of the central part of the Sydney Basin as the following:

- groundwater flow in the Hawkesbury Sandstone and other shallow aquifers is driven by local-scale topography;
- the lower Permian succession forms the Shoalhaven aquitard system with isolated sandstone aquifer systems; and
- limited data from the deeper units of the Sydney Basin (> 2,000 m) indicate low permeability, no water recovery but appears to gas-saturated.

The geological units between the base of the Hawkesbury Sandstone and the top of the Wongawilli Coal seam have been extensively investigated throughout the assessment of the Hume Coal Project. Commonly termed the 'interburden', these units are conceptualised as a single hydrostratigraphic unit (HSU), and includes the following geological units and formations, where present (in order of oldest to youngest):

- Farmborough Claystone – regionally extensive and present in most of the Project area, except where the Hawkesbury Sandstone has eroded down to the top of the Wongawilli Coal ash and coal lithological units;
- Wongawilli R Ply (above the mined seam – it is a ply (layer) within the interburden);
- Lower Eckersley Formation, including UNM3 which consists predominantly of carbonaceous mudstone or shale ranging from structureless to weakly or well laminated;
- Burragorang Claystone member of the Eckersley Formation – observed to be an important stratigraphic marker in the Project area (Jones 2020), and is a very fine grained massive to weakly laminated tuffaceous deposit;

- Upper Eckersley Formation – identified in some drillholes in the Project area but it is difficult to differentiate this fine to medium-grained sandstone where the Burragorang Claystone is absent; and
- Narrabeen Group sediments – observed to be present in the north-east, but absent in the Project area.

Figure 4.1 shows the thickness of the interburden layer included in the Hume Coal groundwater model (layer 8).

Table 4.1 summarises the HSUs identified in the groundwater model area (includes Hume Coal mine and Berrima Colliery area).

**Table 4.1 Hydrostratigraphic units**

| HSU number | Type | Stratigraphy | |
|---|---|---|---|
| 1 | Unconfined aquifer – minor, localised | Alluvium associated with watercourses | |
| 2 | Aquitard - localised | Robertson Basalt | |
| 3 | Aquitard – semi regional | Sediments of the Wianamatta Group | |
| 4 | Unconfined to semi confined aquifer – regional | Hawkesbury Sandstone | |
| 5 | Aquitard – semi regional | Narrabeen Group | INTERBURDEN |
| | | Upper Eckersley Formation | |
| | | Burragorang Claystone | |
| | | Lower Eckersley Formation, including UNM3 | |
| | | Farmborough Claystone | |
| 6 | Aquitard - leaky | Upper Plys of the Wongawilli Coal (above mining section) | |
| 7 | Aquifer – low yielding, regional | Wongawilli Coal – mining section | |
| 8 | Aquifer – regional | Kembla Sandstone | |
| 9 | Aquitard - regional | Shoalhaven Group | |

Note: HSU = hydrostratigraphic unit

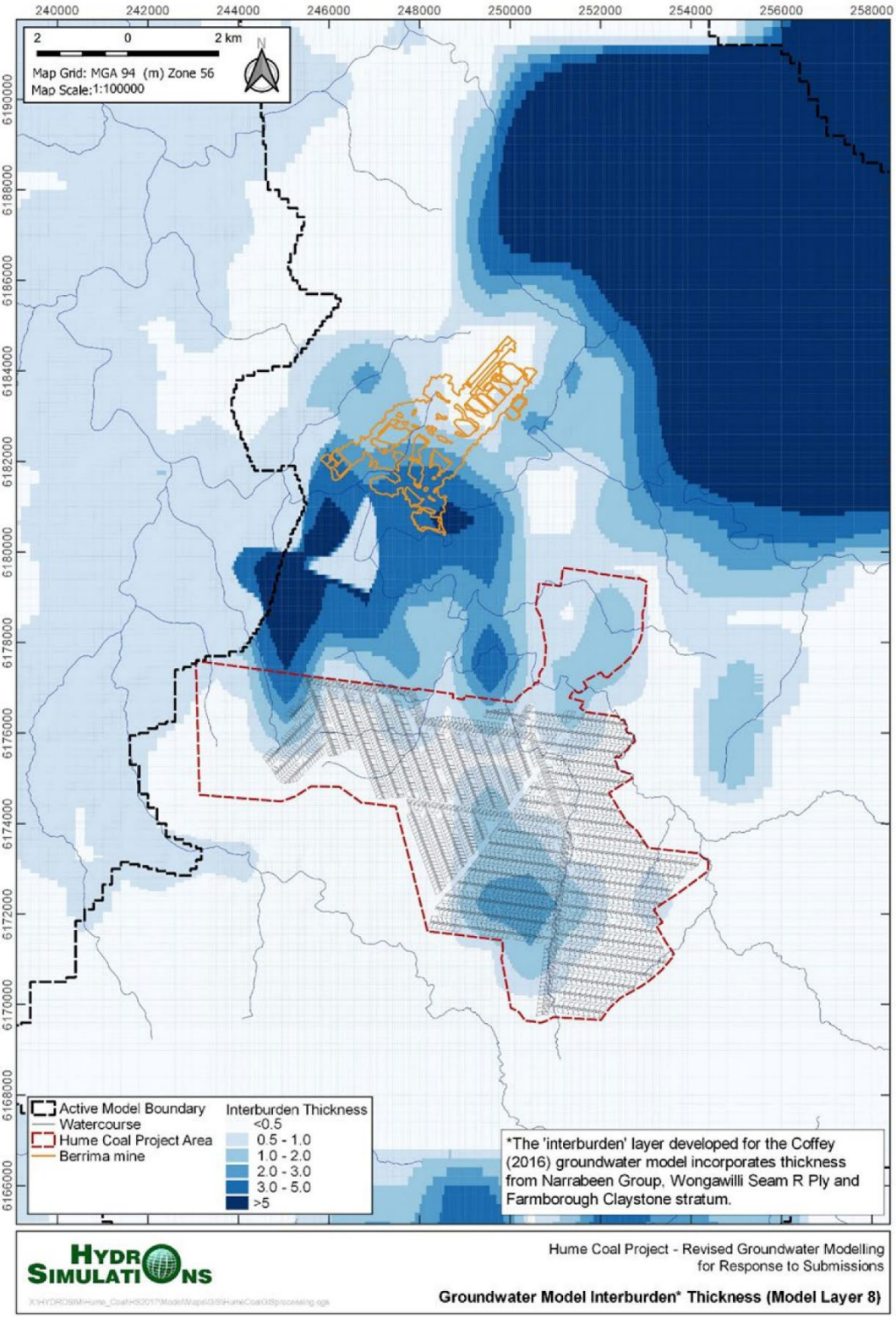



**Figure 4.1 Groundwater model interburden thickness (after EMM 2019)**

## 4.2 Berrima Colliery

The hydrogeology at the Berrima Colliery was evaluated by David (2015) and included the same regional HSUs listed in Section 4.1.

David (2015) updated a conceptual groundwater flow model from previous work done in by CDM Smith in 2014 by Delta Mining in 2012. A summary of the conceptual hydrogeological understanding is provided below:

- rainfall recharge over the mine footprint is enhanced via connected fractures especially where the overburden is shallow;
- groundwater naturally discharges to the Wingecarribee River;
- topography controls the hydraulic gradients in the surficial HSUs, but at depth the horizontal bedding of the geological units controls and their hydraulic conductivity control groundwater flow;
- mine water inflow had stabilised to approximately 2.7 ML/day; and
- groundwater levels in the Hawkesbury Sandstone unit were dewatered but re-pressurisation was occurring with groundwater levels recovering.

David (2015) also updated the Berrima Colliery groundwater model to assess the closure options, which was classified as a Class 1 level as per the Australian Groundwater Model Guidelines confidence classification system (Barnett et al 2012). The mine closure options assessed were fully sealed mine workings, a fully drained option, and a partially sealed option.

The development of the colliery over the past 85 years has resulted in a zone of depressurisation reaching its maximum extent with a steady seepage rate of groundwater into the colliery observed at the time of closure. Groundwater flows into the underground workings via inflow from the coal seam face and seepage through the roof of the coal mine via faults and dykes. The total steady state inflow of groundwater was estimated at approximately 3.0 ML/day (David 2015).

The volume of groundwater intercepted at the colliery varied depending on conditions at the coal face. Generally, 2.5 to 3.0 ML/day was discharged into the Wingecarribee River at the V-notch weir licensed discharge point. The environmental protection license (EPL) for the colliery allowed for up to 10 ML/day. Discharge from the mine to the river has occurred for approximately 90 years (IEC 2019). Flow in the Wingecarribee River is heavily regulated by releases from Wingecarribee Dam.

As part of the data review, conceptualisation and groundwater modelling done as part of the Hume Coal Project EIS and RTS (Coffey 2016a and 2016b), a zone of saturation above the Berrima Colliery is inferred. The extent and location of this saturated zone has not been clear. For a conservative approach, the Hume Coal RTS groundwater model (calibration and predictions) assumes the Hawkesbury Sandstone is desaturated above the full extraction workings in the northern part of Berrima Colliery and as having a local zone of saturation above the first workings in the southern part of the mine. It is likely this local saturated zone is somewhat disconnected from the regional groundwater system, although some leakage from the local system to the regional system is likely to occur. Over time, this saturated zone is expected to increase in size and eventually reconnect with the regional groundwater system as the groundwater above the Berrima Colliery recovers.

Since 2013, the mine has been in various stages of final closure, where groundwater has no longer been pumped to the Village of Medway but allowed to infiltrate the various sumps and flood the internal mine workings. IEC reported in 2019 that the rate of discharge has been below the historic average at a rate of 2.5 ML/day.

### 4.2.1 Monitoring

Environmental practices have changed significantly over the life of the Berrima Colliery (1872 to 2013). Groundwater levels had not been measured at the site until very recently and only at a few locations. Until the installation of vibrating wire piezometers (VWP) in late 2012, the site relied on five local landowner bores to observe groundwater levels with continuous groundwater monitoring commencing in 2007 (CDM Smith 2014). The VWP data has been collected at two locations (B62 and B63), at three installation depths at each location. Due to the age of the Berrima Colliery, there are no pre-mining groundwater level observations available. As stated above, groundwater level data became available in the local area once the mining effects had been observed in local groundwater bores. During the later years of mine operations, some groundwater monitoring bores were installed near the colliery, complementing the local landowner bores used for monitoring. At the time reporting in 2011 (EMGA 2011b), groundwater levels recorded showed a relatively stable trend at one location and a slightly declining trend at two locations in the three-bore monitoring network. This was attributed to below average rainfall over the monitoring period.

### 4.2.2 Hydraulic testing

During a preliminary hydrogeological assessment completed in 2008 by Cook, two aquifer tests (pumping tests) were conducted on bores at the Berrima Colliery location. The two bores tested were the replacement production bore at the Belbin property and the Culpepper monitoring bore on the De Rosa property. Both aquifer tests had limitations in regard to equipment, total test duration and provided some recommendations for further testing and analysis. Preliminary hydrogeological properties were estimated from the tests.

In the *Berrima Colliery Groundwater Assessment and Modelling Update for the Remaining SMP Extraction Area* report by CDM Smith (2014), vertical hydraulic gradients were assessed at the two VWP instrumented sites (B62 and B63). At this time (2014), the vertical hydraulic gradients at the B62 and B63 sites were in a downward direction, from the upper Hawkesbury Sandstone to the lower Hawkesbury Sandstone and to the Wongawilli Coal seam. The upper Hawkesbury Sandstone was saturated (B62) despite the mine development being immediately adjacent and depressurisation occurring at the coal seam level (CDM Smith 2014).

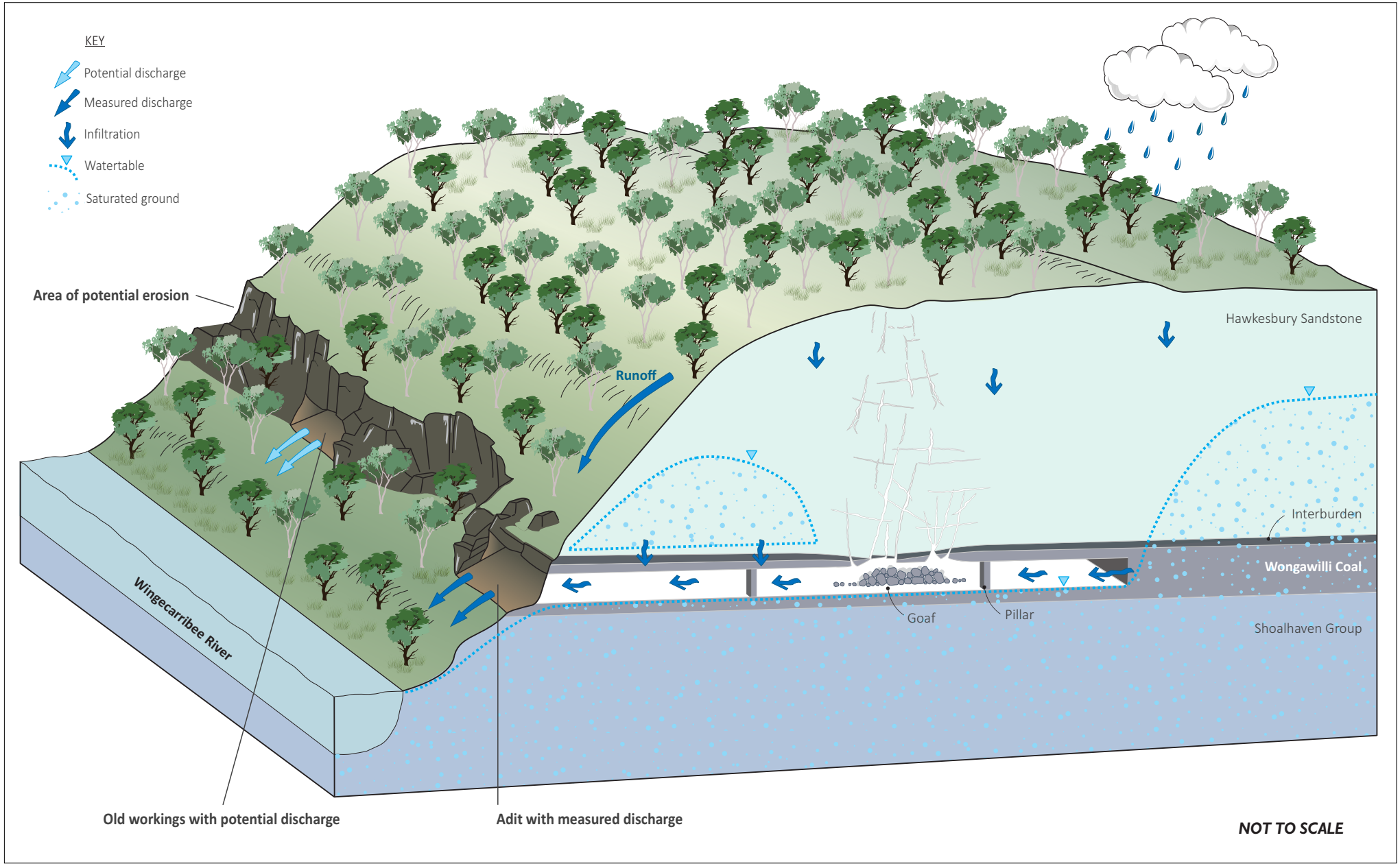
### 4.2.3 Conceptual hydrogeological understanding

The conceptual hydrogeological understanding of the Berrima Colliery, at the end of mining, is illustrated in Figure 4.2. Key features of the conceptualisation and what is illustrated in Figure 4.2 are:

- the Hawkesbury Sandstone is partially desaturated in areas above the mine workings, with leakage occurring into the mine workings;
- groundwater that has drained into the mine workings has been either pumped via sumps or has been naturally flowing under gravity flow to the drainage adit and then to the Wingecarribee River;
- the Berrima Colliery has areas of goaf, where the hydrogeologic properties of the overlying formations have been enhanced. Figure 4.3shows the approximate potentiometric surface (watertable elevation) inferred from registered bores, as reported by AGE in 2010.

Historically, discharge of the groundwater drainage and inflow to the mine workings has occurred under an EPL discharge permit, however it is understood that Boral Cement Limited (owners of the Berrima Colliery) have sealed off (or are in the progress of sealing) the mine to limit groundwater discharge to the Wingecarribee River due to elevated concentrations of chemical analytes of concern (eg manganese). The Berrima closure plan includes the placement of several water-tight bulkheads to seal the workings.

The sealing of the Berrima Colliery will allow for groundwater levels to recover in the HSUs above the mine workings. However, this might be at cost to flows within the Wingecarribee River, as the groundwater discharge has reportedly been a major contributor of flows in periods of drought. Given the area of desaturation above the workings at the Berrima Colliery, the recovery of groundwater levels is estimated to take many years to reach a natural steady system in equilibrium. In the 2015 modelling completed by David, the fully sealed option of Berrima Colliery predicted groundwater level recovery to between approximately 20 m and 50 m above the base of the coal seam after 20 years (Figure 4.4). The predicted groundwater level recovery at the Berrima Colliery may eventually lead to groundwater seepage at known erosional features within the area identified by Boral along the river escarpments (IEC 2015). The areas of potential erosion along the river escarpments is illustrated in Figure 4.2. The groundwater level recovery at the Berrima Colliery will depend on the effectiveness of the bulkheads at/near surface.




Berrima Colliery – End of mining conceptual schematic

Hume Coal Pty Ltd

Hume Coal and Berrima Mine Comparison

Figure 4.2

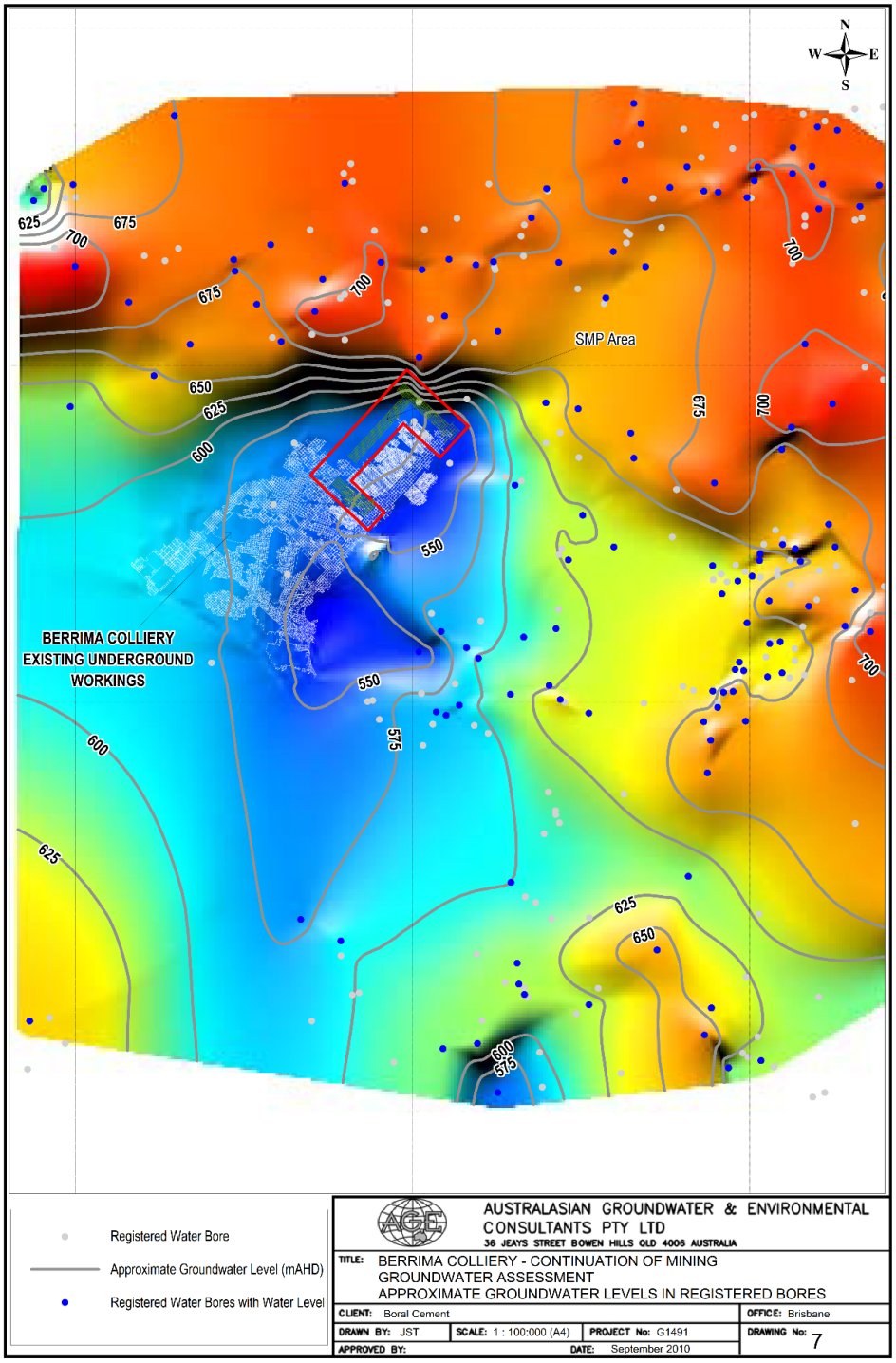



**Figure 4.3** **Groundwater assessment approximate groundwater levels in registered bores (after AGE 2010)**

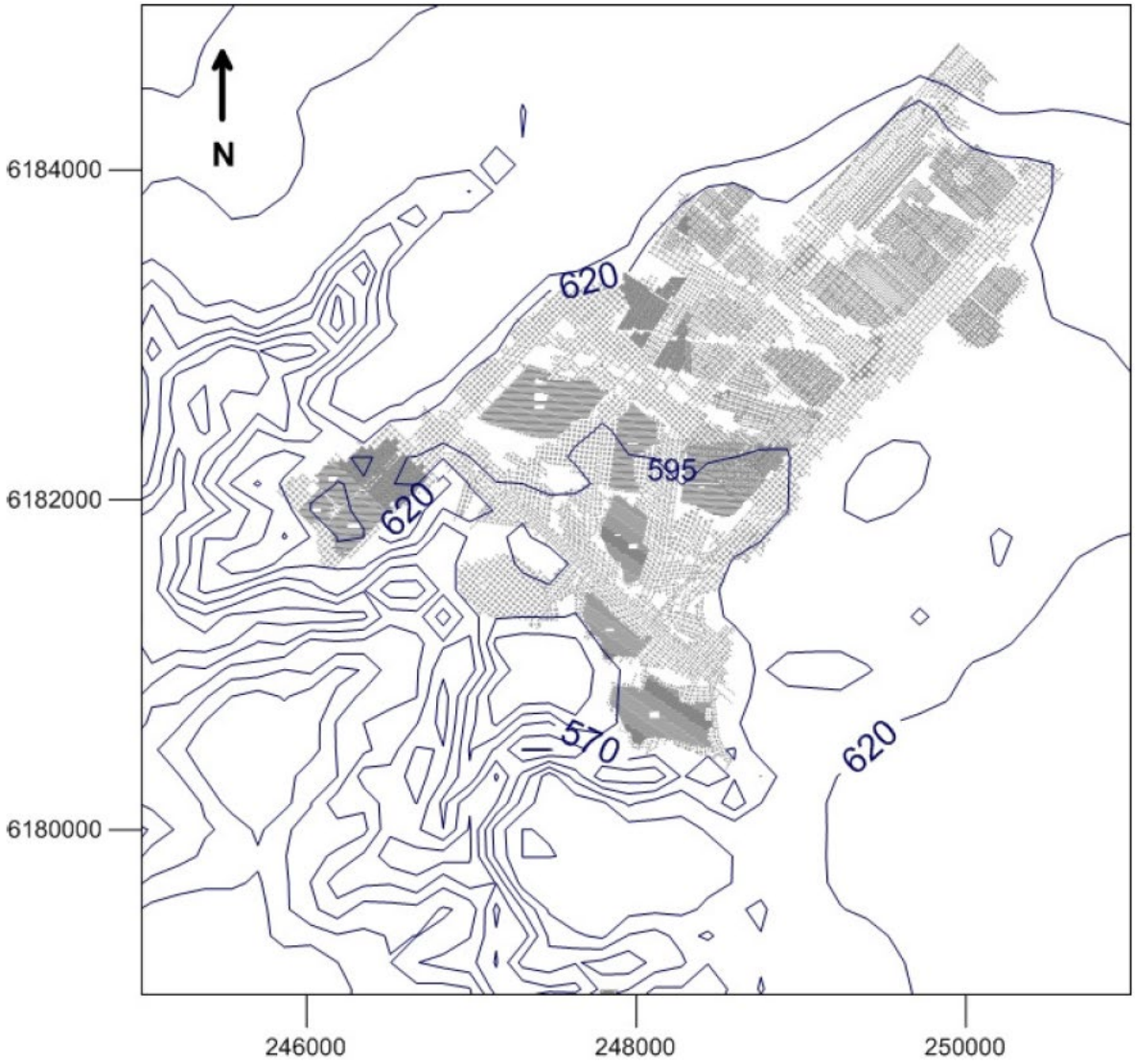



**Figure 4.4** **Predicted head contours in upper Hawkesbury Sandstone Year 20 (mAHD) (after David 2015)**

## 4.3 Hume Coal

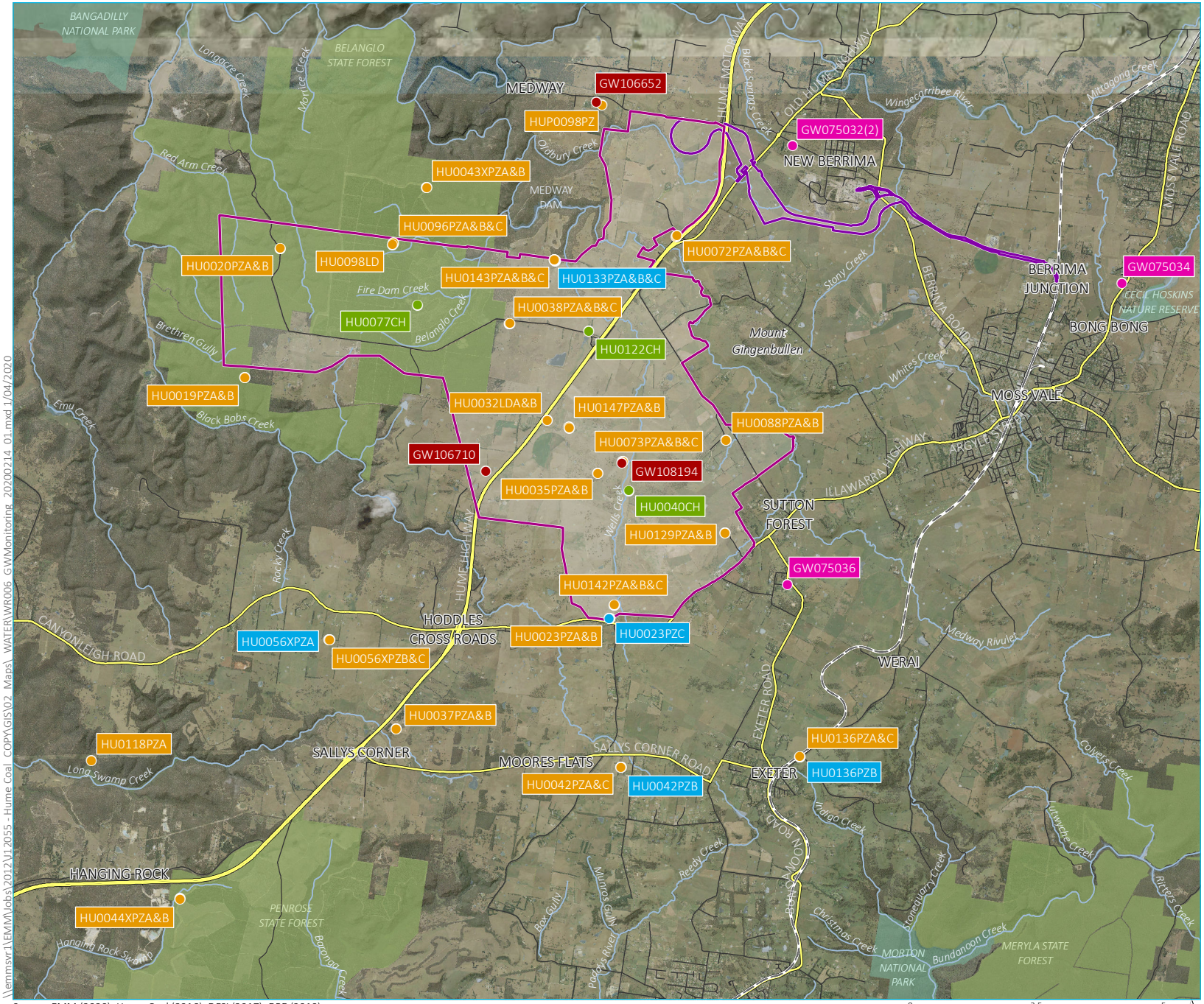
### 4.3.1 Monitoring

A groundwater monitoring program has been implemented to assess and monitor the hydrogeological conditions in the Project area, with monitoring commencing in December 2011. The network consists of 54 groundwater monitoring wells at 22 locations, 11 VWP sensors at three locations and three landowner bores (refer to Figure 4.5).

Specifically, the groundwater network was designed to:

- identify and characterise water bearing units and aquitards in the Project area, with particular focus on characterising groundwater flow and quality within the main groundwater bearing unit, Hawkesbury Sandstone, and the mining target, ICM;
- provide spatial representation and flux of pressure heads across the Project area to investigate potential vertical hydraulic gradients and connectivity between water bearing units and the underlying target coal seam;
- investigate the potential for surface water–groundwater interaction; and
- monitor potential sensitive features, including Medway Dam, Long Swamp, landholder bores and potential groundwater dependent ecosystems.

The majority of the monitoring installation locations comprise of multi-level installations that can be used to monitor the vertical hydraulic gradients at each location.




KEY

- Hume Coal Project area
- Berrima Rail Project area
- Monitoring bore or bore nest
- Decommissioned monitoring bore or bore nest
- Vibrating wire piezometer
- Landholder bores utilised for monitoring
- DI water monitoring bore

Existing environment

- Rail line
- Major road
- Minor road
- Named watercourse
- Waterbody
- NPWS reserve
- State forest

\\emmsvr1\EMM\Jobs\2012\V12055 - Hume Coal COPY\GIS\02 Maps\ WATER\WR006 GWMonitoring 20200214 01.mxd 1/04/2020

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 2.5 5 km

GDA 1994 MGA Zone 56

N

## Groundwater monitoring locations

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 4.5

HUMECOAL PROJECT

EMM creating opportunities

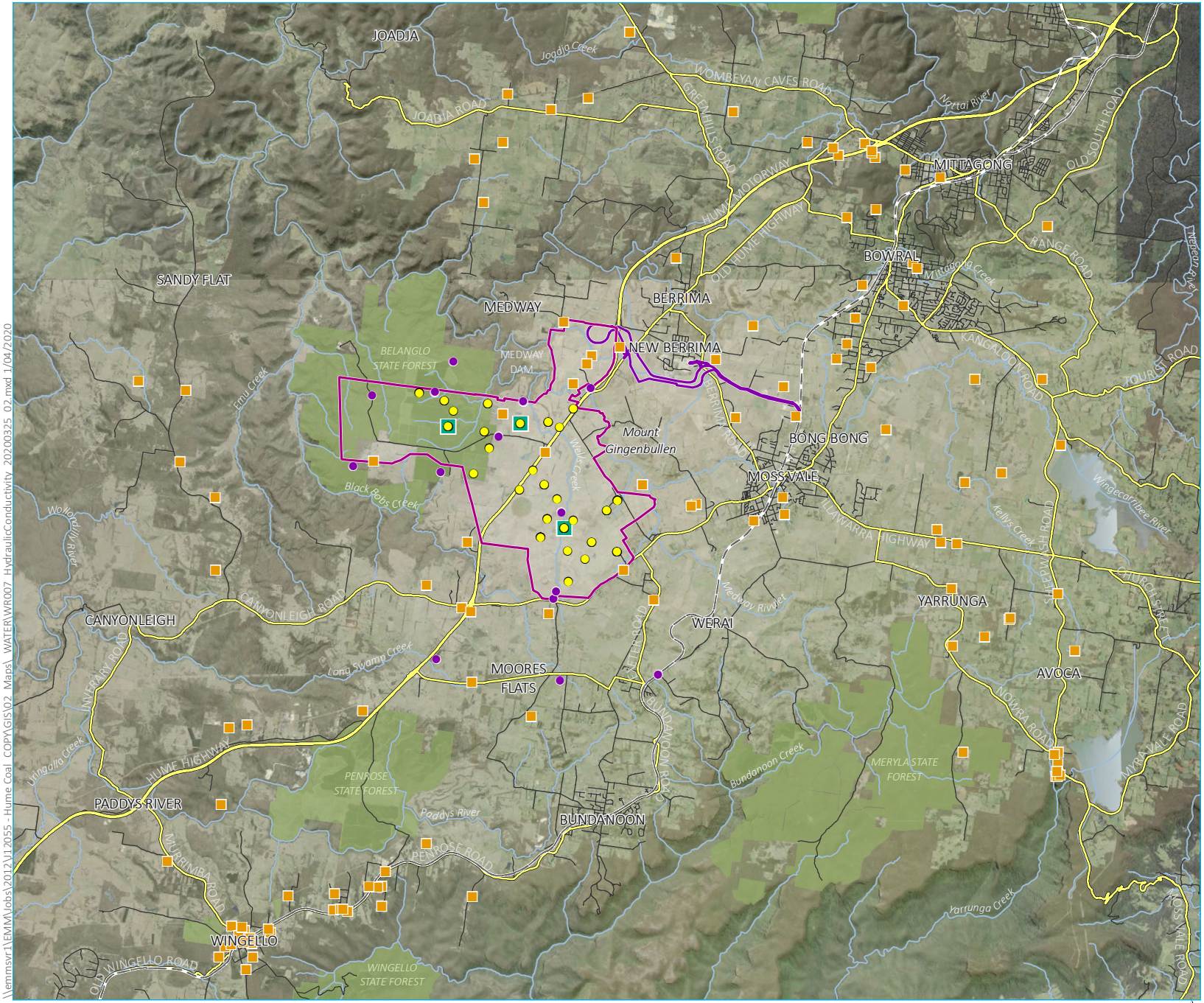
### 4.3.2 Hydraulic testing

A diverse range of hydraulic tests was conducted for the Hume Coal Project to obtain site-specific information on the hydrogeological properties of the geology in the Project area. Hydraulic testing undertaken for the Hume Coal Project has included slug tests, packer tests, core laboratory tests, and in situ aquifer pumping tests. The locations of the groundwater aquifer testing locations are presented on Figure 4.6.

In comparison to the two tests undertaken for the Berrima Colliery, 200 hydraulic tests at 84 locations have been conducted by Hume Coal in the Project area (Table 4.2).

**Table 4.2 Hume Coal hydraulic test summary**

| Test type | Number of tests | Number of locations (bores /drillholes) |
|---|---|---|
| Slug test | 42 | 42 |
| Packer test | 28 | 3 |
| Core test | 128 | 37 |
| Pumping test | 2 | 2 |
| **Total** | **200** | **84** |




KEY

- Hume Coal Project area
- Berrima Rail Project area
- Core testing
- Slug test
- Packer test
- Specific capacity

Existing environment

- Rail line
- Major road
- Minor road
- Named watercourse
- Waterbody
- State forest

Source: EMM (2020); Hume Coal (2016); DFSI (2017); DPE (2019)

0 2.5 5 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMM\Jobs\2012\V12055 - Hume Coal COPY\GIS\02 Maps\ WATER\WR007 HydraulicConductivity 20200325 02.mxd 1/04/2020

## Aquifer testing locations

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 4.6

HUMECOAL PROJECT

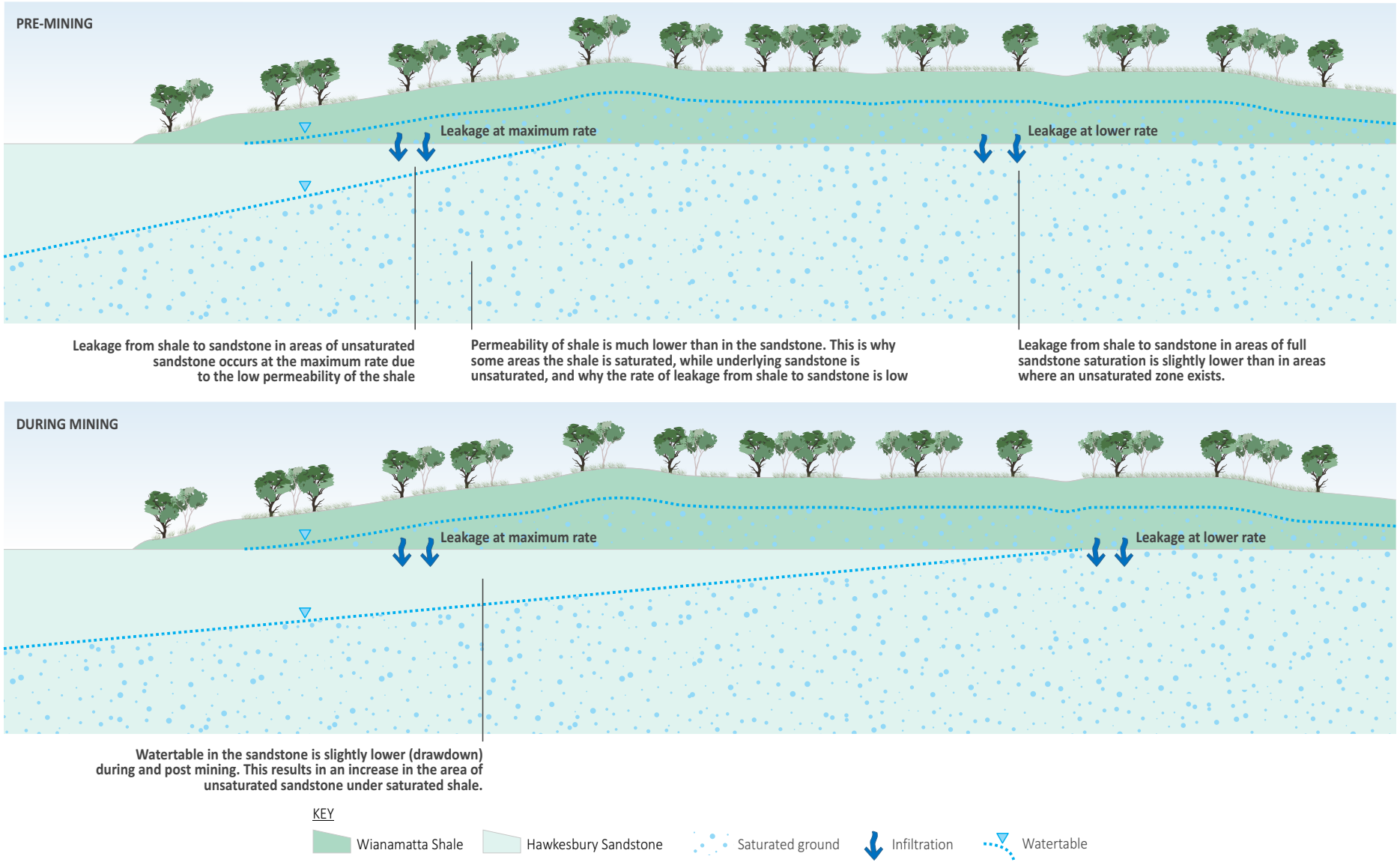
EMM creating opportunities

### 4.3.3 Conceptual hydrogeological understanding

The conceptual hydrogeological understanding of the Project area has been presented in the revised water assessment (EMM 2018b) and is summarised below:

- On average, evaporation exceeds rainfall from September to March.
- HSUs as described in Table 4.1 are relevant for the Project area.
- The proposed mine location is located away from ICM and Hawkesbury Sandstone outcrop locations at watercourses (ie away from natural groundwater discharge areas) such as at Long Acre Creek.
- Regional groundwater flow is influenced by stratigraphic dip and topography, generally towards the east.
- Downward trending gradients have been observed in the north-western part of Project area.
- Hydraulic connection between Hawkesbury Sandstone and ICM occurs where there is minimal interburden between these units (ie in the western edge of the basin).
- In areas where the Wianamatta Group shale is weathered and thin (in the south and west of the Project area), the shale is likely to be unsaturated (ie dry with no groundwater), with the regional watertable located within the Hawkesbury Sandstone underlying the shale. Where the shale thickens (in the east and the north), the watertable is present at varying depths depending on topography and hydrogeological properties of the shale (see Figure 4.7).
- Drainage to surface water (baseflow) is the largest groundwater discharge component.
- Minor localised flow to the north and west associated with local topographic gradients, as presented in Figure 4.8.
- Faults typically do not appear to influence groundwater flow on a regional scale within the Project area as demonstrated by long-term pumping tests. As outlined in the Annexure B (Townley 2020), regional scale groundwater flow systems are sensitive to and depend on average values of hydrogeological properties, with properties averaged over relatively large distances.
- The interburden (comprised of geological units from the upper ICM, including the Farmborough Claystone and Burragorang Claystone) is an important stratigraphic marker for the Hume Coal Project and the presence of this unit clearly illustrates that the Hawkesbury Sandstone has not eroded down to the Wongawilli Coal seam over most of the Project area (Jones 2020).

The hydrogeological conceptual understanding summarised above and presented in the revised water assessment (EMM 2018b) is illustrated in Figure 4.9.




Conceptual schematic representation of Wianamatta Group – Hawkesbury Sandstone relationship

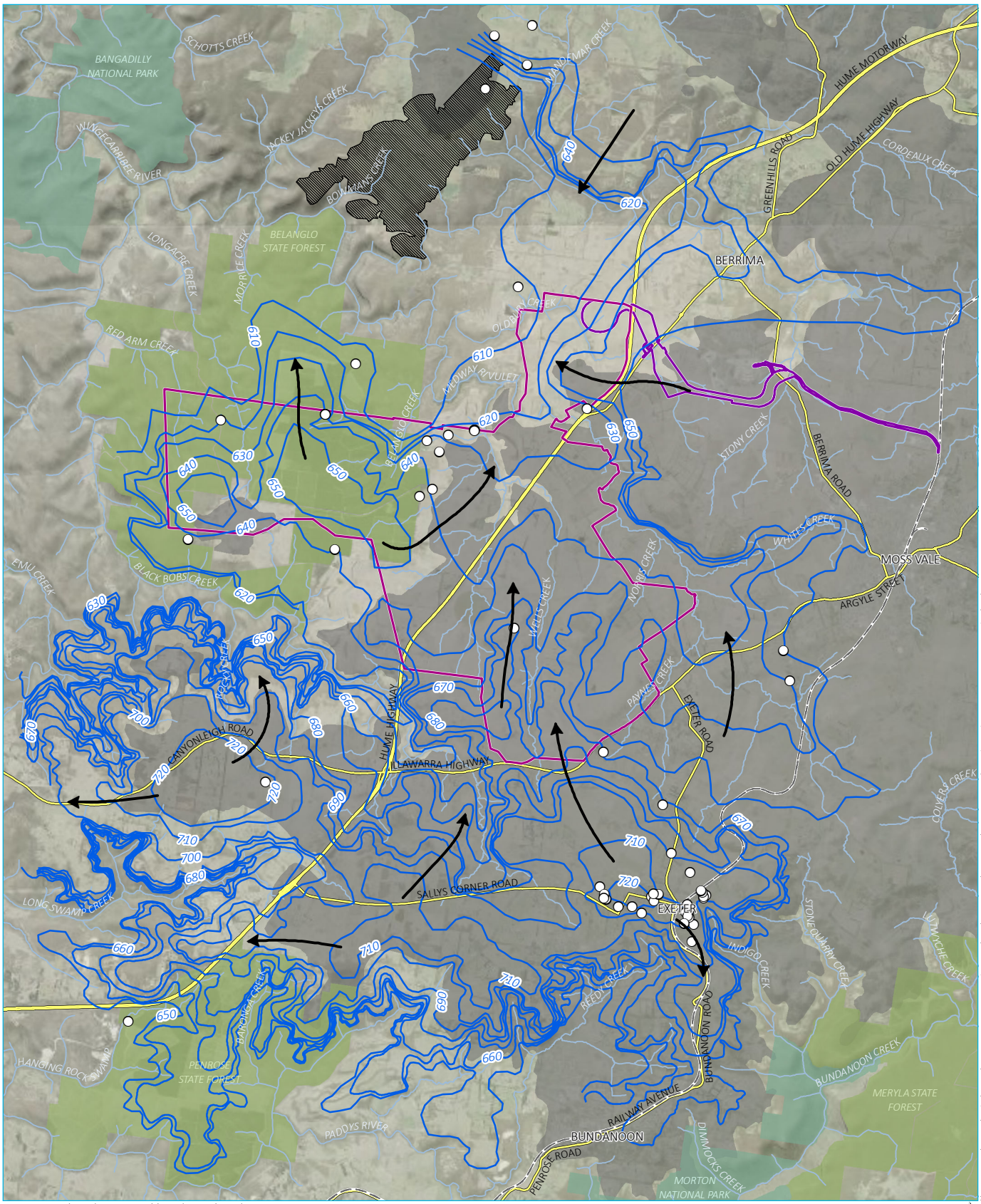
Hume Coal Project

Hume Coal and Berrima Mine Comparison

Figure 4.7

EMM creating opportunities

HUMECOAL PROJECT




*Source: EMM (2020); Hume Coal (2016); DFSI (2017)*

0 2.5 5 km

GDA 1994 MGA Zone 56

N

\\emmsvr1\EMMVJobs\2012\J12055 - Hume Coal_COPY\GIS\02_Maps_WATER\WTR002_InferredWTPlan_20200324_02.mxd 1/04/2020

KEY

- Hume Coal Project area
- Berrima Rail Project area
- Berrima Colliery
- Monitoring bore
- Inferred watertable elevation (mAHD; 5m interval)
- Inferred groundwater flow direction

Existing environment

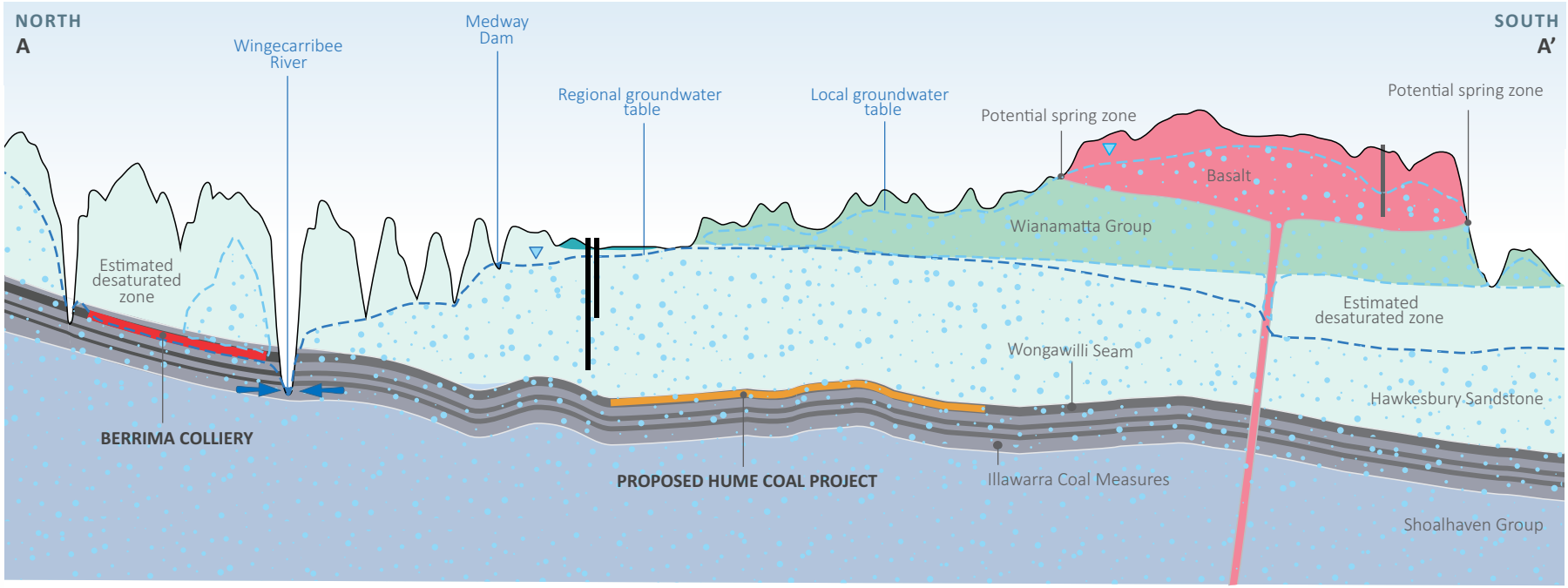
- Rail line
- Major road
- Watercourse/drainage line
- Named waterbody
- NPWS reserve
- State forest
- Shale (250K statewide geology)

# Watertable elevation plan (November 2018)

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 4.8

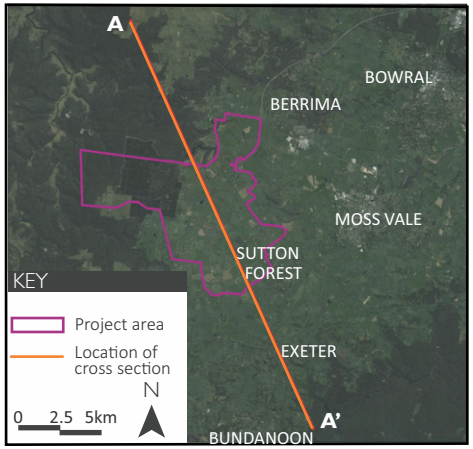
HUMECOAL PROJECT

EMM creating opportunities




Lateral flow dominates
Minimal downward leakage between layers

- Proposed Hume Coal Project – underground mine
- Berrima underground workings
- Robertson Basalt
- Wianamatta Group shale
- Hawkesbury Sandstone
- Illawarra Coal Measures
- Shoalhaven Group
- Coal seam
- Groundwater flow
- Local groundwater table
- Regional groundwater table
- Saturated zone
- Groundwater monitoring bore
- Landholder bore




***NOT TO SCALE***

*(vertical scale is exaggerated and this is a schematic representation only and does not accurately represent the size or locations of bores)*

Interpreted hydrogeological cross section – existing situation

Hume Coal Pty Ltd
Hume Coal and Berrima Mine Comparison
Figure 4.9

EMM creating opportunities

HUMECOAL PROJECT

### 4.3.4 Applicability of data to the Hume Coal groundwater model

The assessment of the potential impact of the Hume Coal Project on the groundwater resource has been assessed via numerous numerical groundwater models. The groundwater modelling, uncertainty analysis and overall assessment of water resources for the Hume Coal Project is world class and has been undertaken by world class modellers. The NSW Government's own independent peer reviewer, Mr Hugh Middlemis of HydroGeoLogic Pty Ltd (HydroGeoLogic), has also deemed it to be fit for purpose (HydroGeoLogic 2017).

#### i Model reviews

As outlined by EMM (2018) and Dr Townley (2020), the groundwater model has undergone greater than 10 reviews and include:

- on behalf of Hume Coal: Dr Noel Merrick, Dr Frans Kalf, Neil Manewell, Liz Webb, and Dr Lloyd Townley;
- on behalf of regulators: Hugh Middlemis (HydroGeoLogic; twice), representatives of IESC, DoI – Water hydrogeologists and WaterNSW hydrogeologists; and
- on behalf of the community: Dr Steven Pells, Doug Anderson, Chris Jewell, and John Lee.

The following reviewers found that the groundwater model is fit for purpose and appropriate for assessing the impacts of the Hume Coal Project:

- Dr Noel Merrick, acting as independent reviewer of the Coffey (2012a and 2012b) work, prior to taking ownership of the groundwater model;
- Dr Frans Kalf, independent reviewer of the EIS and RTS groundwater model;
- Neil Manewell, who conducted an audit of the EIS groundwater model;
- HydroGeoLogic, acting as an expert reviewer for the then DPE and conducted reviews of the EIS and RTS groundwater model versions; and
- Dr Townley (2020), who conducted an expert review of the EIS and RTS groundwater modelling work.

Most recently, Hume Coal engaged Dr Lloyd Townley of GW-SW Pty Ltd, an expert with over 40 years of experience in groundwater modelling, to independently review the groundwater model. The full review is contained in Annexure C of Appendix B to the IPC response report (Townley 2020).

As part of the model build, calibration, modelling of mine impacts, sensitivity and uncertainty analyses, the Hume Coal Project uses data that has been collected at the Project are and at other sites near it.

The findings of the review conducted by Dr Townley (2020) determined that the groundwater model is a Class 2 confidence level and has some elements of Class 3, as per the Australian Groundwater Modelling Guidelines' confidence classification (Barnett et al 2012). Dr Townley's review also finds that the modelling undertaken for the project is fit for purpose, which is predicting groundwater inflows to the proposed mine and drawdown of the watertable within and near the Project area (Townley 2020).

Dr Townley (2020), in his assessment of the model, places emphasis on two key indicators related to (i) the length of time for which predictions are made relative to the time period of calibration, and (ii) the magnitude of future stresses relative to historical stresses during the calibration period. Given the use of available transient data from historical mining at the Berrima Colliery, Dr Townley (2020) advised that the modelling undertaken for the Hume Coal Project should be judged to be Class 2. These two key indicators often lead to models of greenfields mining projects being considered Class 1, but Dr Townley argued that this conclusion is not reasonable for the Hume Coal Project.

In addition, Dr Townley (2020) stated (as summarised):

- The modelling approach is appropriate and consistent with the Australian Groundwater Modelling Guidelines.

- The calibration methodology is consistent with the Australian Groundwater Modelling Guidelines. The calibration is impressive because this is one of the first times that four separate types of data have been used for calibration in a model for a proposed mining project. This is a challenging but robust way to calibrate and has been done in an attempt to balance the different sources of information.

- The calibration methodology is supported by the Australian Groundwater Modelling Guidelines, which explain in Recommendation 5.4 that over-emphasis on fitting a model to observations of piezometric heads using an arbitrary value of SRMS is not appropriate. Therefore, the attempt to fit the model to four separate data sets is aligned to the recommendations of the Australian Groundwater Modelling Guidelines.

- Regional scale groundwater models can never predict watertable elevation or piezometric heads with an accuracy of less than 1 m. No reference to this requirement was provided, and it is unreasonable to suggest that this level of accuracy is ever possible.

### ii Model calibration

The calibration of the Hume Coal groundwater model was undertaken with four independent datasets:

- hydraulic heads: hydraulic head data from monitoring bores within the Hume Coal Project and publicly available groundwater level data has been used in the conceptualisation and calibration;

- hydraulic conductivities: the hydraulic conductivities, estimated from hydraulic tests (Section 4.3.1), were also supplemented with other near site data, and compared to measured data and observations from further afield in the Sydney Basin;

- shallow groundwater discharge as baseflow to streams: estimated baseflow (Coffey 2016a) was compared with predicted shallow groundwater discharge as stream baseflow; and

- deep groundwater discharge as inflow to the Berrima Colliery: the use of the Berrima Colliery groundwater observation data, including the measured discharge, is a valid dataset as the colliery is located within in a similar hydrogeological setting informing the conceptual understanding at Hume Coal.

The use of the multiple datasets reduces the non-uniqueness of the model, by allowing for independent calibration of the model to various sources of data. The groundwater model can be (and has been) tested for calibration on various model layers and for different model parameters due to the nature of the varied datasets, while maintaining realistic bounds on measured values for the calibration dataset. Uncertainty in groundwater models can be reduced by use of conceptual understanding, prior knowledge, calibration and modelling experience. The Berrima Colliery and its measured drainage has provided a significant amount of information that has been used to reduce the uncertainty in the Hume Coal Project groundwater model simulations of past groundwater system responses to a stress (the deep discharge) and its prediction of future outcomes.

The EIS groundwater model (Coffey 2016b) was calibrated manually using changes in parameters to best achieve matches to the calibration metrics and observations.

### a Calibration results

Comparison of the calculated groundwater levels (model generated) and the observed groundwater levels for the EIS groundwater model is presented as a scatterplot in Figure 4.10.

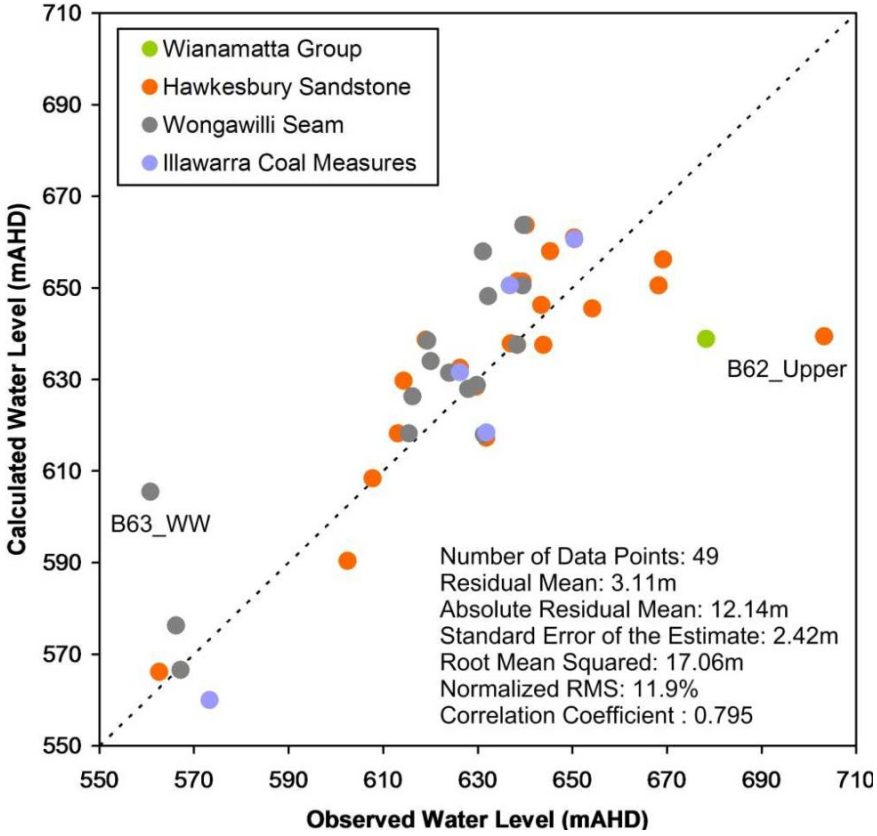



**Figure 4.10 EIS groundwater model calibration statistics (Coffey 2016b)**

Figure 4.11 provides a comparison between the observed (measured) and model-derived deep groundwater discharge from the Berrima Colliery from the EIS model (Coffey 2016b). The modelled average inflow to the Berrima Colliery was simulated as 2.9 ML/day (black line on Figure 4.11).

Following the EIS model, a revised RTS model was completed by HydroSimulations in 2018. Among the changes made, the model code was updated to improve the calibration further and achieve a more stable solution. The model water balance calculations were also modified to provide a consistent time-step reporting that helped improve the errors associated with the site water balance.

Figure 4.12 presents the observed and calibrated groundwater heads for the revised RTS groundwater (also referred to as the "Modified EIS model") using MODFLOW USG. The RTS groundwater model remains appropriately calibrated and is fit for purpose to assess the impacts of the Hume Coal Project.

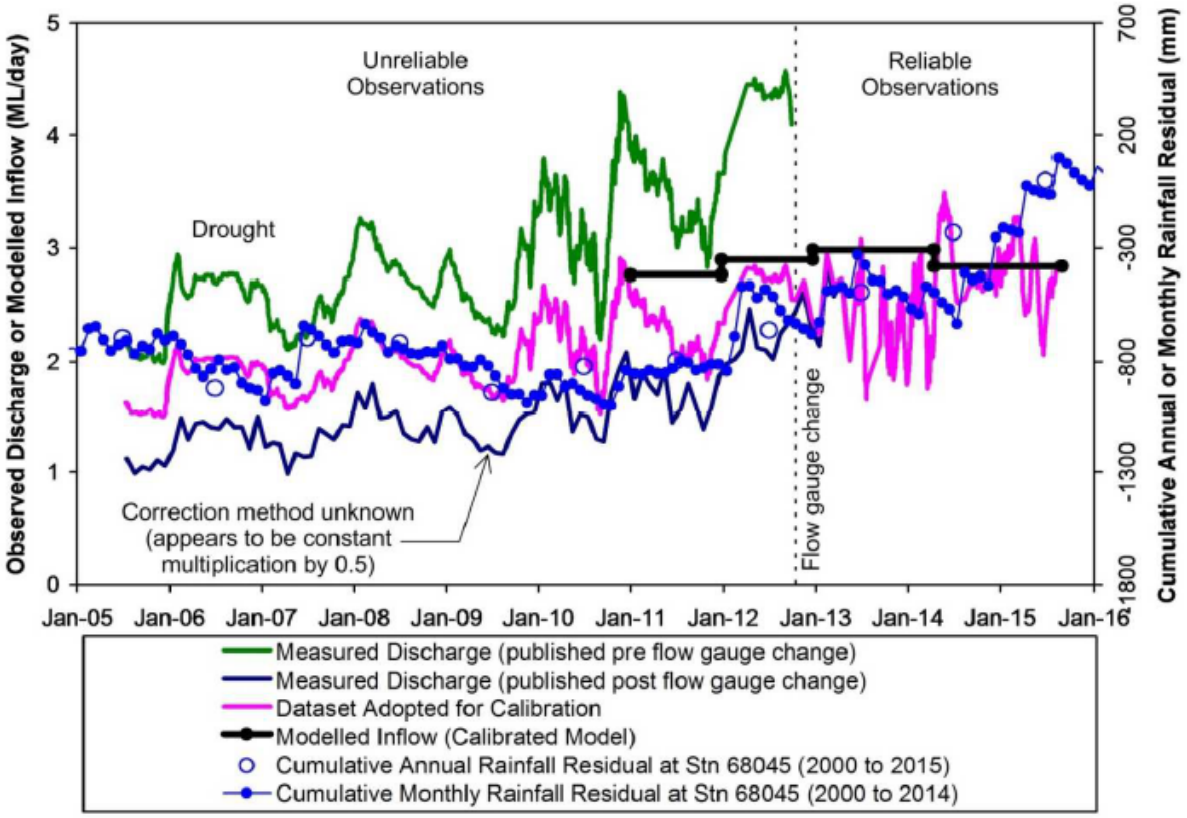



**Figure 4.11** **Comparison between observed discharge and model-derived discharge from the Berrima mine void over the EIS model history match period (Coffey 2016b)**

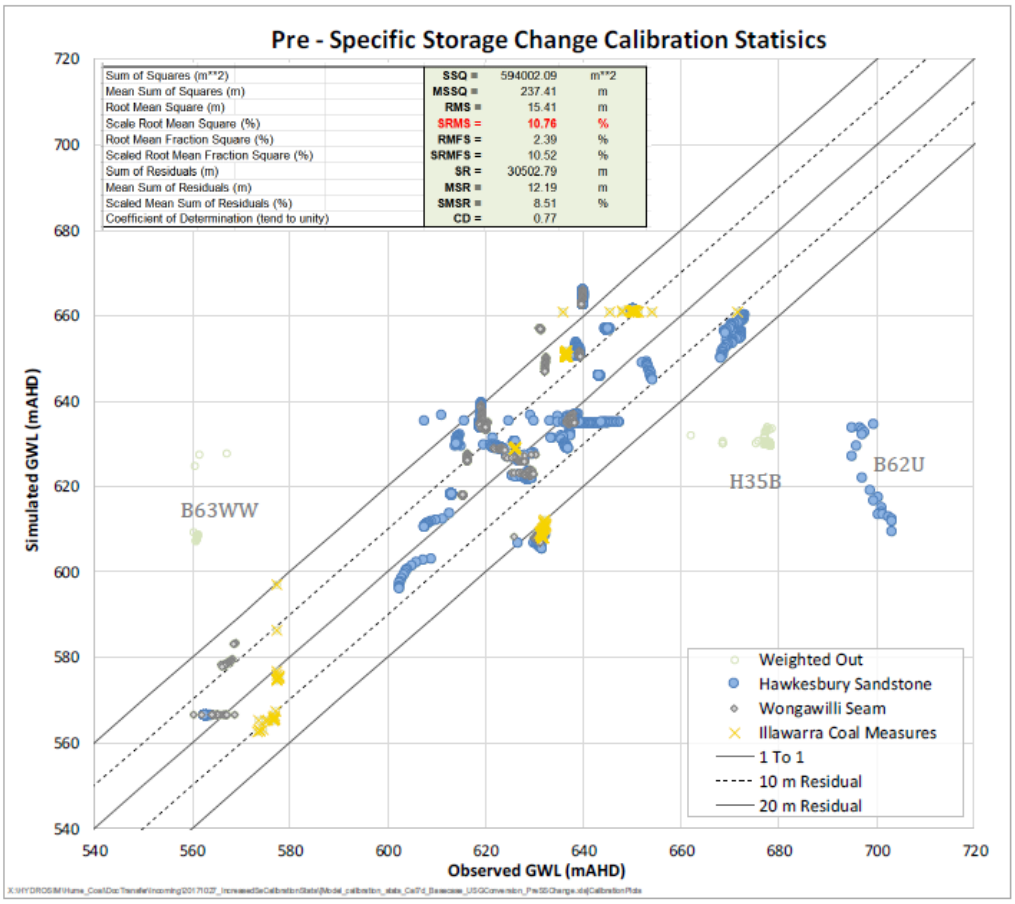



**Figure 4.12 RTS groundwater model calibration statistics (HydroSimulations 2018)**

As part of the RTS groundwater modelling work, HydroSimulations (2018) conducted a detailed uncertainty analysis. This involved using pilot points where the hydraulic conductivity parameter distribution was varied over hundreds of model realisations using the Monte Carlo method with pilot points, in line with the IESC guideline (Middlemis and Peeters 2018). It is noted that this work was very complex, time consuming and onerous, and the results of the work provide an exceptional example of how to apply the IESC guidelines to undertake very detailed uncertainty analysis and reporting of results. The results of the revised groundwater modelling predict 94 landholder bores on 72 properties will observe groundwater level drawdown greater than 2 m as a result of the project, and the uncertainty analysis suggests the model has a narrow uncertainty range in regards to inflow and drawdown prediction.

### iii Appropriateness of the Hume Coal groundwater model

The various iterations of the groundwater model and calibration have been reviewed and commented on by numerous industry experts, the models are determined to be fit for purpose and representative of local conditions for the assessment of project impacts.

# 5 Mining method

## 5.1 Mining method examples

Mining methods have evolved over the years since coal was first discovered in Australia. This report is not a complete and exhaustive list of the different methods however, it does highlight some of the key differences of methods used at different points in time.

Once a mining lease has been approved for an operator, access to the coal seam is the first task in developing the physical mine. This had historically been accomplished via adits, but more recently this has been through drifts or inclined shaft; quite often called a 'decline'.

Common underground coal mining methods include: bord and pillar (first workings), pillar extraction (second workings), longwall mining, shortwall mining, and, more recently, block caving methods. A summary of the common mining methods is presented below:

- Mine development in the early days of coal mining was completed by hand workings, which were usually assisted using explosives to remove coal. Historically, the coal seam was accessed through adits where the coal seam was able to be accessed via formation outcrop. Roof supports were completed by hand using timber and bars, while rail tracks and cars were completed to the coal face, to be hand shovelled and drawn by horse. Over time mechanical aids were introduced to improved ore recovery or help improve mine safety.

- Mechanical workings/aids includes coal cutters to cut narrow channels to open second faces for setting explosives; powered rotary/percussive drills; diesel or battery locomotives; powered loaders for coal loading; rotary roof bolting; conveyor belts and the use of continuous miners that can perform multiple tasks at once (mining, roof support, and conveyor loading).

  Bord and pillar (first workings):

  - This is often referred to as the development phase of a mine, with the building of the roadways, cut-throughs forming pillars between these underground perpendicular systems.

  - According to NSW Mining (2020), bord and pillar (or room and pillar) is the oldest underground mining technique and was common in NSW before longwall mining began in the 1960s. This method uses a grid of tunnels and involves progressively cutting panels into the coal seam whilst leaving behind pillars of coal to support the mine. This method has been in steady decline as more efficient technologies are introduced but is still used in a small number of mines across the state. Pine feather mining is similar to bord and pillar mining as it allows the strata to be supported and does not allow subsidence above mined areas.

- Pillar extraction (second workings):

  - This mining method follows on from the first workings, where the areas between the coal roadways and cut-throughs are removed by various methods that may result in overlying strata collapsing (goaf). Longwall mining is one method of pillar extraction, it can be accomplished by either advancing movement into the coal seam or by retreat where collapse occurs after mining the section of coal. Another method of pillar extraction is using continuous miners.

- According to NSW Mining (2020), longwall mining revolutionised underground coal mining with its capacity for safe, cost effective and efficient large-scale extraction. Longwall mining uses mechanical shearers to cut coal away whilst hydraulic-powered supports hold up the roof of the mine. As coal is removed, the supports are moved forward and the roof is collapsed behind them, which can result in subsidence. Longwall mining is more efficient than bord-and-pillar as it does not leave behind pillars of coal, so more of the mineral resource can be extracted.

- A newer technique of mining is block caving, where the ore is extracted after collapsing has occurred under the weight of the ore deposit. This has been used in thick seams where the equipment cannot mine the entire face but the coal deposit collapse into an access drive and is then collected in extended canopies.

## 5.2 Berrima Colliery and other mines in the area

The initial mining method at Berrima Colliery utilised the bord and pillar method, mining of the basal section of the Wongawilli Coal seam. Mining was originally by manual methods employing pick and shovel and drill and blasting. The mine was later mechanised (around 1968) with the use of a single continuous miner (IEC 2015), that later started mining the original pillars from the first workings. The pillars of coal were extracted using the Wongawilli method (which is a type of pillar extraction) utilising breaker line supports and a continuous miner. The areas of mining varied as the different mining techniques were employed at the Berrima Colliery.

The Wongawilli Coal seam ranges in thickness from approximately 6 m to 10 m and strikes in a northerly direction and dips gently to the east at approximately 1 to2 degrees (Figure 3.4). The underground workings consist of intact coal pillars, partially extracted pillars and full extraction areas resulting in roof collapse (Boral 2015).

It is understood that mine subsidence (goaf collapse) has occurred at Berrima Colliery, resulting from pillar extraction. Boral (2015) reported that the very early mine workings which are located at the Wingecarribee River escarpment caused at least two known erosion features as a result of weathering of the tallus slope. Subsidence levels within the modern workings have been minor and significantly below levels predicted within the various subsidence management plans for the colliery (Boral 2015).

Five mine entry points are reportedly associated with the Berrima Colliery (ICE 2015):

- main drift portal – main mine entrance used for personnel, materials, conveyor, air intake and services;
- fan portal – located adjacent to the main drift portal and housed the ventilation fan;
- drainage adit – original mine entry dating back to 1872, located above the Wingecarribee River escarpment, approximately 700 m south of the main drift portal; the adit was later used to discharge groundwater collected from the mine; and
- two linked entries near Bowmans Creek.

Berrima Colliery had a main entry point (or portal) which was located at the pit top facilities in Medway. ROM coal was transported from underground by conveyor to an onsite crusher and loaded on to trucks to be transported to customers (including predominantly the Berrima Cement Works) or stockpiled at Loch Catherine.

Other historical mining activities in the area include the Loch Catherine Colliery which opened in 1923, operating periodically until its closure in 1959 (EMGA 2011a). It principally provided fuel for the Kiln at the Maldon Cement Works, approximately 60 km to the north-east. The former colliery is contained within the CCL 748 which was last held by Boral and contained the Berrima Colliery. The stockpile area for Berrima Colliery, known as the Loch Catherine Stockpile, was located above the former Loch Catherine Colliery workings.

Loch Catherine has four adits that are located on a bench, between 5 m and 10 m wide, and approximately 30 m above the Medway Rivulet on the northern side of the river gorge (Figure 2.2). The entrances to the adits are shown in photographs 5.1 to 5.4. Minor water discharge has historically been observed from one of the adits. The historical adits were not sealed at the time of reporting in 2011 and plans were being developed for closure of the adits to human entry while maintaining use of the adits to fauna (EMGA 2011a).

**Photograph 5.1 Loch Catherine Adit 1 (EMGA 2011a)**

**Photograph 5.2 Loch Catherine Adit 2 (EMGA 2011a)**

**Photograph 5.3 Loch Catherine Adit 3 (EMGA 2011a)**

**Photograph 5.4 Loch Catherine Adit 4 (EMGA 2011a)**

### 5.2.1 Mine water management

Mine water management at the Berrima Colliery has been relatively simple.

While operating, the Berrima Colliery used groundwater inflows to meet operational requirements and for water supply for some houses at the Village of Medway. The groundwater was collected in several sumps and, using pumps and/or gravity drainage, it was transferred up to 4 km to the lowest mine sump: 400 Panel Main Sump. From there, water overflowed into the old workings and eventually discharged to the Wingecarribee River from the Pit Bottom Sump via the drainage adit.

The drainage adit of the Berrima Colliery is located at a low point in the Wongawilli Coal seam elevation (Figure 3.4). Under gravity drainage, the mine pit water was collected in the underground workings and historically discharged to the Wingecarribee River. The generalised water management model was that the open historical mine workings were a gravity induced groundwater drainage system where the workings provided a pathway to the drainage adit at the low point of the Wongawilli Coal seam. The various historical workings located close to the Wingecarribee River are potential discharge points due to the geological outcropping of the Wongawilli seam along the escarpment. Due to the historical entry (adit entry), the potential exists at the Berrima Colliery (and other locations) for erosion to expose the old workings and create pathways that could have unmeasured releases of groundwater into the natural environment.

In 2019, Boral announced that several watertight bulkheads have been installed to seal the mine workings and prevent the discharge of groundwater inflows to the environment. This would allow groundwater levels to recover in the local area and would limit the release of groundwater with chemical constituents of concern (such as manganese). Figure 5.1 shows a schematic of the underground mine drainage at the Berrima Colliery during operations.

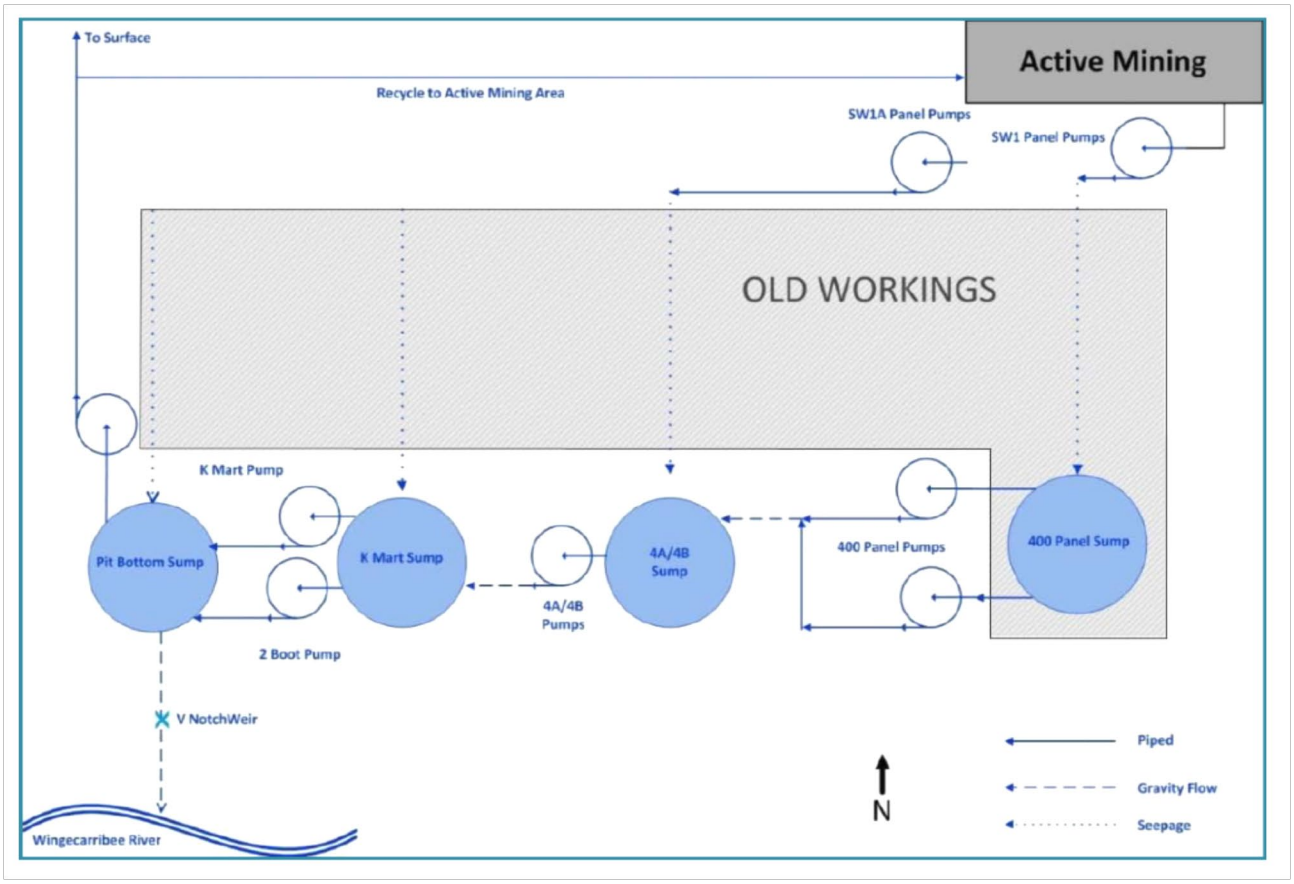



**Figure 5.1 Berrima Colliery active mine water management schematic (IEC 2015)**

## 5.3 Hume Coal

As previously reported in the EIS and RTS, non-caving mining layout and method are planned at the Hume Coal Project. Mining will occur sequentially in panels (not longwall panels) that are separated from each other by solid barriers of unmined coal. The proposed method is low impact and will have negligible surface and subsurface subsidence, and minimal overburden fracturing. Indicative underground mine progression is shown in Figure 5.2. This mining method is similar to the bord and pillar method as it is a stable method of coal extraction, while leaving in place coal pillars that support the overlying strata. The Hume Coal mining method is often referred to as a 'pine feather' method, due to the appearance of the underground mine workings in plan view.

Underground main roadways or 'mains' will be developed, followed by mining panels offset at an angle from the mains, together forming the trunk and limbs of the mine. Continuous miners will be used for mining at typical widths in standard drivages of between 5.2 m to 5.5 m. Over-width drivages (typically up to 6 m) may be developed from time-to-time for specific purposes (for example, niches for equipment), and will be geotechnically assessed on a case-by-case basis.

Following development of the gate roads, a narrow head continuous miner and continuous haulage system will be used to develop a series of parallel drives (also referred to as plunges) off the outside edges of the gate roads. The plunges will each be 4 m wide and angled at 70 degrees to the gate roads. Pillars will vary in size depending on the depth of cover.

Minimal overburden deformation is expected to occur. Most will be small amounts of elastic deformation of the rock mass, while non-elastic deformation will be restricted to the immediate roof over the openings. The height of deformation was estimated to be 2 m into the roof above the panel with sensitivity analysis demonstrating that groundwater inflows would not be sensitive to doubling this height of deformation (Coffey 2016b). Within the deformation (dilated) zone, existing cleats or defects may become enlarged and minor cracking may occur, which could increase hydraulic conductivity. The deformation zone is likely to become desaturated during mining activities. Above this zone, deformation will be negligible and groundwater saturation of the strata would be maintained (Coffey 2016a and HydroSimulations 2018).

Individual mining panels will be separated by wide, solid (unmined) barrier pillars to prevent direct hydraulic connection between panels. The approximately 50 m wide barrier pillars will also aid geotechnical stability.

As reported in the RTS document (EMM 2018a), this mining method has been designed to avoid subsidence impacts across the Project area. The mines first workings will leave pillars of coal in place to help support the overlying strata, as such the surface subsidence impacts will be negligible.

The NSW Resource Regulator has confirmed that the proposed pine feather mine design is a variation of the Wongawilli pillar extraction method (as per the DPE Assessment Report (2019), p.31). The two methods of mining have significant aspects that are very similar, as described below.

The mains development for both systems of mining are identical, as shown in Figure 5.3, using the same continuous miners and associated mining equipment, the same heading widths and heights, and the same pillar size. Depending on the mine the number of headings may change, but this generally ranges from four to seven headings and is often associated with ventilation requirements.

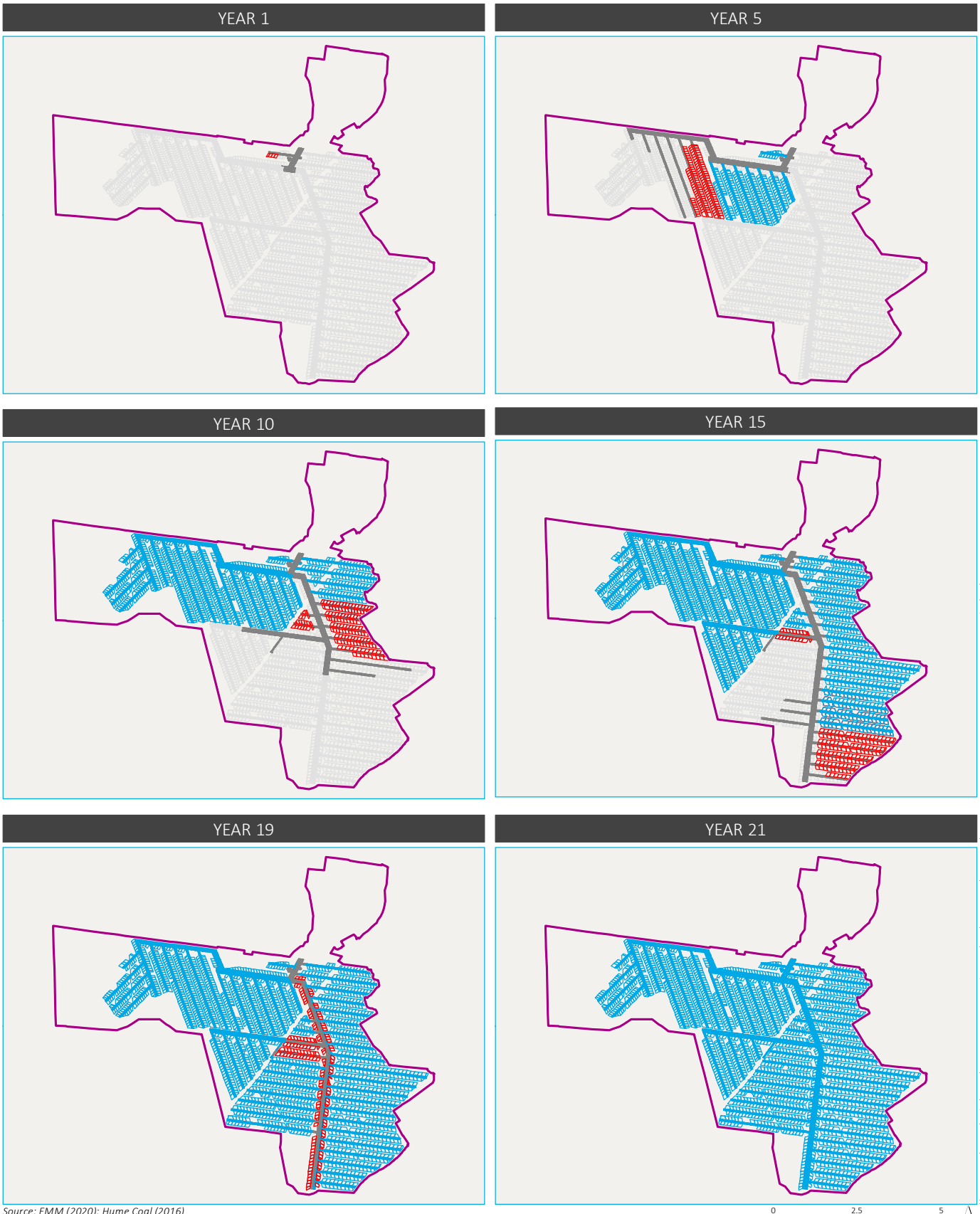
The panel development for both systems of mining are also identical, as shown in Figure 5.3, using the same continuous miners and associated mining equipment, the same heading widths and heights, and the same pillar size. The number of headings in a panel varies but is usually two to three.

The plunges associated with the pine feather method are driven at 70 degrees from the panel direction, whereas the splits associated with the Wongawilli method are generally driven at 90 degrees from the panel direction (Figure 5.3). In the pine feather system, the plunge (heading) width is 4 m in thickness, whereas the width in the split (Wongawilli) will typically be the normal mining width of around 5.5 m in width. These variations are so minor that the two mining systems are effectively the same in this regard.

The difference between the pine feather method and the Wongawilli method is the bringing together of these various machines and technologies in a planned configuration in an underground mine.

The Wongawilli method of mining that requires splitting of the pillar and lifting of the fender (lifts) is secondary extraction. It is a clear example of developing a caving and developing of a goaf. This form of extraction presents a higher risk than simply development of roadways. It differs from the pine feather method in that the fender (web pillar) is left in place and not extracted; there is no holing of pillars, there is no goaf formation or caving, and therefore there is no secondary extraction.

Widths of the web pillars in the pine feather system will vary slightly with the depth of mining, from a minimum of 3.5 m width, increasing with depth of mining to 6 m width at the greater depths (170 to 180 m).




*Source: EMM (2020); Hume Coal (2016)*

0 2.5 5 km

GDA 1994 MGA Zone 56

N

KEY

- Hume Coal Project area
- Active underground workings
- Underground roadway
- Sealed underground workings
- Future underground workings

Indicative underground mine progression

Hume Coal and Berrima Rail Project
Hume Coal and Berrima Mine comparison
Figure 5.2

\\emmsvr1\EMMJobs\2012\J12055 - Hume Coal_COPY\GIS\02_Maps_WATER\WR010_UGMineProgression_20200214_01.mxd 1/04/2020

HUMECOAL PROJECT

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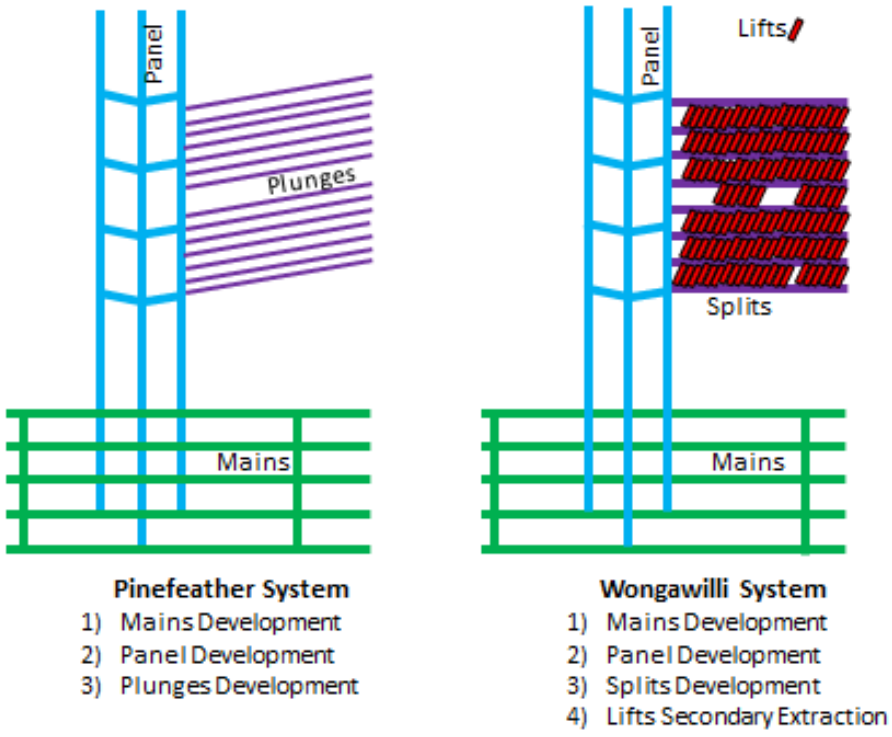



**Figure 5.3 Comparison of the pine feather method with the Wongawilli mine method**

### 5.3.1 Rejects and water management

As previously reported (EMM 2017 and 2018b), once mined, the panels will contain open voids that will be used for the emplacement of coal reject materials. Mine voids will be backfilled with co-disposal reject (comprised of crushed rock rejects and water from the coal processing plant (CPP) mixed with up to 1% limestone), to buffer any potential oxidation reaction of sulfur in the coal. It is estimated that reject and other rock wastes will fill some 36% of the total mined volume (Coffey 2016a) and temporal process for reject emplacement is outlined below:

- For approximately the first 18 months of operation, while underground void space is being created, coal rejects will be mixed with 2% limestone (to buffer pH) and stored in a temporary stockpile at surface, which will be progressively re-shaped, top-dressed and re-vegetated and then remain in place until mining finishes.

- As void space void space becomes available and once it is safe to do so, rejects in the temporary stockpile will be emplaced underground in the mined panels.

- After approximately 18 months of operation, coal rejects from processing will be mixed with water from the CPP and 1% limestone (to buffer pH) and emplaced, essentially immediately, underground to partially back-fill mined-out voids. They will not be stockpiled at surface.

After mining and backfilling operations are complete within a panel, individual panels will progressively be sealed at the entrance with permanent seals (bulkheads) designed to sustain anticipated groundwater pressures, at an appropriate factor of safety (nominally a factor of four). The bulkhead seals will vary in thickness depending on the anticipated groundwater pressure.

Active pumping of water behind the bulkheads will occur once the first bulkhead is sealed through to year 19 of mining, resulting in a decreased volume of groundwater inflow to the workings and faster groundwater recovery post-mining. Once mining ceases (end of year 19) groundwater inflow to the void is expected to continue until all panels are full.

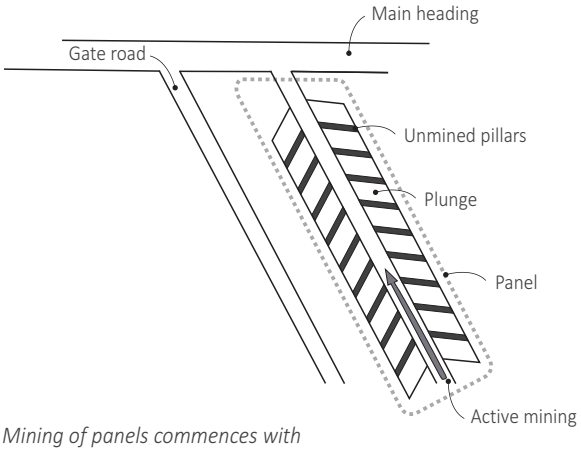
Once panels are sealed and flooded, the void will become part of the greater groundwater source. Relocating mine sump water into the underground sealed voids averts the need for management and /or release of that water at the surface. Facilitating groundwater storage behind the bulkheads naturally and via pumping will also greatly decrease groundwater depressurisation and speed up the groundwater recovery time.

A conceptual diagram of the mine progression, reject emplacement, and water injection is provided in Figure 5.4.

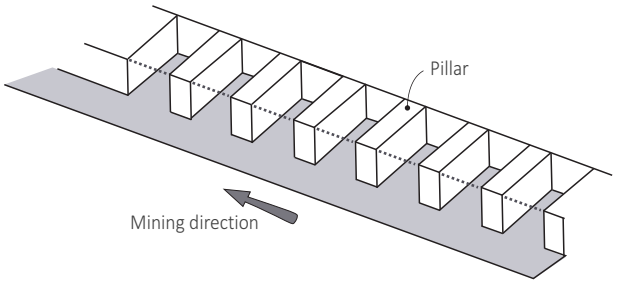
Figure 5.5 presents a conceptual hydrogeological cross section of the local groundwater system at the Hume Coal Project during mining.

**PLAN VIEW** | **SECTION VIEW**

## ACTIVE MINING

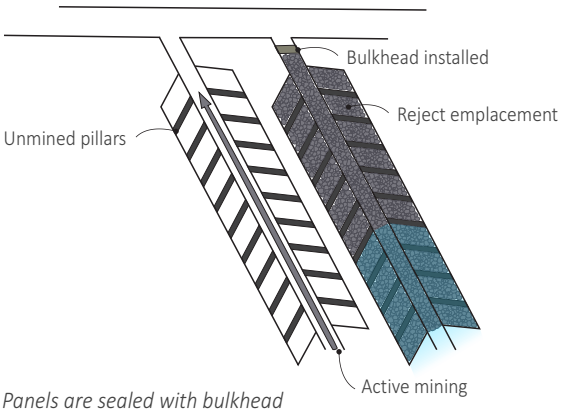



*Note: Mining of panels commences with establishing the gate road, then mining in the plunges back to the main heading*

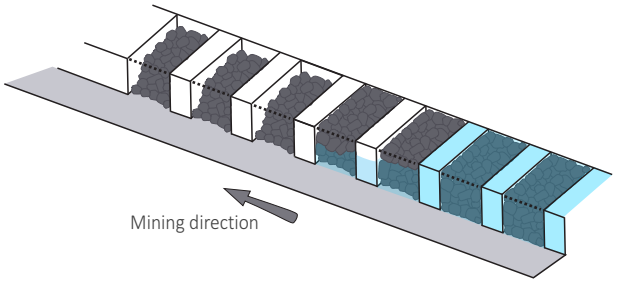



*Note: Active dewatering occurring*

## REJECT EMPLACEMENT

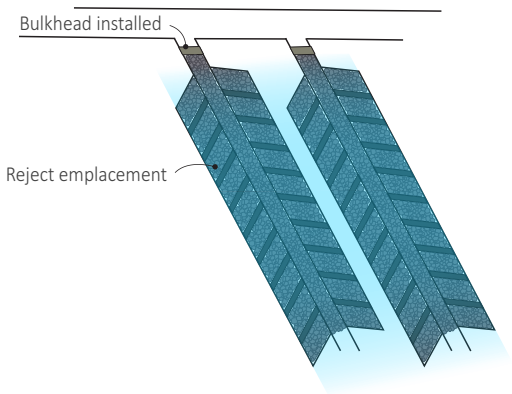


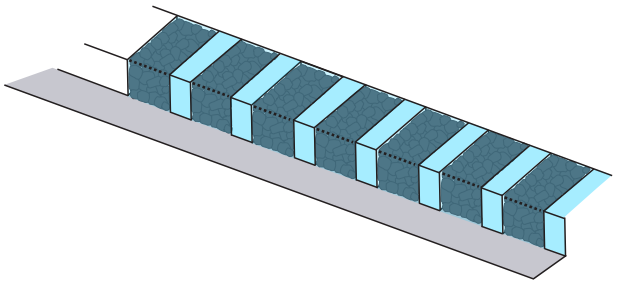

*Note: Panels are sealed with bulkhead immediately after rejects are emplaced in mined plunges*




*Note: Co-disposal reject emplacement occurs in previously mined plunges. Excess mine water is pumped into sealed panel and receives natural groundwater inflow*

## END OF MINING



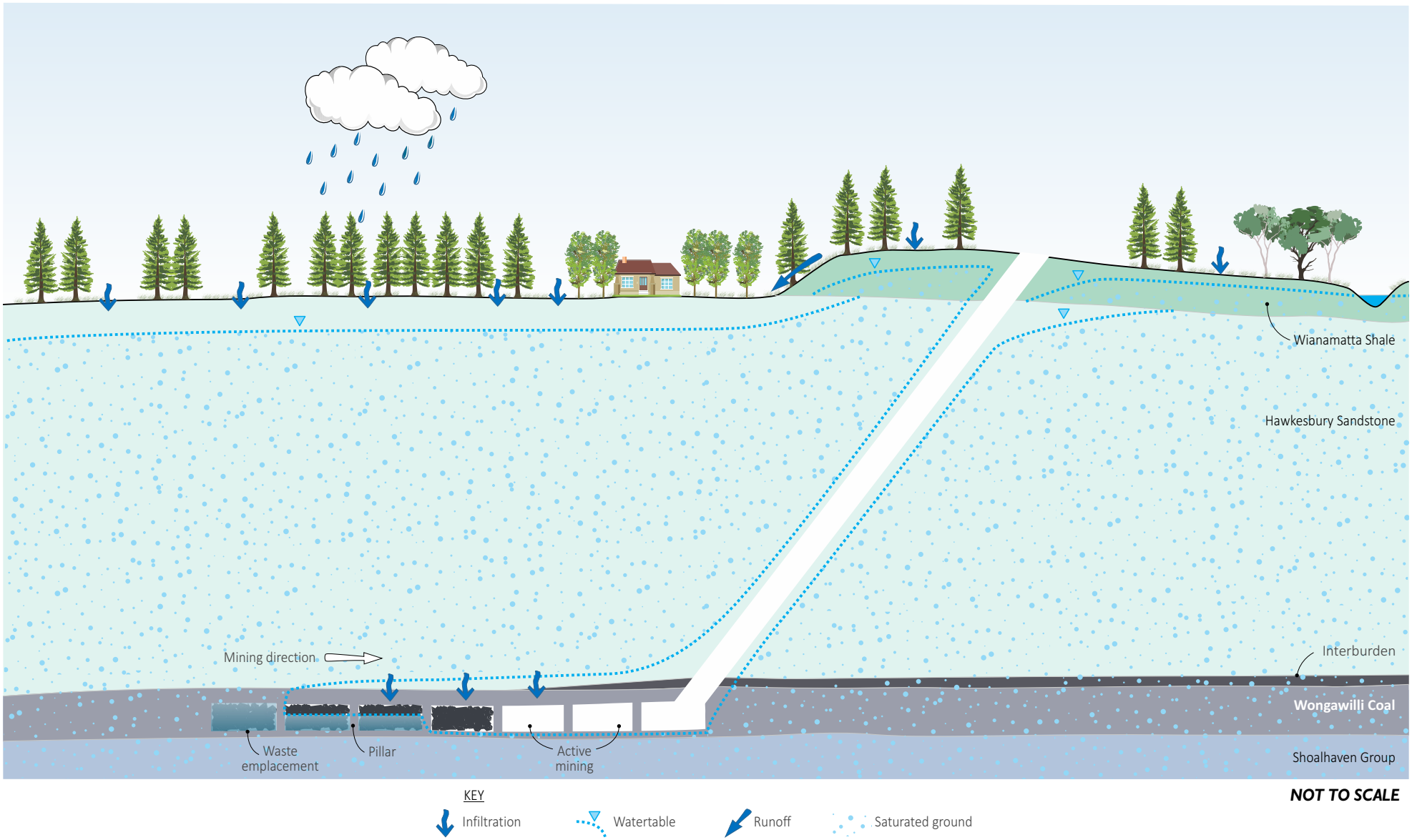



*Note: Void space in panel becomes full and groundwater system becomes fully saturated.*
*In times of water deficit, water in sealed panels may be accessed to meet mine water requirements*

***NOT TO SCALE***
*(This is a schematic representation only and does not accurately represent the size or plan for all panels)*

Hume Coal mine progression, reject emplacement and water injection

Hume Coal Pty Ltd
Hume Coal and Berrima Mine Comparison
Figure 5.4




Hume Coal Project – Active mining conceptual schematic

Hume Coal Pty Ltd

Hume Coal and Berrima Mine Comparison

Figure 5.5

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HUMECOAL PROJECT

# 6 Mine closure

## 6.1 Berrima Colliery

The Berrima Colliery was originally designed to access the coal seam using “adits” (ie horizontal passages accessing the coal from outcrop in the river escarpment). The adits at Berrima Colliery and photos from Loch Catherine are fairly typical of historical workings in the area. Some adits and mining activities have been abandoned and left with little to no reclamation activities that prevent mine water mixing with the local environment.

The historical mines all accessed the coal seam via adits typically from valleys/river escarpments thus potentially creating direct connections between the coal seam and the natural environment.

Since mining has ceased at Berrima Colliery seven years ago in 2013, there has been limited change to the groundwater discharge from the drainage adit. Boral’s (2015) closure plan identified the key environmental issue as the longstanding water drainage into the Wingecarribee River. As part of the closure plan, the five entry points to the Berrima Colliery would be sealed in accordance with regulatory requirements. The drain adit and the two entries near Bowmans Creek required additional roof support as they were constructed at a time when modern roof support systems where not required (Boral 2015).

According to Boral (2019), seven waterproof concrete bulkheads will be installed at strategic locations to seal the mine workings and limit groundwater discharge to the environment. The effectiveness of the bulkheads in regulating groundwater discharge at the drainage adit is being monitored by Boral, and the final plans for closure will progress after monitoring (Boral 2019).

Figure 6.1 presents a conceptual diagram of the local groundwater system at the Berrima Colliery in a transient state of groundwater recovery as a result of the installation of bulkheads. If the closure plan is successful (ie bulkheads are effective in sealing the Berrima mine workings), the recovery of hydraulic heads within the Hawkesbury Sandstone will be enhanced in the area.

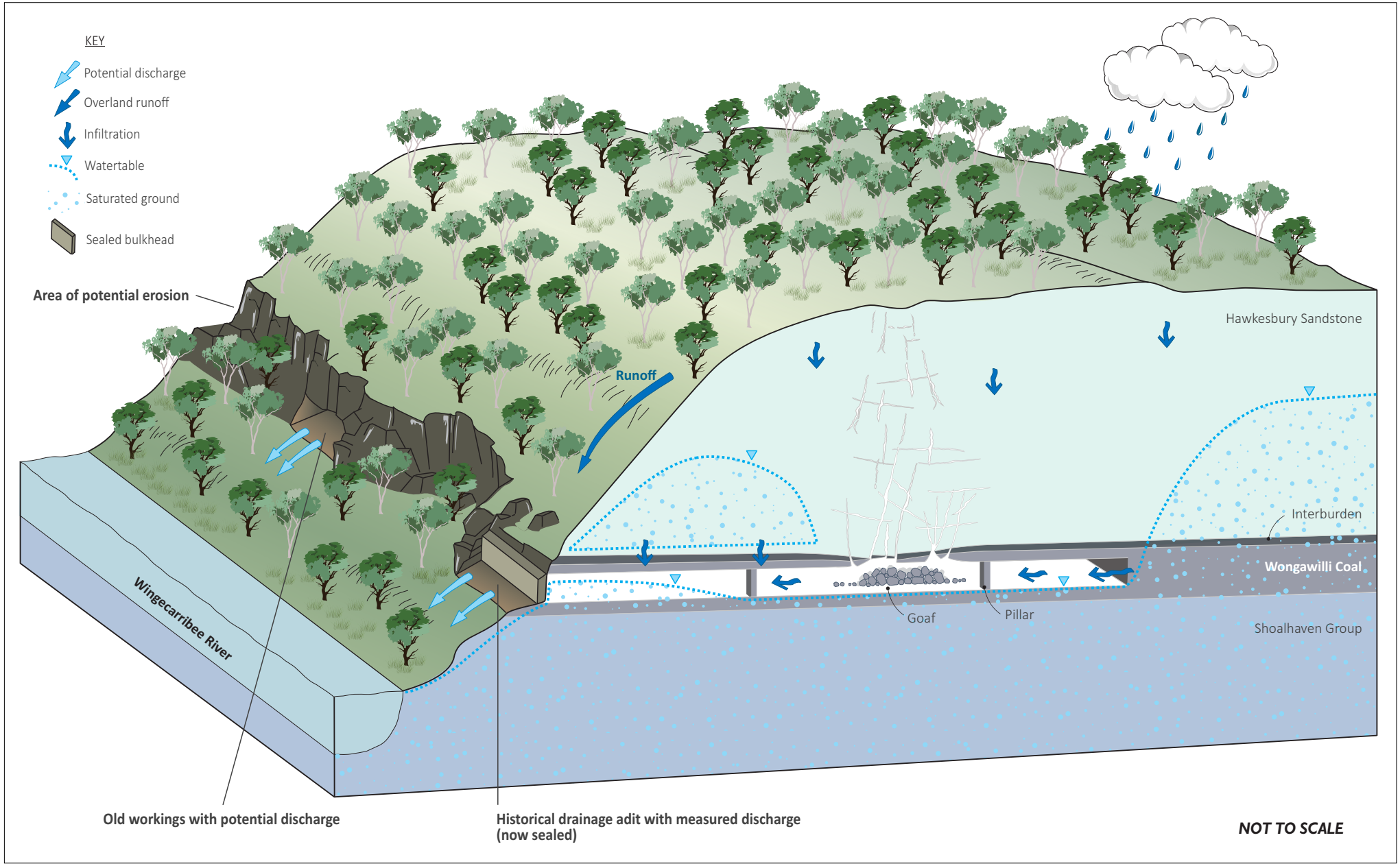
## 6.2 Hume Coal

The location and design of the Berrima Colliery, which allowed for groundwater to drain via gravity into the Wingecarribee River, is very different to the location and design of the Hume Coal Project, where mine water and groundwater inflow will be progressively captured and stored behind bulkheads.

As outlined in Section 5.3, the mining method at Hume Coal includes the progressive backfilling of panels with reject waste material and injection of surplus water behind sealed bulkheads. The mine design will allow for the previously depressurised overlying strata to re-saturate. This process will be completed many times a year to apply less drainage stress to the groundwater system compared to leaving open and dewatered mine voids. By sealing panels and actively injecting water underground throughout the life of mine, the potential impact of the project on the groundwater system will be reduced and groundwater recovery accelerated (in comparison to a case where water is not reinjected underground, such as at Berrima Colliery).

Although it is not explicitly simulated in the RTS groundwater model, Townley (2020) states that the modelling approach is conservative. If backfilling were simulated in more detail, including injection of water into voids behind bulkheads, the groundwater model would predict faster groundwater level recovery after the end of mining and smaller values of maximum drawdown. This would be apparent in every individual simulation undertaken during uncertainty analysis, and therefore in the statistics of the ensemble.

Figure 6.2 provides a schematic of the Hume Coal proposal post-mining where the groundwater levels have recovered to pre-mining conditions.

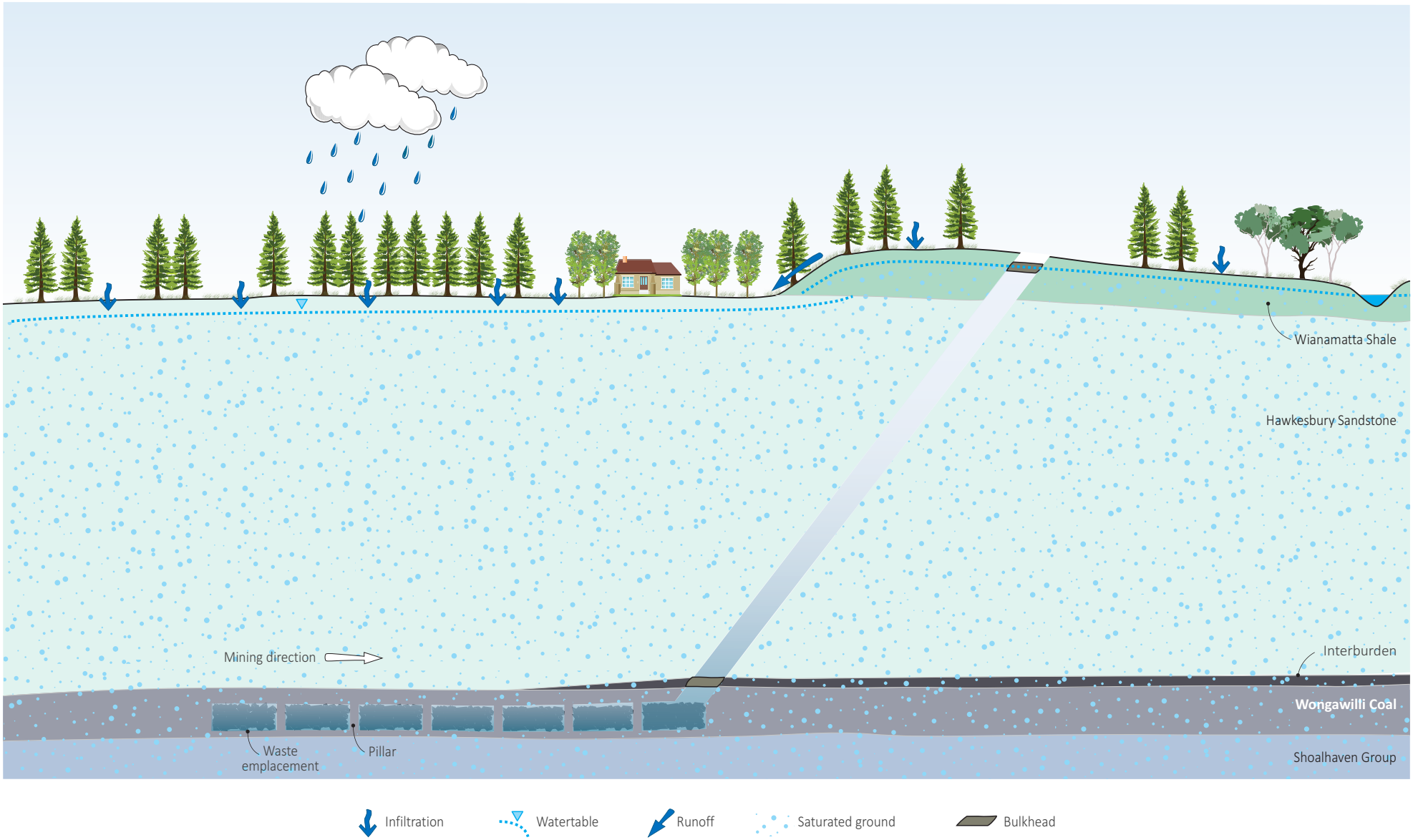



Berrima Colliery – End of mining closure schematic

Hume Coal Pty Ltd

Hume Coal and Berrima Mine Comparison

Figure 6.1




Hume Coal Project – End of mining conceptual schematic

Hume Coal Pty Ltd

Hume Coal and Berrima Mine Comparison

Figure 6.2

EMM creating opportunities

HUMECOAL PROJECT

# 7 Summary of mine comparison

Table 7.1 presents a summary of the Hume Coal and Berrima Colliery mine comparison; details of the comparisons are presented in greater detail following.

**Table 7.1 Summary of Hume Coal and Berrima Colliery comparison**

| Feature | Similarities | Differences | Implications |
|---|---|---|---|
| Landscape location | Both locations are within the Southern Coalfield in the Sydney Basin. | • Berrima Colliery mine workings are in close proximity to Wingecarribee River.<br>• Due to original mine access via Wongawilli Coal seam outcrop and due to mine water management, groundwater has been discharging from the Berrima Colliery drain adit into river for approximately 100 years.<br>• Hume Coal Project will access Wongawilli Coal seam via drifts from ground surface.<br>• The distance of proposed Hume Coal mine from a surficial outcrop of the Wongawilli Coal seam is at least 500 m, and to the north-west of the Project area which is at a higher elevation than in the mine area. | • Due to Hume Coal Project distance to Wongawilli Coal seam outcrop and difference in access, Hume Coal Project will not result in free drainage groundwater discharge to a watercourse.<br>• Depressurisation of Hawkesbury Sandstone at Hume Coal Project will be considerably less due to location in landscape and mining method (Figure 5.5). |
| Mining method | None. | • Berrima Colliery had some areas of full pillar extraction.<br>• Historical access to mine workings at Berrima Colliery was via an adit into outcropping Wongawilli seam.<br>• Hume Coal will maintain pillars to limit subsidence and goaf development.<br>• Hume Coal will progressively place rejects in mined panels and will actively inject water behind sealed bulkheads. | • Hume Coal Project mine will be more stable with low risk of subsidence.<br>• Groundwater recovery will occur faster at Hume Coal Project due to injection of water behind sealed bulkheads. |
| Geology | Stratigraphy is generally consistent at both locations. | • Wianamatta Group shale is absent at Berrima Colliery.<br>• Depth to mining the Wongawilli Coal seam is generally shallower at Berrima Colliery. | • See below (hydrogeology). |

**Table 7.1 Summary of Hume Coal and Berrima Colliery comparison**

| Feature | Similarities | Differences | Implications |
|---|---|---|---|
| Hydrogeology | • Same dominant hydrostratigraphic units (aquifers and aquitards) at both locations.<br>• Hydraulic pressure in the lower Hawkesbury Sandstone will decline due to mining at both locations. | • Hume Coal Project has a substantially more spatially and temporally extensive monitoring network and hydraulic testing dataset compared with Berrima Colliery. | • Baseline monitoring at Hume Coal Project informs for a more robust conceptual understanding and allows continued verification of groundwater model and review of potential impacts. This also allows for a more accurate groundwater model, leading to better understanding and management of potential impacts in advance of them occurring.<br>• Observations (measured discharge) at Berrima Colliery can be used as proxy for mine water inflows to inform Hume Coal Project groundwater model calibration. |
| Mine water management | None | • Berrima Colliery discharged mine water to Wingecarribee River for approximately 100 years.<br>• Gravity flow of intercepted groundwater from workings to river discharge at Berrima Colliery.<br>• Hume Coal will progressively backfill panels with waste reject and inject water behind sealed bulkheads. | • Zero discharge planned at Hume Coal Project.<br>• Reduced groundwater infiltration to mine workings at Hume Coal Project due to progressive sealing of panels.<br>• Faster groundwater recovery at the Hume Coal Project. |

## 7.1 Summary of key differences

### 7.1.1 Hydrogeology

The amount of groundwater data between the Berrima Colliery and Hume Coal sites are significantly different. The Berrima Colliery had been in operation prior to the 1900s and only recently (~2008) a small number of groundwater monitoring locations have been monitored. The Hume Coal Project has had numerous monitoring locations installed with monitoring occurring over many years, providing a considerable baseline dataset. The Hume Coal Project uses the information obtained from the project's monitoring network but also takes into consideration other available data as needed to further enhance the reliability of the predicted effects, and also to expand the spatial coverage of available data.

The substantially larger field dataset available for the Hume Coal Project compared with the Berrima Colliery allows for a substantially more enhanced conceptual hydrogeological understanding and substantially more accurate impact predictions.

### 7.1.2 Mining Method

The major differences in mining techniques used at Berrima Colliery and proposed at the Hume Coal Project is that the project will leave significant amounts of coal in place forming pillars to support the geological material above the mine. Waste material will be stored in individual mined panels and then sealed with designed bulkheads. Water will then be injected into the sealed panels. This mining method and progressive closure of the panels over the life of mine will reduce the time needed for the groundwater system to recover towards pre-mining levels.

In comparison, groundwater has been discharging from the Berrima Colliery to the surface environment from the old mine workings for around 100 years.

The mining methods at the Berrima Colliery enabled the roof of the mine to partially collapse and as such had fracturing propagating into the roof of the mine and up into the overlying Hawkesbury Sandstone. The Hume Coal Project has a significantly different mine design that will ensure stable roof and no intended fracturing in the overlying strata. The Hawkesbury Sandstone will not be damaged, fractured or dewatered as a result of the Hume Coal Project mining method.

The mining method for the Hume Coal Project will allow for substantially greater protection of the Hawkesbury Sandstone aquifer compared to the mining method used at the Berrima Colliery, due to prevention of propagating fractures and faster groundwater system recovery time.

### 7.1.3 Mine closure

Mine closure is another feature that is very different between the two locations. This is mostly due to the different timeframes of the projects and the different regulatory framework under which the Berrima Colliery operated.

Since mining has ceased at Berrima Colliery in 2013, there has been limited change to the groundwater discharge from the drainage adit, although it is acknowledged that Boral have now sealed entry points with bulkheads. The mine workings are in some areas around 150 years old, and parts of them are now inaccessible. The proximity to the surface and the condition of these workings in some places along the river escarpment is unknown. The potential for future erosion events poses a risk of exposing old workings and damaging the integrity of any bulkhead seals installed in the adits or exposing the mine workings directly. The bulkheads at Berrima Colliery would need to be effective at retaining water in the mine workings in perpetuity to limit the risk of a future releases to the Wingecarribee River.

By contrast, the Hume Coal Project will access the coal seam via inclined tunnels (or “drifts”) from the surface. The bulkheads will be installed underground, not at the surface. The bulkheads only need to perform an active function duration the active operational mine life, following which time the drifts will be sealed, and the remainder of the mine workings will naturally fill with water. This process will result in re-equilibration of the groundwater pressures across the underground bulkhead seals.

The Hume Coal Project will provide an enhanced groundwater recovery as excess water, waste material will be stored underground in mined panels, and no groundwater will be discharged to the surface environment.

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Attachment B

# Packer test data

Strata Control Technology

**REPORT TO:**

**PARSONS BRINCKERHOFF**

# Packer Test Report - Boreholes HU0040CH and HU0077CH

**PBA4159**

Mining Research and Consulting Group
SCT Operations Pty Ltd PO Box 824 Wollongong NSW 2520 Australia
sctnsw@sct.gs

| | |
|---|---|
| **REPORT TO** | Louisa Rochford<br>Senior Hydrogeologist<br>Parsons Brinckerhoff<br>GPO Box 5394<br>SYDNEY NSW 2001 |
| **SUBJECT** | Packer Test Report – Boreholes HU0040CH and HU0077CH |
| **REPORT NO** | PBA4159 |
| **PREPARED BY** | Craig Stemp |
| **DATE** | 19 September 2013 |

Craig Stemp
Mining Engineer

Winton J. Gale
Managing Director

## SUMMARY

This report presents the results of Lugeon style packer testing conducted on specific horizons in Boreholes HU0040CH and HU0077CH for Hume Coal. SCT were commissioned by Parsons Brinckerhoff (PB), groundwater consultants for Hume Coal, to conduct packer testing to assist PB in characterising the conductivity of the strata in piezometer holes. Selected horizons were targeted by PB and SCT were instructed to test these intervals. Test interval lengths, typically 6.5-8.5m, were chosen to encompass each target interval.

| Borehole | Test Interval | | Interval Length (m) | Conductivity m/s | Horizon | No. of Fractures |
|---|---|---|---|---|---|---|
| | From (m) | To (m) | | | | |
| HU0040CH | 69.65 | 76.15 | 6.5 | 3.0E-09 | Stone | not logged |
| HU0040CH | 75.65 | 84.15 | 8.5 | 1.1E-07 | Stone | not logged |
| HU0040CH | 99.65 | 108.15 | 8.5 | 1.4E-07 | Stone | not logged |
| HU0040CH | 108.65 | 117.15 | 8.5 | 2.4E-06 | Stone | not logged |
| HU0040CH | 114.65 | 123.15 | 8.5 | 9.9E-07 | Coal | not logged |
| HU0077CH | 75.7 | 84.2 | 8.5 | 2.2E-07 | Stone | 2 |
| HU0077CH | 81.7 | 90.2 | 8.5 | 8.7E-08 | Coal | not logged |
| HU0077CH | 90.7 | 98.59 | 7.89 | 1.0E-11 | Stone | 5 |

There is no distinguishable trend found in the conductivity vs depth profile. The variability of results from no flow to relatively high conductivities indicates that the hydraulic conductivity is primarily facilitated by fracture flow. The number of fractures, fracture aperture and roughness all contribute to the magnitude of conductivity.

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APPENDIX 3 – PACKER TEST RESULTS ..... A3-1

## 1. INTRODUCTION

This report presents the results of Lugeon style packer testing conducted on specific horizons in Boreholes HU0040CH and HU0077CH for Hume Coal. SCT were commissioned by Parsons Brinckerhoff (PB), groundwater consultants for Hume Coal, to conduct packer testing to assist PB in characterising the conductivity of the strata in piezometer holes. Selected horizons were targeted by PB and SCT were instructed to test these intervals. Test interval lengths, typically 6.5-8.5m, were chosen to encompass each target interval.

## 2. METHOD

Packer testing was conducted by SCT in Boreholes HU0040CH and HU0077CH which was drilled by Highland Drilling. The packer testing method involved is a Lugeon style straddle packer test in HQ rods. The test is conducted in 5 pressure stages in which pressure is increased then subsequently decreased. Flow is recorded every minute for 10 minutes at each pressure stage.

## 3. CALCULATIONS

Hydraulic conductivity calculations use the average of the CANMET, Hoek and Bray, and Houlsby methods. The formulae are outlined in the water pressure test result sheets (Appendix 3). The calculations use the Flow/Head gradient which is an average of the plotted test data vs. Total Head. Zero conductivity denotes the lower limit of this style of test which is of the order of $1x10^{-11}$m/s.

## 4. HYDRAULIC CONDUCTIVITY RESULTS

The hydraulic conductivity results for the intervals tested in hole HU0040CH are summarised in Table 1.

**Table 1: Hydraulic Conductivity test results for hole HU0040CH**

| Borehole | Test Interval | | Interval Length (m) | Conductivity m/s | Horizon |
|---|---|---|---|---|---|
| | From (m) | To (m) | | | |
| HU0040CH | 69.65 | 76.15 | 6.5 | 3.0E-09 | Stone |
| HU0040CH | 75.65 | 84.15 | 8.5 | 1.1E-07 | Stone |
| HU0040CH | 99.65 | 108.15 | 8.5 | 1.4E-07 | Stone |
| HU0040CH | 108.65 | 117.15 | 8.5 | 2.4E-06 | Stone |
| HU0040CH | 114.65 | 123.15 | 8.5 | 9.9E-07 | Coal |

The hydraulic conductivity results for the intervals tested in hole HU0077CH are summarised in Table 2.

**Table 2: Hydraulic Conductivity test results for hole HU0077CH**

| Borehole | Test Interval | | Interval Length (m) | Conductivity m/s | Horizon |
|---|---|---|---|---|---|
| | From (m) | To (m) | | | |
| HU0077CH | 75.7 | 84.2 | 8.5 | 2.2E-07 | Stone |
| HU0077CH | 81.7 | 90.2 | 8.5 | 8.7E-08 | Coal |
| HU0077CH | 90.7 | 98.59 | 7.89 | 1.0E-11 | Stone |

The conductivity vs. depth profile for HU0040CH and HU0077CH is presented in Appendix1. The hydraulic conductivity summary including proposed and actual test intervals, fracture frequency and horizons is tabulated in Appendix 2. Raw packer test results and analyses are presented Appendix 3.

## 5. DISCUSSION

The hydraulic conductivity for the Wongawilli Seam in holes HU0040CH and HU0077CH was found to be $9.9x10^{-7}$m/s and $8.7x10^{-8}$m/s, respectively. The hydraulic conductivity for the stone horizons in holes HU0040CH and HU0077CH was found to range between $2.4x10^{-6}$m/s and $1x10^{-11}$m/s or less, which is at the limit of the test sensitivity.

There is no distinguishable trend found in the conductivity vs depth profile in Appendix 1. The variability of results from no flow to relatively high conductivities indicates that the hydraulic conductivity is primarily facilitated by fracture flow. The number of fractures, fracture aperture and roughness all contribute to the magnitude of conductivity.

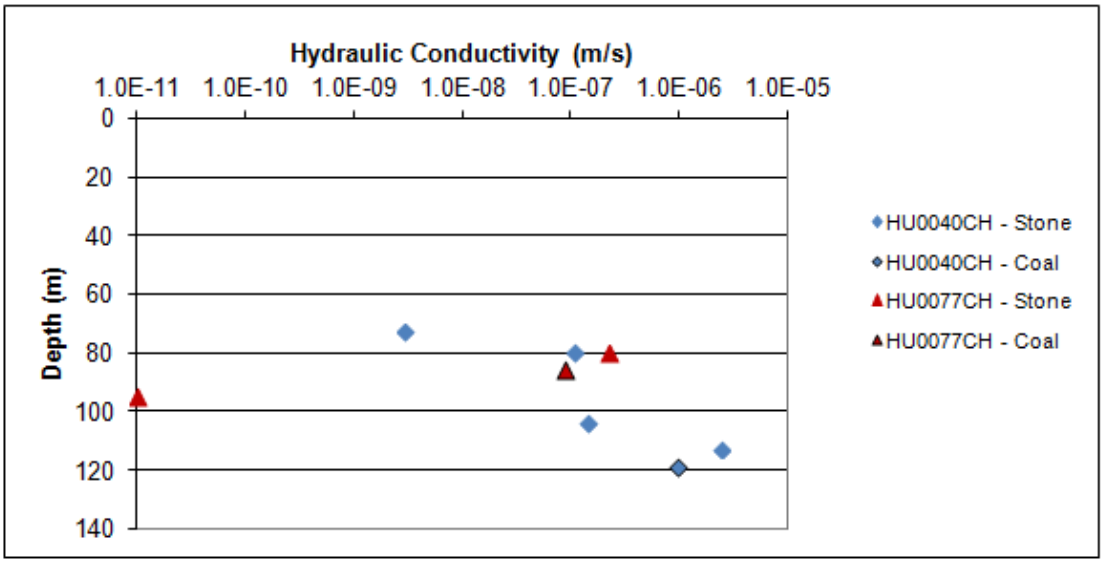
Note that defect logs for most horizons and stratigraphic horizons were unable to be obtained and have therefore not been assessed in relation to conductivity in this program of work.

# APPENDIX 1 HYDRAULIC CONDUCTIVITY SUMMARY

## Hydraulic Conductivity Summary

| | | | |
|---|---|---|---|
| **Mine/Lease:** | | Hume Coal | |
| **Hole:** | | HU0040CH & HU0077CH | |
| **Total Depth (m):** | | 123.15 & 98.59 | |
| **No. of Tests:** | 8 | **Test Interval (m):** | 6.5, 7.9 & 8.5 |

**Hydraulic Conductivity vs Depth**




Note: Tests with conductivity less than the test sensitivity are plotted at 1.00E-11m/s

# APPENDIX 2 – CONDUCTIVITY SUMMARY

| Borehole | Target Horizon | | Test Interval | | Interval Length (m) | Conductivity m/s | Horizon | No. of Fractures |
|---|---|---|---|---|---|---|---|---|
| | From (m) | To (m) | From (m) | To (m) | | | | |
| HU0040CH | 70 | 76 | 69.65 | 76.15 | 6.5 | 3.0E-09 | Stone | not logged |
| HU0040CH | 77 | 83 | 75.65 | 84.15 | 8.5 | 1.1E-07 | Stone | not logged |
| HU0040CH | 101 | 107 | 99.65 | 108.15 | 8.5 | 1.4E-07 | Stone | not logged |
| HU0040CH | 110 | 116 | 108.65 | 117.15 | 8.5 | 2.4E-06 | Stone | not logged |
| HU0040CH | 117 | 123 | 114.65 | 123.15 | 8.5 | 9.9E-07 | Coal | not logged |
| HU0077CH | 77 | 83 | 75.7 | 84.2 | 8.5 | 2.2E-07 | Stone | 2 |
| HU0077CH | 83 | 89 | 81.7 | 90.2 | 8.5 | 8.7E-08 | Coal | not logged |
| HU0077CH | 90 | 96 | 90.7 | 98.59 | 7.89 | 1.0E-11 | Stone | 5 |

Conductivity based on test interval length

# APPENDIX 3 – PACKER TEST RESULTS

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal DATE: 03-Sep-13 HOLE DIP: 90

DIP Direction: -

SITE NUMBER: HD Rig 20 BORE I.D.: HU0040CH BORE NAME: HU0040CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 123.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 114.65 | | |
| LENGTH OF STAGE TEST (m): | 8.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 24.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 180 | 1 | 483 | 518 | | | 35 | 35 |
| 180 | 2 | 518 | 551 | | | 33 | 33 |
| 180 | 3 | 551 | 588 | | | 37 | 37 |
| 180 | 4 | 588 | 624 | | | 36 | 36 |
| 180 | 5 | 624 | 666 | | | 42 | 42 |
| 180 | 6 | 666 | 705 | | | 39 | 39 |
| 180 | 7 | 705 | 735 | | | 30 | 30 |
| 180 | 8 | 735 | 770 | | | 35 | 35 |
| 180 | 9 | 770 | 810 | | | 40 | 40 |
| 180 | 10 | 810 | 839 | | | 29 | 29 |
| 360 | 1 | 1880 | 1929 | | | 49 | 49 |
| 360 | 2 | 1929 | 1973 | | | 44 | 44 |
| 360 | 3 | 1973 | 2015 | | | 42 | 42 |
| 360 | 4 | 2015 | 2055 | | | 40 | 40 |
| 360 | 5 | 2055 | 2096 | | | 41 | 41 |
| 360 | 6 | 2096 | 2138 | | | 42 | 42 |
| 360 | 7 | 2138 | 2181 | | | 43 | 43 |
| 360 | 8 | 2181 | 2222 | | | 41 | 41 |
| 360 | 9 | 2222 | 2264 | | | 42 | 42 |
| 360 | 10 | 2264 | 2305 | | | 41 | 41 |
| 540 | 1 | 2350 | 2396 | | | 46 | 46 |
| 540 | 2 | 2396 | 2438 | | | 42 | 42 |
| 540 | 3 | 2438 | 2482 | | | 44 | 44 |
| 540 | 4 | 2482 | 2525 | | | 43 | 43 |
| 540 | 5 | 2525 | 2563 | | | 38 | 38 |
| 540 | 6 | 2563 | 2603 | | | 40 | 40 |
| 540 | 7 | 2603 | 2644 | | | 41 | 41 |
| 540 | 8 | 2644 | 2684 | | | 40 | 40 |
| 540 | 9 | 2684 | 2725 | | | 41 | 41 |
| 540 | 10 | 2725 | 2766 | | | 41 | 41 |
| 360 | 1 | 2782 | 2818 | | | 36 | 36 |
| 360 | 2 | 2818 | 2850 | | | 32 | 32 |
| 360 | 3 | 2850 | 2883 | | | 33 | 33 |
| 360 | 4 | 2883 | 2915 | | | 32 | 32 |
| 360 | 5 | 2915 | 2949 | | | 34 | 34 |
| 360 | 6 | 2949 | 2980 | | | 31 | 31 |
| 360 | 7 | 2980 | 3010 | | | 30 | 30 |
| 360 | 8 | 3010 | 3040 | | | 30 | 30 |
| 360 | 9 | 3040 | 3070 | | | 30 | 30 |
| 360 | 10 | 3070 | 3100 | | | 30 | 30 |
| 180 | 1 | 3110 | 3131 | | | 21 | 21 |

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|---|---|---|---|---|---|---|---|
| 180 | 2 | 3131 | 3154 | | | 23 | 23 |
| 180 | 3 | 3154 | 3176 | | | 22 | 22 |
| 180 | 4 | 3176 | 3198 | | | 22 | 22 |
| 180 | 5 | 3198 | 3219 | | | 21 | 21 |
| 180 | 6 | 3219 | 3242 | | | 23 | 23 |
| 180 | 7 | 3242 | 3264 | | | 22 | 22 |
| 180 | 8 | 3264 | 3285 | | | 21 | 21 |
| 180 | 9 | 3285 | 3306 | | | 21 | 21 |
| 180 | 10 | 3306 | 3328 | | | 22 | 22 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal DATE: 04-Sep-13 HOLE DIP: 90

DIP Direction: -

SITE NUMBER: HD Rig 20 BORE I.D.: HU0040CH BORE NAME: HU0040CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 117.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 108.65 | | |
| LENGTH OF STAGE TEST (m): | 8.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 24.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 180 | 1 | 3950 | 4020 | | | 70 | 70 |
| 180 | 2 | 4020 | 4097 | | | 77 | 77 |
| 180 | 3 | 4097 | 4182 | | | 85 | 85 |
| 180 | 4 | 4182 | 4258 | | | 76 | 76 |
| 180 | 5 | 4258 | 4309 | | | 51 | 51 |
| 180 | 6 | 4309 | 4381 | | | 72 | 72 |
| 180 | 7 | 4381 | 4450 | | | 69 | 69 |
| 180 | 8 | 4450 | 4519 | | | 69 | 69 |
| 180 | 9 | 4519 | 4588 | | | 69 | 69 |
| 180 | 10 | 4588 | 4656 | | | 68 | 68 |
| 250 | 1 | 5072 | 5150 | | | 78 | 78 |
| 250 | 2 | 5150 | 5247 | | | 97 | 97 |
| 250 | 3 | 5247 | 5310 | | | 63 | 63 |
| 250 | 4 | 5310 | 5390 | | | 80 | 80 |
| 250 | 5 | 5390 | 5474 | | | 84 | 84 |
| 250 | 6 | 5474 | 5567 | | | 93 | 93 |
| 250 | 7 | 5567 | 5637 | | | 70 | 70 |
| 250 | 8 | 5637 | 5717 | | | 80 | 80 |
| 250 | 9 | 5717 | 5797 | | | 80 | 80 |
| 250 | 10 | 5797 | 5876 | | | 79 | 79 |
| 300 | 1 | 5910 | 5996 | | | 86 | 86 |
| 300 | 2 | 5996 | 6082 | | | 86 | 86 |
| 300 | 3 | 6082 | 6160 | | | 78 | 78 |
| 300 | 4 | 6275 | 6364 | | | 89 | 89 |
| 300 | 5 | 6364 | 6448 | | | 84 | 84 |
| 300 | 6 | 6448 | 6507 | | | 59 | 59 |
| 300 | 7 | 6507 | 6585 | | | 78 | 78 |
| 300 | 8 | 6585 | 6649 | | | 64 | 64 |
| 300 | 9 | 6649 | 6740 | | | 91 | 91 |
| 300 | 10 | 6740 | 6799 | | | 59 | 59 |
| 250 | 1 | 6820 | 6884 | | | 64 | 64 |
| 250 | 2 | 6884 | 6950 | | | 66 | 66 |
| 250 | 3 | 6950 | 7011 | | | 61 | 61 |
| 250 | 4 | 7011 | 7080 | | | 69 | 69 |
| 250 | 5 | 7080 | 7140 | | | 60 | 60 |
| 250 | 6 | 7140 | 7210 | | | 70 | 70 |
| 250 | 7 | 7210 | 7260 | | | 50 | 50 |
| 250 | 8 | 7260 | 7321 | | | 61 | 61 |
| 250 | 9 | 7321 | 7379 | | | 58 | 58 |
| 250 | 10 | 7379 | 7438 | | | 59 | 59 |
| 180 | 1 | 7455 | 7504 | | | 49 | 49 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 180 | 2 | 7504 | 7551 | | | 47 | 47 |
| 180 | 3 | 7551 | 7598 | | | 47 | 47 |
| 180 | 4 | 7598 | 7649 | | | 51 | 51 |
| 180 | 5 | 7649 | 7689 | | | 40 | 40 |
| 180 | 6 | 7689 | 7737 | | | 48 | 48 |
| 180 | 7 | 7737 | 7785 | | | 48 | 48 |
| 180 | 8 | 7785 | 7825 | | | 40 | 40 |
| 180 | 9 | 7825 | 7870 | | | 45 | 45 |
| 180 | 10 | 7870 | 7914 | | | 44 | 44 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal DATE: 04-Sep-13 HOLE DIP: 90

DIP Direction: -

SITE NUMBER: HD Rig 20 BORE I.D.: HU0040CH BORE NAME: HU0040CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 108.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 99.65 | | |
| LENGTH OF STAGE TEST (m): | 8.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 24.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 180 | 1 | 8242 | 8248 | | | 6 | 6 |
| 180 | 2 | 8248 | 8257 | | | 9 | 9 |
| 180 | 3 | 8257 | 8263.3 | | | 6.3 | 6.3 |
| 180 | 4 | 8263.3 | 8269.5 | | | 6.2 | 6.2 |
| 180 | 5 | 8269.5 | 8275.5 | | | 6 | 6 |
| 180 | 6 | 8275.5 | 8281 | | | 5.5 | 5.5 |
| 180 | 7 | 8281 | 8286 | | | 5 | 5 |
| 180 | 8 | 8286 | 8291.5 | | | 5.5 | 5.5 |
| 180 | 9 | 8291.5 | 8297 | | | 5.5 | 5.5 |
| 180 | 10 | 8297 | 8301.5 | | | 4.5 | 4.5 |
| 360 | 1 | 311 | 323.5 | | | 12.5 | 12.5 |
| 360 | 2 | 323.5 | 333.2 | | | 9.7 | 9.7 |
| 360 | 3 | 333.2 | 334 | | | 0.8 | 0.8 |
| 360 | 4 | 334 | 347 | | | 13 | 13 |
| 360 | 5 | 347 | 354.5 | | | 7.5 | 7.5 |
| 360 | 6 | 354.5 | 360.5 | | | 6 | 6 |
| 360 | 7 | 360.5 | 366.5 | | | 6 | 6 |
| 360 | 8 | 366.5 | 373 | | | 6.5 | 6.5 |
| 360 | 9 | 373 | 379 | | | 6 | 6 |
| 360 | 10 | 379 | 384.5 | | | 5.5 | 5.5 |
| 540 | 1 | 389 | 403 | | | 14 | 14 |
| 540 | 2 | 403 | 412.5 | | | 9.5 | 9.5 |
| 540 | 3 | 412.5 | 421 | | | 8.5 | 8.5 |
| 540 | 4 | 421 | 427.5 | | | 6.5 | 6.5 |
| 540 | 5 | 427.5 | 434.5 | | | 7 | 7 |
| 540 | 6 | 434.5 | 442 | | | 7.5 | 7.5 |
| 540 | 7 | 442 | 448 | | | 6 | 6 |
| 540 | 8 | 448 | 454 | | | 6 | 6 |
| 540 | 9 | 454 | 460 | | | 6 | 6 |
| 540 | 10 | 460 | 466 | | | 6 | 6 |
| 360 | 1 | 467.5 | 472 | | | 4.5 | 4.5 |
| 360 | 2 | 472 | 476 | | | 4 | 4 |
| 360 | 3 | 476 | 480 | | | 4 | 4 |
| 360 | 4 | 480 | 485 | | | 5 | 5 |
| 360 | 5 | 967 | 971.5 | | | 4.5 | 4.5 |
| 360 | 6 | 971.5 | 975.6 | | | 4.1 | 4.1 |
| 360 | 7 | 975.6 | 979.5 | | | 3.9 | 3.9 |
| 360 | 8 | 979.5 | 983.5 | | | 4 | 4 |
| 360 | 9 | 983.5 | 987.5 | | | 4 | 4 |
| 360 | 10 | 987.5 | 991 | | | 3.5 | 3.5 |
| 180 | 1 | 95 | 97.3 | | | 2.3 | 2.3 |

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|---|---|---|---|---|---|---|---|
| 180 | 2 | 97.3 | 99.5 | | | 2.2 | 2.2 |
| 180 | 3 | 99.5 | 102.3 | | | 2.8 | 2.8 |
| 180 | 4 | 102.3 | 105.7 | | | 3.4 | 3.4 |
| 180 | 5 | 105.7 | 107.2 | | | 1.5 | 1.5 |
| 180 | 6 | 107.2 | 109.2 | | | 2 | 2 |
| 180 | 7 | 109.2 | 109.4 | | | 0.2 | 0.2 |
| 180 | 8 | 109.4 | 109.5 | | | 0.1 | 0.1 |
| 180 | 9 | 109.5 | 112 | | | 2.5 | 2.5 |
| 180 | 10 | 112 | 114.2 | | | 2.2 | 2.2 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal DATE: 04-Sep-13 HOLE DIP: 90

DIP Direction: -

SITE NUMBER: HD Rig 20 BORE I.D.: HU0040CH BORE NAME: HU0040CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 84.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 75.65 | STATIC GROUNDWATER LEVEL: (m below ground level) | 24.0 |
| LENGTH OF STAGE TEST (m): | 8.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 150 | 1 | 188.5 | 194.6 | | | 6.1 | 6.1 |
| 150 | 2 | 194.6 | 199.4 | | | 4.8 | 4.8 |
| 150 | 3 | 199.4 | 204 | | | 4.6 | 4.6 |
| 150 | 4 | 204 | 207.8 | | | 3.8 | 3.8 |
| 150 | 5 | 207.8 | 211.5 | | | 3.7 | 3.7 |
| 150 | 6 | 211.5 | 215.4 | | | 3.9 | 3.9 |
| 150 | 7 | 215.4 | 219 | | | 3.6 | 3.6 |
| 150 | 8 | 219 | 222.8 | | | 3.8 | 3.8 |
| 150 | 9 | 222.8 | 226.4 | | | 3.6 | 3.6 |
| 150 | 10 | 226.4 | 229 | | | 2.6 | 2.6 |
| 300 | 1 | 232.5 | 238.8 | | | 6.3 | 6.3 |
| 300 | 2 | 238.8 | 244.5 | | | 5.7 | 5.7 |
| 300 | 3 | 244.5 | 250.8 | | | 6.3 | 6.3 |
| 300 | 4 | 250.8 | 258 | | | 7.2 | 7.2 |
| 300 | 5 | 258 | 259 | | | 1 | 1 |
| 300 | 6 | 259 | 260 | | | 1 | 1 |
| 300 | 7 | 260 | 262.5 | | | 2.5 | 2.5 |
| 300 | 8 | 262.5 | 266.5 | | | 4 | 4 |
| 300 | 9 | 266.5 | 270.5 | | | 4 | 4 |
| 300 | 10 | 270.5 | 274.5 | | | 4 | 4 |
| 450 | 1 | 278 | 283.5 | | | 5.5 | 5.5 |
| 450 | 2 | 283.5 | 288.2 | | | 4.7 | 4.7 |
| 450 | 3 | 288.2 | 298 | | | 9.8 | 9.8 |
| 450 | 4 | 298 | 302 | | | 4 | 4 |
| 450 | 5 | 302 | 308 | | | 6 | 6 |
| 450 | 6 | 308 | 312 | | | 4 | 4 |
| 450 | 7 | 312 | 317 | | | 5 | 5 |
| 450 | 8 | 317 | 321.6 | | | 4.6 | 4.6 |
| 450 | 9 | 321.6 | 326.5 | | | 4.9 | 4.9 |
| 450 | 10 | 326.5 | 330.5 | | | 4 | 4 |
| 300 | 1 | 332 | 334.8 | | | 2.8 | 2.8 |
| 300 | 2 | 334.8 | 337.6 | | | 2.8 | 2.8 |
| 300 | 3 | 337.6 | 340.4 | | | 2.8 | 2.8 |
| 300 | 4 | 340.4 | 343 | | | 2.6 | 2.6 |
| 300 | 5 | 343 | 345.6 | | | 2.6 | 2.6 |
| 300 | 6 | 345.6 | 348.2 | | | 2.6 | 2.6 |
| 300 | 7 | 348.2 | 351.5 | | | 3.3 | 3.3 |
| 300 | 8 | 351.5 | 353.8 | | | 2.3 | 2.3 |
| 300 | 9 | 353.8 | 356.2 | | | 2.4 | 2.4 |
| 300 | 10 | 356.2 | 358.6 | | | 2.4 | 2.4 |
| 150 | 1 | 364.1 | 365.1 | | | 1 | 1 |

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|---|---|---|---|---|---|---|---|
| 150 | 2 | 365.1 | 366.3 | | | 1.2 | 1.2 |
| 150 | 3 | 366.3 | 367.5 | | | 1.2 | 1.2 |
| 150 | 4 | 367.5 | 368.8 | | | 1.3 | 1.3 |
| 150 | 5 | 368.8 | 369.5 | | | 0.7 | 0.7 |
| 150 | 6 | 369.5 | 370.2 | | | 0.7 | 0.7 |
| 150 | 7 | 370.2 | 371 | | | 0.8 | 0.8 |
| 150 | 8 | 371 | 371.6 | | | 0.6 | 0.6 |
| 150 | 9 | 371.6 | 372.5 | | | 0.9 | 0.9 |
| 150 | 10 | 372.5 | 373.2 | | | 0.7 | 0.7 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 05-Sep-13 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 20 | BORE I.D.: HU0040CH | BORE NAME: HU0040CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 76.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 69.65 | STATIC GROUNDWATER LEVEL: (m below ground level) | 24.0 |
| LENGTH OF STAGE TEST (m): | 6.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 200 | 1 | 634 | 634 | | | 0 | 0 |
| 200 | 2 | 634 | 634 | | | 0 | 0 |
| 200 | 3 | 634 | 634 | | | 0 | 0 |
| 200 | 4 | 634 | 634 | | | 0 | 0 |
| 200 | 5 | 634 | 634.1 | | | 0.1 | 0.1 |
| 200 | 6 | 634.1 | 634.1 | | | 0 | 0 |
| 200 | 7 | 634.1 | 634.2 | | | 0.1 | 0.1 |
| 200 | 8 | 634.2 | 634.2 | | | 0 | 0 |
| 200 | 9 | 634.2 | 634.2 | | | 0 | 0 |
| 200 | 10 | 634.2 | 634.25 | | | 0.05 | 0.05 |
| 250 | 1 | 634.5 | 634.7 | | | 0.2 | 0.2 |
| 250 | 2 | 634.7 | 634.8 | | | 0.1 | 0.1 |
| 250 | 3 | 634.8 | 634.9 | | | 0.1 | 0.1 |
| 250 | 4 | 634.9 | 635 | | | 0.1 | 0.1 |
| 250 | 5 | 635 | 635.1 | | | 0.1 | 0.1 |
| 250 | 6 | 635.1 | 635.2 | | | 0.1 | 0.1 |
| 250 | 7 | 635.2 | 635.3 | | | 0.1 | 0.1 |
| 250 | 8 | 635.3 | 635.4 | | | 0.1 | 0.1 |
| 250 | 9 | 635.4 | 635.5 | | | 0.1 | 0.1 |
| 250 | 10 | 635.5 | 635.7 | | | 0.2 | 0.2 |
| 350 | 1 | 636.3 | 636.5 | | | 0.2 | 0.2 |
| 350 | 2 | 636.5 | 636.6 | | | 0.1 | 0.1 |
| 350 | 3 | 636.6 | 636.7 | | | 0.1 | 0.1 |
| 350 | 4 | 636.7 | 636.9 | | | 0.2 | 0.2 |
| 350 | 5 | 636.9 | 637 | | | 0.1 | 0.1 |
| 350 | 6 | 637 | 637.2 | | | 0.2 | 0.2 |
| 350 | 7 | 637.2 | 637.4 | | | 0.2 | 0.2 |
| 350 | 8 | 637.4 | 637.5 | | | 0.1 | 0.1 |
| 350 | 9 | 637.5 | 637.8 | | | 0.3 | 0.3 |
| 350 | 10 | 637.8 | 638.2 | | | 0.4 | 0.4 |
| 250 | 1 | 637.8 | 637.8 | | | 0 | 0 |
| 250 | 2 | 637.8 | 637.8 | | | 0 | 0 |
| 250 | 3 | 637.8 | 637.8 | | | 0 | 0 |
| 250 | 4 | 637.8 | 637.8 | | | 0 | 0 |
| 250 | 5 | 637.8 | 637.8 | | | 0 | 0 |
| 250 | 6 | 637.8 | 637.8 | | | 0 | 0 |
| 250 | 7 | 637.8 | 638 | | | 0.2 | 0.2 |
| 250 | 8 | 638 | 638 | | | 0 | 0 |
| 250 | 9 | 638 | 638.2 | | | 0.2 | 0.2 |
| 250 | 10 | 638.2 | 638.2 | | | 0 | 0 |
| 200 | 1 | 638.2 | 638.2 | | | 0 | 0 |

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|---|---|---|---|---|---|---|---|
| 200 | 2 | 638.2 | 638.2 | | | 0 | 0 |
| 200 | 3 | 638.2 | 638.2 | | | 0 | 0 |
| 200 | 4 | 638.2 | 638.3 | | | 0.1 | 0.1 |
| 200 | 5 | 638.3 | 638.4 | | | 0.1 | 0.1 |
| 200 | 6 | 638.4 | 638.4 | | | 0 | 0 |
| 200 | 7 | 638.4 | 638.4 | | | 0 | 0 |
| 200 | 8 | 638.4 | 638.4 | | | 0 | 0 |
| 200 | 9 | 638.4 | 638.4 | | | 0 | 0 |
| 200 | 10 | 638.4 | 638.5 | | | 0.1 | 0.1 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 05-Sep-13 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0077CH | BORE NAME: HU0077CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 98.59 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 90.7 | STATIC GROUNDWATER LEVEL: (m below ground level) | 49.0 |
| LENGTH OF STAGE TEST (TERMINAL) (m): | 7.89 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 150 | 1 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 2 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 3 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 4 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 5 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 6 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 7 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 8 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 9 | 863.9 | 863.9 | | | 0 | 0 |
| 150 | 10 | 863.9 | 863.9 | | | 0 | 0 |
| 300 | 1 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 2 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 3 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 4 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 5 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 6 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 7 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 8 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 9 | 866.1 | 866.1 | | | 0 | 0 |
| 300 | 10 | 866.1 | 866.1 | | | 0 | 0 |
| 450 | 1 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 2 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 3 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 4 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 5 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 6 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 7 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 8 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 9 | 867.5 | 867.5 | | | 0 | 0 |
| 450 | 10 | 867.5 | 867.5 | | | 0 | 0 |
| 300 | 1 | 0 | 0 | | | 0 | 0 |
| 300 | 2 | 0 | 0 | | | 0 | 0 |
| 300 | 3 | 0 | 0 | | | 0 | 0 |
| 300 | 4 | 0 | 0 | | | 0 | 0 |
| 300 | 5 | 0 | 0 | | | 0 | 0 |
| 300 | 6 | 0 | 0 | | | 0 | 0 |
| 300 | 7 | 0 | 0 | | | 0 | 0 |
| 300 | 8 | 0 | 0 | | | 0 | 0 |
| 300 | 9 | 0 | 0 | | | 0 | 0 |
| 300 | 10 | 0 | 0 | | | 0 | 0 |
| 150 | 1 | 0 | 0 | | | 0 | 0 |

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|---|---|---|---|---|---|---|---|
| 150 | 2 | 0 | 0 | | | 0 | 0 |
| 150 | 3 | 0 | 0 | | | 0 | 0 |
| 150 | 4 | 0 | 0 | | | 0 | 0 |
| 150 | 5 | 0 | 0 | | | 0 | 0 |
| 150 | 6 | 0 | 0 | | | 0 | 0 |
| 150 | 7 | 0 | 0 | | | 0 | 0 |
| 150 | 8 | 0 | 0 | | | 0 | 0 |
| 150 | 9 | 0 | 0 | | | 0 | 0 |
| 150 | 10 | 0 | 0 | | | 0 | 0 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 05-Sep-13 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0077CH | BORE NAME: HU0077CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 90.2 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 81.7 | | |
| LENGTH OF STAGE TEST (TERMINAL) (m): | 8.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 49.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 200 | 1 | 119.2 | 124 | | | 4.8 | 4.8 |
| 200 | 2 | 124 | 127.4 | | | 3.4 | 3.4 |
| 200 | 3 | 127.4 | 130.8 | | | 3.4 | 3.4 |
| 200 | 4 | 130.8 | 134.2 | | | 3.4 | 3.4 |
| 200 | 5 | 134.2 | 137.5 | | | 3.3 | 3.3 |
| 200 | 6 | 137.5 | 140.6 | | | 3.1 | 3.1 |
| 200 | 7 | 140.6 | 143.5 | | | 2.9 | 2.9 |
| 200 | 8 | 143.5 | 146.5 | | | 3 | 3 |
| 200 | 9 | 146.5 | 149.6 | | | 3.1 | 3.1 |
| 200 | 10 | 149.6 | 152.5 | | | 2.9 | 2.9 |
| 300 | 1 | 156 | 161.5 | | | 5.5 | 5.5 |
| 300 | 2 | 161.5 | 166.5 | | | 5 | 5 |
| 300 | 3 | 166.5 | 170.3 | | | 3.8 | 3.8 |
| 300 | 4 | 170.3 | 174.2 | | | 3.9 | 3.9 |
| 300 | 5 | 174.2 | 177.8 | | | 3.6 | 3.6 |
| 300 | 6 | 177.8 | 181.5 | | | 3.7 | 3.7 |
| 300 | 7 | 181.5 | 185 | | | 3.5 | 3.5 |
| 300 | 8 | 185 | 188.8 | | | 3.8 | 3.8 |
| 300 | 9 | 188.8 | 192.5 | | | 3.7 | 3.7 |
| 300 | 10 | 192.5 | 196 | | | 3.5 | 3.5 |
| 450 | 1 | 204 | 214 | | | 10 | 10 |
| 450 | 2 | 214 | 221.5 | | | 7.5 | 7.5 |
| 450 | 3 | 221.5 | 229.5 | | | 8 | 8 |
| 450 | 4 | 229.5 | 236.5 | | | 7 | 7 |
| 450 | 5 | 236.5 | 242 | | | 5.5 | 5.5 |
| 450 | 6 | 242 | 248.5 | | | 6.5 | 6.5 |
| 450 | 7 | 248.5 | 255.5 | | | 7 | 7 |
| 450 | 8 | 255.5 | 261 | | | 5.5 | 5.5 |
| 450 | 9 | 261 | 267.5 | | | 6.5 | 6.5 |
| 450 | 10 | 267.5 | 273.5 | | | 6 | 6 |
| 300 | 1 | 275 | 278.5 | | | 3.5 | 3.5 |
| 300 | 2 | 278.5 | 282 | | | 3.5 | 3.5 |
| 300 | 3 | 282 | 286 | | | 4 | 4 |
| 300 | 4 | 286 | 289.5 | | | 3.5 | 3.5 |
| 300 | 5 | 289.5 | 293.5 | | | 4 | 4 |
| 300 | 6 | 293.5 | 297 | | | 3.5 | 3.5 |
| 300 | 7 | 297 | 301 | | | 4 | 4 |
| 300 | 8 | 301 | 305.2 | | | 4.2 | 4.2 |
| 300 | 9 | 305.2 | 308 | | | 2.8 | 2.8 |
| 300 | 10 | 308 | 312.2 | | | 4.2 | 4.2 |
| 200 | 1 | 313 | 315.5 | | | 2.5 | 2.5 |

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|---|---|---|---|---|---|---|---|
| 200 | 2 | 315.5 | 318.5 | | | 3 | 3 |
| 200 | 3 | 318.5 | 321.5 | | | 3 | 3 |
| 200 | 4 | 321.5 | 324.5 | | | 3 | 3 |
| 200 | 5 | 324.5 | 327.8 | | | 3.3 | 3.3 |
| 200 | 6 | 327.8 | 330.5 | | | 2.7 | 2.7 |
| 200 | 7 | 330.5 | 333.8 | | | 3.3 | 3.3 |
| 200 | 8 | 333.8 | 337 | | | 3.2 | 3.2 |
| 200 | 9 | 337 | 340 | | | 3 | 3 |
| 200 | 10 | 340 | 343 | | | 3 | 3 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal DATE: 05-Sep-13 HOLE DIP: 90

DIP Direction: -

SITE NUMBER: HD Rig 1 BORE I.D.: HU0077CH BORE NAME: HU0077CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 84.2 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 75.7 | STATIC GROUNDWATER LEVEL: (m below ground level) | 49.0 |
| LENGTH OF STAGE TEST (TERMINAL) (m): | 8.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 200 | 1 | 644 | 656.8 | | | 12.8 | 12.8 |
| 200 | 2 | 656.8 | 667.8 | | | 11 | 11 |
| 200 | 3 | 667.8 | 679.8 | | | 12 | 12 |
| 200 | 4 | 679.8 | 689.5 | | | 9.7 | 9.7 |
| 200 | 5 | 689.5 | 699.8 | | | 10.3 | 10.3 |
| 200 | 6 | 0 | 0 | | | 0 | 0 |
| 200 | 7 | 0 | 0 | | | 0 | 0 |
| 200 | 8 | 0 | 0 | | | 0 | 0 |
| 200 | 9 | 0 | 0 | | | 0 | 0 |
| 200 | 10 | 0 | 0 | | | 0 | 0 |
| 300 | 1 | 709 | 719.8 | | | 10.8 | 10.8 |
| 300 | 2 | 719.8 | 729.5 | | | 9.7 | 9.7 |
| 300 | 3 | 729.5 | 740 | | | 10.5 | 10.5 |
| 300 | 4 | 740 | 750 | | | 10 | 10 |
| 300 | 5 | 750 | 760 | | | 10 | 10 |
| 300 | 6 | 760 | 0 | | | 0 | 0 |
| 300 | 7 | 0 | 0 | | | 0 | 0 |
| 300 | 8 | 0 | 0 | | | 0 | 0 |
| 300 | 9 | 0 | 0 | | | 0 | 0 |
| 300 | 10 | 0 | 0 | | | 0 | 0 |
| 450 | 1 | 768 | 784 | | | 16 | 16 |
| 450 | 2 | 784 | 798.5 | | | 14.5 | 14.5 |
| 450 | 3 | 798.5 | 811.5 | | | 13 | 13 |
| 450 | 4 | 811.5 | 824.5 | | | 13 | 13 |
| 450 | 5 | 824.5 | 837.5 | | | 13 | 13 |
| 450 | 6 | 837.5 | 0 | | | 0 | 0 |
| 450 | 7 | 0 | 0 | | | 0 | 0 |
| 450 | 8 | 0 | 0 | | | 0 | 0 |
| 450 | 9 | 0 | 0 | | | 0 | 0 |
| 450 | 10 | 0 | 0 | | | 0 | 0 |
| 300 | 1 | 840.5 | 849.5 | | | 9 | 9 |
| 300 | 2 | 849.5 | 858.5 | | | 9 | 9 |
| 300 | 3 | 858.5 | 861 | | | 2.5 | 2.5 |
| 300 | 4 | 861 | 876 | | | 15 | 15 |
| 300 | 5 | 876 | 884.8 | | | 8.8 | 8.8 |
| 300 | 6 | 884.8 | 0 | | | 0 | 0 |
| 300 | 7 | 0 | 0 | | | 0 | 0 |
| 300 | 8 | 0 | 0 | | | 0 | 0 |
| 300 | 9 | 0 | 0 | | | 0 | 0 |
| 300 | 10 | 0 | 0 | | | 0 | 0 |
| 200 | 1 | 887 | 894.5 | | | 7.5 | 7.5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 200 | 2 | 894.5 | 903.8 | | | 9.3 | 9.3 |
| 200 | 3 | 903.8 | 913.2 | | | 9.4 | 9.4 |
| 200 | 4 | 913.2 | 923 | | | 9.8 | 9.8 |
| 200 | 5 | 923 | 933 | | | 10 | 10 |
| 200 | 6 | 933 | 0 | | | 0 | 0 |
| 200 | 7 | 0 | 0 | | | 0 | 0 |
| 200 | 8 | 0 | 0 | | | 0 | 0 |
| 200 | 9 | 0 | 0 | | | 0 | 0 |
| 200 | 10 | 0 | 0 | | | 0 | 0 |
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Lenght of rubber hos m packer type & number:
casing: m quality of seal:
drum capacity litres pump type & capacity:
drum calibration: litres water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

Strata Control Technology

**REPORT TO:**

**PARSONS BRINCKERHOFF**

Packer Testing

**PBA4389**

Mining Research and Consulting Group
SCT Operations Pty Ltd PO Box 824 Wollongong NSW 2520 Australia
sctnsw@sct.gs

| | |
|---|---|
| **REPORT TO** | Louisa Rochford<br>Principal Hydrogeologist<br>Parsons Brinckerhoff<br>Level 27, Ernst & Young Centre,<br>680 George Street Sydney NSW<br>2000 |
| **SUBJECT** | Packer Test |
| **REPORT NO** | PBA4389 |
| **PREPARED BY** | Craig Stemp |
| **DATE** | 15 April 2015 |

Craig Stemp
Mining Engineer

Winton J. Gale
Managing Director

## SUMMARY

SCT Operations (SCT) were commissioned by Parsons Brinckerhoff (PB), groundwater consultants, to conduct packer testing in exploration hole HU0146CH for Hume Coal. The packer testing aimed to assist PB in characterising the conductivity of the Wongawilli Seam and overlying Hawkesbury Sandstone. This report presents the results of Lugeon style packer testing conducted on the entire hole in borehole HU0146CH.

As requested by PB, the entire borehole was straddle packer tested at 6.5m intervals, except for the coal which was tested at 3.5m intervals. The bottom hole test was a terminal test at a 9m interval. SCT determined the specific intervals based on PB's instructions, the borehole caliper log and the rod length restrictions. These test intervals encompassed the entire borehole and captured more detail for the coal seam conductivities.

The results for the testing are presented in Table S1.

**Table S1: Hydraulic conductivity results for borehole HU0146CH.**

| Borehole | Test Interval | | Interval Length (m) | Conductivity m/s | Horizon | No. of Fractures |
|---|---|---|---|---|---|---|
| | From (m) | To (m) | | | | |
| HU0146CH | 8.64 | 15.14 | 6.5 | 1.9E-06 | Stone | not logged |
| HU0146CH | 14.64 | 21.14 | 6.5 | 2.1E-06 | Stone | not logged |
| HU0146CH | 20.64 | 27.14 | 6.5 | 1.9E-06 | Stone | not logged |
| HU0146CH | 26.64 | 33.14 | 6.5 | 1.2E-06 | Stone | not logged |
| HU0146CH | 32.64 | 39.14 | 6.5 | 1.4E-06 | Stone | not logged |
| HU0146CH | 38.64 | 45.14 | 6.5 | 1.2E-06 | Stone | not logged |
| HU0146CH | 44.8 | 51.3 | 6.5 | 4.4E-06 | Stone | not logged |
| HU0146CH | 51.64 | 58.14 | 6.5 | 4.9E-06 | Stone | not logged |
| HU0146CH | 57.64 | 64.14 | 6.5 | 6.8E-06 | Stone | not logged |
| HU0146CH | 63.64 | 70.14 | 6.5 | 3.7E-07 | Stone | not logged |
| HU0146CH | 69.64 | 76.14 | 6.5 | 1.6E-06 | Stone | not logged |
| HU0146CH | 75.64 | 82.14 | 6.5 | 6.7E-06 | Stone | not logged |
| HU0146CH | 81.64 | 88.14 | 6.5 | 1.1E-06 | Stone | not logged |
| HU0146CH | 87.64 | 94.14 | 6.5 | 4.2E-06 | Stone | not logged |
| HU0146CH | 93.64 | 100.14 | 6.5 | 4.3E-07 | Stone | not logged |
| HU0146CH | 99.64 | 106.14 | 6.5 | 1.4E-07 | Stone | not logged |
| HU0146CH | 105.64 | 109.14 | 3.5 | 1.4E-07 | Stone | 1 |
| HU0146CH | 108.64 | 112.14 | 3.5 | 4.5E-07 | Coal | 2 |
| HU0146CH | 111.64 | 115.14 | 3.5 | 6.2E-07 | Coal | 4 |
| HU0146CH | 114.64 | 123.6 | 8.96 | 8.2E-07 | Stone | 6 |

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3. CALCULATIONS ..... 3

4. HYDRAULIC CONDUCTIVITY RESULTS ..... 3

5. DISCUSSION ..... 5

## 1. INTRODUCTION

SCT Operations (SCT) were commissioned by Parsons Brinckerhoff (PB), groundwater consultants, to conduct packer testing in exploration hole HU0146CH, for Hume Coal. The packer testing aimed to assist PB in characterising the conductivity of the Wongawilli Seam and overlying Hawkesbury Sandstone. This report presents the results of Lugeon style packer testing conducted on the entire hole in borehole HU0146CH.

As requested by PB, the entire borehole was straddle packer tested at 6.5m intervals, except for the coal which was tested at 3.5m intervals. The bottom hole test was a terminal test at a 9m interval. The total depth of the borehole is 123.6m (Driller's depth). SCT determined the specific intervals based on PB's instructions, the borehole caliper log and the rod length restrictions. These test intervals encompassed the entire borehole and captured more detail for the coal seam conductivities.

## 2. METHOD

Packer testing was conducted by SCT in Borehole HU0146CH which was drilled by Highland Drilling. The packer testing method involved is a Lugeon style straddle packer test in HQ rods. The test is conducted in 5 pressure stages in which pressure is increased then subsequently decreased. Flow is recorded every minute for 10 minutes at each pressure stage.

## 3. CALCULATIONS

Hydraulic conductivity calculations use the average of the CANMET, Hoek and Bray, and Houlsby methods. The formulae are outlined in the water pressure test result sheets (Appendix A). The calculations use the Flow/Head gradient which is an average of the plotted test data vs. Total Head. Zero conductivity denotes the lower limit of this style of test which is of the order of $1x10^{-11}$m/s.

## 4. HYDRAULIC CONDUCTIVITY RESULTS

The hydraulic conductivity results for the intervals tested in hole HU0146CH are summarised in Table 1. Raw packer test results and analyses are presented Appendix A.

The conductivity vs. depth profile for HU0146CH is presented in Figure 1. The hydraulic conductivity for the Wongawilli Seam in hole HU0146CH was found to be $4.5x10^{-7}$m/s and $6.2x10^{-7}$m/s, for the upper and lower sections, respectively. The hydraulic conductivity for the stone horizon above the coal seam in hole HU0146CH was found to be $1.4x10^{-7}$m/s. The range in permeability over the entire hole length tested was found to vary from $6.8x10^{-6}$m/s to $1.4x10^{-7}$m/s.

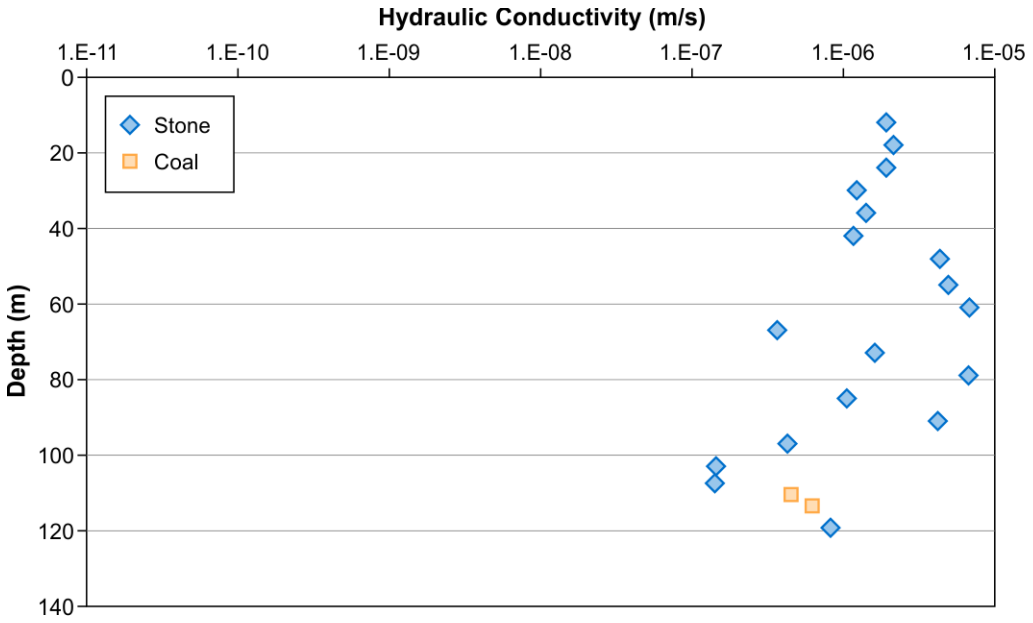


**Figure 1: Hydraulic conductivity vs depth profile for HU0146CH.**

**Table 1: Hydraulic Conductivity test results for hole HU0146CH**

| Borehole | Test Interval | | Interval Length (m) | Conductivity m/s | Horizon | No. of Fractures |
|---|---|---|---|---|---|---|
| | From (m) | To (m) | | | | |
| HU0146CH | 8.64 | 15.14 | 6.5 | 1.9E-06 | Stone | not logged |
| HU0146CH | 14.64 | 21.14 | 6.5 | 2.1E-06 | Stone | not logged |
| HU0146CH | 20.64 | 27.14 | 6.5 | 1.9E-06 | Stone | not logged |
| HU0146CH | 26.64 | 33.14 | 6.5 | 1.2E-06 | Stone | not logged |
| HU0146CH | 32.64 | 39.14 | 6.5 | 1.4E-06 | Stone | not logged |
| HU0146CH | 38.64 | 45.14 | 6.5 | 1.2E-06 | Stone | not logged |
| HU0146CH | 44.8 | 51.3 | 6.5 | 4.4E-06 | Stone | not logged |
| HU0146CH | 51.64 | 58.14 | 6.5 | 4.9E-06 | Stone | not logged |
| HU0146CH | 57.64 | 64.14 | 6.5 | 6.8E-06 | Stone | not logged |
| HU0146CH | 63.64 | 70.14 | 6.5 | 3.7E-07 | Stone | not logged |
| HU0146CH | 69.64 | 76.14 | 6.5 | 1.6E-06 | Stone | not logged |
| HU0146CH | 75.64 | 82.14 | 6.5 | 6.7E-06 | Stone | not logged |
| HU0146CH | 81.64 | 88.14 | 6.5 | 1.1E-06 | Stone | not logged |
| HU0146CH | 87.64 | 94.14 | 6.5 | 4.2E-06 | Stone | not logged |
| HU0146CH | 93.64 | 100.14 | 6.5 | 4.3E-07 | Stone | not logged |
| HU0146CH | 99.64 | 106.14 | 6.5 | 1.4E-07 | Stone | not logged |
| HU0146CH | 105.64 | 109.14 | 3.5 | 1.4E-07 | Stone | 1 |
| HU0146CH | 108.64 | 112.14 | 3.5 | 4.5E-07 | Coal | 2 |
| HU0146CH | 111.64 | 115.14 | 3.5 | 6.2E-07 | Coal | 4 |
| HU0146CH | 114.64 | 123.6 | 8.96 | 8.2E-07 | Stone | 6 |

## 5. DISCUSSION

The conductivity results show a general trend of decreasing conductivity with increasing depth, however the highest conductivity results were observed between 50m and 90m. The general trend of decreasing conductivity with depth generally relates to the confining stress on the fractures which increases with depth. This trend is more difficult to see with the test depth ranging only 120m.

The Hawkesbury Sandstone is also known to have significant primary conductivity in parts, which can be of the same order of the secondary conductivity of the fracture network. It may be useful to conduct conductivity testing on the core for comparison with borehole data to determine whether the flow is secondary or primary flow.

## APPENDIX 1 PACKER TEST RESULTS AND ANALYSES

(PDF Only)

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal DATE: 27-Mar-15 HOLE DIP: 90

DIP Direction: -

SITE NUMBER: HD Rig 1 BORE I.D.: HU0146CH BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 123.60 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 114.64 | | |
| LENGTH OF STAGE TEST (m): | 9.0 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 180 | 1 | 853 | 866 | | | 13 | 13 |
| 180 | 2 | 866 | 877 | | | 11 | 11 |
| 180 | 3 | 877 | 890 | | | 13 | 13 |
| 180 | 4 | 890 | 909 | | | 19 | 19 |
| 180 | 5 | 909 | 915 | | | 6 | 6 |
| 180 | 6 | 915 | 930 | | | 15 | 15 |
| 180 | 7 | 930 | 952 | | | 22 | 22 |
| 180 | 8 | 952 | 976 | | | 24 | 24 |
| 180 | 9 | 976 | 990 | | | 14 | 14 |
| 180 | 10 | 990 | 1004 | | | 14 | 14 |
| 360 | 1 | 81 | 106 | | | 25 | 25 |
| 360 | 2 | 106 | 131 | | | 25 | 25 |
| 360 | 3 | 131 | 155 | | | 24 | 24 |
| 360 | 4 | 155 | 179 | | | 24 | 24 |
| 360 | 5 | 179 | 204 | | | 25 | 25 |
| 360 | 6 | 204 | 228 | | | 24 | 24 |
| 360 | 7 | 228 | 252 | | | 24 | 24 |
| 360 | 8 | 252 | 276 | | | 24 | 24 |
| 360 | 9 | 276 | 295 | | | 19 | 19 |
| 360 | 10 | 295 | 318 | | | 23 | 23 |
| 540 | 1 | 367 | 405 | | | 38 | 38 |
| 540 | 2 | 405 | 440 | | | 35 | 35 |
| 540 | 3 | 440 | 469 | | | 29 | 29 |
| 540 | 4 | 469 | 502 | | | 33 | 33 |
| 540 | 5 | 502 | 533 | | | 31 | 31 |
| 540 | 6 | 533 | 566 | | | 33 | 33 |
| 540 | 7 | 566 | 600 | | | 34 | 34 |
| 540 | 8 | 600 | 633 | | | 33 | 33 |
| 540 | 9 | 633 | 658 | | | 25 | 25 |
| 540 | 10 | 658 | 690 | | | 32 | 32 |
| 360 | 1 | 704 | 725 | | | 21 | 21 |
| 360 | 2 | 725 | 746 | | | 21 | 21 |
| 360 | 3 | 746 | 773 | | | 27 | 27 |
| 360 | 4 | 773 | 790 | | | 17 | 17 |
| 360 | 5 | 790 | 810 | | | 20 | 20 |
| 360 | 6 | 810 | 830 | | | 20 | 20 |
| 360 | 7 | 830 | 852 | | | 22 | 22 |
| 360 | 8 | 852 | 873 | | | 21 | 21 |
| 360 | 9 | 873 | 900 | | | 27 | 27 |
| 360 | 10 | 900 | 921 | | | 21 | 21 |
| 180 | 1 | 937 | 951 | | | 14 | 14 |

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|---|---|---|---|---|---|---|---|
| 180 | 2 | 951 | 966 | | | 15 | 15 |
| 180 | 3 | 966 | 976 | | | 10 | 10 |
| 180 | 4 | 976 | 989 | | | 13 | 13 |
| 180 | 5 | 989 | 1002 | | | 13 | 13 |
| 180 | 6 | 1002 | 1015 | | | 13 | 13 |
| 180 | 7 | 1015 | 1027 | | | 12 | 12 |
| 180 | 8 | 1027 | 1040 | | | 13 | 13 |
| 180 | 9 | 1040 | 1054 | | | 14 | 14 |
| 180 | 10 | 1054 | 1066 | | | 12 | 12 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 27-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 115.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 111.64 | | |
| LENGTH OF STAGE TEST (m): | 3.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 180 | 1 | 165 | 176 | | | 11 | 11 |
| 180 | 2 | 176 | 184 | | | 8 | 8 |
| 180 | 3 | 184 | 193 | | | 9 | 9 |
| 180 | 4 | 193 | 201 | | | 8 | 8 |
| 180 | 5 | 201 | 209 | | | 8 | 8 |
| 180 | 6 | 209 | 217 | | | 8 | 8 |
| 180 | 7 | 217 | 225 | | | 8 | 8 |
| 180 | 8 | 225 | 234 | | | 9 | 9 |
| 180 | 9 | 234 | 240 | | | 6 | 6 |
| 180 | 10 | 240 | 246 | | | 6 | 6 |
| 360 | 1 | 255 | 265 | | | 10 | 10 |
| 360 | 2 | 265 | 278 | | | 13 | 13 |
| 360 | 3 | 278 | 284 | | | 6 | 6 |
| 360 | 4 | 284 | 293 | | | 9 | 9 |
| 360 | 5 | 293 | 298 | | | 5 | 5 |
| 360 | 6 | 298 | 306 | | | 8 | 8 |
| 360 | 7 | 306 | 313 | | | 7 | 7 |
| 360 | 8 | 313 | 320 | | | 7 | 7 |
| 360 | 9 | 320 | 327 | | | 7 | 7 |
| 360 | 10 | 327 | 333 | | | 6 | 6 |
| 540 | 1 | 344 | 358 | | | 14 | 14 |
| 540 | 2 | 358 | 370 | | | 12 | 12 |
| 540 | 3 | 370 | 382 | | | 12 | 12 |
| 540 | 4 | 382 | 391 | | | 9 | 9 |
| 540 | 5 | 391 | 401 | | | 10 | 10 |
| 540 | 6 | 401 | 412 | | | 11 | 11 |
| 540 | 7 | 412 | 421 | | | 9 | 9 |
| 540 | 8 | 421 | 430 | | | 9 | 9 |
| 540 | 9 | 430 | 441 | | | 11 | 11 |
| 540 | 10 | 441 | 452 | | | 11 | 11 |
| 360 | 1 | 457 | 462 | | | 5 | 5 |
| 360 | 2 | 462 | 467 | | | 5 | 5 |
| 360 | 3 | 467 | 472 | | | 5 | 5 |
| 360 | 4 | 472 | 476 | | | 4 | 4 |
| 360 | 5 | 476 | 480 | | | 4 | 4 |
| 360 | 6 | 480 | 485 | | | 5 | 5 |
| 360 | 7 | 485 | 489 | | | 4 | 4 |
| 360 | 8 | 489 | 493 | | | 4 | 4 |
| 360 | 9 | 493 | 495 | | | 2 | 2 |
| 360 | 10 | 495 | 501 | | | 6 | 6 |
| 180 | 1 | 503 | 505 | | | 2 | 2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 180 | 2 | 505 | 507 | | | 2 | 2 |
| 180 | 3 | 507 | 510 | | | 3 | 3 |
| 180 | 4 | 510 | 512 | | | 2 | 2 |
| 180 | 5 | 512 | 514 | | | 2 | 2 |
| 180 | 6 | 514 | 516 | | | 2 | 2 |
| 180 | 7 | 516 | 518 | | | 2 | 2 |
| 180 | 8 | 518 | 520 | | | 2 | 2 |
| 180 | 9 | 520 | 522 | | | 2 | 2 |
| 180 | 10 | 522 | 524 | | | 2 | 2 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 27-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 112.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 108.64 | | |
| LENGTH OF STAGE TEST (m): | 3.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 180 | 1 | 622 | 628.3 | | | 6.3 | 6.3 |
| 180 | 2 | 628.3 | 633 | | | 4.7 | 4.7 |
| 180 | 3 | 633 | 638 | | | 5 | 5 |
| 180 | 4 | 638 | 641.4 | | | 3.4 | 3.4 |
| 180 | 5 | 641.4 | 645.4 | | | 4 | 4 |
| 180 | 6 | 645.4 | 649 | | | 3.6 | 3.6 |
| 180 | 7 | 649 | 652.7 | | | 3.7 | 3.7 |
| 180 | 8 | 652.7 | 656.4 | | | 3.7 | 3.7 |
| 180 | 9 | 656.4 | 660 | | | 3.6 | 3.6 |
| 180 | 10 | 660 | 663.4 | | | 3.4 | 3.4 |
| 360 | 1 | 668.5 | 674.4 | | | 5.9 | 5.9 |
| 360 | 2 | 674.4 | 680 | | | 5.6 | 5.6 |
| 360 | 3 | 680 | 685.4 | | | 5.4 | 5.4 |
| 360 | 4 | 685.4 | 690.4 | | | 5 | 5 |
| 360 | 5 | 690.4 | 697.3 | | | 6.9 | 6.9 |
| 360 | 6 | 697.3 | 700.8 | | | 3.5 | 3.5 |
| 360 | 7 | 700.8 | 705.8 | | | 5 | 5 |
| 360 | 8 | 705.8 | 711 | | | 5.2 | 5.2 |
| 360 | 9 | 711 | 715 | | | 4 | 4 |
| 360 | 10 | 715 | 718.7 | | | 3.7 | 3.7 |
| 540 | 1 | 125 | 134 | | | 9 | 9 |
| 540 | 2 | 134 | 145 | | | 11 | 11 |
| 540 | 3 | 145 | 153 | | | 8 | 8 |
| 540 | 4 | 153 | 165 | | | 12 | 12 |
| 540 | 5 | 165 | 174 | | | 9 | 9 |
| 540 | 6 | 174 | 183 | | | 9 | 9 |
| 540 | 7 | 183 | 192 | | | 9 | 9 |
| 540 | 8 | 192 | 200.5 | | | 8.5 | 8.5 |
| 540 | 9 | 200.5 | 208 | | | 7.5 | 7.5 |
| 540 | 10 | 208 | 214.8 | | | 6.8 | 6.8 |
| 360 | 1 | 817 | 821.2 | | | 4.2 | 4.2 |
| 360 | 2 | 821.2 | 825 | | | 3.8 | 3.8 |
| 360 | 3 | 825 | 829 | | | 4 | 4 |
| 360 | 4 | 829 | 833 | | | 4 | 4 |
| 360 | 5 | 833 | 837 | | | 4 | 4 |
| 360 | 6 | 837 | 840 | | | 3 | 3 |
| 360 | 7 | 840 | 844 | | | 4 | 4 |
| 360 | 8 | 844 | 848.5 | | | 4.5 | 4.5 |
| 360 | 9 | 848.5 | 853 | | | 4.5 | 4.5 |
| 360 | 10 | 853 | 855.4 | | | 2.4 | 2.4 |
| 180 | 1 | 857 | 859.2 | | | 2.2 | 2.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 180 | 2 | 859.2 | 861.5 | | | 2.3 | 2.3 |
| 180 | 3 | 861.5 | 863.8 | | | 2.3 | 2.3 |
| 180 | 4 | 863.8 | 866.2 | | | 2.4 | 2.4 |
| 180 | 5 | 866.2 | 868.2 | | | 2 | 2 |
| 180 | 6 | 868.2 | 870.4 | | | 2.2 | 2.2 |
| 180 | 7 | 870.4 | 872.5 | | | 2.1 | 2.1 |
| 180 | 8 | 872.5 | 875 | | | 2.5 | 2.5 |
| 180 | 9 | 875 | 876.8 | | | 1.8 | 1.8 |
| 180 | 10 | 876.8 | 878.8 | | | 2 | 2 |
| | | | | | | | |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 27-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 109.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 105.64 | | |
| LENGTH OF STAGE TEST (m): | 3.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 180 | 1 | 916 | 918 | | | 2 | 2 |
| 180 | 2 | 918 | 919.8 | | | 1.8 | 1.8 |
| 180 | 3 | 919.8 | 921.2 | | | 1.4 | 1.4 |
| 180 | 4 | 921.2 | 922.5 | | | 1.3 | 1.3 |
| 180 | 5 | 922.5 | 923.8 | | | 1.3 | 1.3 |
| 180 | 6 | 923.8 | 925.2 | | | 1.4 | 1.4 |
| 180 | 7 | 925.2 | 926.2 | | | 1 | 1 |
| 180 | 8 | 926.2 | 927.5 | | | 1.3 | 1.3 |
| 180 | 9 | 927.5 | 928.5 | | | 1 | 1 |
| 180 | 10 | 928.5 | 929.5 | | | 1 | 1 |
| 360 | 1 | 932 | 934 | | | 2 | 2 |
| 360 | 2 | 934 | 936.2 | | | 2.2 | 2.2 |
| 360 | 3 | 936.2 | 938 | | | 1.8 | 1.8 |
| 360 | 4 | 938 | 939.6 | | | 1.6 | 1.6 |
| 360 | 5 | 939.6 | 941.4 | | | 1.8 | 1.8 |
| 360 | 6 | 941.4 | 943.1 | | | 1.7 | 1.7 |
| 360 | 7 | 943.1 | 944.8 | | | 1.7 | 1.7 |
| 360 | 8 | 944.8 | 946.4 | | | 1.6 | 1.6 |
| 360 | 9 | 946.4 | 948 | | | 1.6 | 1.6 |
| 360 | 10 | 948 | 949.5 | | | 1.5 | 1.5 |
| 540 | 1 | 951 | 953.8 | | | 2.8 | 2.8 |
| 540 | 2 | 953.8 | 957 | | | 3.2 | 3.2 |
| 540 | 3 | 957 | 959.5 | | | 2.5 | 2.5 |
| 540 | 4 | 959.5 | 962 | | | 2.5 | 2.5 |
| 540 | 5 | 962 | 964.5 | | | 2.5 | 2.5 |
| 540 | 6 | 964.5 | 967.2 | | | 2.7 | 2.7 |
| 540 | 7 | 967.2 | 970 | | | 2.8 | 2.8 |
| 540 | 8 | 970 | 972.1 | | | 2.1 | 2.1 |
| 540 | 9 | 972.1 | 974 | | | 1.9 | 1.9 |
| 540 | 10 | 974 | 976.2 | | | 2.2 | 2.2 |
| 360 | 1 | 977.4 | 979 | | | 1.6 | 1.6 |
| 360 | 2 | 979 | 980.3 | | | 1.3 | 1.3 |
| 360 | 3 | 980.3 | 981.6 | | | 1.3 | 1.3 |
| 360 | 4 | 981.6 | 982.9 | | | 1.3 | 1.3 |
| 360 | 5 | 982.9 | 984.3 | | | 1.4 | 1.4 |
| 360 | 6 | 984.3 | 985.6 | | | 1.3 | 1.3 |
| 360 | 7 | 985.6 | 986.9 | | | 1.3 | 1.3 |
| 360 | 8 | 986.9 | 988 | | | 1.1 | 1.1 |
| 360 | 9 | 988 | 989.4 | | | 1.4 | 1.4 |
| 360 | 10 | 989.4 | 990.4 | | | 1 | 1 |
| 180 | 1 | 990.6 | 991 | | | 0.4 | 0.4 |

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|---|---|---|---|---|---|---|---|
| 180 | 2 | 991 | 991.6 | | | 0.6 | 0.6 |
| 180 | 3 | 991.6 | 992.3 | | | 0.7 | 0.7 |
| 180 | 4 | 992.3 | 993 | | | 0.7 | 0.7 |
| 180 | 5 | 993 | 993.6 | | | 0.6 | 0.6 |
| 180 | 6 | 993.6 | 994.3 | | | 0.7 | 0.7 |
| 180 | 7 | 994.3 | 995 | | | 0.7 | 0.7 |
| 180 | 8 | 995 | 995.8 | | | 0.8 | 0.8 |
| 180 | 9 | 995.8 | 996.4 | | | 0.6 | 0.6 |
| 180 | 10 | 996.4 | 997.1 | | | 0.7 | 0.7 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 30-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 106.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 99.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 150 | 1 | 60 | 62.5 | | | 2.5 | 2.5 |
| 150 | 2 | 62.5 | 64.5 | | | 2 | 2 |
| 150 | 3 | 64.5 | 67 | | | 2.5 | 2.5 |
| 150 | 4 | 67 | 69 | | | 2 | 2 |
| 150 | 5 | 69 | 70.8 | | | 1.8 | 1.8 |
| 150 | 6 | 70.8 | 72.8 | | | 2 | 2 |
| 150 | 7 | 72.8 | 74.8 | | | 2 | 2 |
| 150 | 8 | 74.8 | 76.8 | | | 2 | 2 |
| 150 | 9 | 76.8 | 78.8 | | | 2 | 2 |
| 150 | 10 | 78.8 | 80.2 | | | 1.4 | 1.4 |
| 300 | 1 | 85 | 88.4 | | | 3.4 | 3.4 |
| 300 | 2 | 88.4 | 91.4 | | | 3 | 3 |
| 300 | 3 | 91.4 | 94.6 | | | 3.2 | 3.2 |
| 300 | 4 | 94.6 | 98.2 | | | 3.6 | 3.6 |
| 300 | 5 | 98.2 | 101.2 | | | 3 | 3 |
| 300 | 6 | 101.2 | 104.2 | | | 3 | 3 |
| 300 | 7 | 104.2 | 106.8 | | | 2.6 | 2.6 |
| 300 | 8 | 106.8 | 109.8 | | | 3 | 3 |
| 300 | 9 | 109.8 | 112.6 | | | 2.8 | 2.8 |
| 300 | 10 | 112.6 | 115.4 | | | 2.8 | 2.8 |
| 450 | 1 | 20 | 24 | | | 4 | 4 |
| 450 | 2 | 24 | 28 | | | 4 | 4 |
| 450 | 3 | 28 | 31.6 | | | 3.6 | 3.6 |
| 450 | 4 | 31.6 | 35.6 | | | 4 | 4 |
| 450 | 5 | 35.6 | 39.2 | | | 3.6 | 3.6 |
| 450 | 6 | 39.2 | 42.2 | | | 3 | 3 |
| 450 | 7 | 42.2 | 46.4 | | | 4.2 | 4.2 |
| 450 | 8 | 46.4 | 49.4 | | | 3 | 3 |
| 450 | 9 | 49.4 | 52.6 | | | 3.2 | 3.2 |
| 450 | 10 | 52.6 | 56 | | | 3.4 | 3.4 |
| 300 | 1 | 57.5 | 59.5 | | | 2 | 2 |
| 300 | 2 | 59.5 | 61.6 | | | 2.1 | 2.1 |
| 300 | 3 | 61.6 | 63.6 | | | 2 | 2 |
| 300 | 4 | 63.6 | 66 | | | 2.4 | 2.4 |
| 300 | 5 | 66 | 68 | | | 2 | 2 |
| 300 | 6 | 68 | 70 | | | 2 | 2 |
| 300 | 7 | 70 | 72.2 | | | 2.2 | 2.2 |
| 300 | 8 | 72.2 | 74.2 | | | 2 | 2 |
| 300 | 9 | 74.2 | 76.4 | | | 2.2 | 2.2 |
| 300 | 10 | 76.4 | 79 | | | 2.6 | 2.6 |
| 150 | 1 | 79.7 | 80.6 | | | 0.9 | 0.9 |

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|---|---|---|---|---|---|---|---|
| 150 | 2 | 80.6 | 81.4 | | | 0.8 | 0.8 |
| 150 | 3 | 81.4 | 82.4 | | | 1 | 1 |
| 150 | 4 | 82.4 | 83.4 | | | 1 | 1 |
| 150 | 5 | 83.4 | 84.4 | | | 1 | 1 |
| 150 | 6 | 84.4 | 85.4 | | | 1 | 1 |
| 150 | 7 | 85.4 | 86.4 | | | 1 | 1 |
| 150 | 8 | 86.4 | 87.4 | | | 1 | 1 |
| 150 | 9 | 87.4 | 88.2 | | | 0.8 | 0.8 |
| 150 | 10 | 88.2 | 88.9 | | | 0.7 | 0.7 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 30-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 100.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 93.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 150 | 1 | 17 | 24.5 | | | 7.5 | 7.5 |
| 150 | 2 | 24.5 | 31.5 | | | 7 | 7 |
| 150 | 3 | 31.5 | 38.2 | | | 6.7 | 6.7 |
| 150 | 4 | 38.2 | 44.8 | | | 6.6 | 6.6 |
| 150 | 5 | 44.8 | 51.2 | | | 6.4 | 6.4 |
| 150 | 6 | 51.2 | 58 | | | 6.8 | 6.8 |
| 150 | 7 | 58 | 64.2 | | | 6.2 | 6.2 |
| 150 | 8 | 64.2 | 70 | | | 5.8 | 5.8 |
| 150 | 9 | 70 | 76 | | | 6 | 6 |
| 150 | 10 | 76 | 82 | | | 6 | 6 |
| 300 | 1 | 390 | 401 | | | 11 | 11 |
| 300 | 2 | 401 | 412.5 | | | 11.5 | 11.5 |
| 300 | 3 | 412.5 | 423 | | | 10.5 | 10.5 |
| 300 | 4 | 423 | 433 | | | 10 | 10 |
| 300 | 5 | 433 | 441.5 | | | 8.5 | 8.5 |
| 300 | 6 | 441.5 | 451 | | | 9.5 | 9.5 |
| 300 | 7 | 451 | 461 | | | 10 | 10 |
| 300 | 8 | 461 | 470.8 | | | 9.8 | 9.8 |
| 300 | 9 | 470.8 | 481.2 | | | 10.4 | 10.4 |
| 300 | 10 | 481.2 | 490 | | | 8.8 | 8.8 |
| 450 | 1 | 500 | 511 | | | 11 | 11 |
| 450 | 2 | 511 | 523 | | | 12 | 12 |
| 450 | 3 | 523 | 535 | | | 12 | 12 |
| 450 | 4 | 535 | 547 | | | 12 | 12 |
| 450 | 5 | 547 | 559 | | | 12 | 12 |
| 450 | 6 | 559 | 567.5 | | | 8.5 | 8.5 |
| 450 | 7 | 567.5 | 581 | | | 13.5 | 13.5 |
| 450 | 8 | 581 | 591.5 | | | 10.5 | 10.5 |
| 450 | 9 | 591.5 | 602 | | | 10.5 | 10.5 |
| 450 | 10 | 602 | 610.5 | | | 8.5 | 8.5 |
| 300 | 1 | 13 | 18 | | | 5 | 5 |
| 300 | 2 | 18 | 22.8 | | | 4.8 | 4.8 |
| 300 | 3 | 22.8 | 28 | | | 5.2 | 5.2 |
| 300 | 4 | 28 | 33 | | | 5 | 5 |
| 300 | 5 | 33 | 38 | | | 5 | 5 |
| 300 | 6 | 38 | 43 | | | 5 | 5 |
| 300 | 7 | 43 | 47.2 | | | 4.2 | 4.2 |
| 300 | 8 | 47.2 | 52 | | | 4.8 | 4.8 |
| 300 | 9 | 52 | 57 | | | 5 | 5 |
| 300 | 10 | 57 | 61.5 | | | 4.5 | 4.5 |
| 150 | 1 | 63.5 | 65.7 | | | 2.2 | 2.2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 150 | 2 | 65.7 | 68 | | | 2.3 | 2.3 |
| 150 | 3 | 68 | 71 | | | 3 | 3 |
| 150 | 4 | 71 | 72.8 | | | 1.8 | 1.8 |
| 150 | 5 | 72.8 | 75.2 | | | 2.4 | 2.4 |
| 150 | 6 | 75.2 | 77.8 | | | 2.6 | 2.6 |
| 150 | 7 | 77.8 | 80 | | | 2.2 | 2.2 |
| 150 | 8 | 80 | 81.8 | | | 1.8 | 1.8 |
| 150 | 9 | 81.8 | 84.2 | | | 2.4 | 2.4 |
| 150 | 10 | 84.2 | 86.6 | | | 2.4 | 2.4 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 30-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 94.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 87.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 150 | 1 | 59 | 129 | | | 70 | 70 |
| 150 | 2 | 129 | 172 | | | 43 | 43 |
| 150 | 3 | 172 | 228 | | | 56 | 56 |
| 150 | 4 | 228 | 276 | | | 48 | 48 |
| 150 | 5 | 276 | 323 | | | 47 | 47 |
| 150 | 6 | 323 | 373 | | | 50 | 50 |
| 150 | 7 | 373 | 434 | | | 61 | 61 |
| 150 | 8 | 434 | 475 | | | 41 | 41 |
| 150 | 9 | 475 | 522 | | | 47 | 47 |
| 150 | 10 | 522 | 572 | | | 50 | 50 |
| 300 | 1 | 733 | 821 | | | 88 | 88 |
| 300 | 2 | 821 | 888 | | | 67 | 67 |
| 300 | 3 | 888 | 967 | | | 79 | 79 |
| 300 | 4 | 967 | 1036 | | | 69 | 69 |
| 300 | 5 | 1036 | 1119 | | | 83 | 83 |
| 300 | 6 | 1119 | 1200 | | | 81 | 81 |
| 300 | 7 | 1200 | 1264 | | | 64 | 64 |
| 300 | 8 | 1264 | 1340 | | | 76 | 76 |
| 300 | 9 | 1340 | 1417 | | | 77 | 77 |
| 300 | 10 | 1417 | 1500 | | | 83 | 83 |
| 150 | 1 | 203 | 240 | | | 37 | 37 |
| 150 | 2 | 240 | 265 | | | 25 | 25 |
| 150 | 3 | 265 | 286 | | | 21 | 21 |
| 150 | 4 | 286 | 306 | | | 20 | 20 |
| 150 | 5 | 306 | 328 | | | 22 | 22 |
| 150 | 6 | 328 | 350 | | | 22 | 22 |
| 150 | 7 | 350 | 372 | | | 22 | 22 |
| 150 | 8 | 372 | 390 | | | 18 | 18 |
| 150 | 9 | 390 | 409 | | | 19 | 19 |
| 150 | 10 | 409 | 428 | | | 19 | 19 |
| 300 | 1 | | | | | 0 | 0 |
| 300 | 2 | | | | | 0 | 0 |
| 300 | 3 | | | | | 0 | 0 |
| 300 | 4 | | | | | 0 | 0 |
| 300 | 5 | | | | | 0 | 0 |
| 300 | 6 | | | | | 0 | 0 |
| 300 | 7 | | | | | 0 | 0 |
| 300 | 8 | | | | | 0 | 0 |
| 300 | 9 | | | | | 0 | 0 |
| 300 | 10 | | | | | 0 | 0 |
| 150 | 1 | | | | | 0 | 0 |

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|---|---|---|---|---|---|---|---|
| 150 | 2 | | | | | 0 | 0 |
| 150 | 3 | | | | | 0 | 0 |
| 150 | 4 | | | | | 0 | 0 |
| 150 | 5 | | | | | 0 | 0 |
| 150 | 6 | | | | | 0 | 0 |
| 150 | 7 | | | | | 0 | 0 |
| 150 | 8 | | | | | 0 | 0 |
| 150 | 9 | | | | | 0 | 0 |
| 150 | 10 | | | | | 0 | 0 |
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Lenght of rubber hos m packer type & number:
casing: m quality of seal:
drum capacity litres pump type & capacity:
drum calibration: litres water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 30-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 88.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 81.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 100 | 1 | 505 | 521 | | | 16 | 16 |
| 100 | 2 | 521 | 536 | | | 15 | 15 |
| 100 | 3 | 536 | 548 | | | 12 | 12 |
| 100 | 4 | 548 | 564 | | | 16 | 16 |
| 100 | 5 | 564 | 578 | | | 14 | 14 |
| 100 | 6 | 578 | 592 | | | 14 | 14 |
| 100 | 7 | 592 | 603 | | | 11 | 11 |
| 100 | 8 | 603 | 618 | | | 15 | 15 |
| 100 | 9 | 618 | 631 | | | 13 | 13 |
| 100 | 10 | 631 | 642 | | | 11 | 11 |
| 200 | 1 | 644 | 655 | | | 11 | 11 |
| 200 | 2 | 655 | 668 | | | 13 | 13 |
| 200 | 3 | 668 | 680 | | | 12 | 12 |
| 200 | 4 | 680 | 695 | | | 15 | 15 |
| 200 | 5 | 695 | 706 | | | 11 | 11 |
| 200 | 6 | 706 | 719 | | | 13 | 13 |
| 200 | 7 | 719 | 728 | | | 9 | 9 |
| 200 | 8 | 728 | 740 | | | 12 | 12 |
| 200 | 9 | 740 | 751 | | | 11 | 11 |
| 200 | 10 | 751 | 761 | | | 10 | 10 |
| 300 | 1 | 772 | 794 | | | 22 | 22 |
| 300 | 2 | 794 | 818 | | | 24 | 24 |
| 300 | 3 | 818 | 842 | | | 24 | 24 |
| 300 | 4 | 842 | 865 | | | 23 | 23 |
| 300 | 5 | 865 | 889 | | | 24 | 24 |
| 300 | 6 | 889 | 906 | | | 17 | 17 |
| 300 | 7 | 906 | 928 | | | 22 | 22 |
| 300 | 8 | 928 | 951 | | | 23 | 23 |
| 300 | 9 | 951 | 970 | | | 19 | 19 |
| 300 | 10 | 970 | 990 | | | 20 | 20 |
| 200 | 1 | 1020 | 1028 | | | 8 | 8 |
| 200 | 2 | 1028 | 1036 | | | 8 | 8 |
| 200 | 3 | 1036 | 1044 | | | 8 | 8 |
| 200 | 4 | 1044 | 1052 | | | 8 | 8 |
| 200 | 5 | 1052 | 1062 | | | 10 | 10 |
| 200 | 6 | 1062 | 1075 | | | 13 | 13 |
| 200 | 7 | 1075 | 1085 | | | 10 | 10 |
| 200 | 8 | 1085 | 1095 | | | 10 | 10 |
| 200 | 9 | 1095 | 1107 | | | 12 | 12 |
| 200 | 10 | 1107 | 1121 | | | 14 | 14 |
| 100 | 1 | 128 | 134 | | | 6 | 6 |

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|---|---|---|---|---|---|---|---|
| 100 | 2 | 134 | 140 | | | 6 | 6 |
| 100 | 3 | 140 | 145 | | | 5 | 5 |
| 100 | 4 | 145 | 151 | | | 6 | 6 |
| 100 | 5 | 151 | 156 | | | 5 | 5 |
| 100 | 6 | 156 | 163 | | | 7 | 7 |
| 100 | 7 | 163 | 168 | | | 5 | 5 |
| 100 | 8 | 168 | 173 | | | 5 | 5 |
| 100 | 9 | 173 | 178 | | | 5 | 5 |
| 100 | 10 | 178 | 183 | | | 5 | 5 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 27-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 82.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 75.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 100 | 1 | 522 | 561 | | | 39 | 39 |
| 100 | 2 | 561 | 600 | | | 39 | 39 |
| 100 | 3 | 600 | 697 | | | 97 | 97 |
| 100 | 4 | 697 | 751 | | | 54 | 54 |
| 100 | 5 | 751 | 806 | | | 55 | 55 |
| 100 | 6 | 806 | 866 | | | 60 | 60 |
| 100 | 7 | 866 | 910 | | | 44 | 44 |
| 100 | 8 | 910 | 965 | | | 55 | 55 |
| 100 | 9 | 965 | 1018 | | | 53 | 53 |
| 100 | 10 | 1018 | 1076 | | | 58 | 58 |
| 150 | 1 | 110 | 173 | | | 63 | 63 |
| 150 | 2 | 173 | 244 | | | 71 | 71 |
| 150 | 3 | 244 | 305 | | | 61 | 61 |
| 150 | 4 | 305 | 369 | | | 64 | 64 |
| 150 | 5 | 369 | 423 | | | 54 | 54 |
| 150 | 6 | 423 | 485 | | | 62 | 62 |
| 150 | 7 | 485 | 548 | | | 63 | 63 |
| 150 | 8 | 548 | 628 | | | 80 | 80 |
| 150 | 9 | 628 | 680 | | | 52 | 52 |
| 150 | 10 | 680 | 736 | | | 56 | 56 |
| 180 | 1 | 2796 | 2875 | | | 79 | 79 |
| 180 | 2 | 2875 | 2946 | | | 71 | 71 |
| 180 | 3 | 2946 | 3005 | | | 59 | 59 |
| 180 | 4 | 3005 | 3072 | | | 67 | 67 |
| 180 | 5 | 3072 | 3142 | | | 70 | 70 |
| 180 | 6 | 3142 | 3220 | | | 78 | 78 |
| 180 | 7 | 3220 | 3290 | | | 70 | 70 |
| 180 | 8 | 3290 | 3349 | | | 59 | 59 |
| 180 | 9 | 3349 | 3420 | | | 71 | 71 |
| 180 | 10 | 3420 | 3487 | | | 67 | 67 |
| 150 | 1 | 518 | 576 | | | 58 | 58 |
| 150 | 2 | 576 | 633 | | | 57 | 57 |
| 150 | 3 | 633 | 696 | | | 63 | 63 |
| 150 | 4 | 696 | 748 | | | 52 | 52 |
| 150 | 5 | 748 | 813 | | | 65 | 65 |
| 150 | 6 | 813 | 864 | | | 51 | 51 |
| 150 | 7 | 864 | 916 | | | 52 | 52 |
| 150 | 8 | 916 | 966 | | | 50 | 50 |
| 150 | 9 | 966 | 1035 | | | 69 | 69 |
| 150 | 10 | 1035 | 1093 | | | 58 | 58 |
| 100 | 1 | 112 | 159 | | | 47 | 47 |

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|---|---|---|---|---|---|---|---|
| 100 | 2 | 159 | 205 | | | 46 | 46 |
| 100 | 3 | 205 | 259 | | | 54 | 54 |
| 100 | 4 | 259 | 297 | | | 38 | 38 |
| 100 | 5 | 297 | 343 | | | 46 | 46 |
| 100 | 6 | 343 | 390 | | | 47 | 47 |
| 100 | 7 | 390 | 435 | | | 45 | 45 |
| 100 | 8 | 435 | 480 | | | 45 | 45 |
| 100 | 9 | 480 | 525 | | | 45 | 45 |
| 100 | 10 | 525 | 570 | | | 45 | 45 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 31-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 76.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 69.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 100 | 1 | 600 | 618 | | | 18 | 18 |
| 100 | 2 | 618 | 636 | | | 18 | 18 |
| 100 | 3 | 636 | 652 | | | 16 | 16 |
| 100 | 4 | 652 | 669 | | | 17 | 17 |
| 100 | 5 | 669 | 686 | | | 17 | 17 |
| 100 | 6 | 686 | 701 | | | 15 | 15 |
| 100 | 7 | 701 | 718 | | | 17 | 17 |
| 100 | 8 | 718 | 734 | | | 16 | 16 |
| 100 | 9 | 734 | 752 | | | 18 | 18 |
| 100 | 10 | 752 | 765 | | | 13 | 13 |
| 200 | 1 | 785 | 811 | | | 26 | 26 |
| 200 | 2 | 811 | 830 | | | 19 | 19 |
| 200 | 3 | 830 | 862 | | | 32 | 32 |
| 200 | 4 | 862 | 881 | | | 19 | 19 |
| 200 | 5 | 881 | 898 | | | 17 | 17 |
| 200 | 6 | 898 | 916 | | | 18 | 18 |
| 200 | 7 | 916 | 934 | | | 18 | 18 |
| 200 | 8 | 934 | 952 | | | 18 | 18 |
| 200 | 9 | 952 | 969 | | | 17 | 17 |
| 200 | 10 | 969 | 991 | | | 22 | 22 |
| 300 | 1 | 5 | 34 | | | 29 | 29 |
| 300 | 2 | 34 | 63 | | | 29 | 29 |
| 300 | 3 | 63 | 77 | | | 14 | 14 |
| 300 | 4 | 77 | 93 | | | 16 | 16 |
| 300 | 5 | 93 | 125 | | | 32 | 32 |
| 300 | 6 | 125 | 154 | | | 29 | 29 |
| 300 | 7 | 154 | 182 | | | 28 | 28 |
| 300 | 8 | 182 | 216 | | | 34 | 34 |
| 300 | 9 | 216 | 237 | | | 21 | 21 |
| 300 | 10 | 237 | 295 | | | 58 | 58 |
| 200 | 1 | 310 | 330 | | | 20 | 20 |
| 200 | 2 | 330 | 352 | | | 22 | 22 |
| 200 | 3 | 352 | 367 | | | 15 | 15 |
| 200 | 4 | 367 | 387 | | | 20 | 20 |
| 200 | 5 | 387 | 406 | | | 19 | 19 |
| 200 | 6 | 406 | 426 | | | 20 | 20 |
| 200 | 7 | 426 | 446 | | | 20 | 20 |
| 200 | 8 | 446 | 460 | | | 14 | 14 |
| 200 | 9 | 460 | 479 | | | 19 | 19 |
| 200 | 10 | 479 | 498 | | | 19 | 19 |
| 100 | 1 | 1 | 10 | | | 9 | 9 |

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|---|---|---|---|---|---|---|---|
| 100 | 2 | 10 | 19 | | | 9 | 9 |
| 100 | 3 | 19 | 28 | | | 9 | 9 |
| 100 | 4 | 28 | 37 | | | 9 | 9 |
| 100 | 5 | 37 | 45 | | | 8 | 8 |
| 100 | 6 | 45 | 54 | | | 9 | 9 |
| 100 | 7 | 54 | 63 | | | 9 | 9 |
| 100 | 8 | 63 | 70 | | | 7 | 7 |
| 100 | 9 | 70 | 79 | | | 9 | 9 |
| 100 | 10 | 79 | 86 | | | 7 | 7 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 31-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 70.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 63.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 100 | 1 | 9 | 13 | | | 4 | 4 |
| 100 | 2 | 13 | 16 | | | 3 | 3 |
| 100 | 3 | 16 | 19 | | | 3 | 3 |
| 100 | 4 | 19 | 24 | | | 5 | 5 |
| 100 | 5 | 24 | 32 | | | 8 | 8 |
| 100 | 6 | 32 | 36.5 | | | 4.5 | 4.5 |
| 100 | 7 | 36.5 | 39 | | | 2.5 | 2.5 |
| 100 | 8 | 39 | 41 | | | 2 | 2 |
| 100 | 9 | 41 | 45 | | | 4 | 4 |
| 100 | 10 | 45 | 48 | | | 3 | 3 |
| 200 | 1 | 756.5 | 763 | | | 6.5 | 6.5 |
| 200 | 2 | 763 | 771 | | | 8 | 8 |
| 200 | 3 | 771 | 775 | | | 4 | 4 |
| 200 | 4 | 775 | 780 | | | 5 | 5 |
| 200 | 5 | 780 | 784 | | | 4 | 4 |
| 200 | 6 | 784 | 789 | | | 5 | 5 |
| 200 | 7 | 789 | 793 | | | 4 | 4 |
| 200 | 8 | 793 | 796 | | | 3 | 3 |
| 200 | 9 | 796 | 802 | | | 6 | 6 |
| 200 | 10 | 802 | 805 | | | 3 | 3 |
| 300 | 1 | 10 | 20 | | | 10 | 10 |
| 300 | 2 | 20 | 30 | | | 10 | 10 |
| 300 | 3 | 30 | 38 | | | 8 | 8 |
| 300 | 4 | 38 | 46 | | | 8 | 8 |
| 300 | 5 | 46 | 55 | | | 9 | 9 |
| 300 | 6 | 55 | 61.5 | | | 6.5 | 6.5 |
| 300 | 7 | 61.5 | 69 | | | 7.5 | 7.5 |
| 300 | 8 | 69 | 77 | | | 8 | 8 |
| 300 | 9 | 77 | 83 | | | 6 | 6 |
| 300 | 10 | 83 | 90 | | | 7 | 7 |
| 200 | 1 | 891 | 894 | | | 3 | 3 |
| 200 | 2 | 894 | 897 | | | 3 | 3 |
| 200 | 3 | 897 | 900 | | | 3 | 3 |
| 200 | 4 | 900 | 903 | | | 3 | 3 |
| 200 | 5 | 903 | 906 | | | 3 | 3 |
| 200 | 6 | 906 | 909 | | | 3 | 3 |
| 200 | 7 | 909 | 912 | | | 3 | 3 |
| 200 | 8 | 912 | 914 | | | 2 | 2 |
| 200 | 9 | 914 | 916 | | | 2 | 2 |
| 200 | 10 | 916 | 919 | | | 3 | 3 |
| 100 | 1 | 21 | 22.6 | | | 1.6 | 1.6 |

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|---|---|---|---|---|---|---|---|
| 100 | 2 | 22.6 | 24 | | | 1.4 | 1.4 |
| 100 | 3 | 24 | 25.5 | | | 1.5 | 1.5 |
| 100 | 4 | 25.5 | 27 | | | 1.5 | 1.5 |
| 100 | 5 | 27 | 28.5 | | | 1.5 | 1.5 |
| 100 | 6 | 28.5 | 29.5 | | | 1 | 1 |
| 100 | 7 | 29.5 | 31 | | | 1.5 | 1.5 |
| 100 | 8 | 31 | 32.5 | | | 1.5 | 1.5 |
| 100 | 9 | 32.5 | 33.6 | | | 1.1 | 1.1 |
| 100 | 10 | 33.6 | 35 | | | 1.4 | 1.4 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 31-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 64.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 57.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 100 | 1 | 110 | 153 | | | 43 | 43 |
| 100 | 2 | 153 | 186 | | | 33 | 33 |
| 100 | 3 | 186 | 216 | | | 30 | 30 |
| 100 | 4 | 216 | 252 | | | 36 | 36 |
| 100 | 5 | 252 | 280 | | | 28 | 28 |
| 100 | 6 | 280 | 324 | | | 44 | 44 |
| 100 | 7 | 324 | 357 | | | 33 | 33 |
| 100 | 8 | 357 | 403 | | | 46 | 46 |
| 100 | 9 | 403 | 431 | | | 28 | 28 |
| 100 | 10 | 431 | 469 | | | 38 | 38 |
| 200 | 1 | 519 | 575 | | | 56 | 56 |
| 200 | 2 | 575 | 634 | | | 59 | 59 |
| 200 | 3 | 634 | 686 | | | 52 | 52 |
| 200 | 4 | 686 | 742 | | | 56 | 56 |
| 200 | 5 | 742 | 801 | | | 59 | 59 |
| 200 | 6 | 801 | 858 | | | 57 | 57 |
| 200 | 7 | 858 | 910 | | | 52 | 52 |
| 200 | 8 | 910 | 970 | | | 60 | 60 |
| 200 | 9 | 970 | 1020 | | | 50 | 50 |
| 200 | 10 | 1020 | 1099 | | | 79 | 79 |
| 250 | 1 | 250 | 336 | | | 86 | 86 |
| 250 | 2 | 336 | 425 | | | 89 | 89 |
| 250 | 3 | 425 | 515 | | | 90 | 90 |
| 250 | 4 | 515 | 595 | | | 80 | 80 |
| 250 | 5 | 595 | 665 | | | 70 | 70 |
| 250 | 6 | 665 | 750 | | | 85 | 85 |
| 250 | 7 | 750 | 852 | | | 102 | 102 |
| 250 | 8 | 852 | 936 | | | 84 | 84 |
| 250 | 9 | 936 | 1036 | | | 100 | 100 |
| 250 | 10 | 1036 | 1110 | | | 74 | 74 |
| 200 | 1 | 136 | 230 | | | 94 | 94 |
| 200 | 2 | 230 | 310 | | | 80 | 80 |
| 200 | 3 | 310 | 390 | | | 80 | 80 |
| 200 | 4 | 390 | 470 | | | 80 | 80 |
| 200 | 5 | 470 | 552 | | | 82 | 82 |
| 200 | 6 | 552 | 642 | | | 90 | 90 |
| 200 | 7 | 642 | 724 | | | 82 | 82 |
| 200 | 8 | 724 | 791 | | | 67 | 67 |
| 200 | 9 | 791 | 879 | | | 88 | 88 |
| 200 | 10 | 879 | 947 | | | 68 | 68 |
| 100 | 1 | 988 | 1065 | | | 77 | 77 |

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|---|---|---|---|---|---|---|---|
| 100 | 2 | 1065 | 1108 | | | 43 | 43 |
| 100 | 3 | 1108 | 1223 | | | 115 | 115 |
| 100 | 4 | 1223 | 1266 | | | 43 | 43 |
| 100 | 5 | 1266 | 1308 | | | 42 | 42 |
| 100 | 6 | 1308 | 1349 | | | 41 | 41 |
| 100 | 7 | 1349 | 1411 | | | 62 | 62 |
| 100 | 8 | 1411 | 1471 | | | 60 | 60 |
| 100 | 9 | 1471 | 1522 | | | 51 | 51 |
| 100 | 10 | 1522 | 1581 | | | 59 | 59 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 31-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 58.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 51.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 100 | 1 | 741 | 768 | | | 27 | 27 |
| 100 | 2 | 768 | 793 | | | 25 | 25 |
| 100 | 3 | 793 | 822 | | | 29 | 29 |
| 100 | 4 | 822 | 847 | | | 25 | 25 |
| 100 | 5 | 847 | 872 | | | 25 | 25 |
| 100 | 6 | 872 | 891 | | | 19 | 19 |
| 100 | 7 | 891 | 920 | | | 29 | 29 |
| 100 | 8 | 920 | 942 | | | 22 | 22 |
| 100 | 9 | 942 | 965 | | | 23 | 23 |
| 100 | 10 | 965 | 990 | | | 25 | 25 |
| 200 | 1 | 17 | 74 | | | 57 | 57 |
| 200 | 2 | 74 | 123 | | | 49 | 49 |
| 200 | 3 | 123 | 175 | | | 52 | 52 |
| 200 | 4 | 175 | 224 | | | 49 | 49 |
| 200 | 5 | 224 | 282 | | | 58 | 58 |
| 200 | 6 | 282 | 348 | | | 66 | 66 |
| 200 | 7 | 348 | 398 | | | 50 | 50 |
| 200 | 8 | 398 | 445 | | | 47 | 47 |
| 200 | 9 | 445 | 494 | | | 49 | 49 |
| 200 | 10 | 494 | 545 | | | 51 | 51 |
| 220 | 1 | 630 | 704 | | | 74 | 74 |
| 220 | 2 | 704 | 775 | | | 71 | 71 |
| 220 | 3 | 775 | 856 | | | 81 | 81 |
| 220 | 4 | 856 | 921 | | | 65 | 65 |
| 220 | 5 | 921 | 992 | | | 71 | 71 |
| 220 | 6 | 992 | 1064 | | | 72 | 72 |
| 220 | 7 | 1064 | 1136 | | | 72 | 72 |
| 220 | 8 | 1136 | 1208 | | | 72 | 72 |
| 220 | 9 | 1208 | 1280 | | | 72 | 72 |
| 220 | 10 | 1280 | 1351 | | | 71 | 71 |
| 200 | 1 | 376 | 435 | | | 59 | 59 |
| 200 | 2 | 435 | 495 | | | 60 | 60 |
| 200 | 3 | 495 | 555 | | | 60 | 60 |
| 200 | 4 | 555 | 616 | | | 61 | 61 |
| 200 | 5 | 616 | 676 | | | 60 | 60 |
| 200 | 6 | 676 | 736 | | | 60 | 60 |
| 200 | 7 | 736 | 792 | | | 56 | 56 |
| 200 | 8 | 792 | 852 | | | 60 | 60 |
| 200 | 9 | 852 | 912 | | | 60 | 60 |
| 200 | 10 | 912 | 982 | | | 70 | 70 |
| 100 | 1 | 24 | 53 | | | 29 | 29 |

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|---|---|---|---|---|---|---|---|
| 100 | 2 | 53 | 82 | | | 29 | 29 |
| 100 | 3 | 82 | 104 | | | 22 | 22 |
| 100 | 4 | 104 | 136 | | | 32 | 32 |
| 100 | 5 | 136 | 157 | | | 21 | 21 |
| 100 | 6 | 157 | 193 | | | 36 | 36 |
| 100 | 7 | 193 | 218 | | | 25 | 25 |
| 100 | 8 | 218 | 243 | | | 25 | 25 |
| 100 | 9 | 243 | 268 | | | 25 | 25 |
| 100 | 10 | 268 | 288 | | | 20 | 20 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal DATE: 27-Mar-15 HOLE DIP: 90

DIP Direction: -

SITE NUMBER: HD Rig 1 BORE I.D.: HU0146CH BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 51.30 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 44.80 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 50 | 1 | 475 | 495 | | | 20 | 20 |
| 50 | 2 | 495 | 516 | | | 21 | 21 |
| 50 | 3 | 516 | 536 | | | 20 | 20 |
| 50 | 4 | 536 | 555 | | | 19 | 19 |
| 50 | 5 | 555 | 579 | | | 24 | 24 |
| 50 | 6 | 579 | 599 | | | 20 | 20 |
| 50 | 7 | 599 | 619 | | | 20 | 20 |
| 50 | 8 | 619 | 639 | | | 20 | 20 |
| 50 | 9 | 639 | 660 | | | 21 | 21 |
| 50 | 10 | 660 | 679 | | | 19 | 19 |
| 100 | 1 | 611 | 644 | | | 33 | 33 |
| 100 | 2 | 644 | 679 | | | 35 | 35 |
| 100 | 3 | 679 | 713 | | | 34 | 34 |
| 100 | 4 | 713 | 748 | | | 35 | 35 |
| 100 | 5 | 748 | 772 | | | 24 | 24 |
| 100 | 6 | 772 | 806 | | | 34 | 34 |
| 100 | 7 | 806 | 840 | | | 34 | 34 |
| 100 | 8 | 840 | 874 | | | 34 | 34 |
| 100 | 9 | 874 | 908 | | | 34 | 34 |
| 100 | 10 | 908 | 942 | | | 34 | 34 |
| 150 | 1 | 789 | 843 | | | 54 | 54 |
| 150 | 2 | 843 | 886 | | | 43 | 43 |
| 150 | 3 | 886 | 934 | | | 48 | 48 |
| 150 | 4 | 934 | 983 | | | 49 | 49 |
| 150 | 5 | 983 | 1032 | | | 49 | 49 |
| 150 | 6 | 1032 | 1078 | | | 46 | 46 |
| 150 | 7 | 1078 | 1124 | | | 46 | 46 |
| 150 | 8 | 1124 | 1170 | | | 46 | 46 |
| 150 | 9 | 1170 | 1216 | | | 46 | 46 |
| 150 | 10 | 1216 | 1262 | | | 46 | 46 |
| 100 | 1 | 48 | 79 | | | 31 | 31 |
| 100 | 2 | 79 | 110 | | | 31 | 31 |
| 100 | 3 | 110 | 141 | | | 31 | 31 |
| 100 | 4 | 141 | 175 | | | 34 | 34 |
| 100 | 5 | 175 | 206 | | | 31 | 31 |
| 100 | 6 | 206 | 237 | | | 31 | 31 |
| 100 | 7 | 237 | 268 | | | 31 | 31 |
| 100 | 8 | 268 | 299 | | | 31 | 31 |
| 100 | 9 | 299 | 330 | | | 31 | 31 |
| 100 | 10 | 330 | 361 | | | 31 | 31 |
| 50 | 1 | 213 | 231 | | | 18 | 18 |

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|---|---|---|---|---|---|---|---|
| 50 | 2 | 231 | 245 | | | 14 | 14 |
| 50 | 3 | 245 | 260 | | | 15 | 15 |
| 50 | 4 | 260 | 275 | | | 15 | 15 |
| 50 | 5 | 275 | 291 | | | 16 | 16 |
| 50 | 6 | 291 | 306 | | | 15 | 15 |
| 50 | 7 | 306 | 321 | | | 15 | 15 |
| 50 | 8 | 321 | 336 | | | 15 | 15 |
| 50 | 9 | 336 | 351 | | | 15 | 15 |
| 50 | 10 | 351 | 366 | | | 15 | 15 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 01-Apr-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 45.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 38.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 80 | 1 | 421.5 | 425 | | | 3.5 | 3.5 |
| 80 | 2 | 425 | 428.5 | | | 3.5 | 3.5 |
| 80 | 3 | 428.5 | 432 | | | 3.5 | 3.5 |
| 80 | 4 | 432 | 433.5 | | | 1.5 | 1.5 |
| 80 | 5 | 433.5 | 436.8 | | | 3.3 | 3.3 |
| 80 | 6 | 436.8 | 440.3 | | | 3.5 | 3.5 |
| 80 | 7 | 440.3 | 441.6 | | | 1.3 | 1.3 |
| 80 | 8 | 441.6 | 444 | | | 2.4 | 2.4 |
| 80 | 9 | 444 | 446.8 | | | 2.8 | 2.8 |
| 80 | 10 | 446.8 | 448.8 | | | 2 | 2 |
| 150 | 1 | 462 | 474 | | | 12 | 12 |
| 150 | 2 | 474 | 486.8 | | | 12.8 | 12.8 |
| 150 | 3 | 486.8 | 495.6 | | | 8.8 | 8.8 |
| 150 | 4 | 495.6 | 506.8 | | | 11.2 | 11.2 |
| 150 | 5 | 506.8 | 519.8 | | | 13 | 13 |
| 150 | 6 | 519.8 | 531.8 | | | 12 | 12 |
| 150 | 7 | 531.8 | 543.8 | | | 12 | 12 |
| 150 | 8 | 543.8 | 556.8 | | | 13 | 13 |
| 150 | 9 | 556.8 | 570.5 | | | 13.7 | 13.7 |
| 150 | 10 | 570.5 | 580 | | | 9.5 | 9.5 |
| 240 | 1 | 642 | 668 | | | 26 | 26 |
| 240 | 2 | 668 | 693 | | | 25 | 25 |
| 240 | 3 | 693 | 717 | | | 24 | 24 |
| 240 | 4 | 717 | 741 | | | 24 | 24 |
| 240 | 5 | 741 | 766 | | | 25 | 25 |
| 240 | 6 | 766 | 789 | | | 23 | 23 |
| 240 | 7 | 789 | 813 | | | 24 | 24 |
| 240 | 8 | 813 | 837 | | | 24 | 24 |
| 240 | 9 | 837 | 861 | | | 24 | 24 |
| 240 | 10 | 861 | 886 | | | 25 | 25 |
| 150 | 1 | 901 | 911 | | | 10 | 10 |
| 150 | 2 | 911 | 922 | | | 11 | 11 |
| 150 | 3 | 922 | 932 | | | 10 | 10 |
| 150 | 4 | 932 | 941 | | | 9 | 9 |
| 150 | 5 | 941 | 952 | | | 11 | 11 |
| 150 | 6 | 952 | 962 | | | 10 | 10 |
| 150 | 7 | 962 | 973 | | | 11 | 11 |
| 150 | 8 | 973 | 983 | | | 10 | 10 |
| 150 | 9 | 983 | 992 | | | 9 | 9 |
| 150 | 10 | 992 | 1002 | | | 10 | 10 |
| 80 | 1 | 47 | 49.5 | | | 2.5 | 2.5 |

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|---|---|---|---|---|---|---|---|
| 80 | 2 | 49.5 | 52 | | | 2.5 | 2.5 |
| 80 | 3 | 52 | 54.2 | | | 2.2 | 2.2 |
| 80 | 4 | 54.2 | 56.8 | | | 2.6 | 2.6 |
| 80 | 5 | 56.8 | 59.3 | | | 2.5 | 2.5 |
| 80 | 6 | 59.3 | 61.9 | | | 2.6 | 2.6 |
| 80 | 7 | 61.9 | 64.4 | | | 2.5 | 2.5 |
| 80 | 8 | 64.4 | 66.7 | | | 2.3 | 2.3 |
| 80 | 9 | 66.7 | 69.2 | | | 2.5 | 2.5 |
| 80 | 10 | 69.2 | 71.7 | | | 2.5 | 2.5 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 01-Apr-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 39.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 32.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 80 | 1 | 55 | 56.8 | | | 1.8 | 1.8 |
| 80 | 2 | 56.8 | 58.3 | | | 1.5 | 1.5 |
| 80 | 3 | 58.3 | 59.5 | | | 1.2 | 1.2 |
| 80 | 4 | 59.5 | 60.8 | | | 1.3 | 1.3 |
| 80 | 5 | 60.8 | 62 | | | 1.2 | 1.2 |
| 80 | 6 | 62 | 63.4 | | | 1.4 | 1.4 |
| 80 | 7 | 63.4 | 64.4 | | | 1 | 1 |
| 80 | 8 | 64.4 | 65.6 | | | 1.2 | 1.2 |
| 80 | 9 | 65.6 | 67 | | | 1.4 | 1.4 |
| 80 | 10 | 67 | 68 | | | 1 | 1 |
| 150 | 1 | 75.2 | 85.2 | | | 10 | 10 |
| 150 | 2 | 85.2 | 96.8 | | | 11.6 | 11.6 |
| 150 | 3 | 96.8 | 107.5 | | | 10.7 | 10.7 |
| 150 | 4 | 107.5 | 117.5 | | | 10 | 10 |
| 150 | 5 | 117.5 | 128.5 | | | 11 | 11 |
| 150 | 6 | 128.5 | 141 | | | 12.5 | 12.5 |
| 150 | 7 | 141 | 150.5 | | | 9.5 | 9.5 |
| 150 | 8 | 150.5 | 162 | | | 11.5 | 11.5 |
| 150 | 9 | 162 | 172 | | | 10 | 10 |
| 150 | 10 | 172 | 182 | | | 10 | 10 |
| 200 | 1 | 197 | 227 | | | 30 | 30 |
| 200 | 2 | 227 | 260 | | | 33 | 33 |
| 200 | 3 | 260 | 290 | | | 30 | 30 |
| 200 | 4 | 290 | 313 | | | 23 | 23 |
| 200 | 5 | 313 | 343 | | | 30 | 30 |
| 200 | 6 | 343 | 376 | | | 33 | 33 |
| 200 | 7 | 376 | 399 | | | 23 | 23 |
| 200 | 8 | 399 | 429 | | | 30 | 30 |
| 200 | 9 | 429 | 463 | | | 34 | 34 |
| 200 | 10 | 463 | 486 | | | 23 | 23 |
| 150 | 1 | 497 | 517 | | | 20 | 20 |
| 150 | 2 | 517 | 532 | | | 15 | 15 |
| 150 | 3 | 532 | 549 | | | 17 | 17 |
| 150 | 4 | 549 | 564 | | | 15 | 15 |
| 150 | 5 | 564 | 580 | | | 16 | 16 |
| 150 | 6 | 580 | 598 | | | 18 | 18 |
| 150 | 7 | 598 | 613 | | | 15 | 15 |
| 150 | 8 | 613 | 630 | | | 17 | 17 |
| 150 | 9 | 630 | 646 | | | 16 | 16 |
| 150 | 10 | 646 | 663 | | | 17 | 17 |
| 80 | 1 | 666.4 | 667.7 | | | 1.3 | 1.3 |

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|---|---|---|---|---|---|---|---|
| 80 | 2 | 667.7 | 669 | | | 1.3 | 1.3 |
| 80 | 3 | 669 | 670.3 | | | 1.3 | 1.3 |
| 80 | 4 | 670.3 | 672 | | | 1.7 | 1.7 |
| 80 | 5 | 672 | 673.2 | | | 1.2 | 1.2 |
| 80 | 6 | 673.2 | 674.5 | | | 1.3 | 1.3 |
| 80 | 7 | 674.5 | 675.5 | | | 1 | 1 |
| 80 | 8 | 675.5 | 677 | | | 1.5 | 1.5 |
| 80 | 9 | 677 | 678 | | | 1 | 1 |
| 80 | 10 | 678 | 679.5 | | | 1.5 | 1.5 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 01-Apr-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 33.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 26.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 80 | 1 | 35 | 39.2 | | | 4.2 | 4.2 |
| 80 | 2 | 39.2 | 43.2 | | | 4 | 4 |
| 80 | 3 | 43.2 | 48.5 | | | 5.3 | 5.3 |
| 80 | 4 | 48.5 | 52 | | | 3.5 | 3.5 |
| 80 | 5 | 52 | 56 | | | 4 | 4 |
| 80 | 6 | 56 | 60 | | | 4 | 4 |
| 80 | 7 | 60 | 64 | | | 4 | 4 |
| 80 | 8 | 64 | 68 | | | 4 | 4 |
| 80 | 9 | 68 | 71.8 | | | 3.8 | 3.8 |
| 80 | 10 | 71.8 | 75.5 | | | 3.7 | 3.7 |
| 150 | 1 | 881 | 890 | | | 9 | 9 |
| 150 | 2 | 890 | 897.5 | | | 7.5 | 7.5 |
| 150 | 3 | 897.5 | 906 | | | 8.5 | 8.5 |
| 150 | 4 | 906 | 914 | | | 8 | 8 |
| 150 | 5 | 914 | 923 | | | 9 | 9 |
| 150 | 6 | 923 | 931 | | | 8 | 8 |
| 150 | 7 | 931 | 937 | | | 6 | 6 |
| 150 | 8 | 937 | 946 | | | 9 | 9 |
| 150 | 9 | 946 | 953 | | | 7 | 7 |
| 150 | 10 | 953 | 961 | | | 8 | 8 |
| 200 | 1 | 970 | 996 | | | 26 | 26 |
| 200 | 2 | 996 | 1021 | | | 25 | 25 |
| 200 | 3 | 1021 | 1046 | | | 25 | 25 |
| 200 | 4 | 1046 | 1072 | | | 26 | 26 |
| 200 | 5 | 1072 | 1097 | | | 25 | 25 |
| 200 | 6 | 1097 | 1123 | | | 26 | 26 |
| 200 | 7 | 1123 | 1154 | | | 31 | 31 |
| 200 | 8 | 1154 | 1176 | | | 22 | 22 |
| 200 | 9 | 1176 | 1202 | | | 26 | 26 |
| 200 | 10 | 1202 | 1234 | | | 32 | 32 |
| 150 | 1 | 242 | 252 | | | 10 | 10 |
| 150 | 2 | 252 | 261 | | | 9 | 9 |
| 150 | 3 | 261 | 270 | | | 9 | 9 |
| 150 | 4 | 270 | 281 | | | 11 | 11 |
| 150 | 5 | 281 | 290 | | | 9 | 9 |
| 150 | 6 | 290 | 299 | | | 9 | 9 |
| 150 | 7 | 299 | 308 | | | 9 | 9 |
| 150 | 8 | 308 | 318 | | | 10 | 10 |
| 150 | 9 | 318 | 326 | | | 8 | 8 |
| 150 | 10 | 326 | 335 | | | 9 | 9 |
| 80 | 1 | 337 | 340.5 | | | 3.5 | 3.5 |

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|---|---|---|---|---|---|---|---|
| 80 | 2 | 340.5 | 343.6 | | | 3.1 | 3.1 |
| 80 | 3 | 343.6 | 346.6 | | | 3 | 3 |
| 80 | 4 | 346.6 | 349.5 | | | 2.9 | 2.9 |
| 80 | 5 | 349.5 | 353 | | | 3.5 | 3.5 |
| 80 | 6 | 353 | 356 | | | 3 | 3 |
| 80 | 7 | 356 | 359 | | | 3 | 3 |
| 80 | 8 | 359 | 362 | | | 3 | 3 |
| 80 | 9 | 362 | 365 | | | 3 | 3 |
| 80 | 10 | 365 | 368 | | | 3 | 3 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 27-Mar-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 27.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 20.64 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| LENGTH OF STAGE TEST (m): | 6.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 80 | 1 | 280 | 291 | | | 11 | 11 |
| 80 | 2 | 291 | 301 | | | 10 | 10 |
| 80 | 3 | 301 | 313 | | | 12 | 12 |
| 80 | 4 | 313 | 322 | | | 9 | 9 |
| 80 | 5 | 322 | 335 | | | 13 | 13 |
| 80 | 6 | 335 | 343 | | | 8 | 8 |
| 80 | 7 | 343 | 353 | | | 10 | 10 |
| 80 | 8 | 353 | 365 | | | 12 | 12 |
| 80 | 9 | 365 | 373 | | | 8 | 8 |
| 80 | 10 | 373 | 382 | | | 9 | 9 |
| 150 | 1 | 393 | 412 | | | 19 | 19 |
| 150 | 2 | 412 | 433 | | | 21 | 21 |
| 150 | 3 | 433 | 450 | | | 17 | 17 |
| 150 | 4 | 450 | 468 | | | 18 | 18 |
| 150 | 5 | 468 | 487 | | | 19 | 19 |
| 150 | 6 | 487 | 505 | | | 18 | 18 |
| 150 | 7 | 505 | 522 | | | 17 | 17 |
| 150 | 8 | 522 | 541 | | | 19 | 19 |
| 150 | 9 | 541 | 559 | | | 18 | 18 |
| 150 | 10 | 559 | 578 | | | 19 | 19 |
| 200 | 1 | 532 | 558 | | | 26 | 26 |
| 200 | 2 | 558 | 583 | | | 25 | 25 |
| 200 | 3 | 583 | 612 | | | 29 | 29 |
| 200 | 4 | 612 | 638 | | | 26 | 26 |
| 200 | 5 | 638 | 666 | | | 28 | 28 |
| 200 | 6 | 666 | 692 | | | 26 | 26 |
| 200 | 7 | 692 | 720 | | | 28 | 28 |
| 200 | 8 | 720 | 746 | | | 26 | 26 |
| 200 | 9 | 746 | 774 | | | 28 | 28 |
| 200 | 10 | 774 | 800 | | | 26 | 26 |
| 150 | 1 | 712 | 730 | | | 18 | 18 |
| 150 | 2 | 730 | 747 | | | 17 | 17 |
| 150 | 3 | 747 | 764 | | | 17 | 17 |
| 150 | 4 | 764 | 781 | | | 17 | 17 |
| 150 | 5 | 781 | 798 | | | 17 | 17 |
| 150 | 6 | 798 | 815 | | | 17 | 17 |
| 150 | 7 | 815 | 832 | | | 17 | 17 |
| 150 | 8 | 832 | 849 | | | 17 | 17 |
| 150 | 9 | 849 | 866 | | | 17 | 17 |
| 150 | 10 | 866 | 883 | | | 17 | 17 |
| 80 | 1 | 818 | 823 | | | 5 | 5 |

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|---|---|---|---|---|---|---|---|
| 80 | 2 | 823 | 831 | | | 8 | 8 |
| 80 | 3 | 831 | 839 | | | 8 | 8 |
| 80 | 4 | 839 | 847 | | | 8 | 8 |
| 80 | 5 | 847 | 855 | | | 8 | 8 |
| 80 | 6 | 855 | 862 | | | 7 | 7 |
| 80 | 7 | 862 | 870 | | | 8 | 8 |
| 80 | 8 | 870 | 878 | | | 8 | 8 |
| 80 | 9 | 878 | 887 | | | 9 | 9 |
| 80 | 10 | 887 | 894 | | | 7 | 7 |
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|---|---|---|---|
| Lenght of rubber hos | m | packer type & number: | |
| casing: | m | quality of seal: | |
| drum capacity | litres | pump type & capacity: | |
| drum calibration: | litres | water meter No. & calibration date: | |
| | | pressure gauge No. & calibration date: | |

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 01-Apr-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 21.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 14.64 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| LENGTH OF STAGE TEST (m): | 6.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 80 | 1 | 68 | 80 | | | 12 | 12 |
| 80 | 2 | 80 | 93 | | | 13 | 13 |
| 80 | 3 | 93 | 105 | | | 12 | 12 |
| 80 | 4 | 105 | 119 | | | 14 | 14 |
| 80 | 5 | 119 | 131 | | | 12 | 12 |
| 80 | 6 | 131 | 143 | | | 12 | 12 |
| 80 | 7 | 143 | 154 | | | 11 | 11 |
| 80 | 8 | 154 | 165 | | | 11 | 11 |
| 80 | 9 | 165 | 177 | | | 12 | 12 |
| 80 | 10 | 177 | 189 | | | 12 | 12 |
| 150 | 1 | 437 | 459 | | | 22 | 22 |
| 150 | 2 | 459 | 478 | | | 19 | 19 |
| 150 | 3 | 478 | 494 | | | 16 | 16 |
| 150 | 4 | 494 | 512 | | | 18 | 18 |
| 150 | 5 | 512 | 531 | | | 19 | 19 |
| 150 | 6 | 531 | 548 | | | 17 | 17 |
| 150 | 7 | 548 | 565 | | | 17 | 17 |
| 150 | 8 | 565 | 581 | | | 16 | 16 |
| 150 | 9 | 581 | 599 | | | 18 | 18 |
| 150 | 10 | 599 | 615 | | | 16 | 16 |
| 200 | 1 | 542 | 575 | | | 33 | 33 |
| 200 | 2 | 575 | 605 | | | 30 | 30 |
| 200 | 3 | 605 | 635 | | | 30 | 30 |
| 200 | 4 | 635 | 667 | | | 32 | 32 |
| 200 | 5 | 667 | 699 | | | 32 | 32 |
| 200 | 6 | 699 | 735 | | | 36 | 36 |
| 200 | 7 | 735 | 768 | | | 33 | 33 |
| 200 | 8 | 768 | 795 | | | 27 | 27 |
| 200 | 9 | 795 | 825 | | | 30 | 30 |
| 200 | 10 | 825 | 860 | | | 35 | 35 |
| 150 | 1 | 886.8 | 890 | | | 3.2 | 3.2 |
| 150 | 2 | 890 | 907 | | | 17 | 17 |
| 150 | 3 | 907 | 929 | | | 22 | 22 |
| 150 | 4 | 929 | 944 | | | 15 | 15 |
| 150 | 5 | 944 | 963 | | | 19 | 19 |
| 150 | 6 | 963 | 975 | | | 12 | 12 |
| 150 | 7 | 975 | 991 | | | 16 | 16 |
| 150 | 8 | 991 | 1006 | | | 15 | 15 |
| 150 | 9 | 1006 | 1021 | | | 15 | 15 |
| 150 | 10 | 1021 | 1037 | | | 16 | 16 |
| 80 | 1 | 974 | 984 | | | 10 | 10 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 80 | 2 | 984 | 994 | | | 10 | 10 |
| 80 | 3 | 994 | 1004 | | | 10 | 10 |
| 80 | 4 | 1004 | 1014 | | | 10 | 10 |
| 80 | 5 | 1014 | 1025 | | | 11 | 11 |
| 80 | 6 | 1025 | 1035 | | | 10 | 10 |
| 80 | 7 | 1035 | 1043 | | | 8 | 8 |
| 80 | 8 | 1043 | 1052 | | | 9 | 9 |
| 80 | 9 | 1052 | 1062 | | | 10 | 10 |
| 80 | 10 | 1062 | 1072 | | | 10 | 10 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal | DATE: 02-Apr-15 | HOLE DIP: 90 | DIP Direction: -

SITE NUMBER: HD Rig 1 | BORE I.D.: HU0146CH | BORE NAME: HU0146CH

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): | 15.14 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 8.64 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 5.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 50 | 1 | 45.5 | 47.5 | | | 2 | 2 |
| 50 | 2 | 47.5 | 49.5 | | | 2 | 2 |
| 50 | 3 | 49.5 | 51.6 | | | 2.1 | 2.1 |
| 50 | 4 | 51.6 | 53.6 | | | 2 | 2 |
| 50 | 5 | 53.6 | 55.5 | | | 1.9 | 1.9 |
| 50 | 6 | 55.5 | 56.5 | | | 1 | 1 |
| 50 | 7 | 56.5 | 58.5 | | | 2 | 2 |
| 50 | 8 | 58.5 | 61.4 | | | 2.9 | 2.9 |
| 50 | 9 | 61.4 | 63.4 | | | 2 | 2 |
| 50 | 10 | 63.4 | 65.2 | | | 1.8 | 1.8 |
| 100 | 1 | 69 | 73 | | | 4 | 4 |
| 100 | 2 | 73 | 76 | | | 3 | 3 |
| 100 | 3 | 76 | 79.2 | | | 3.2 | 3.2 |
| 100 | 4 | 79.2 | 82.6 | | | 3.4 | 3.4 |
| 100 | 5 | 82.6 | 86.6 | | | 4 | 4 |
| 100 | 6 | 86.6 | 89.8 | | | 3.2 | 3.2 |
| 100 | 7 | 89.8 | 93.6 | | | 3.8 | 3.8 |
| 100 | 8 | 93.6 | 98.5 | | | 4.9 | 4.9 |
| 100 | 9 | 98.5 | 103 | | | 4.5 | 4.5 |
| 100 | 10 | 103 | 107.5 | | | 4.5 | 4.5 |
| 130 | 1 | 321 | 336 | | | 15 | 15 |
| 130 | 2 | 336 | 351.2 | | | 15.2 | 15.2 |
| 130 | 3 | 351.2 | 369 | | | 17.8 | 17.8 |
| 130 | 4 | 369 | 383 | | | 14 | 14 |
| 130 | 5 | 383 | 399.4 | | | 16.4 | 16.4 |
| 130 | 6 | 399.4 | 416.2 | | | 16.8 | 16.8 |
| 130 | 7 | 416.2 | 433.5 | | | 17.3 | 17.3 |
| 130 | 8 | 433.5 | 448.5 | | | 15 | 15 |
| 130 | 9 | 448.5 | 469.4 | | | 20.9 | 20.9 |
| 130 | 10 | 469.4 | 488 | | | 18.6 | 18.6 |
| 100 | 1 | 498 | 515.4 | | | 17.4 | 17.4 |
| 100 | 2 | 515.4 | 533 | | | 17.6 | 17.6 |
| 100 | 3 | 533 | 551 | | | 18 | 18 |
| 100 | 4 | 551 | 567 | | | 16 | 16 |
| 100 | 5 | 567 | 592 | | | 25 | 25 |
| 100 | 6 | 592 | 613 | | | 21 | 21 |
| 100 | 7 | 613 | 629 | | | 16 | 16 |
| 100 | 8 | 629 | 653 | | | 24 | 24 |
| 100 | 9 | 653 | 669 | | | 16 | 16 |
| 100 | 10 | 669 | 690 | | | 21 | 21 |
| 50 | 1 | 699 | 716 | | | 17 | 17 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 50 | 2 | 716 | 734 | | | 18 | 18 |
| 50 | 3 | 734 | 753 | | | 19 | 19 |
| 50 | 4 | 753 | 768 | | | 15 | 15 |
| 50 | 5 | 768 | 786.4 | | | 18.4 | 18.4 |
| 50 | 6 | 786.4 | 805 | | | 18.6 | 18.6 |
| 50 | 7 | 805 | 824 | | | 19 | 19 |
| 50 | 8 | 824 | 845 | | | 21 | 21 |
| 50 | 9 | 845 | 863.5 | | | 18.5 | 18.5 |
| 50 | 10 | 863.5 | 879.5 | | | 16 | 16 |
| | | | | | | | |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)

Reference Method: WATROCK

Strata Control Technology

**HUME COAL**

Packer Test Report for Borehole HU0147PZB

**HUME4744_REV1**

Mining Research and Consulting Group

**SCT Operations Pty Ltd** PO Box 824 Wollongong NSW 2520 Australia
Phone: +61 2 4222 2777 Email: sctnsw@sct.gs Website: www.sct.gs
ABN 23 078 328 953

**REPORT TO** Joshua Reid
Hume Coal
Unit 7-8
Clarence House
9 Clarence Street
Moss Vale NSW 2577

**TITLE** Packer Test Report for Borehole HU0147PZB

**REPORT NO** HUME4744_Rev1

**PREPARED BY** Yvette Heritage

**DATE** 1 December 2017

Yvette Heritage
Senior Geotechnical Engineer

| Report No | Version | Date |
|---|---|---|
| HUME4744 | 1 | 15 November 2017 |
| HUME4744_Rev1 | 2 | 1 December 2017 |
| | | |
| | | |
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Winton Gale
Director

## SUMMARY

Hume Coal commissioned SCT Operations Pty Ltd (SCT) to conduct Lugeon-style packer testing in Borehole HU0147PZB to determine the hydraulic conductivity of selected horizons. Testing was conducted from 30th October to 1st November 2017 on seven horizons. The test horizons were chosen by EMM Consulting, with specific intervals confirmed between SCT and Hume Coal. This report presents the results of this testing.

The testing results are summarised as hydraulic conductivity in the following table.

| Depth From (mbgl) | Depth To (mbgl) | Horizon | Hydraulic Conductivity (m/s) |
|---|---|---|---|
| 123.65 | 130.15 | Wongawilli Seam | $1.9 \times 10^{-8}$ |
| 138.65 | 145.15 | Tongarra Seam | $5.3 \times 10^{-9}$ |
| 154.65 | 161.15 | Woonona Seam | $4.0 \times 10^{-8}$ |
| 160.65 | 167.15 | Standard rock | $1.7 \times 10^{-7}$ |
| 177.65 | 184.15 | Higher Density | $1.0 \times 10^{-11}$ |
| 216.65 | 227.18 | Base of hole | $1.7 \times 10^{-8}$ |

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## 1. INTRODUCTION

Hume Coal commissioned SCT Operations Pty Ltd (SCT) to conduct Lugeon-style packer testing in Borehole HU0147PZB to determine the hydraulic conductivity of selected horizons. Testing was conducted from 30th October to 1st November 2017 on seven horizons. The test horizons were chosen by EMM Consulting, with specific intervals confirmed between SCT and Hume Coal. This report presents the results of this testing.

The testing procedure is described in Section 2 and details of the analytical approach are described in Section 3. The hydraulic conductivity results are presented in Section 4 and a brief interpretation of the results is provided in Section 5. The raw packer test data and analyses are presented in Appendix A.

## 2. METHOD

Lugeon-style packer testing was conducted using a nitrogen inflated packer system. The tested section of the borehole was cored using HQ (96mm) size drilling equipment. The packers were deployed on the wireline through the drill pipe that also doubled as the test tubing.

The packer testing method undertaken is a Lugeon-style straddle packer test or terminal packer test where water is injected into an isolated section of the borehole. The test is conducted in five pressure stages. The pressure is incrementally increased at each stage then subsequently decreased. Flow is recorded every minute for 10 minutes at each pressure stage.

## 3. CALCULATIONS

Hydraulic conductivity calculations use the average of the CANMET, Hoek and Bray, and Houlsby methods. The formulae are outlined in the water pressure test result sheets (Appendix A). The calculations use the flow/head gradient which is an average of the plotted test data vs. total head. Zero conductivity denotes the lower limit of this style of test which is of the order of $1x10^{-11}$m/s.

The groundwater level was based on the geophysics for the hole which indicated a groundwater level at 18m depth below ground level.

## 4. LUGEON TESTING RESULTS

Seven selected tests were conducted in borehole HU0147PZB over the interval 123.65-227.18m, corresponding with the total depth of the borehole. The stratigraphy through the borehole consisted of the Hawkesbury Sandstone (0-122m) through to below the Woonona Seam.

The hydraulic conductivity results are presented in Table 1. Packer testing was conducted from the bottom of the hole up. The deepest test interval was a terminal test, where the bottom of the hole was the end of the test interval. Subsequent tests were straddle tests.

The second packer test could not be confidently analysed due to post testing determination that the test was impacted by an airline leak creating negative flow.

**Table 1: Hydraulic Conductivity Results**

| Test No. | Depth From (m) | Depth To (m) | Mid Depth (m) | Interval (m) | Horizon | Hydraulic Conductivity (m/s) |
|---|---|---|---|---|---|---|
| 1 | 216.65 | 227.18 | 221.92 | 10.53 | Base of hole | $1.7x10^{-8}$ |
| 2 | 210.65 | 217.15 | 213.9 | 6.5 | Change in clay content? | Failed Test - Airline leak |
| 3 | 177.65 | 184.15 | 180.9 | 6.5 | Higher Density | $1x10^{-11}$ |
| 4 | 160.65 | 167.15 | 163.9 | 6.5 | Standard rock | $1.7 \times 10^{-7}$ |
| 5 | 154.65 | 161.15 | 157.9 | 6.5 | Woonona Seam | $4.0 \times 10^{-8}$ |
| 6 | 138.65 | 145.15 | 141.9 | 6.5 | Tongarra Seam | $5.3x10^{-9}$ |
| 7 | 123.65 | 130.15 | 126.9 | 6.5 | Wongawilli Seam | $1.9x10^{-8}$ |

The hydraulic conductivity is a measure of the rate of flow of water through the rock. Figure 1 presents the profile of hydraulic conductivity plotted against depth. A decrease in hydraulic conductivity with increasing depth commonly occurs as a result of increasing confining stress acting on the fractures within the strata. In borehole HU0147PZB the depth range is small and the variation in conductivity appears to be linked to the presence of fractures and coal seams.

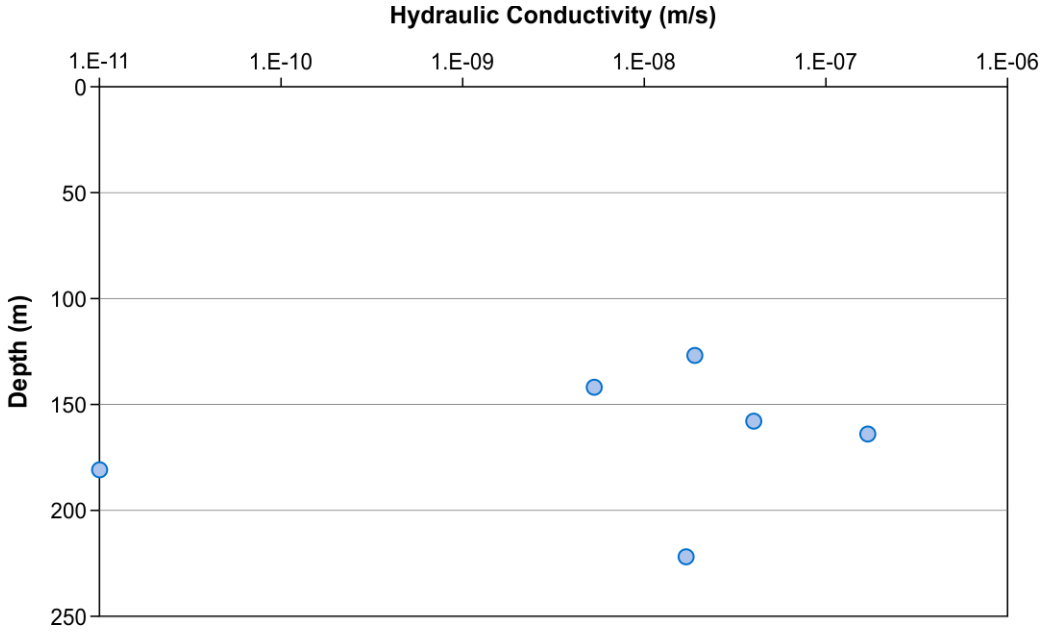



**Figure 1: Hydraulic Conductivity vs Depth**

Figure 2 shows a comparison of the current test results with previous packer testing conducted by SCT at Hume Coal. The increase in vertical stress with increasing depth, begins to close the horizontal fractures creating a reduced fracture aperture and resulting reduction in fracture conductivity. The latest results at a greater depth than previous testing support the trend of reduction in conductivity with depth.

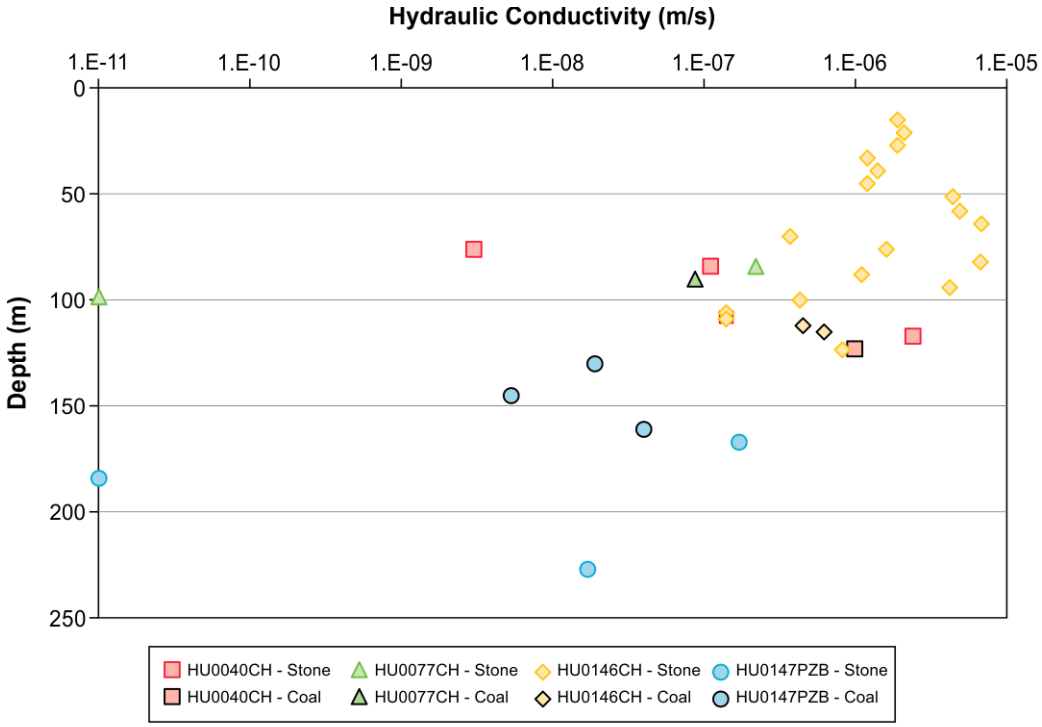



**Figure 2: Hume Packer Test Data Comparison**

## 5. CONCLUSION

Borehole HU0147PZB has a hydraulic conductivity range of no flow (estimated at $1x10^{-11}$m/s) and $2x10^{-7}$m/s. The Wongawilli Seam showed a conductivity of $2x10^{-8}$m/s and the Tongarra Seam showed a conductivity of $5x10^{-9}$m/s.

# APPENDIX A – PACKER TEST RESULTS

Job No: HUME4744

# Location: Hume Coal Project — Borehole: HU0147PZB — Depth Range: 216.65 -227.18 m

## PACKER TEST RESULTS: — K = 1.7E-08 m/s

**PROJECT:** Hume Coal Project **BORE NAME:** HU0147PZB **HOLE DIP:** 90 **DIP Direction:** **DATE:** 30 0ctober 2017

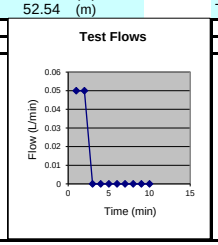
| | | | | | |
|---|---|---|---|---|---|
| Depth To Bottm Packer Test interval: | 227.18 | m | HEIGHT OF PRESSURE GAUGE: | 0 | m (above ground level) |
| Depth To Top Packer Test interval: | 216.65 | m | STATIC GROUNDWATER LEVEL: | 18.0 | m (below ground level) |
| LENGTH OF STAGE TEST: | 10.53 | m | | | |
| BORE DIAMETER: | 96 | mm | | | |

## Recorded flow readings at indicated applied pressure heads.

### Stage 1

| | | |
|---|---|---|
| Gauge Pressure | 230 | (kPa) |
| Gauge Pressure | 23.45 | (m) |
| Static Pressure | 29.1 | (m) |
| Head without loss correction | 52.54 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 52.54 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 98.5 | |
| 1 | 98.55 | 0.05 |
| 2 | 98.6 | 0.05 |
| 3 | 98.6 | 0 |
| 4 | 98.6 | 0 |
| 5 | 98.6 | 0 |
| 6 | 98.6 | 0 |
| 7 | 98.6 | 0 |
| 8 | 98.6 | 0 |
| 9 | 98.6 | 0 |
| 10 | 98.6 | 0 |

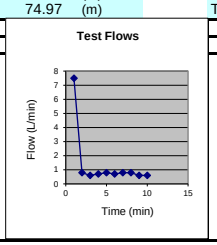



Arithmatic average = 0.01 (L/min)
Adopted average = 0.00 (L/min)

### Stage 2

| | | |
|---|---|---|
| Gauge Pressure | 450 | (kPa) |
| Gauge Pressure | 45.87 | (m) |
| Static Pressure | 29.1 | (m) |
| Head without loss correction | 74.97 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 74.97 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 98.6 | |
| 1 | 106.1 | 7.5 |
| 2 | 106.9 | 0.8 |
| 3 | 107.5 | 0.6 |
| 4 | 108.2 | 0.7 |
| 5 | 109 | 0.8 |
| 6 | 109.7 | 0.7 |
| 7 | 110.5 | 0.8 |
| 8 | 111.3 | 0.8 |
| 9 | 111.9 | 0.6 |
| 10 | 112.5 | 0.6 |

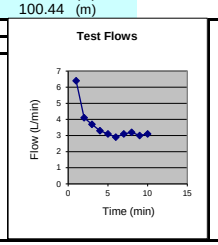



Arithmatic average = 1.39 (L/min)
Adopted average = 0.71 (L/min)

### Stage 3

| | | |
|---|---|---|
| Gauge Pressure | 700 | (kPa) |
| Gauge Pressure | 71.36 | (m) |
| Static Pressure | 29.1 | (m) |
| Head without loss correction | 100.45 | (m) |
| Head loss | 0.01 | (m) |
| High flow pressure calibratio | 0.00 | (m) |
| Total Head | 100.44 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 112.5 | |
| 1 | 118.9 | 6.4 |
| 2 | 123 | 4.1 |
| 3 | 126.7 | 3.7 |
| 4 | 130 | 3.3 |
| 5 | 133.1 | 3.1 |
| 6 | 136 | 2.9 |
| 7 | 139.1 | 3.1 |
| 8 | 142.3 | 3.2 |
| 9 | 145.3 | 3 |
| 10 | 148.4 | 3.1 |

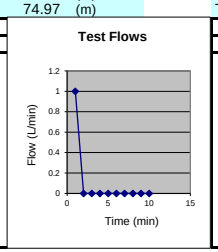



Arithmatic average = 3.59 (L/min)
Adopted average = 3.10 (L/min)

### Stage 4

| | | |
|---|---|---|
| Gauge Pressure | 450 | (kPa) |
| Gauge Pressure | 45.87 | (m) |
| Static Pressure | 29.1 | (m) |
| Head without loss correction | 74.97 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 74.97 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 146.9 | |
| 1 | 147.9 | 1 |
| 2 | 147.9 | 0 |
| 3 | 147.9 | 0 |
| 4 | 147.9 | 0 |
| 5 | 147.9 | 0 |
| 6 | 147.9 | 0 |
| 7 | 147.9 | 0 |
| 8 | 147.9 | 0 |
| 9 | 147.9 | 0 |
| 10 | 147.9 | 0 |

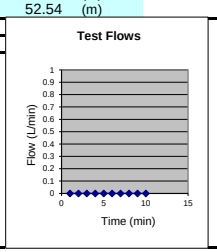



Arithmatic average = 0.10 (L/min)
Adopted average = 0.00 (L/min)

### Stage 5

| | | |
|---|---|---|
| Gauge Pressure | 230 | (kPa) |
| Gauge Pressure | 23.45 | (m) |
| Static Pressure | 29.1 | (m) |
| Head without loss correction | 52.54 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 52.54 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 144.3 | |
| 1 | 144.3 | 0 |
| 2 | 144.3 | 0 |
| 3 | 144.3 | 0 |
| 4 | 144.3 | 0 |
| 5 | 144.3 | 0 |
| 6 | 144.3 | 0 |
| 7 | 144.3 | 0 |
| 8 | 144.3 | 0 |
| 9 | 144.3 | 0 |
| 10 | 144.3 | 0 |




Arithmatic average = 0.00 (L/min)
Adopted average = 0.00 (L/min)

**Comments:**

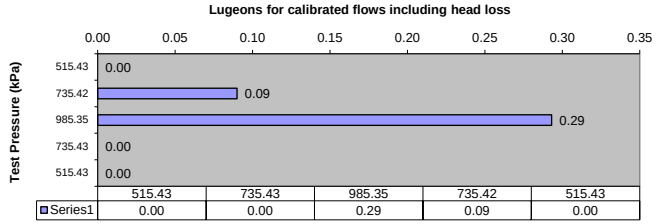
**Calculations used:**

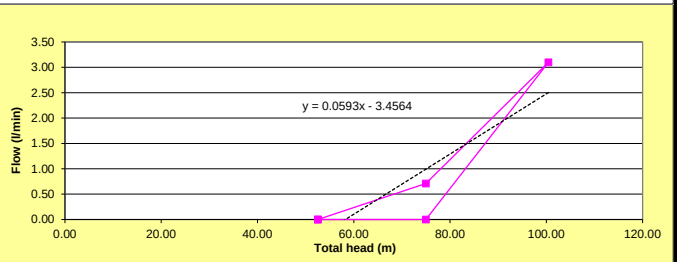
$$k = \frac{5.833}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot 10^{-5} \text{ m/s} \quad \text{(CANMET)}$$

$$k = \frac{8.333}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot \ln\left(\frac{L}{r}\right)\cdot 10^{-6} \text{ m/s} \quad \text{(HOEK \& BRAY)}$$

$$lugeon = \frac{Q}{L\sin\alpha}\cdot\frac{100}{H_T} \text{ l/m/min} \quad \text{(HOULSBY)}$$

| Stage | Total Head (m) | Flow (l/min) | Calculated Lugeon values: Test Pressure | Q (L/m/min) | Lugeons (L/m/min) | Chosen Lugeon (L/m/min) |
|---|---|---|---|---|---|---|
| 1 | 52.54 | 0.00 | 515.43 | 0.00 | 0.00 | |
| 2 | 74.97 | 0.71 | 735.42 | 0.07 | 0.09 | |
| 3 | 100.44 | 3.10 | 985.35 | 0.29 | 0.29 | 0.077 |
| 4 | 74.97 | 0.00 | 735.43 | 0.00 | 0.00 | |
| 5 | 52.54 | 0 | 515.43 | 0.00 | 0.00 | |




| Conductivity Calculations: | | | MEAN |
|---|---|---|---|
| MEAN Q/$H_T$ | CANMET | HOEK & BRAY | LUGEONS 0.08 |
| 0.014 | 2.4E-08 | 1.8E-08 | 1.0E-08 m/s |
| Mean Conductivity | K = | 1.7E-08 | m/s |

Job No: HUME4744

# Location: Hume Coal Project — Borehole: HU0147PZB — Depth Range: 177.65 -184.15 m

## PACKER TEST RESULTS: — K = 1.0E-11 m/s

**PROJECT:** Hume Coal Project **BORE NAME:** HU0147PZB **HOLE DIP:** 90 **DIP Direction:** **DATE:** 31-Oct-17

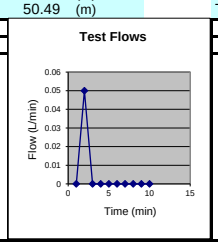
| | | | | | |
|---|---|---|---|---|---|
| Depth To Bottm Packer Test interval: | 184.15 | m | HEIGHT OF PRESSURE GAUGE: | 0 | m (above ground level) |
| Depth To Top Packer Test interval: | 177.65 | m | STATIC GROUNDWATER LEVEL: | 18.0 | m (below ground level) |
| LENGTH OF STAGE TEST: | 6.50 | m | | | |
| BORE DIAMETER: | 96 | mm | | | |

## Recorded flow readings at indicated applied pressure heads.

### Stage 1

| | | |
|---|---|---|
| Gauge Pressure | 230 | (kPa) |
| Gauge Pressure | 23.45 | (m) |
| Static Pressure | 27.0 | (m) |
| Head without loss correction | 50.49 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 50.49 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 389.2 | |
| 1 | 389.2 | 0 |
| 2 | 389.25 | 0.05 |
| 3 | 389.25 | 0 |
| 4 | 389.25 | 0 |
| 5 | 389.25 | 0 |
| 6 | 389.25 | 0 |
| 7 | 389.25 | 0 |
| 8 | 389.25 | 0 |
| 9 | 389.25 | 0 |
| 10 | 389.25 | 0 |

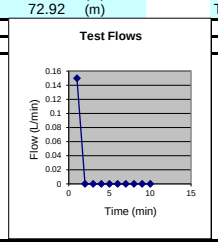



Arithmatic average = 0.01 (L/min)
Adopted average = 0.00 (L/min)

### Stage 2

| | | |
|---|---|---|
| Gauge Pressure | 450 | (kPa) |
| Gauge Pressure | 45.87 | (m) |
| Static Pressure | 27.0 | (m) |
| Head without loss correction | 72.92 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 72.92 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 389.25 | |
| 1 | 389.4 | 0.15 |
| 2 | 389.4 | 0 |
| 3 | 389.4 | 0 |
| 4 | 389.4 | 0 |
| 5 | 389.4 | 0 |
| 6 | 389.4 | 0 |
| 7 | 389.4 | 0 |
| 8 | 389.4 | 0 |
| 9 | 389.4 | 0 |
| 10 | 389.4 | 0 |

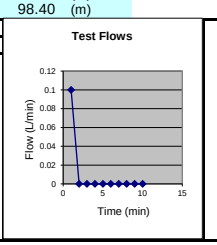



Arithmatic average = 0.01 (L/min)
Adopted average = 0.00 (L/min)

### Stage 3

| | | |
|---|---|---|
| Gauge Pressure | 700 | (kPa) |
| Gauge Pressure | 71.36 | (m) |
| Static Pressure | 27.0 | (m) |
| Head without loss correction | 98.40 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibratio | 0.00 | (m) |
| Total Head | 98.40 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 389.4 | |
| 1 | 389.5 | 0.1 |
| 2 | 389.5 | 0 |
| 3 | 389.5 | 0 |
| 4 | 389.5 | 0 |
| 5 | 389.5 | 0 |
| 6 | 389.5 | 0 |
| 7 | 389.5 | 0 |
| 8 | 389.5 | 0 |
| 9 | 389.5 | 0 |
| 10 | 389.5 | 0 |

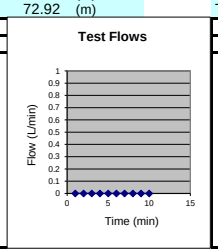



Arithmatic average = 0.01 (L/min)
Adopted average = 0.00 (L/min)

### Stage 4

| | | |
|---|---|---|
| Gauge Pressure | 450 | (kPa) |
| Gauge Pressure | 45.87 | (m) |
| Static Pressure | 27.0 | (m) |
| Head without loss correction | 72.92 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 72.92 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 389.5 | |
| 1 | 389.5 | 0 |
| 2 | 389.5 | 0 |
| 3 | 389.5 | 0 |
| 4 | 389.5 | 0 |
| 5 | 389.5 | 0 |
| 6 | 389.5 | 0 |
| 7 | 389.5 | 0 |
| 8 | 389.5 | 0 |
| 9 | 389.5 | 0 |
| 10 | 389.5 | 0 |

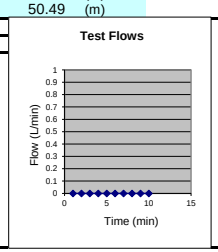



Arithmatic average = 0.00 (L/min)
Adopted average = 0.00 (L/min)

### Stage 5

| | | |
|---|---|---|
| Gauge Pressure | 230 | (kPa) |
| Gauge Pressure | 23.45 | (m) |
| Static Pressure | 27.0 | (m) |
| Head without loss correction | 50.49 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 50.49 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 289.45 | |
| 1 | 389.45 | 0 |
| 2 | 389.45 | 0 |
| 3 | 389.45 | 0 |
| 4 | 389.45 | 0 |
| 5 | 389.45 | 0 |
| 6 | 389.45 | 0 |
| 7 | 389.45 | 0 |
| 8 | 389.45 | 0 |
| 9 | 389.45 | 0 |
| 10 | 389.45 | 0 |




Arithmatic average = 0.00 (L/min)
Adopted average = 0.00 (L/min)

**Comments:** No flow was observed. Due to the test sensitivity of 0.1L over 10 minutes, a maximum conductivity of $1x10^{-11}$m/s is estimated.

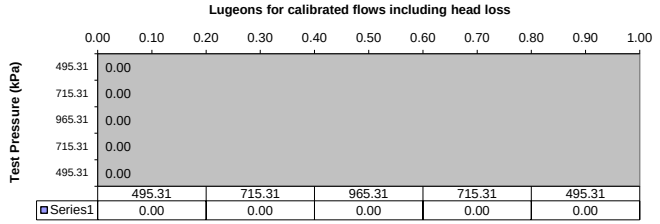
**Calculations used:**

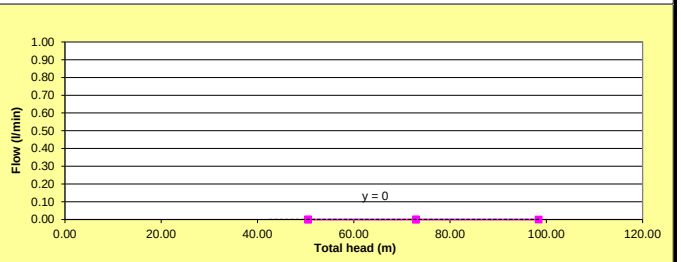
$$k = \frac{5.833}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot 10^{-5} \text{ m/s} \quad \text{(CANMET)}$$

$$k = \frac{8.333}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot \ln\left(\frac{L}{r}\right)\cdot 10^{-6} \text{ m/s} \quad \text{(HOEK \& BRAY)}$$

$$lugeon = \frac{Q}{L\sin\alpha}\cdot\frac{100}{H_T} \text{ l/m/min} \quad \text{(HOULSBY)}$$

| Stage | Total Head (m) | Flow (l/min) | Calculated Lugeon values: Test Pressure | Q (L/m/min) | Lugeons (L/m/min) | Chosen Lugeon (L/m/min) |
|---|---|---|---|---|---|---|
| 1 | 50.49 | 0.00 | 495.31 | 0.00 | 0.00 | |
| 2 | 72.92 | 0.00 | 715.31 | 0.00 | 0.00 | |
| 3 | 98.40 | 0.00 | 965.31 | 0.00 | 0.00 | 0.000 |
| 4 | 72.92 | 0.00 | 715.31 | 0.00 | 0.00 | |
| 5 | 50.49 | 0 | 495.31 | 0.00 | 0.00 | |




## Conductivity Calculations:

| MEAN Q/$H_T$ | CANMET | HOEK & BRAY | MEAN LUGEONS | |
|---|---|---|---|---|
| 0.000 | 0.0E+00 | 0.0E+00 | 0.0E+00 | m/s |
| | | | Mean Conductivity K = | 1.0E-11 m/s |

Job No: HUME4744

# Location: Hume Coal Project — Borehole: HU0147PZB — Depth Range: 160.65 -167.15 m

## PACKER TEST RESULTS: — K = 1.7E-07 m/s

**PROJECT:** Hume Coal Project **BORE NAME:** HU0147PZB **HOLE DIP:** 90 **DIP Direction:** **DATE:** 31-Oct-17

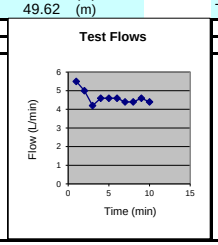
| | | | | | |
|---|---|---|---|---|---|
| Depth To Bottm Packer Test interval: | 167.15 | m | HEIGHT OF PRESSURE GAUGE: | 0 | m (above ground level) |
| Depth To Top Packer Test interval: | 160.65 | m | STATIC GROUNDWATER LEVEL: | 18.0 | m (below ground level) |
| LENGTH OF STAGE TEST: | 6.50 | m | | | |
| BORE DIAMETER: | 96 | mm | | | |

## Recorded flow readings at indicated applied pressure heads.

### Stage 1

| | | |
|---|---|---|
| Gauge Pressure | 230 | (kPa) |
| Gauge Pressure | 23.45 | (m) |
| Static Pressure | 26.2 | (m) |
| Head without loss correction | 49.64 | (m) |
| Head loss | 0.02 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 49.62 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 573 | |
| 1 | 578.5 | 5.5 |
| 2 | 583.5 | 5 |
| 3 | 587.7 | 4.2 |
| 4 | 592.3 | 4.6 |
| 5 | 596.9 | 4.6 |
| 6 | 601.5 | 4.6 |
| 7 | 605.9 | 4.4 |
| 8 | 610.3 | 4.4 |
| 9 | 614.9 | 4.6 |
| 10 | 619.3 | 4.4 |

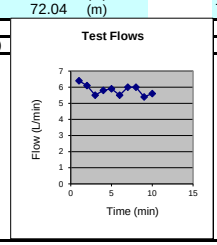



**Arithmatic average =** 4.53 (L/min)
**Adopted average =** 4.53 (L/min)

### Stage 2

| | | |
|---|---|---|
| Gauge Pressure | 450 | (kPa) |
| Gauge Pressure | 45.87 | (m) |
| Static Pressure | 26.2 | (m) |
| Head without loss correction | 72.07 | (m) |
| Head loss | 0.03 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 72.04 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 619.3 | |
| 1 | 625.7 | 6.4 |
| 2 | 631.8 | 6.1 |
| 3 | 637.3 | 5.5 |
| 4 | 643.1 | 5.8 |
| 5 | 649 | 5.9 |
| 6 | 654.5 | 5.5 |
| 7 | 660.5 | 6 |
| 8 | 666.5 | 6 |
| 9 | 671.9 | 5.4 |
| 10 | 677.5 | 5.6 |

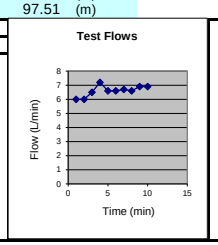



**Arithmatic average =** 5.82 (L/min)
**Adopted average =** 5.82 (L/min)

### Stage 3

| | | |
|---|---|---|
| Gauge Pressure | 700 | (kPa) |
| Gauge Pressure | 71.36 | (m) |
| Static Pressure | 26.2 | (m) |
| Head without loss correction | 97.55 | (m) |
| Head loss | 0.04 | (m) |
| High flow pressure calibratio | 0.00 | (m) |
| Total Head | 97.51 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 688 | |
| 1 | 694 | 6 |
| 2 | 700 | 6 |
| 3 | 706.5 | 6.5 |
| 4 | 713.7 | 7.2 |
| 5 | 720.3 | 6.6 |
| 6 | 726.9 | 6.6 |
| 7 | 733.6 | 6.7 |
| 8 | 740.2 | 6.6 |
| 9 | 747.1 | 6.9 |
| 10 | 754 | 6.9 |

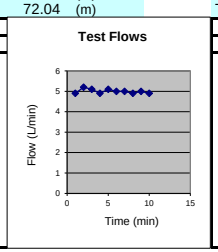



**Arithmatic average =** 6.60 (L/min)
**Adopted average =** 6.60 (L/min)

### Stage 4

| | | |
|---|---|---|
| Gauge Pressure | 450 | (kPa) |
| Gauge Pressure | 45.87 | (m) |
| Static Pressure | 26.2 | (m) |
| Head without loss correction | 72.07 | (m) |
| Head loss | 0.02 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 72.04 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 754 | |
| 1 | 758.9 | 4.9 |
| 2 | 764.1 | 5.2 |
| 3 | 769.2 | 5.1 |
| 4 | 774.1 | 4.9 |
| 5 | 779.2 | 5.1 |
| 6 | 784.2 | 5 |
| 7 | 789.2 | 5 |
| 8 | 794.1 | 4.9 |
| 9 | 799.1 | 5 |
| 10 | 804 | 4.9 |

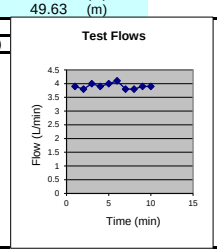



**Arithmatic average =** 5.00 (L/min)
**Adopted average =** 5.00 (L/min)

### Stage 5

| | | |
|---|---|---|
| Gauge Pressure | 230 | (kPa) |
| Gauge Pressure | 23.45 | (m) |
| Static Pressure | 26.2 | (m) |
| Head without loss correction | 49.64 | (m) |
| Head loss | 0.01 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 49.63 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 804 | |
| 1 | 807.9 | 3.9 |
| 2 | 811.7 | 3.8 |
| 3 | 815.7 | 4 |
| 4 | 819.6 | 3.9 |
| 5 | 823.6 | 4 |
| 6 | 827.7 | 4.1 |
| 7 | 831.5 | 3.8 |
| 8 | 835.3 | 3.8 |
| 9 | 839.2 | 3.9 |
| 10 | 843.1 | 3.9 |




**Arithmatic average =** 3.91 (L/min)
**Adopted average =** 3.91 (L/min)

**Comments:**

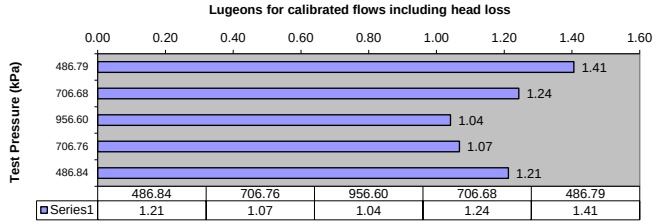
### Calculations used:

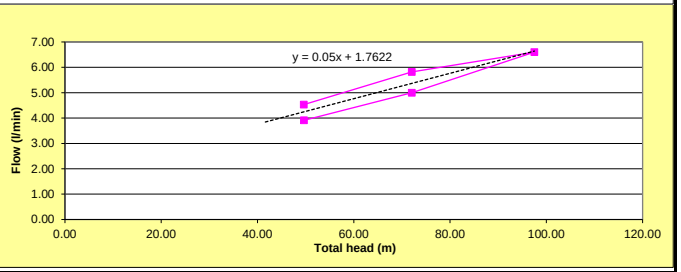
$$k = \frac{5.833}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot 10^{-5} \text{ m/s} \quad \text{(CANMET)}$$

$$k = \frac{8.333}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot \ln\left(\frac{L}{r}\right)\cdot 10^{-6} \text{ m/s} \quad \text{(HOEK \& BRAY)}$$

$$lugeon = \frac{Q}{L\sin\alpha}\cdot\frac{100}{H_T} \text{ l/m/min} \quad \text{(HOULSBY)}$$

| Stage | Total Head (m) | Flow (l/min) | Calculated Lugeon values: Test Pressure | Q (L/m/min) | Lugeons (L/m/min) | Chosen Lugeon (L/m/min) |
|---|---|---|---|---|---|---|
| 1 | 49.62 | 4.53 | 486.79 | 0.70 | 1.41 | |
| 2 | 72.04 | 5.82 | 706.68 | 0.90 | 1.24 | |
| 3 | 97.51 | 6.60 | 956.60 | 1.02 | 1.04 | 1.194 |
| 4 | 72.04 | 5.00 | 706.76 | 0.77 | 1.07 | |
| 5 | 49.63 | 3.91 | 486.84 | 0.60 | 1.21 | |




| Conductivity Calculations: | | | MEAN LUGEONS | |
|---|---|---|---|---|
| MEAN $Q/H_T$ | CANMET | HOEK & BRAY | 1.19 | |
| 0.074 | 2.1E-07 | 1.5E-07 | 1.6E-07 | m/s |
| **Mean Conductivity** | | **K =** | **1.7E-07** | **m/s** |

Job No: HUME4744

# Location: Hume Coal Project — Borehole: HU0147PZB — Depth Range: 154.65 -161.15 m

## PACKER TEST RESULTS: — K = 4.0E-08 m/s

**PROJECT:** Hume Coal Project — **BORE NAME:** HU0147PZB — **HOLE DIP:** 90 — **DIP Direction:** — **DATE:** 31-Oct-17

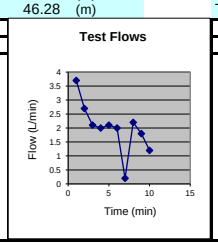
| | | | | | |
|---|---|---|---|---|---|
| Depth To Bottm Packer Test interval: | 161.15 | m | HEIGHT OF PRESSURE GAUGE: | 0 | m (above ground level) |
| Depth To Top Packer Test interval: | 154.65 | m | STATIC GROUNDWATER LEVEL: | 18.0 | m (below ground level) |
| LENGTH OF STAGE TEST: | 6.50 | m | | | |
| BORE DIAMETER: | 96 | mm | | | |

## Recorded flow readings at indicated applied pressure heads.

### Stage 1

| | | |
|---|---|---|
| Gauge Pressure | 200 | (kPa) |
| Gauge Pressure | 20.39 | (m) |
| Static Pressure | 25.9 | (m) |
| Head without loss correction | 46.28 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 46.28 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 20 | |
| 1 | 23.7 | 3.7 |
| 2 | 26.4 | 2.7 |
| 3 | 28.5 | 2.1 |
| 4 | 30.5 | 2 |
| 5 | 32.6 | 2.1 |
| 6 | 34.6 | 2 |
| 7 | 34.8 | 0.2 |
| 8 | 37 | 2.2 |
| 9 | 38.8 | 1.8 |
| 10 | 40 | 1.2 |

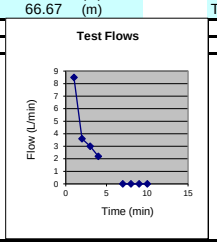



Arithmatic average = 2.00 (L/min)
Adopted average = 2.00 (L/min)

### Stage 2

| | | |
|---|---|---|
| Gauge Pressure | 400 | (kPa) |
| Gauge Pressure | 40.77 | (m) |
| Static Pressure | 25.9 | (m) |
| Head without loss correction | 66.67 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 66.67 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 40 | |
| 1 | 48.5 | 8.5 |
| 2 | 52.1 | 3.6 |
| 3 | 55.1 | 3 |
| 4 | 57.3 | 2.2 |
| 5 | 57.1 | |
| 6 | 57 | |
| 7 | 57 | 0 |
| 8 | 57 | 0 |
| 9 | 57 | 0 |
| 10 | 57 | 0 |

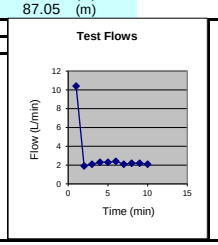



Arithmatic average = 1.26 (L/min)
Adopted average = 1.26 (L/min)

### Stage 3

| | | |
|---|---|---|
| Gauge Pressure | 600 | (kPa) |
| Gauge Pressure | 61.16 | (m) |
| Static Pressure | 25.9 | (m) |
| Head without loss correction | 87.06 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibratio | 0.00 | (m) |
| Total Head | 87.05 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 57 | |
| 1 | 67.4 | 10.4 |
| 2 | 69.3 | 1.9 |
| 3 | 71.4 | 2.1 |
| 4 | 73.7 | 2.3 |
| 5 | 76 | 2.3 |
| 6 | 78.4 | 2.4 |
| 7 | 80.5 | 2.1 |
| 8 | 82.7 | 2.2 |
| 9 | 84.9 | 2.2 |
| 10 | 87 | 2.1 |

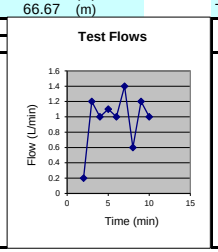



Arithmatic average = 2.18 (L/min)
Adopted average = 2.18 (L/min)

### Stage 4

| | | |
|---|---|---|
| Gauge Pressure | 400 | (kPa) |
| Gauge Pressure | 40.77 | (m) |
| Static Pressure | 25.9 | (m) |
| Head without loss correction | 66.67 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 66.67 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 87 | |
| 1 | 79.7 | |
| 2 | 79.9 | 0.2 |
| 3 | 81.1 | 1.2 |
| 4 | 82.1 | 1 |
| 5 | 83.2 | 1.1 |
| 6 | 84.2 | 1 |
| 7 | 85.6 | 1.4 |
| 8 | 86.2 | 0.6 |
| 9 | 87.4 | 1.2 |
| 10 | 88.4 | 1 |

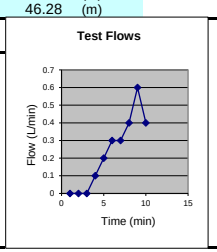



Arithmatic average = 0.87 (L/min)
Adopted average = 0.87 (L/min)

### Stage 5

| | | |
|---|---|---|
| Gauge Pressure | 200 | (kPa) |
| Gauge Pressure | 20.39 | (m) |
| Static Pressure | 25.9 | (m) |
| Head without loss correction | 46.28 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 46.28 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 77.8 | |
| 1 | 77.8 | 0 |
| 2 | 77.8 | 0 |
| 3 | 77.8 | 0 |
| 4 | 77.9 | 0.1 |
| 5 | 78.1 | 0.2 |
| 6 | 78.4 | 0.3 |
| 7 | 78.7 | 0.3 |
| 8 | 79.1 | 0.4 |
| 9 | 79.7 | 0.6 |
| 10 | 80.1 | 0.4 |




Arithmatic average = 0.23 (L/min)
Adopted average = 0.23 (L/min)

**Comments:**

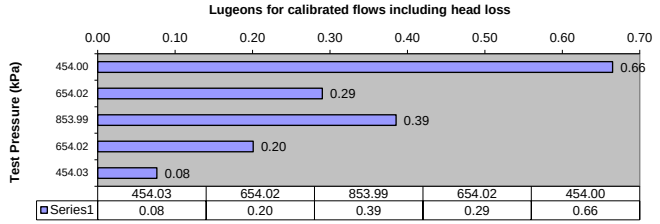
### Calculations used:

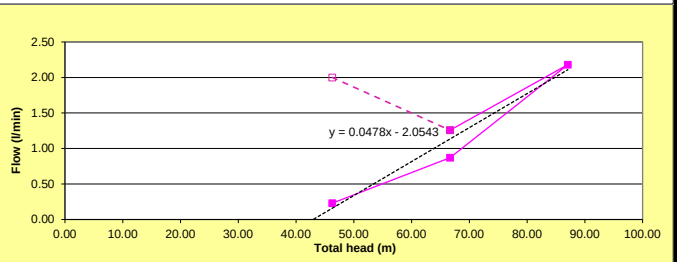
$$k = \frac{5.833}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot 10^{-5} \text{ m/s} \quad \text{(CANMET)}$$

$$k = \frac{8.333}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot \ln\left(\frac{L}{r}\right)\cdot 10^{-6} \text{ m/s} \quad \text{(HOEK \& BRAY)}$$

$$lugeon = \frac{Q}{L\sin\alpha}\cdot\frac{100}{H_T} \text{ l/m/min} \quad \text{(HOULSBY)}$$

| Stage | Total Head (m) | Flow (l/min) | Calculated Lugeon values: Test Pressure | Q (L/m/min) | Lugeons (L/m/min) | Chosen Lugeon (L/m/min) |
|---|---|---|---|---|---|---|
| 1 | 46.28 | 2.00 | 454.00 | 0.31 | 0.66 | |
| 2 | 66.67 | 1.26 | 654.02 | 0.19 | 0.29 | |
| 3 | 87.05 | 2.18 | 853.99 | 0.34 | 0.39 | 0.238 |
| 4 | 66.67 | 0.87 | 654.02 | 0.13 | 0.20 | |
| 5 | 46.28 | 0.23 | 454.03 | 0.04 | 0.08 | |




### Conductivity Calculations:

| MEAN Q/$H_T$ | CANMET | HOEK & BRAY | MEAN LUGEONS 0.24 | |
|---|---|---|---|---|
| 0.018 | 5.3E-08 | 3.7E-08 | 3.1E-08 | m/s |

**Mean Conductivity K = 4.0E-08 m/s**

Job No: HUME4744

# Location: Hume Coal Project — Borehole: HU014PZB — Depth Range: 138.65 -145.15 m

## PACKER TEST RESULTS: — K = 5.3E-09 m/s

**PROJECT:** Hume Coal Project **BORE NAME:** HU014PZB **HOLE DIP:** 90 **DIP Direction:** **DATE:** 31-Oct-17

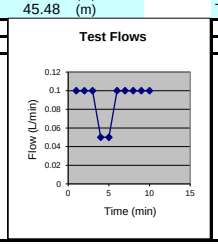
| | | | | | |
|---|---|---|---|---|---|
| Depth To Bottm Packer Test interval: | 145.15 | m | HEIGHT OF PRESSURE GAUGE: | 0 | m (above ground level) |
| Depth To Top Packer Test interval: | 138.65 | m | STATIC GROUNDWATER LEVEL: | 18.0 | m (below ground level) |
| LENGTH OF STAGE TEST: | 6.50 | m | | | |
| BORE DIAMETER: | 96 | mm | | | |

## Recorded flow readings at indicated applied pressure heads.

### Stage 1

| | | |
|---|---|---|
| Gauge Pressure | 200 | (kPa) |
| Gauge Pressure | 20.39 | (m) |
| Static Pressure | 25.1 | (m) |
| Head without loss correction | 45.48 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 45.48 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 275.9 | |
| 1 | 276 | 0.1 |
| 2 | 276.1 | 0.1 |
| 3 | 276.2 | 0.1 |
| 4 | 276.25 | 0.05 |
| 5 | 276.3 | 0.05 |
| 6 | 276.4 | 0.1 |
| 7 | 276.5 | 0.1 |
| 8 | 276.6 | 0.1 |
| 9 | 276.7 | 0.1 |
| 10 | 276.8 | 0.1 |

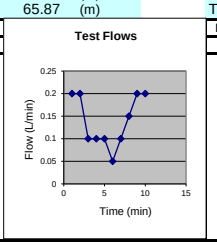



**Arithmatic average =** 0.09 (L/min)
**Adopted average =** 0.09 (L/min)

### Stage 2

| | | |
|---|---|---|
| Gauge Pressure | 400 | (kPa) |
| Gauge Pressure | 40.77 | (m) |
| Static Pressure | 25.1 | (m) |
| Head without loss correction | 65.87 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 65.87 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 277 | |
| 1 | 277.2 | 0.2 |
| 2 | 277.4 | 0.2 |
| 3 | 277.5 | 0.1 |
| 4 | 277.6 | 0.1 |
| 5 | 277.7 | 0.1 |
| 6 | 277.75 | 0.05 |
| 7 | 277.85 | 0.1 |
| 8 | 278 | 0.15 |
| 9 | 278.2 | 0.2 |
| 10 | 278.4 | 0.2 |

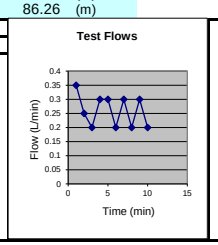



**Arithmatic average =** 0.14 (L/min)
**Adopted average =** 0.14 (L/min)

### Stage 3

| | | |
|---|---|---|
| Gauge Pressure | 600 | (kPa) |
| Gauge Pressure | 61.16 | (m) |
| Static Pressure | 25.1 | (m) |
| Head without loss correction | 86.26 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibratio | 0.00 | (m) |
| Total Head | 86.26 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 278.4 | |
| 1 | 278.75 | 0.35 |
| 2 | 279 | 0.25 |
| 3 | 279.2 | 0.2 |
| 4 | 279.5 | 0.3 |
| 5 | 279.8 | 0.3 |
| 6 | 280 | 0.2 |
| 7 | 280.3 | 0.3 |
| 8 | 280.5 | 0.2 |
| 9 | 280.8 | 0.3 |
| 10 | 281 | 0.2 |

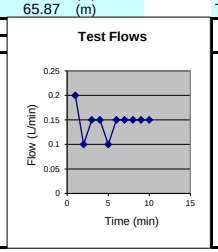



**Arithmatic average =** 0.26 (L/min)
**Adopted average =** 0.26 (L/min)

### Stage 4

| | | |
|---|---|---|
| Gauge Pressure | 400 | (kPa) |
| Gauge Pressure | 40.77 | (m) |
| Static Pressure | 25.1 | (m) |
| Head without loss correction | 65.87 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 65.87 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 281 | |
| 1 | 281.2 | 0.2 |
| 2 | 281.3 | 0.1 |
| 3 | 281.45 | 0.15 |
| 4 | 281.6 | 0.15 |
| 5 | 281.7 | 0.1 |
| 6 | 281.85 | 0.15 |
| 7 | 282 | 0.15 |
| 8 | 282.15 | 0.15 |
| 9 | 282.3 | 0.15 |
| 10 | 282.45 | 0.15 |

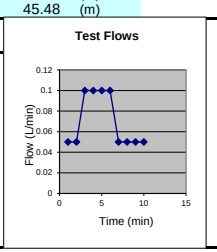



**Arithmatic average =** 0.14 (L/min)
**Adopted average =** 0.14 (L/min)

### Stage 5

| | | |
|---|---|---|
| Gauge Pressure | 200 | (kPa) |
| Gauge Pressure | 20.39 | (m) |
| Static Pressure | 25.1 | (m) |
| Head without loss correction | 45.48 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 45.48 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 282.45 | |
| 1 | 282.5 | 0.05 |
| 2 | 282.55 | 0.05 |
| 3 | 282.65 | 0.1 |
| 4 | 282.75 | 0.1 |
| 5 | 282.85 | 0.1 |
| 6 | 282.95 | 0.1 |
| 7 | 283 | 0.05 |
| 8 | 283.05 | 0.05 |
| 9 | 283.1 | 0.05 |
| 10 | 283.15 | 0.05 |




**Arithmatic average =** 0.07 (L/min)
**Adopted average =** 0.07 (L/min)

**Comments:**

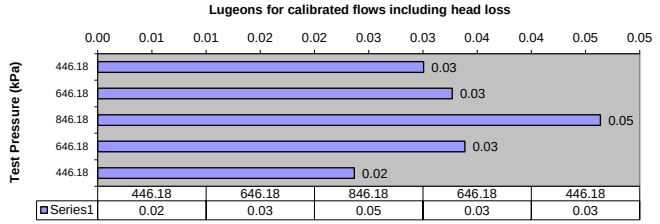
### Calculations used:

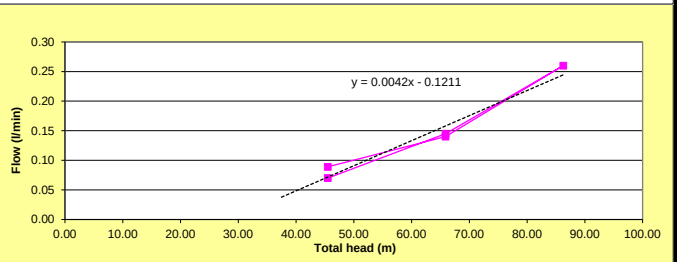
$$k = \frac{5.833}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot 10^{-5} \text{ m/s} \quad \text{(CANMET)}$$

$$k = \frac{8.333}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot \ln\left(\frac{L}{r}\right)\cdot 10^{-6} \text{ m/s} \quad \text{(HOEK \& BRAY)}$$

$$lugeon = \frac{Q}{L\sin\alpha}\cdot\frac{100}{H_T} \text{ l/m/min} \quad \text{(HOULSBY)}$$

| Stage | Total Head (m) | Flow (l/min) | Calculated Lugeon values: Test Pressure | Q (L/m/min) | Lugeons (L/m/min) | Chosen Lugeon (L/m/min) |
|---|---|---|---|---|---|---|
| 1 | 45.48 | 0.09 | 446.18 | 0.01 | 0.03 | |
| 2 | 65.87 | 0.14 | 646.18 | 0.02 | 0.03 | |
| 3 | 86.26 | 0.26 | 846.18 | 0.04 | 0.05 | 0.033 |
| 4 | 65.87 | 0.14 | 646.18 | 0.02 | 0.03 | |
| 5 | 45.48 | 0.07 | 446.18 | 0.01 | 0.02 | |




### Conductivity Calculations:

| MEAN Q/$H_T$ | CANMET | HOEK & BRAY | MEAN LUGEONS 0.03 | |
|---|---|---|---|---|
| 0.002 | 6.8E-09 | 4.8E-09 | 4.3E-09 | m/s |

**Mean Conductivity K = 5.3E-09 m/s**

Job No: HUME4744

# Location: Hume Coal Project — Borehole: HU0147PZB — Depth Range: 123.65 -130.15 m

## PACKER TEST RESULTS: — K = 1.9E-08 m/s

**PROJECT:** Hume Coal Project **BORE NAME:** HU0147PZB **HOLE DIP:** 90 **DIP Direction:** **DATE:** 01-Nov-17

| | | | | | |
|---|---|---|---|---|---|
| Depth To Bottm Packer Test interval: | 130.15 | m | HEIGHT OF PRESSURE GAUGE: | 0 | m (above ground level) |
| Depth To Top Packer Test interval: | 123.65 | m | STATIC GROUNDWATER LEVEL: | 18.0 | m (below ground level) |
| LENGTH OF STAGE TEST: | 6.50 | m | | | |
| BORE DIAMETER: | 96 | mm | | | |

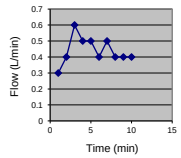
## Recorded flow readings at indicated applied pressure heads.

### Stage 1

| | | |
|---|---|---|
| Gauge Pressure | 200 | (kPa) |
| Gauge Pressure | 20.39 | (m) |
| Static Pressure | 24.3 | (m) |
| Head without loss correction | 44.73 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 44.73 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 395.5 | |
| 1 | 395.8 | 0.3 |
| 2 | 396.2 | 0.4 |
| 3 | 396.8 | 0.6 |
| 4 | 397.3 | 0.5 |
| 5 | 397.8 | 0.5 |
| 6 | 398.2 | 0.4 |
| 7 | 398.7 | 0.5 |
| 8 | 399.1 | 0.4 |
| 9 | 399.5 | 0.4 |
| 10 | 399.9 | 0.4 |

Test Flows



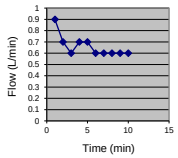

Arithmatic average = 0.44 (L/min)
Adopted average = 0.44 (L/min)

### Stage 2

| | | |
|---|---|---|
| Gauge Pressure | 400 | (kPa) |
| Gauge Pressure | 40.77 | (m) |
| Static Pressure | 24.3 | (m) |
| Head without loss correction | 65.12 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 65.12 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 399.9 | |
| 1 | 400.8 | 0.9 |
| 2 | 401.5 | 0.7 |
| 3 | 402.1 | 0.6 |
| 4 | 402.8 | 0.7 |
| 5 | 403.5 | 0.7 |
| 6 | 404.1 | 0.6 |
| 7 | 404.7 | 0.6 |
| 8 | 405.3 | 0.6 |
| 9 | 405.9 | 0.6 |
| 10 | 406.5 | 0.6 |

Test Flows



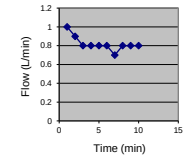

Arithmatic average = 0.66 (L/min)
Adopted average = 0.63 (L/min)

### Stage 3

| | | |
|---|---|---|
| Gauge Pressure | 600 | (kPa) |
| Gauge Pressure | 61.16 | (m) |
| Static Pressure | 24.3 | (m) |
| Head without loss correction | 85.51 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibratio | 0.00 | (m) |
| Total Head | 85.51 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 406.5 | |
| 1 | 407.5 | 1 |
| 2 | 408.4 | 0.9 |
| 3 | 409.2 | 0.8 |
| 4 | 410 | 0.8 |
| 5 | 410.8 | 0.8 |
| 6 | 411.6 | 0.8 |
| 7 | 412.3 | 0.7 |
| 8 | 413.1 | 0.8 |
| 9 | 413.9 | 0.8 |
| 10 | 414.7 | 0.8 |

Test Flows



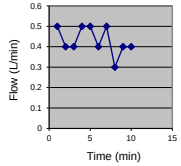

Arithmatic average = 0.82 (L/min)
Adopted average = 0.82 (L/min)

### Stage 4

| | | |
|---|---|---|
| Gauge Pressure | 400 | (kPa) |
| Gauge Pressure | 40.77 | (m) |
| Static Pressure | 24.3 | (m) |
| Head without loss correction | 65.12 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 65.12 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 415.2 | |
| 1 | 415.7 | 0.5 |
| 2 | 416.1 | 0.4 |
| 3 | 416.5 | 0.4 |
| 4 | 417 | 0.5 |
| 5 | 417.5 | 0.5 |
| 6 | 417.9 | 0.4 |
| 7 | 418.4 | 0.5 |
| 8 | 418.7 | 0.3 |
| 9 | 419.1 | 0.4 |
| 10 | 419.5 | 0.4 |

Test Flows



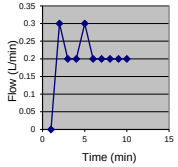

Arithmatic average = 0.43 (L/min)
Adopted average = 0.43 (L/min)

### Stage 5

| | | |
|---|---|---|
| Gauge Pressure | 200 | (kPa) |
| Gauge Pressure | 20.39 | (m) |
| Static Pressure | 24.3 | (m) |
| Head without loss correction | 44.73 | (m) |
| Head loss | 0.00 | (m) |
| High flow pressure calibration | 0.00 | (m) |
| Total Head | 44.73 | (m) |

| Minutes of test | Flowmet read (L) | Flow (L/min) |
|---|---|---|
| 0 | 419.5 | |
| 1 | 419.5 | 0 |
| 2 | 419.8 | 0.3 |
| 3 | 420 | 0.2 |
| 4 | 420.2 | 0.2 |
| 5 | 420.5 | 0.3 |
| 6 | 420.7 | 0.2 |
| 7 | 420.9 | 0.2 |
| 8 | 421.1 | 0.2 |
| 9 | 421.3 | 0.2 |
| 10 | 421.5 | 0.2 |

Test Flows




Arithmatic average = 0.20 (L/min)
Adopted average = 0.22 (L/min)

**Comments:**

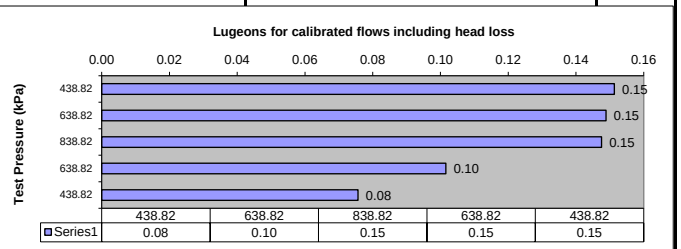
### Calculations used:

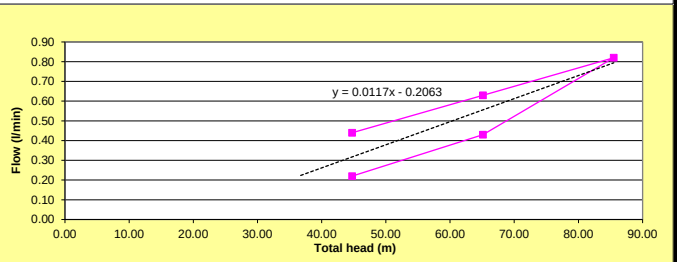
$$k = \frac{5.833}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot 10^{-5} \text{ m/s} \quad \text{(CANMET)}$$

$$k = \frac{8.333}{\pi L \sin\alpha}\left(\frac{Q}{H_T}\right)\cdot \ln\left(\frac{L}{r}\right)\cdot 10^{-6} \text{ m/s} \quad \text{(HOEK \& BRAY)}$$

$$lugeon = \frac{Q}{L\sin\alpha}\cdot\frac{100}{H_T} \text{ l/m/min} \quad \text{(HOULSBY)}$$

| Stage | Total Head (m) | Flow (l/min) | Calculated Lugeon values: Test Pressure | Q (L/m/min) | Lugeons (L/m/min) | Chosen Lugeon (L/m/min) |
|---|---|---|---|---|---|---|
| 1 | 44.73 | 0.44 | 438.82 | 0.07 | 0.15 | |
| 2 | 65.12 | 0.63 | 638.82 | 0.10 | 0.15 | |
| 3 | 85.51 | 0.82 | 838.82 | 0.13 | 0.15 | 0.125 |
| 4 | 65.12 | 0.43 | 638.82 | 0.07 | 0.10 | |
| 5 | 44.73 | 0.22 | 438.82 | 0.03 | 0.08 | |




### Conductivity Calculations:

| MEAN Q/$H_T$ | CANMET | HOEK & BRAY | MEAN LUGEONS 0.12 | |
|---|---|---|---|---|
| 0.009 | 2.4E-08 | 1.7E-08 | 1.6E-08 | m/s |

**Mean Conductivity K = 1.9E-08 m/s**

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal Project DATE: 30 0ctober 2017 HOLE DIP: 90

Transducer Start Time DIP Direction:

SITE NUMBER: HU0147PZB BORE I.D.: HU0147PZ BORE NAME: HU0147PZB

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): falling head | 227.18 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 216.65 | | |
| | | STATIC GROUNDWATER LEVEL: (m below ground level) | 18.0 |
| LENGTH OF STAGE TEST (m): | 10.53 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 230 | 1 | 98.5 | 98.55 | | | | 0.05 |
| 230 | 2 | 98.55 | 98.6 | | | | 0.05 |
| 230 | 3 | 98.6 | 98.6 | | | | 0 |
| 230 | 4 | 98.6 | 98.6 | | | | 0 |
| 230 | 5 | 98.6 | 98.6 | | | | 0 |
| 230 | 6 | 98.6 | 98.6 | | | | 0 |
| 230 | 7 | 98.6 | 98.6 | | | | 0 |
| 230 | 8 | 98.6 | 98.6 | | | | 0 |
| 230 | 9 | 98.6 | 98.6 | | | | 0 |
| 230 | 10 | 98.6 | 98.6 | | | | 0 |
| 450 | 1 | 98.6 | 106.1 | | | | 7.5 |
| 450 | 2 | 106.1 | 106.9 | | | | 0.8 |
| 450 | 3 | 106.9 | 107.5 | | | | 0.6 |
| 450 | 4 | 107.5 | 108.2 | | | | 0.7 |
| 450 | 5 | 108.2 | 109 | | | | 0.8 |
| 450 | 6 | 109 | 109.7 | | | | 0.7 |
| 450 | 7 | 109.7 | 110.5 | | | | 0.8 |
| 450 | 8 | 110.5 | 111.3 | | | | 0.8 |
| 450 | 9 | 111.3 | 111.9 | | | | 0.6 |
| 450 | 10 | 111.9 | 112.5 | | | | 0.6 |
| 700 | 1 | 112.5 | 118.9 | | | | 6.4 |
| 700 | 2 | 118.9 | 123 | | | | 4.1 |
| 700 | 3 | 123 | 126.7 | | | | 3.7 |
| 700 | 4 | 126.7 | 130 | | | | 3.3 |
| 700 | 5 | 130 | 133.1 | | | | 3.1 |
| 700 | 6 | 133.1 | 136 | | | | 2.9 |
| 700 | 7 | 136 | 139.1 | | | | 3.1 |
| 700 | 8 | 139.1 | 142.3 | | | | 3.2 |
| 700 | 9 | 142.3 | 145.3 | | | | 3 |
| 700 | 10 | 145.3 | 148.4 | | | | 3.1 |
| 450 | 1 | 146.9 | 147.9 | | | | 1 |
| 450 | 2 | 147.9 | 147.9 | | | | 0 |
| 450 | 3 | 147.9 | 147.9 | | | | 0 |
| 450 | 4 | 147.9 | 147.9 | | | | 0 |
| 450 | 5 | 147.9 | 147.9 | | | | 0 |
| 450 | 6 | 147.9 | 147.9 | | | | 0 |
| 450 | 7 | 147.9 | 147.9 | | | | 0 |
| 450 | 8 | 147.9 | 147.9 | | | | 0 |
| 450 | 9 | 147.9 | 147.9 | | | | 0 |
| 450 | 10 | 147.9 | 147.9 | | | | 0 |
| 230 | 1 | 147.9 | 144.3 | | | | -3.6 |

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|---|---|---|---|---|---|---|---|
| 230 | 2 | 144.3 | 144.3 | | | | 0 |
| 230 | 3 | 144.3 | 144.3 | | | | 0 |
| 230 | 4 | 144.3 | 144.3 | | | | 0 |
| 230 | 5 | 144.3 | 144.3 | | | | 0 |
| 230 | 6 | 144.3 | 144.3 | | | | 0 |
| 230 | 7 | 144.3 | 144.3 | | | | 0 |
| 230 | 8 | 144.3 | 144.3 | | | | 0 |
| 230 | 9 | 144.3 | 144.3 | | | | 0 |
| 230 | 10 | 144.3 | 144.3 | | | | 0 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)
Start falling head test at

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal Project DATE: 31-Oct-17 HOLE DIP: 90

Transducer Start Time DIP Direction:

SITE NUMBER: HU0147PZB BORE I.D.: HU0147PZ BORE NAME: HU0147PZB

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): falling head | 184.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 177.65 | | |
| | | STATIC GROUNDWATER LEVEL: (m below ground level) | 18.0 |
| LENGTH OF STAGE TEST (m): | 6.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 230 | 1 | 389.2 | 389.2 | | | | 0 |
| 230 | 2 | 389.2 | 389.25 | | | | 0.05 |
| 230 | 3 | 389.25 | 389.25 | | | | 0 |
| 230 | 4 | 389.25 | 389.25 | | | | 0 |
| 230 | 5 | 389.25 | 389.25 | | | | 0 |
| 230 | 6 | 389.25 | 389.25 | | | | 0 |
| 230 | 7 | 389.25 | 389.25 | | | | 0 |
| 230 | 8 | 389.25 | 389.25 | | | | 0 |
| 230 | 9 | 389.25 | 389.25 | | | | 0 |
| 230 | 10 | 389.25 | 389.25 | | | | 0 |
| 450 | 1 | 389.25 | 389.4 | | | | 0.15 |
| 450 | 2 | 389.4 | 389.4 | | | | 0 |
| 450 | 3 | 389.4 | 389.4 | | | | 0 |
| 450 | 4 | 389.4 | 389.4 | | | | 0 |
| 450 | 5 | 389.4 | 389.4 | | | | 0 |
| 450 | 6 | 389.4 | 389.4 | | | | 0 |
| 450 | 7 | 389.4 | 389.4 | | | | 0 |
| 450 | 8 | 389.4 | 389.4 | | | | 0 |
| 450 | 9 | 389.4 | 389.4 | | | | 0 |
| 450 | 10 | 389.4 | 389.4 | | | | 0 |
| 700 | 1 | 389.4 | 389.5 | | | | 0.1 |
| 700 | 2 | 389.5 | 389.5 | | | | 0 |
| 700 | 3 | 389.5 | 389.5 | | | | 0 |
| 700 | 4 | 389.5 | 389.5 | | | | 0 |
| 700 | 5 | 389.5 | 389.5 | | | | 0 |
| 700 | 6 | 389.5 | 389.5 | | | | 0 |
| 700 | 7 | 389.5 | 389.5 | | | | 0 |
| 700 | 8 | 389.5 | 389.5 | | | | 0 |
| 700 | 9 | 389.5 | 389.5 | | | | 0 |
| 700 | 10 | 389.5 | 389.5 | | | | 0 |
| 450 | 1 | 389.5 | 389.5 | | | | 0 |
| 450 | 2 | 389.5 | 389.5 | | | | 0 |
| 450 | 3 | 389.5 | 389.5 | | | | 0 |
| 450 | 4 | 389.5 | 389.5 | | | | 0 |
| 450 | 5 | 389.5 | 389.5 | | | | 0 |
| 450 | 6 | 389.5 | 389.5 | | | | 0 |
| 450 | 7 | 389.5 | 389.5 | | | | 0 |
| 450 | 8 | 389.5 | 389.5 | | | | 0 |
| 450 | 9 | 389.5 | 389.5 | | | | 0 |
| 450 | 10 | 389.5 | 389.5 | | | | 0 |
| 230 | 1 | 389.5 | 389.45 | | | | -0.05 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 230 | 2 | 389.45 | 389.45 | | | | 0 |
| 230 | 3 | 389.45 | 389.45 | | | | 0 |
| 230 | 4 | 389.45 | 389.45 | | | | 0 |
| 230 | 5 | 389.45 | 389.45 | | | | 0 |
| 230 | 6 | 389.45 | 389.45 | | | | 0 |
| 230 | 7 | 389.45 | 389.45 | | | | 0 |
| 230 | 8 | 389.45 | 389.45 | | | | 0 |
| 230 | 9 | 389.45 | 389.45 | | | | 0 |
| 230 | 10 | 389.45 | 389.45 | | | | 0 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)
Start falling head test at

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal Project DATE: 31-Oct-17 HOLE DIP: 90

Transducer Start Time DIP Direction:

SITE NUMBER: HU014PZB BORE I.D.: HU0147PZ BORE NAME: HU0147PZB

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): falling head | 167.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 160.65 | | |
| | | STATIC GROUNDWATER LEVEL: (m below ground level) | 18.0 |
| LENGTH OF STAGE TEST (m): | 6.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 230 | 1 | 573 | 578.5 | | | | 5.5 |
| 230 | 2 | 578.5 | 583.5 | | | | 5 |
| 230 | 3 | 583.5 | 587.7 | | | | 4.2 |
| 230 | 4 | 587.7 | 592.3 | | | | 4.6 |
| 230 | 5 | 592.3 | 596.9 | | | | 4.6 |
| 230 | 6 | 596.9 | 601.5 | | | | 4.6 |
| 230 | 7 | 601.5 | 605.9 | | | | 4.4 |
| 230 | 8 | 605.9 | 610.3 | | | | 4.4 |
| 230 | 9 | 610.3 | 614.9 | | | | 4.6 |
| 230 | 10 | 614.9 | 619.3 | | | | 4.4 |
| 450 | 1 | 619.3 | 625.7 | | | | 6.4 |
| 450 | 2 | 625.7 | 631.8 | | | | 6.1 |
| 450 | 3 | 631.8 | 637.3 | | | | 5.5 |
| 450 | 4 | 637.3 | 643.1 | | | | 5.8 |
| 450 | 5 | 643.1 | 649 | | | | 5.9 |
| 450 | 6 | 649 | 654.5 | | | | 5.5 |
| 450 | 7 | 654.5 | 660.5 | | | | 6 |
| 450 | 8 | 660.5 | 666.5 | | | | 6 |
| 450 | 9 | 666.5 | 671.9 | | | | 5.4 |
| 450 | 10 | 671.9 | 677.5 | | | | 5.6 |
| 700 | 1 | 688 | 694 | | | | 6 |
| 700 | 2 | 694 | 700 | | | | 6 |
| 700 | 3 | 700 | 706.5 | | | | 6.5 |
| 700 | 4 | 706.5 | 713.7 | | | | 7.2 |
| 700 | 5 | 713.7 | 720.3 | | | | 6.6 |
| 700 | 6 | 720.3 | 726.9 | | | | 6.6 |
| 700 | 7 | 726.9 | 733.6 | | | | 6.7 |
| 700 | 8 | 733.6 | 740.2 | | | | 6.6 |
| 700 | 9 | 740.2 | 747.1 | | | | 6.9 |
| 700 | 10 | 747.1 | 754 | | | | 6.9 |
| 450 | 1 | 754 | 758.9 | | | | 4.9 |
| 450 | 2 | 758.9 | 764.1 | | | | 5.2 |
| 450 | 3 | 764.1 | 769.2 | | | | 5.1 |
| 450 | 4 | 769.2 | 774.1 | | | | 4.9 |
| 450 | 5 | 774.1 | 779.2 | | | | 5.1 |
| 450 | 6 | 779.2 | 784.2 | | | | 5 |
| 450 | 7 | 784.2 | 789.2 | | | | 5 |
| 450 | 8 | 789.2 | 794.1 | | | | 4.9 |
| 450 | 9 | 794.1 | 799.1 | | | | 5 |
| 450 | 10 | 799.1 | 804 | | | | 4.9 |
| 230 | 1 | 804 | 807.9 | | | | 3.9 |

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|---|---|---|---|---|---|---|---|
| 230 | 2 | 807.9 | 811.7 | | | | 3.8 |
| 230 | 3 | 811.7 | 815.7 | | | | 4 |
| 230 | 4 | 815.7 | 819.6 | | | | 3.9 |
| 230 | 5 | 819.6 | 823.6 | | | | 4 |
| 230 | 6 | 823.6 | 827.7 | | | | 4.1 |
| 230 | 7 | 827.7 | 831.5 | | | | 3.8 |
| 230 | 8 | 831.5 | 835.3 | | | | 3.8 |
| 230 | 9 | 835.3 | 839.2 | | | | 3.9 |
| 230 | 10 | 839.2 | 843.1 | | | | 3.9 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)
Start falling head test at

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal Project DATE: 31-Oct-17 HOLE DIP: 90

Transducer Start Time DIP Direction:

SITE NUMBER: HU014PZB BORE I.D.: HU0147PZ BORE NAME: HU0147PZB

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): falling head | 161.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 154.65 | | |
| | | STATIC GROUNDWATER LEVEL: (m below ground level) | 18.0 |
| LENGTH OF STAGE TEST (m): | 6.5 | | |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 200 | 1 | 20 | 23.7 | | | | 3.7 |
| 200 | 2 | 23.7 | 26.4 | | | | 2.7 |
| 200 | 3 | 26.4 | 28.5 | | | | 2.1 |
| 200 | 4 | 28.5 | 30.5 | | | | 2 |
| 200 | 5 | 30.5 | 32.6 | | | | 2.1 |
| 200 | 6 | 32.6 | 34.6 | | | | 2 |
| 200 | 7 | 34.6 | 34.8 | | | | 0.2 |
| 200 | 8 | 34.8 | 37 | | | | 2.2 |
| 200 | 9 | 37 | 38.8 | | | | 1.8 |
| 200 | 10 | 38.8 | 40 | | | | 1.2 |
| 400 | 1 | 40 | 48.5 | | | | 8.5 |
| 400 | 2 | 48.5 | 52.1 | | | | 3.6 |
| 400 | 3 | 52.1 | 55.1 | | | | 3 |
| 400 | 4 | 55.1 | 57.3 | | | | 2.2 |
| 400 | 5 | 57.3 | 57.1 | | | | -0.2 |
| 400 | 6 | 57.1 | 57 | | | | -0.1 |
| 400 | 7 | 57 | 57 | | | | 0 |
| 400 | 8 | 57 | 57 | | | | 0 |
| 400 | 9 | 57 | 57 | | | | 0 |
| 400 | 10 | 57 | 57 | | | | 0 |
| 600 | 1 | 57 | 67.4 | | | | 10.4 |
| 600 | 2 | 67.4 | 69.3 | | | | 1.9 |
| 600 | 3 | 69.3 | 71.4 | | | | 2.1 |
| 600 | 4 | 71.4 | 73.7 | | | | 2.3 |
| 600 | 5 | 73.7 | 76 | | | | 2.3 |
| 600 | 6 | 76 | 78.4 | | | | 2.4 |
| 600 | 7 | 78.4 | 80.5 | | | | 2.1 |
| 600 | 8 | 80.5 | 82.7 | | | | 2.2 |
| 600 | 9 | 82.7 | 84.9 | | | | 2.2 |
| 600 | 10 | 84.9 | 87 | | | | 2.1 |
| 400 | 1 | 87 | 79.7 | | | | -7.3 |
| 400 | 2 | 79.7 | 79.9 | | | | 0.2 |
| 400 | 3 | 79.9 | 81.1 | | | | 1.2 |
| 400 | 4 | 81.1 | 82.1 | | | | 1 |
| 400 | 5 | 82.1 | 83.2 | | | | 1.1 |
| 400 | 6 | 83.2 | 84.2 | | | | 1 |
| 400 | 7 | 84.2 | 85.6 | | | | 1.4 |
| 400 | 8 | 85.6 | 86.2 | | | | 0.6 |
| 400 | 9 | 86.2 | 87.4 | | | | 1.2 |
| 400 | 10 | 87.4 | 88.4 | | | | 1 |
| 200 | 1 | 77.8 | 77.8 | | | | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 200 | 2 | 77.8 | 77.8 | | | | 0 |
| 200 | 3 | 77.8 | 77.8 | | | | 0 |
| 200 | 4 | 77.8 | 77.9 | | | | 0.1 |
| 200 | 5 | 77.9 | 78.1 | | | | 0.2 |
| 200 | 6 | 78.1 | 78.4 | | | | 0.3 |
| 200 | 7 | 78.4 | 78.7 | | | | 0.3 |
| 200 | 8 | 78.7 | 79.1 | | | | 0.4 |
| 200 | 9 | 79.1 | 79.7 | | | | 0.6 |
| 200 | 10 | 79.7 | 80.1 | | | | 0.4 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)
Start falling head test at

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal Project DATE: 31-Oct-17 HOLE DIP: 90

Transducer Start Time DIP Direction:

SITE NUMBER: HU0147PZB BORE I.D.: HU0147PZ BORE NAME: HU014PZB

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): falling head | 145.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 138.65 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 18.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 200 | 1 | 275.9 | 276 | | | | 0.1 |
| 200 | 2 | 276 | 276.1 | | | | 0.1 |
| 200 | 3 | 276.1 | 276.2 | | | | 0.1 |
| 200 | 4 | 276.2 | 276.25 | | | | 0.05 |
| 200 | 5 | 276.25 | 276.3 | | | | 0.05 |
| 200 | 6 | 276.3 | 276.4 | | | | 0.1 |
| 200 | 7 | 276.4 | 276.5 | | | | 0.1 |
| 200 | 8 | 276.5 | 276.6 | | | | 0.1 |
| 200 | 9 | 276.6 | 276.7 | | | | 0.1 |
| 200 | 10 | 276.7 | 276.8 | | | | 0.1 |
| 400 | 1 | 277 | 277.2 | | | | 0.2 |
| 400 | 2 | 277.2 | 277.4 | | | | 0.2 |
| 400 | 3 | 277.4 | 277.5 | | | | 0.1 |
| 400 | 4 | 277.5 | 277.6 | | | | 0.1 |
| 400 | 5 | 277.6 | 277.7 | | | | 0.1 |
| 400 | 6 | 277.7 | 277.75 | | | | 0.05 |
| 400 | 7 | 277.75 | 277.85 | | | | 0.1 |
| 400 | 8 | 277.85 | 278 | | | | 0.15 |
| 400 | 9 | 278 | 278.2 | | | | 0.2 |
| 400 | 10 | 278.2 | 278.4 | | | | 0.2 |
| 600 | 1 | 278.4 | 278.75 | | | | 0.35 |
| 600 | 2 | 278.75 | 279 | | | | 0.25 |
| 600 | 3 | 279 | 279.2 | | | | 0.2 |
| 600 | 4 | 279.2 | 279.5 | | | | 0.3 |
| 600 | 5 | 279.5 | 279.8 | | | | 0.3 |
| 600 | 6 | 279.8 | 280 | | | | 0.2 |
| 600 | 7 | 280 | 280.3 | | | | 0.3 |
| 600 | 8 | 280.3 | 280.5 | | | | 0.2 |
| 600 | 9 | 280.5 | 280.8 | | | | 0.3 |
| 600 | 10 | 280.8 | 281 | | | | 0.2 |
| 400 | 1 | 281 | 281.2 | | | | 0.2 |
| 400 | 2 | 281.2 | 281.3 | | | | 0.1 |
| 400 | 3 | 281.3 | 281.45 | | | | 0.15 |
| 400 | 4 | 281.45 | 281.6 | | | | 0.15 |
| 400 | 5 | 281.6 | 281.7 | | | | 0.1 |
| 400 | 6 | 281.7 | 281.85 | | | | 0.15 |
| 400 | 7 | 281.85 | 282 | | | | 0.15 |
| 400 | 8 | 282 | 282.15 | | | | 0.15 |
| 400 | 9 | 282.15 | 282.3 | | | | 0.15 |
| 400 | 10 | 282.3 | 282.45 | | | | 0.15 |
| 200 | 1 | 282.45 | 282.5 | | | | 0.05 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 200 | 2 | 282.5 | 282.55 | | | | 0.05 |
| 200 | 3 | 282.55 | 282.65 | | | | 0.1 |
| 200 | 4 | 282.65 | 282.75 | | | | 0.1 |
| 200 | 5 | 282.75 | 282.85 | | | | 0.1 |
| 200 | 6 | 282.85 | 282.95 | | | | 0.1 |
| 200 | 7 | 282.95 | 283 | | | | 0.05 |
| 200 | 8 | 283 | 283.05 | | | | 0.05 |
| 200 | 9 | 283.05 | 283.1 | | | | 0.05 |
| 200 | 10 | 283.1 | 283.15 | | | | 0.05 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

Remarks: (including calibration details of 200 litre drum, if used)
Start falling head test at

Reference Method: WATROCK

# WATER PRESSURE TEST RESULTS

PROJECT: Hume Coal Project DATE: 01-Nov-17 HOLE DIP: 90

Transducer Start Time DIP Direction:

SITE NUMBER: HU0147PZB BORE I.D.: HU014PZB BORE NAME: HU0147PZB

| | | | |
|---|---|---|---|
| Depth To Bottom Of Packer Test interval (m): falling head | 130.15 | HEIGHT OF PRESSURE GAUGE (m): (above ground level) | 0 |
| Depth To Top Of Packer Test interval (m): | 123.65 | | |
| LENGTH OF STAGE TEST (m): | 6.5 | STATIC GROUNDWATER LEVEL: (m below ground level) | 18.0 |
| BORE DIAMETER (mm): | 96 | SURFACE R.L. (m) | |

| GAUGE PRESSURE (Kpa) | DURATION OF TEST STAGE (min) | FLOW METER READINGS | | DRUM READINGS | | | VOLUME (litre) |
|---|---|---|---|---|---|---|---|
| | | INITIAL (litre) | FINAL (litre) | INITIAL (litre) or (mm) | FINAL (litre) or (mm) | DIFFERENCE (litre) or (mm) | |
| 200 | 1 | 395.5 | 395.8 | | | | 0.3 |
| 200 | 2 | 395.8 | 396.2 | | | | 0.4 |
| 200 | 3 | 396.2 | 396.8 | | | | 0.6 |
| 200 | 4 | 396.8 | 397.3 | | | | 0.5 |
| 200 | 5 | 397.3 | 397.8 | | | | 0.5 |
| 200 | 6 | 397.8 | 398.2 | | | | 0.4 |
| 200 | 7 | 398.2 | 398.7 | | | | 0.5 |
| 200 | 8 | 398.7 | 399.1 | | | | 0.4 |
| 200 | 9 | 399.1 | 399.5 | | | | 0.4 |
| 200 | 10 | 399.5 | 399.9 | | | | 0.4 |
| 400 | 1 | 399.9 | 400.8 | | | | 0.9 |
| 400 | 2 | 400.8 | 401.5 | | | | 0.7 |
| 400 | 3 | 401.5 | 402.1 | | | | 0.6 |
| 400 | 4 | 402.1 | 402.8 | | | | 0.7 |
| 400 | 5 | 402.8 | 403.5 | | | | 0.7 |
| 400 | 6 | 403.5 | 404.1 | | | | 0.6 |
| 400 | 7 | 404.1 | 404.7 | | | | 0.6 |
| 400 | 8 | 404.7 | 405.3 | | | | 0.6 |
| 400 | 9 | 405.3 | 405.9 | | | | 0.6 |
| 400 | 10 | 405.9 | 406.5 | | | | 0.6 |
| 600 | 1 | 406.5 | 407.5 | | | | 1 |
| 600 | 2 | 407.5 | 408.4 | | | | 0.9 |
| 600 | 3 | 408.4 | 409.2 | | | | 0.8 |
| 600 | 4 | 409.2 | 410 | | | | 0.8 |
| 600 | 5 | 410 | 410.8 | | | | 0.8 |
| 600 | 6 | 410.8 | 411.6 | | | | 0.8 |
| 600 | 7 | 411.6 | 412.3 | | | | 0.7 |
| 600 | 8 | 412.3 | 413.1 | | | | 0.8 |
| 600 | 9 | 413.1 | 413.9 | | | | 0.8 |
| 600 | 10 | 413.9 | 414.7 | | | | 0.8 |
| 400 | 1 | 415.2 | 415.7 | | | | 0.5 |
| 400 | 2 | 415.7 | 416.1 | | | | 0.4 |
| 400 | 3 | 416.1 | 416.5 | | | | 0.4 |
| 400 | 4 | 416.5 | 417 | | | | 0.5 |
| 400 | 5 | 417 | 417.5 | | | | 0.5 |
| 400 | 6 | 417.5 | 417.9 | | | | 0.4 |
| 400 | 7 | 417.9 | 418.4 | | | | 0.5 |
| 400 | 8 | 418.4 | 418.7 | | | | 0.3 |
| 400 | 9 | 418.7 | 419.1 | | | | 0.4 |
| 400 | 10 | 419.1 | 419.5 | | | | 0.4 |
| 200 | 1 | 419.5 | 419.5 | | | | 0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 200 | 2 | 419.5 | 419.8 | | | | 0.3 |
| 200 | 3 | 419.8 | 420 | | | | 0.2 |
| 200 | 4 | 420 | 420.2 | | | | 0.2 |
| 200 | 5 | 420.2 | 420.5 | | | | 0.3 |
| 200 | 6 | 420.5 | 420.7 | | | | 0.2 |
| 200 | 7 | 420.7 | 420.9 | | | | 0.2 |
| 200 | 8 | 420.9 | 421.1 | | | | 0.2 |
| 200 | 9 | 421.1 | 421.3 | | | | 0.2 |
| 200 | 10 | 421.3 | 421.5 | | | | 0.2 |
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Lenght of rubber hos m
casing: m
drum capacity litres
drum calibration: litres

packer type & number:
quality of seal:
pump type & capacity:
water meter No. & calibration date:
pressure gauge No. & calibration date:

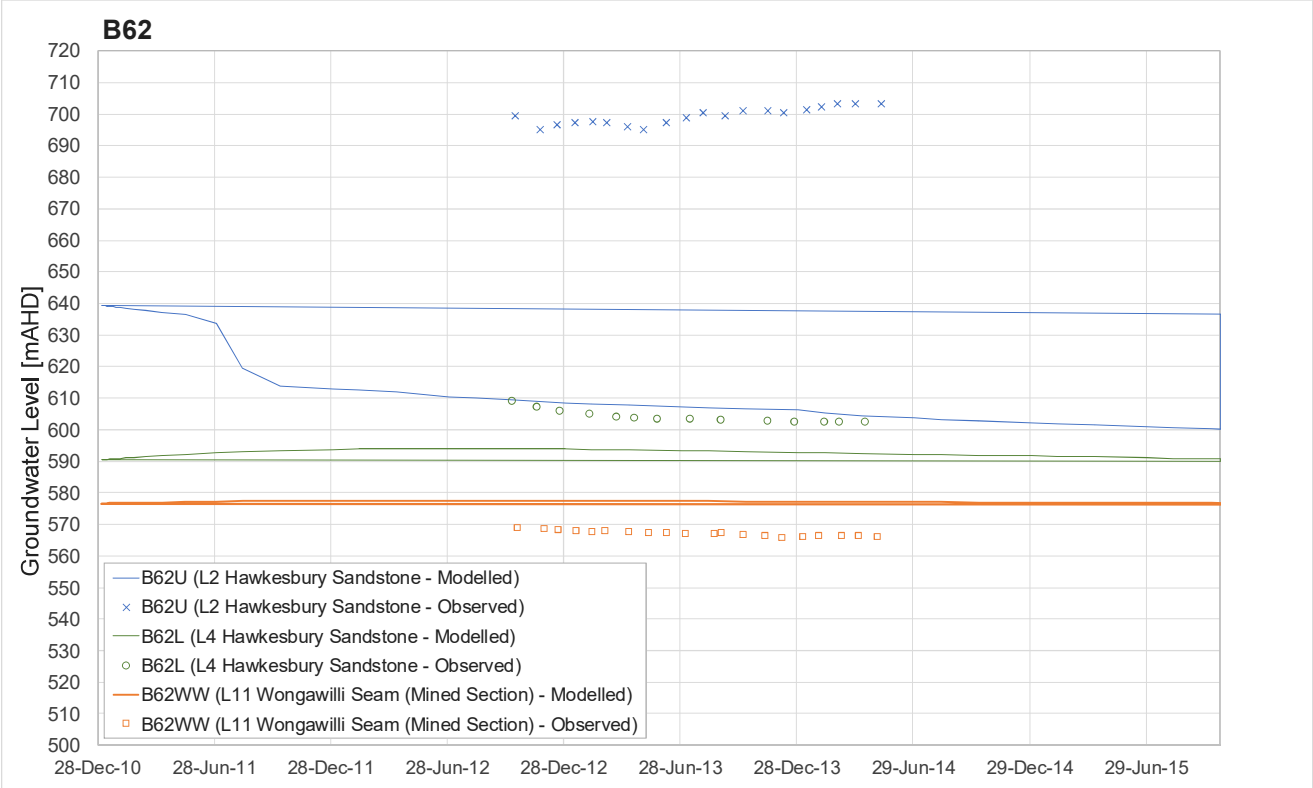
Remarks: (including calibration details of 200 litre drum, if used)
Start falling head test at

Reference Method: WATROCK

Attachment C

# RTS groundwater model hydrographs

## C.1 Extracts from HydroSimulations 2018



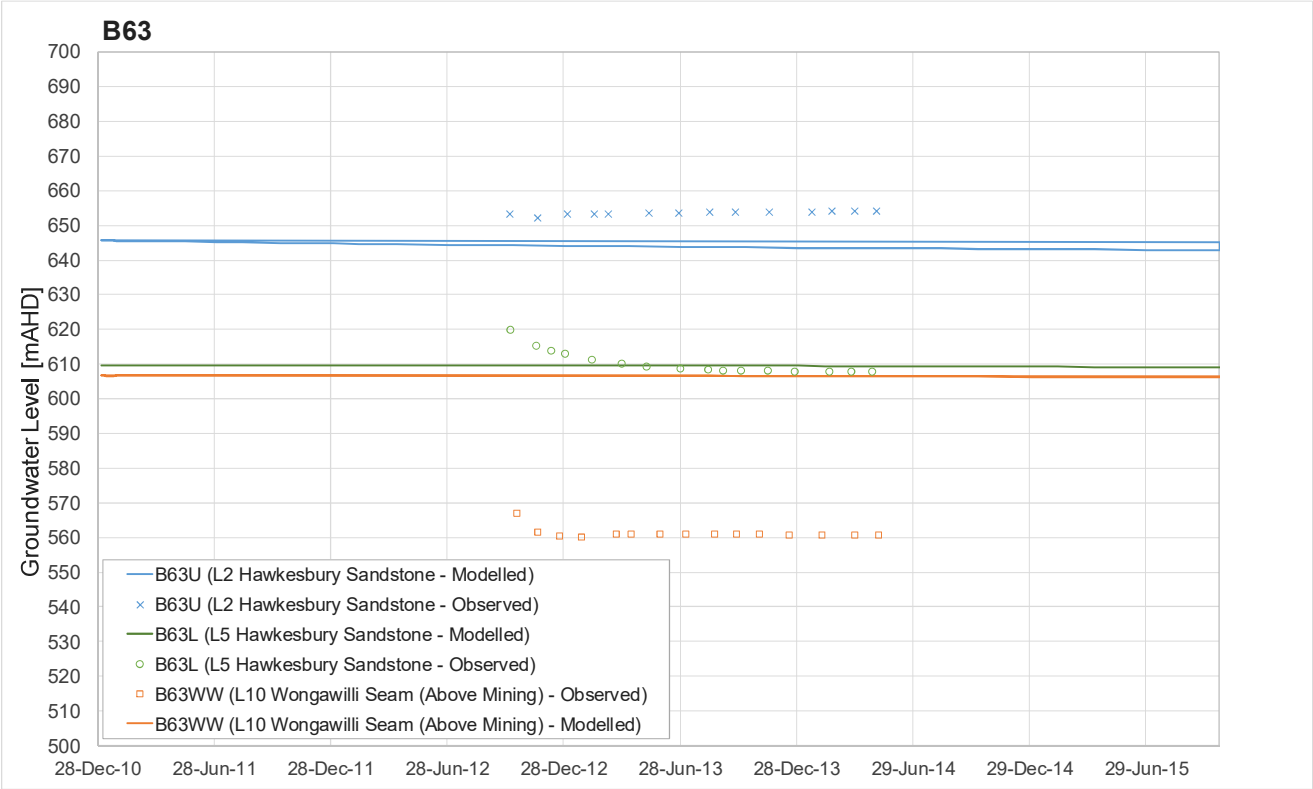
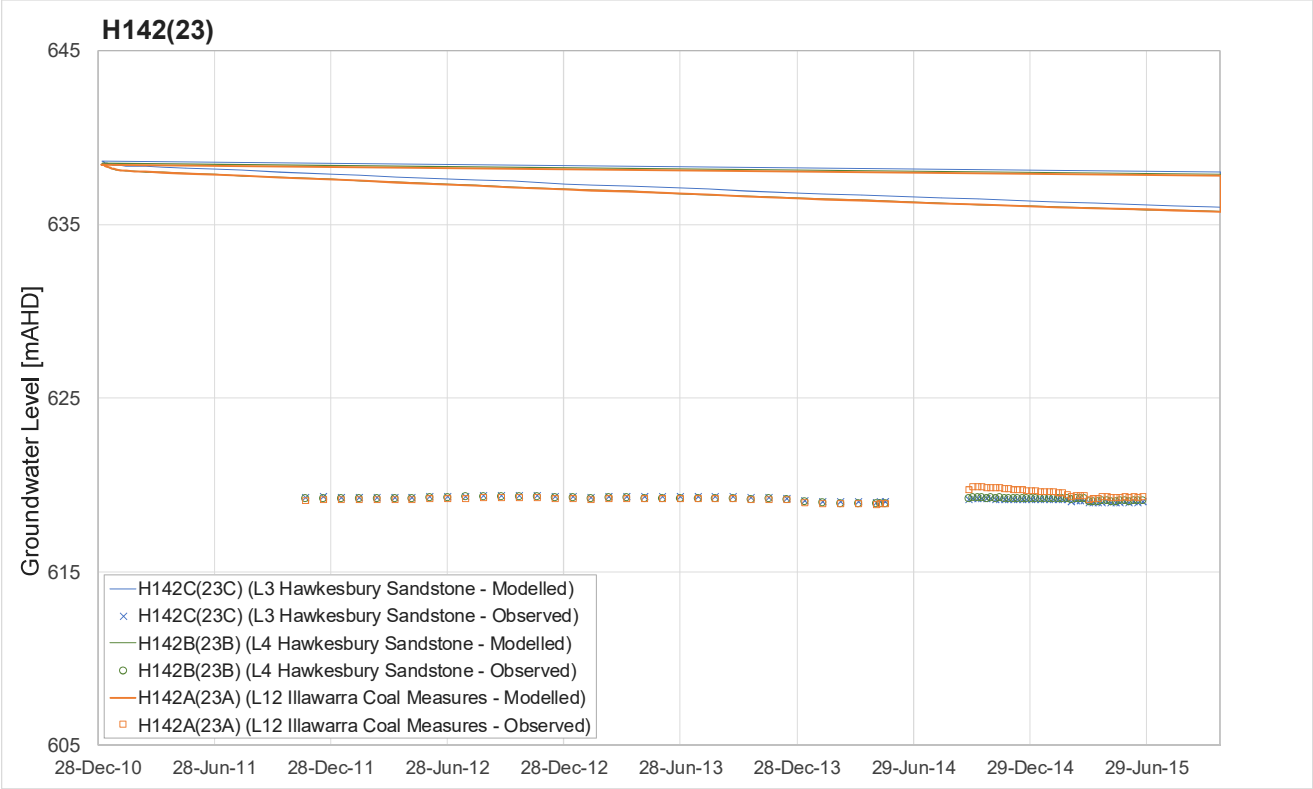




**Figure 5 Multi sensor calibration hydrographs for B62 and B63**



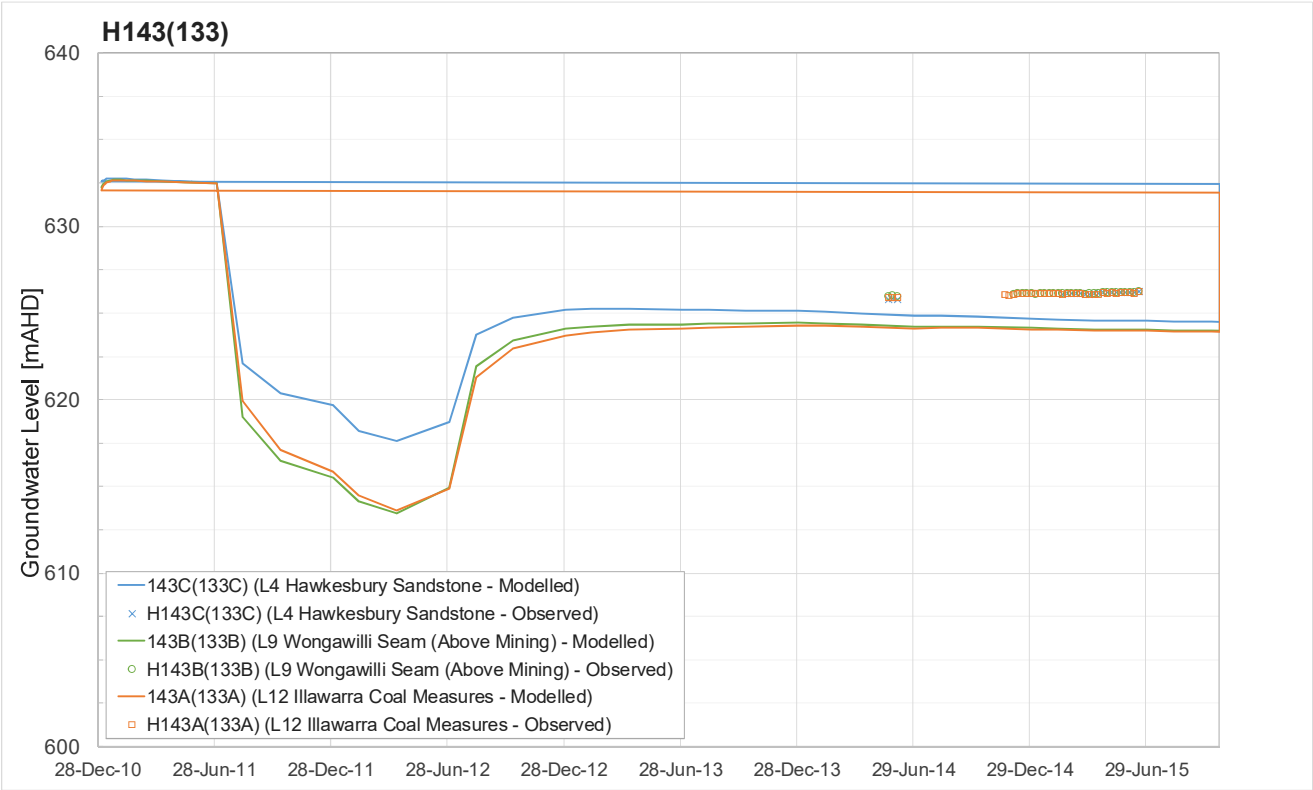
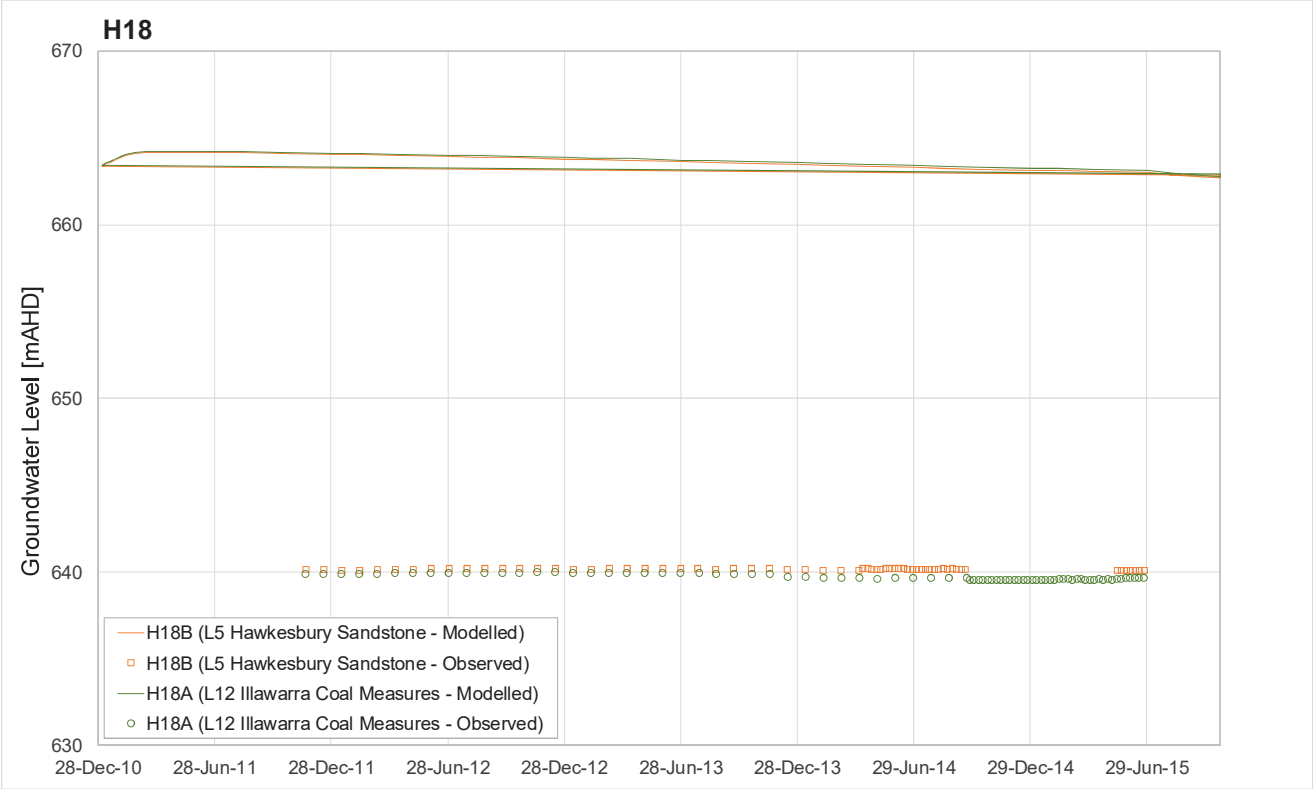




**Figure 6 Multi sensor calibration hydrographs for H142(23) and H143(133)**



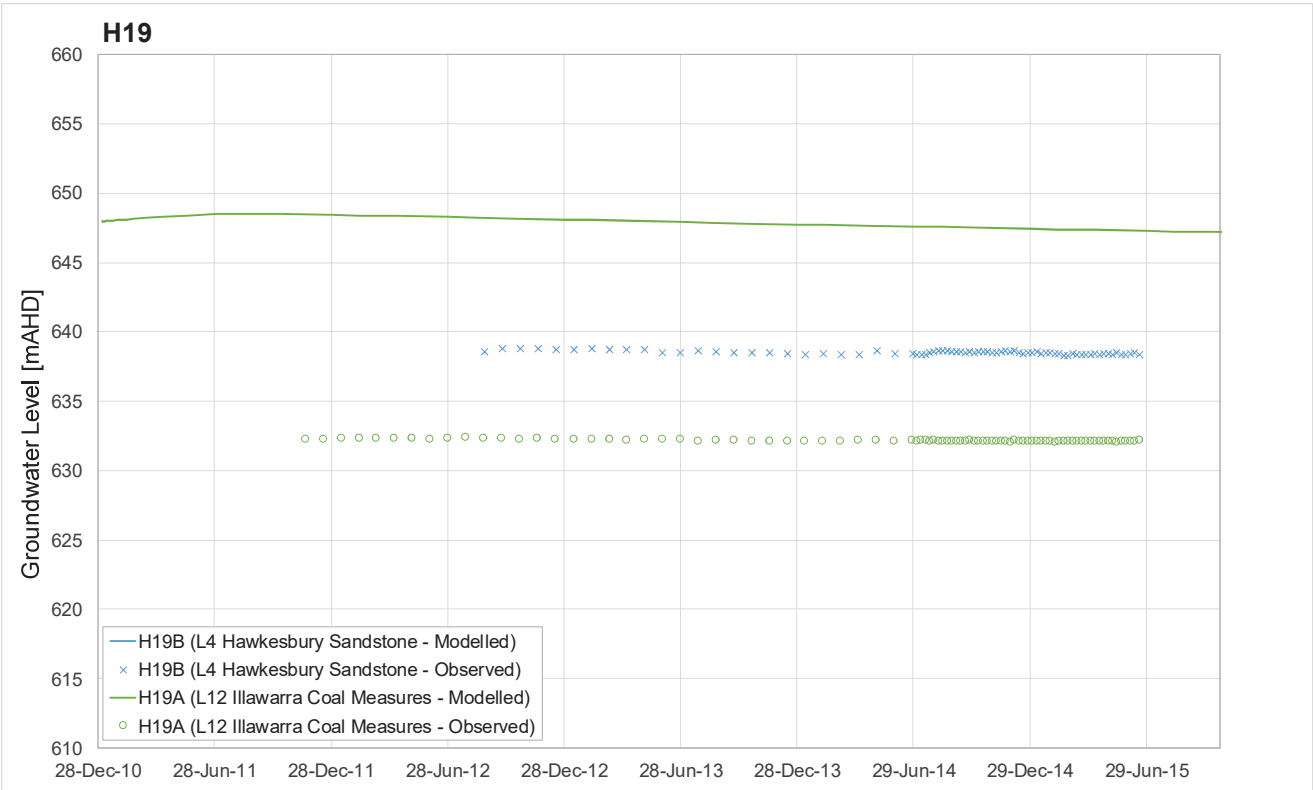




**Figure 7 Multi sensor calibration hydrographs for H18 and H19**

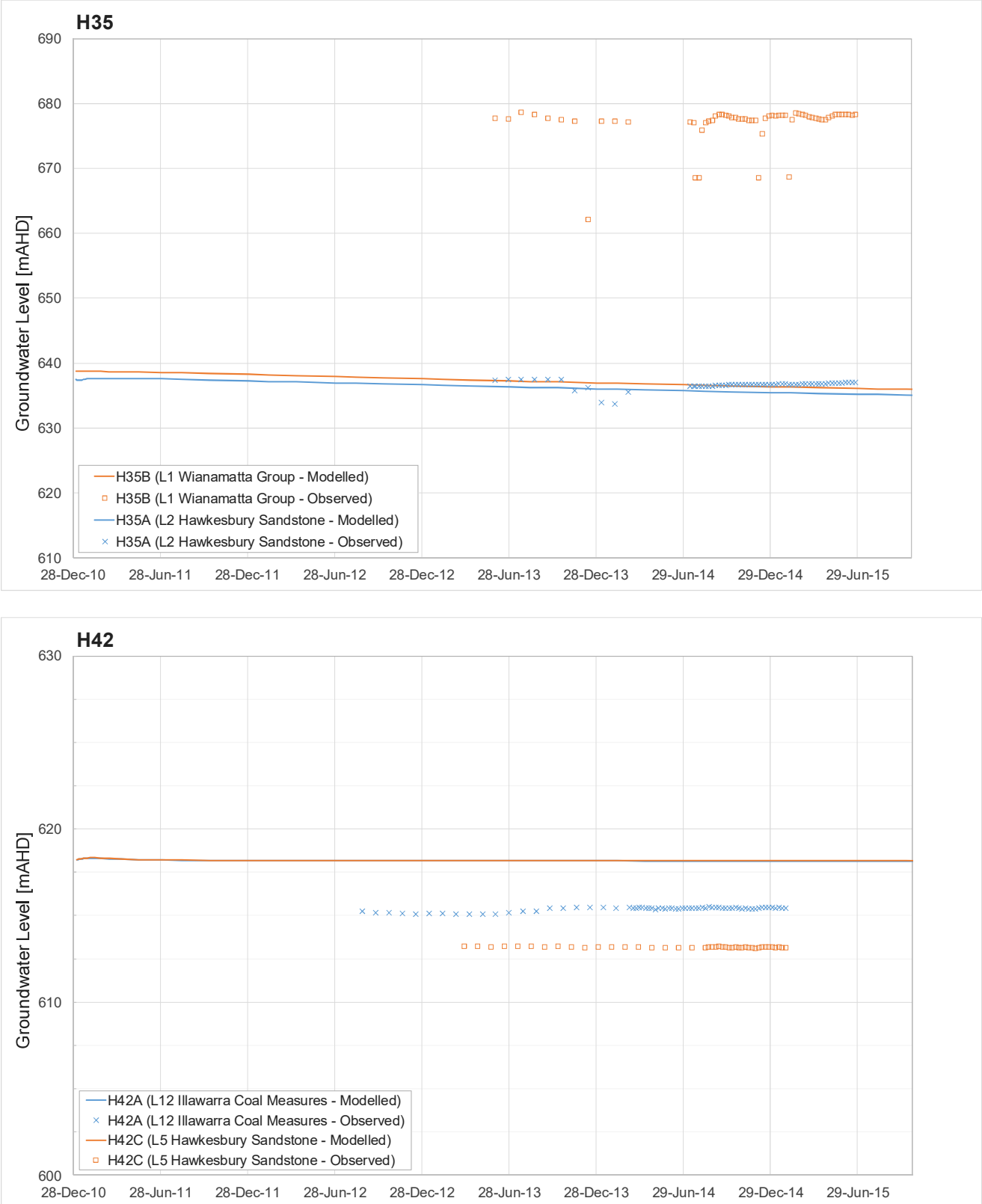
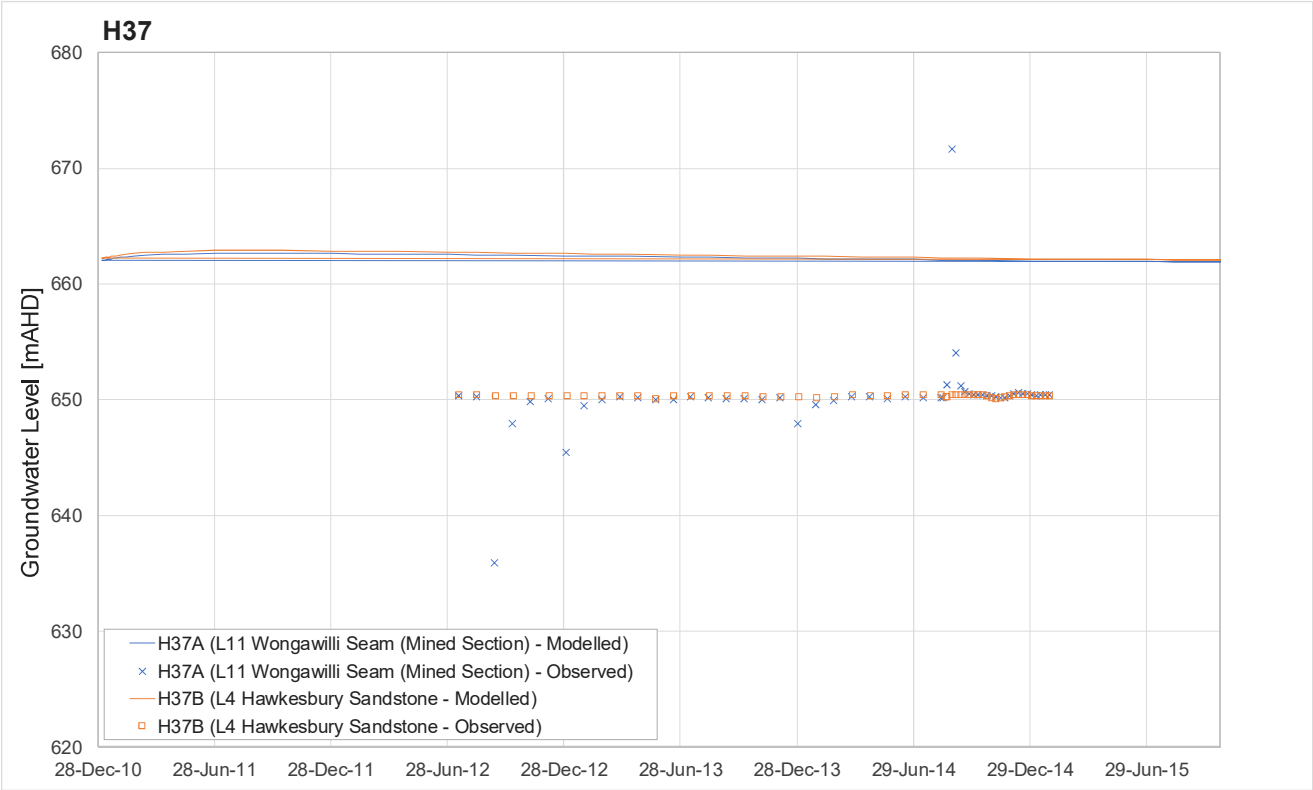



**Figure 8 Multi sensor calibration hydrographs for H35 and H42**



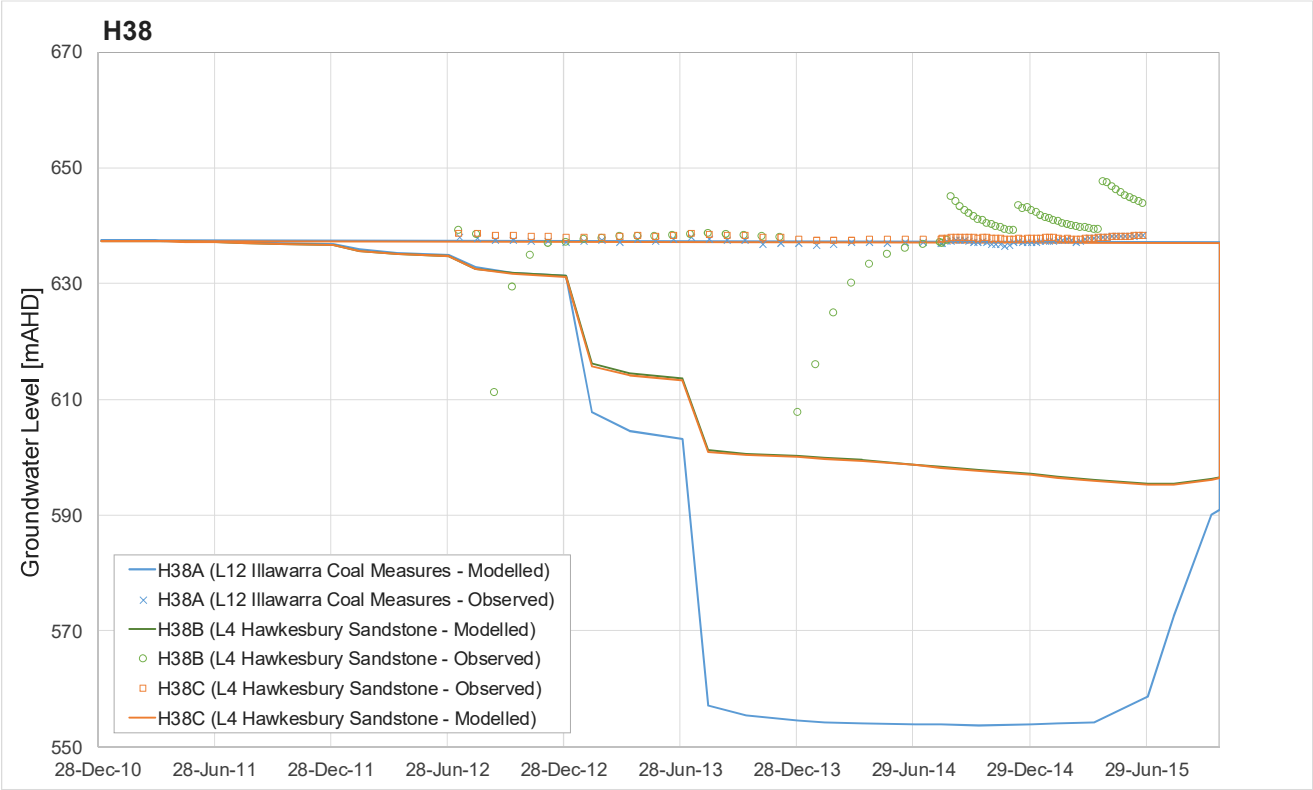




**Figure 9 Multi sensor calibration hydrographs for H37 and H38**

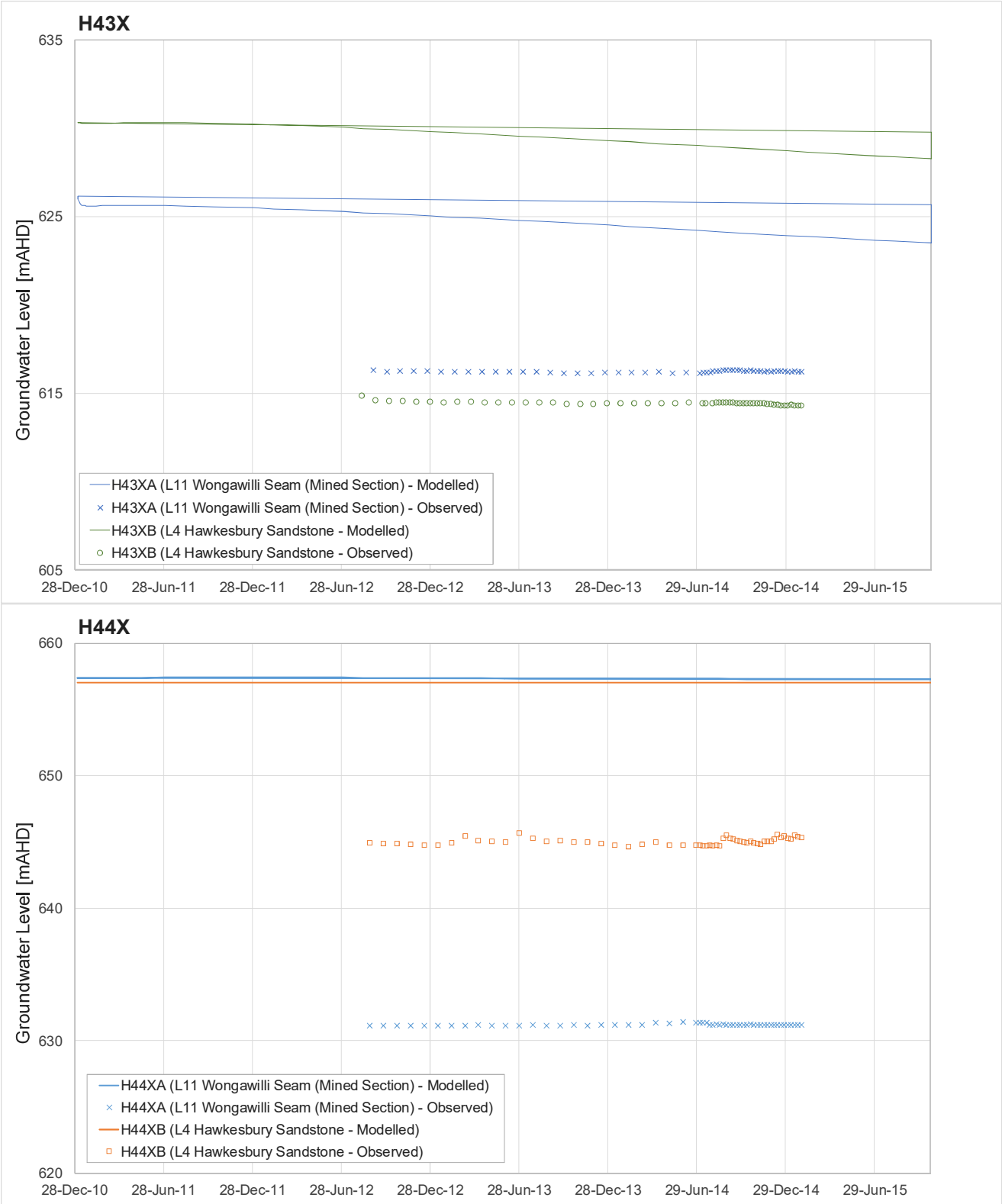
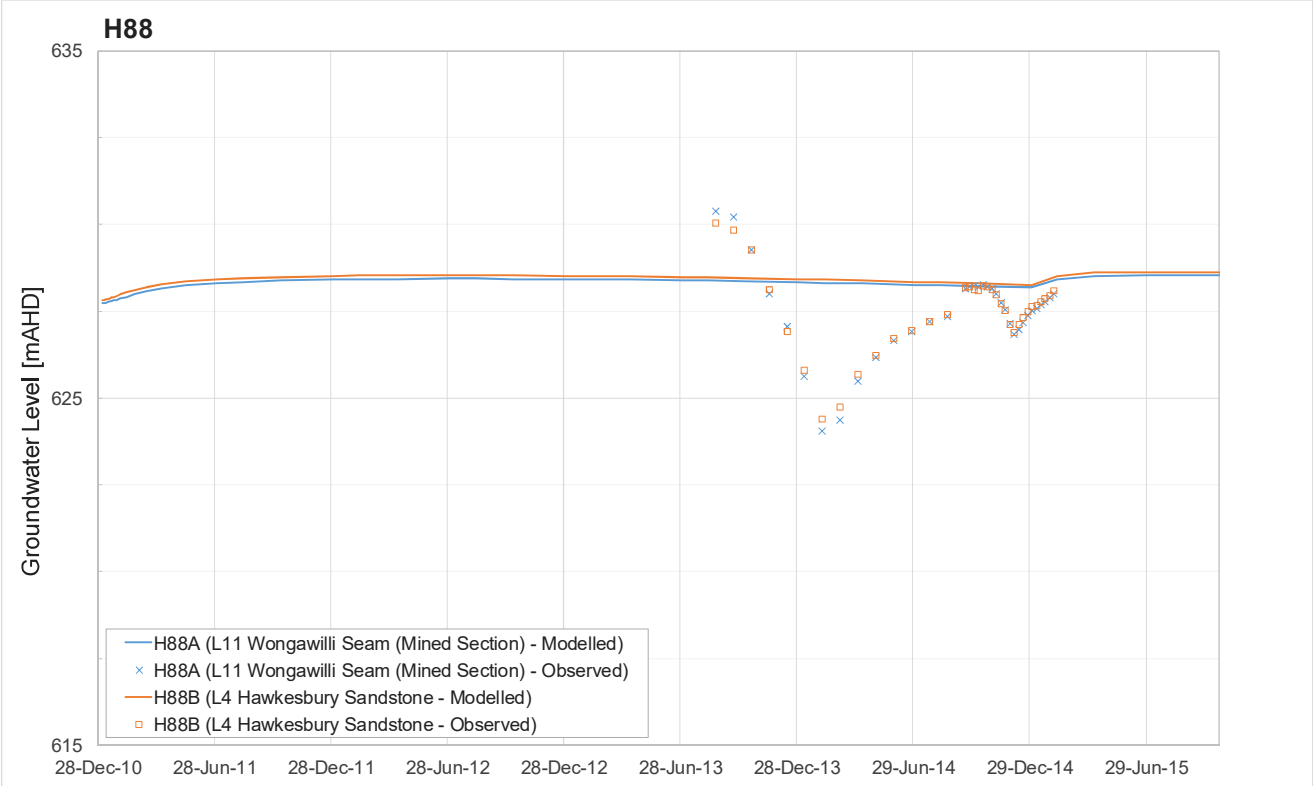



**Figure 10 Multi sensor calibration hydrographs for H43X and H44X**



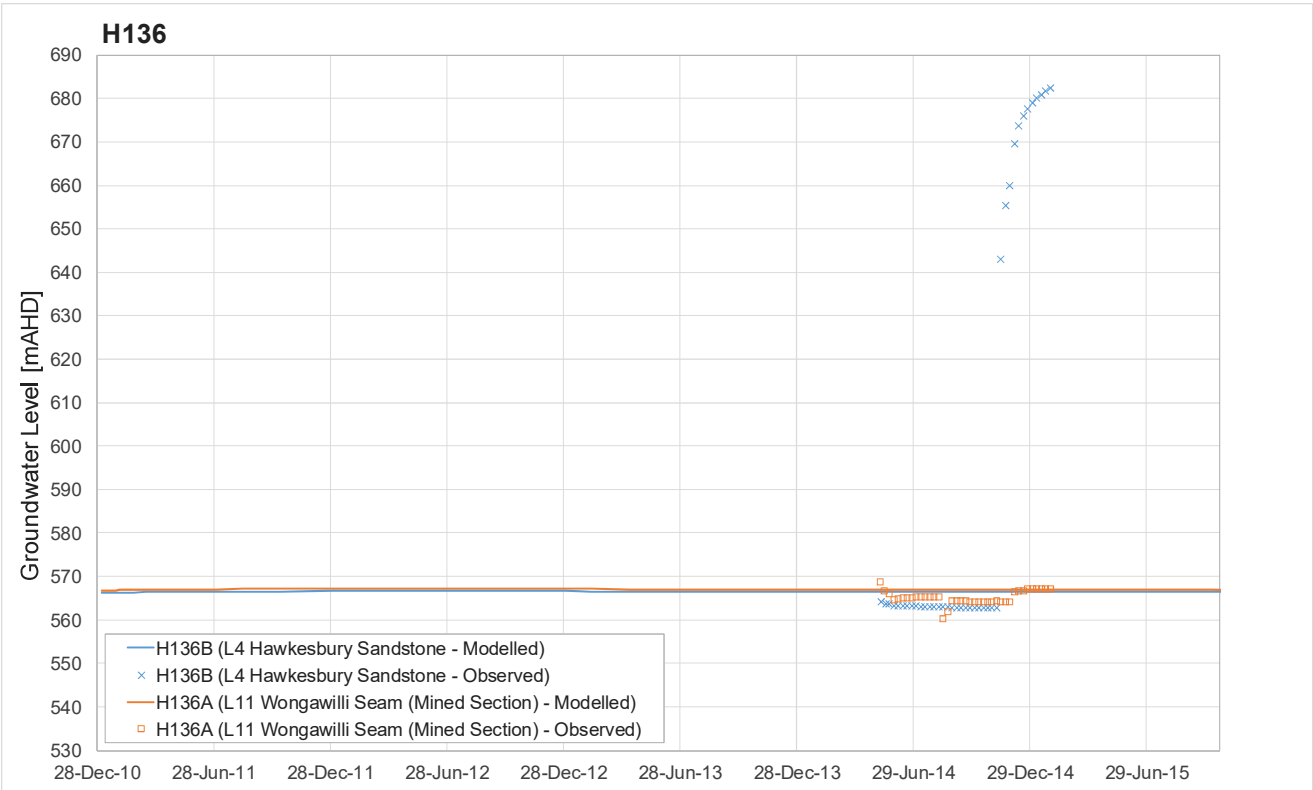
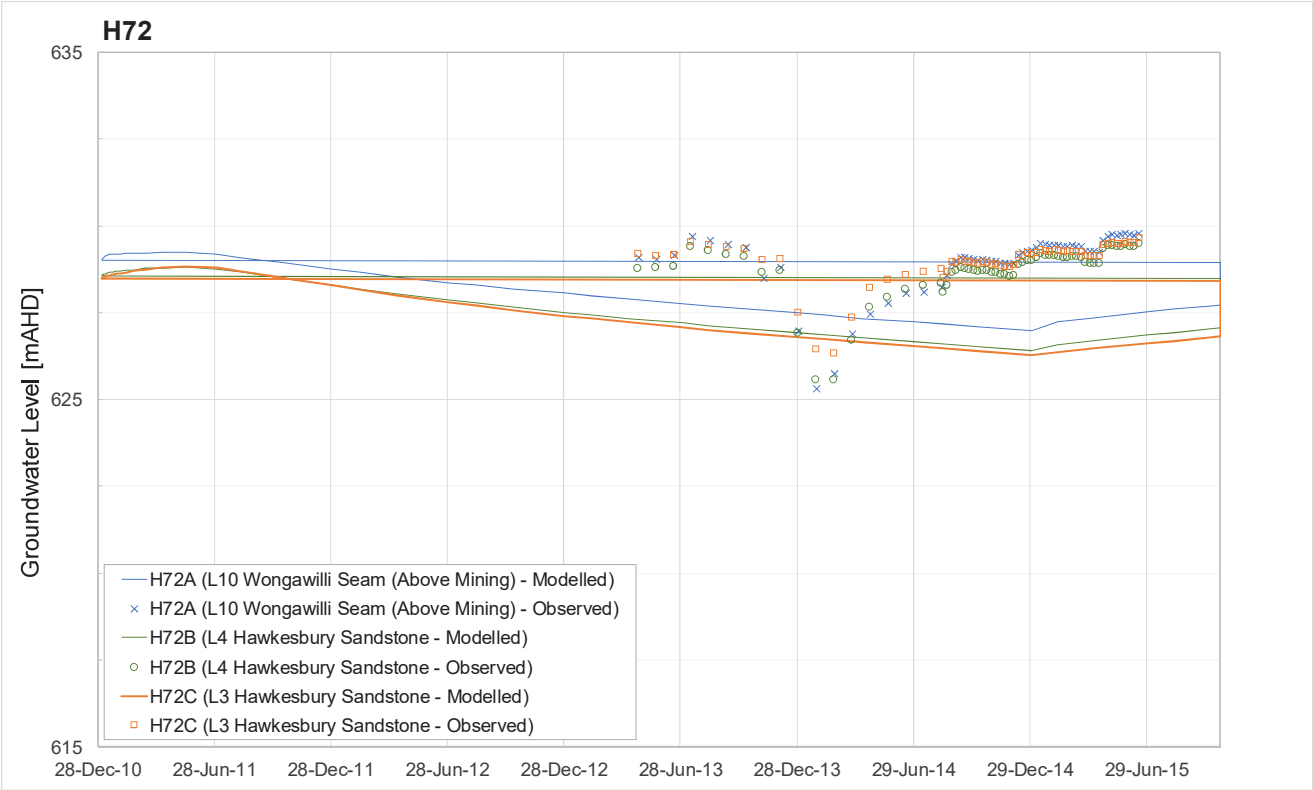




**Figure 11 Multi sensor calibration hydrographs for H88 and H136**



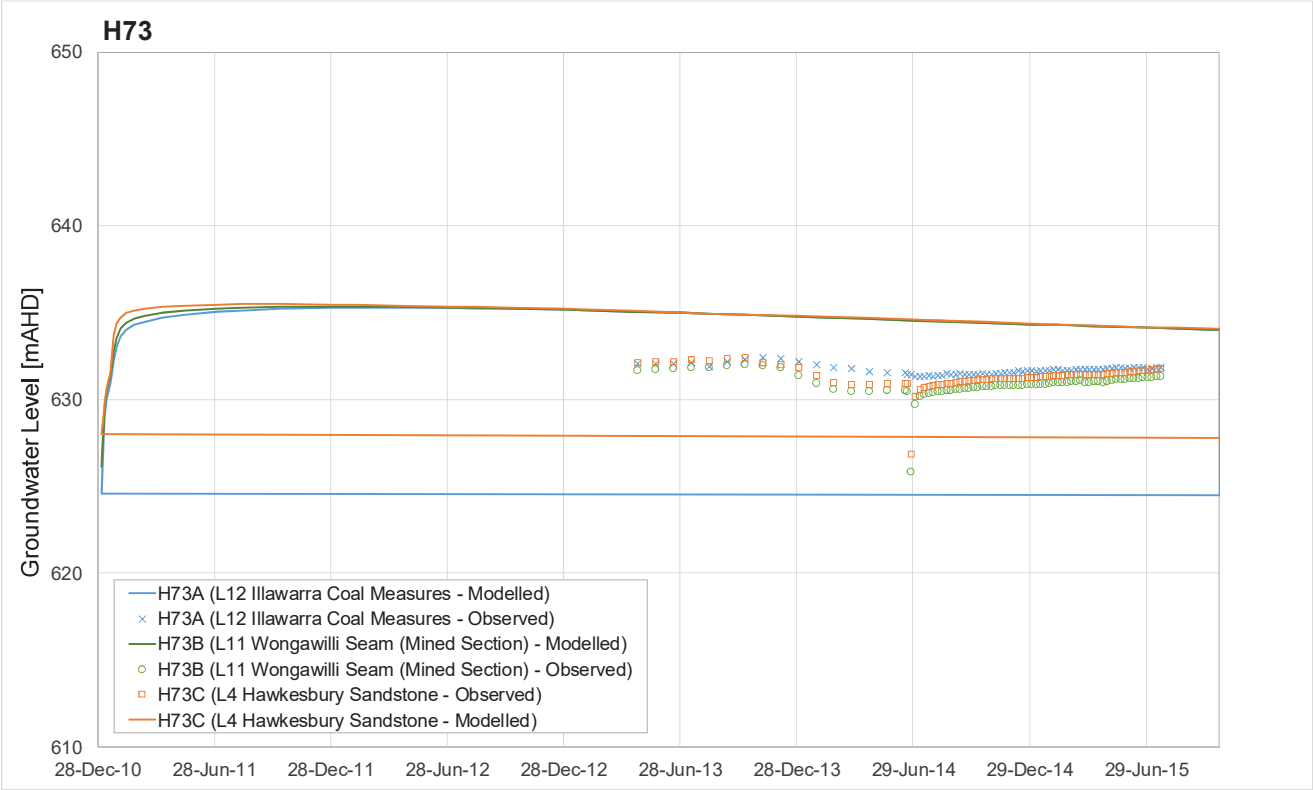




**Figure 12 Multi sensor calibration hydrographs for H72 and H73**

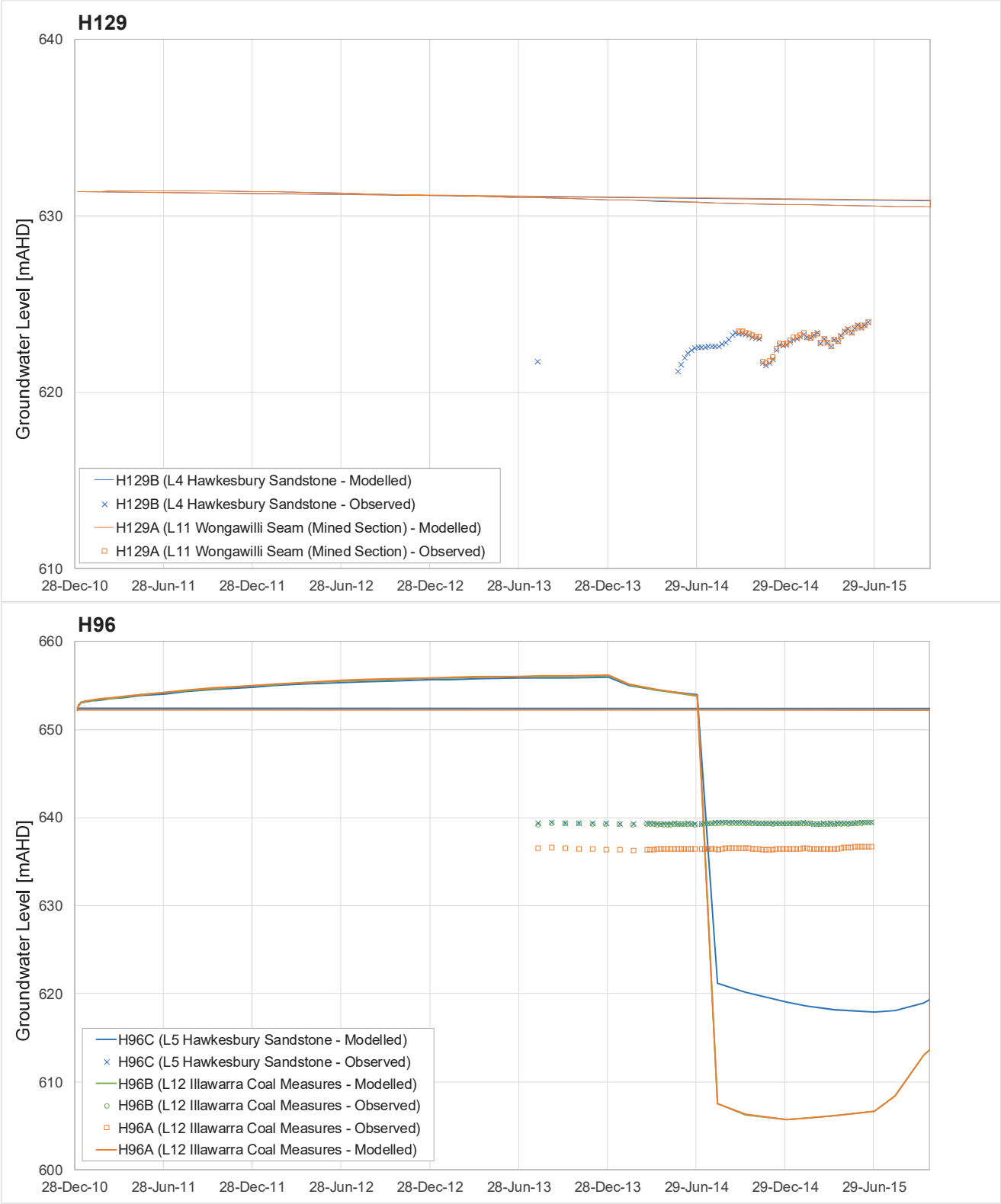
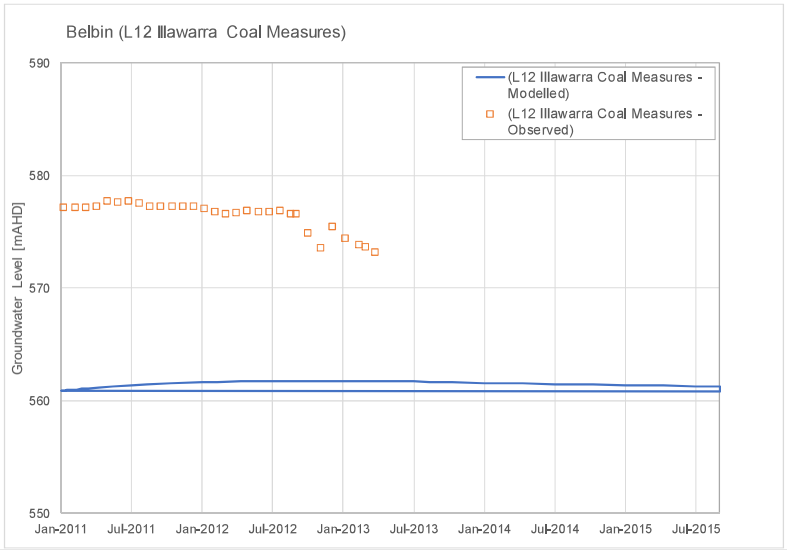
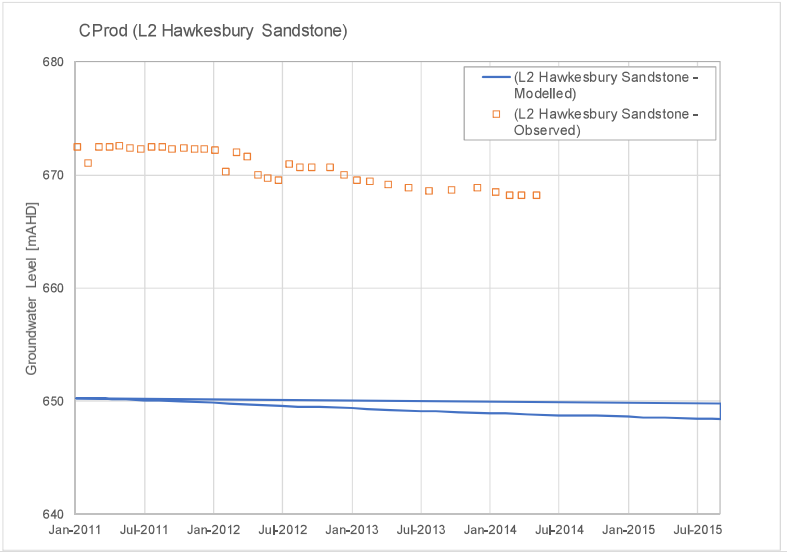
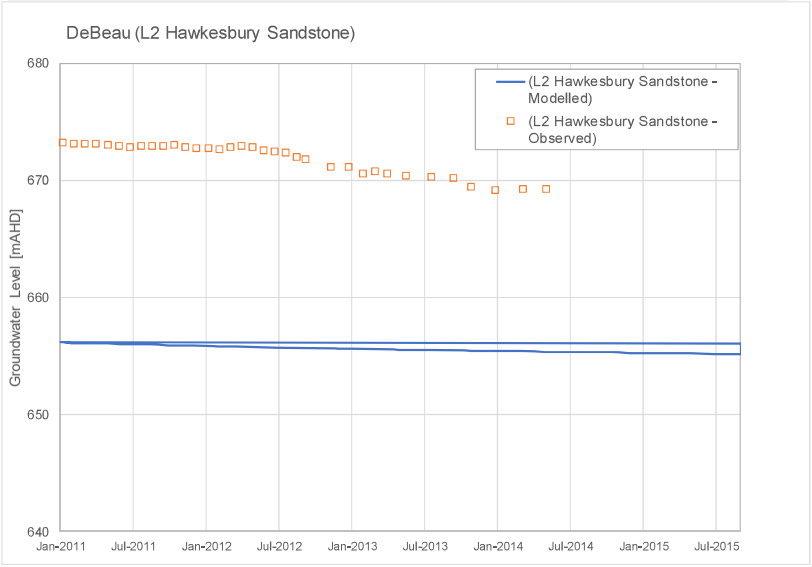



**Figure 13 Multi sensor calibration hydrographs for H129 and H96**



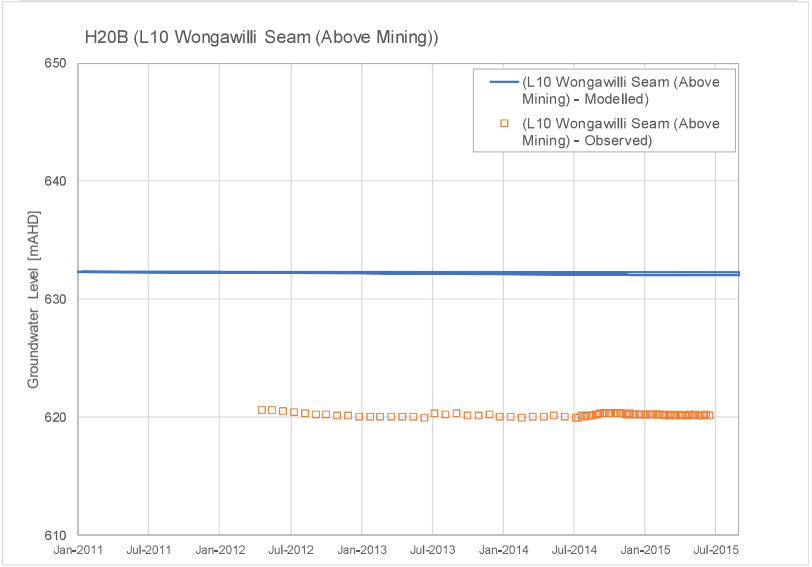




**Figure 14 Calibration hydrographs for Belbin, CProd, DeBeau, H20B**

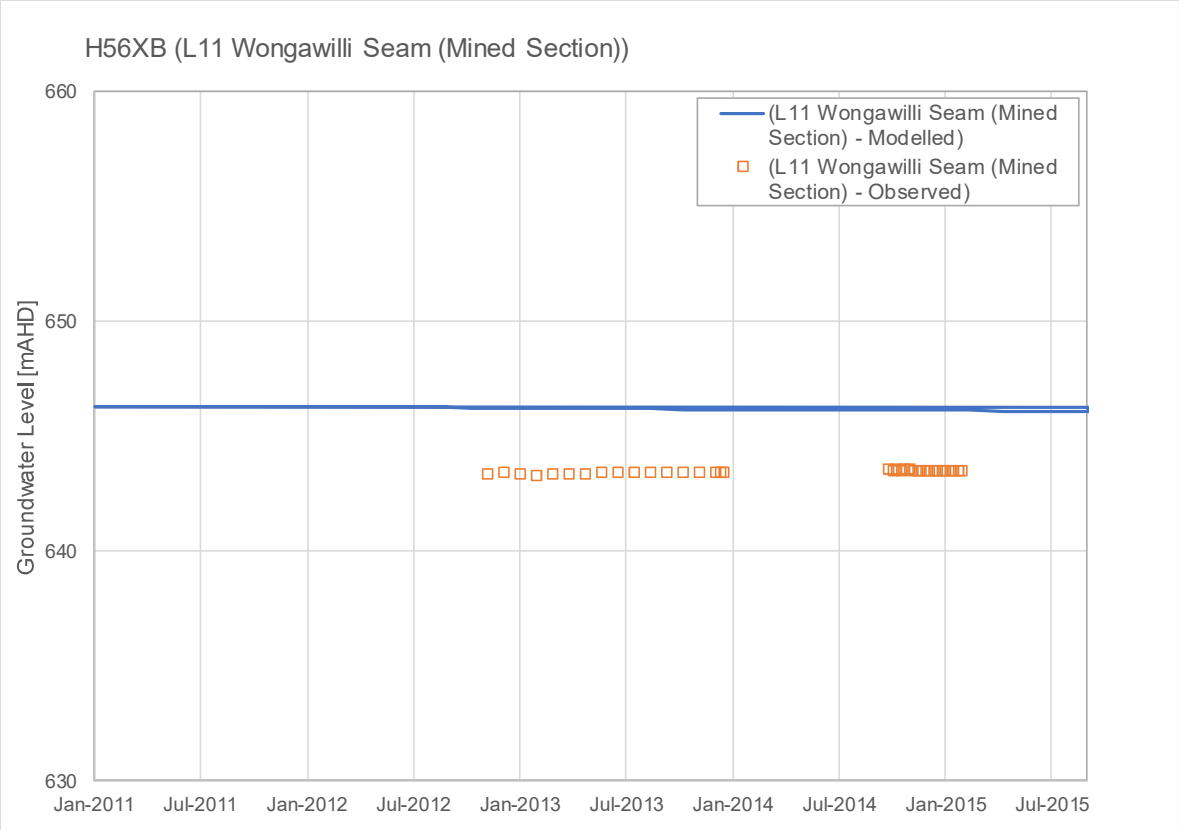



**Figure 15 Calibration hydrograph H56XB**

Annexure B

# Hume Coal detailed geology report

**Introduction**

In May 2019 the NSW Governments' Independent Planning Commission (IPC) issued a Report on the Hume Coal and Berrima Rail Projects. The IPC raised two specific concerns that relate to the high permeability of the Hawkesbury Sandstone and its proximity to the coal seam to be mined. The relevant paragraphs are copied below, the bolding is the author's emphasis. It is important to note that these cited paragraphs are not "Recommendations" of the IPC, but nevertheless Hume Coal considered it was appropriate to respond to them directly. These concerns also seem to be widespread among many submissions made about the Projects. This report seeks to allay those concerns and place the facts before the IPC.

> *No 123 – With regard to hydraulic conductivity (permeability) decreasing with depth, DOI-Water stated that, "In summary,* ***we do not believe that the data presented by the proponent demonstrates clear field evidence for the assertion that hydraulic conductivity decreases with depth****."*
>
> *No 140 –* ***Of particular interest to the Commission is the possibility that the Hawkesbury Sandstone's hydraulic conductivity (Kh and Kv) is highest immediately above the coal seam to be mined.*** *There was no representation of this in the model realisations, despite apparently being requested by DOI-Water at a previous modelling meeting. This work would have been useful to check the possibility of larger water inflows to the mine. Likewise, a larger range of drainage conductance values could have been modelled to eliminate the* ***speculation about the interburden layer*** *acting as a bottleneck to flow.*

The purpose of this section is to provide a systematic approach to addressing the concerns of the IPC report at the abovementioned paragraphs. While these concerns primarily focus on permeability they also require an understanding of the local geology and specifically of the interburden strata (i.e. the strata between the base of the Hawkesbury Sandstone and the base of the Farmborough Claystone.) Several reports were prepared and cover the following aspects;

- a detailed review of the interburden strata,
- an investigation into geophysical logs reflecting porosity of the Hawkesbury Sandstone,
- a review of groundwater bores in the local area,
- a commentary regarding the recent permeability data testing in 2020,
- a response to Mr Lindsay's comments regarding the Interburden in the Coal Free Southern Highlands (CFSH) private meeting with the IPC, and
- a summary report on the geological information that Hume Coal has covering the A349 area.

More specifically these items can be summarise as:-

1. ***"Analysis of the Wongawilli Coal to Hawkesbury Sandstone succession in the Hume Coal Project area."*** Prepared by Dr. Brian G. Jones, PhD, (Sedpet Services) his report addresses the strata in the layers described by Hume Coal as the Interburden. Jones describes the

stratigraphic layers from the Wongawilli Seam rising up through the Farmborough Claystone Member, the WWR (the rider coal), through the Unnamed Member No 3, the Lower Eckersley Formation, the Burragorang Claystone, the Upper Eckersley Formation and into the Hawkesbury Sandstone.

2. A review by Mr Scott Thomson (Coalbed Energy Consultants) has studied the porosity and permeability of the Hawkesbury Sandstone using geophysical logs along an east west and north south section, studying a variety of boreholes. His report is titled, ***"Log Analysis Study For Hume Coal Pty Limited."***
3. The third report examined data from the Groundwater Database of the NSW Government. This was undertaken by the Exploration Manager for Hume Coal, Mr Rod Doyle. This review study is titled, ***"Commentary on the New South Wales Office of Water Groundwater Bore Database In and Around Authorisation A349."***
4. Presentation of ***recent Vertical Permeability*** test data conducted in 2020.
5. A response to Mr Lindsay's comments regarding the ***Interburden*** and some publicly available bore log data.
6. A summary of the ***Geology in the A349 Area***.

What follows is a brief summary of what are considered to be the three main reports followed with concluding remarks. These reports are also appended.

**Report 1 – A review of the NSW Office of Water – Ground Water Bores Report**

A review of the New South Wales Office of Water database (now DPIE-W) for groundwater bores (GWB) in and around the A349 Authorisation has been conducted. The main findings of this study can be summarised as follows:-

- GWB data reflects the local site-specific conditions of the aquifer/s present in the area of A349. The Hawkesbury Sandstone (HBSS) contributes the most water to GWB primarily through layered beds and secondarily through contributions via geological structures, such as jointing and fracture permeability.
- Data suggests that that GWB flow rates of the uppermost portion of the HBSS contributes more water than other horizons. The assertion that the lowest portion of the HBSS. i.e. the sandstone closest to the Wongawilli Coal seam is the most prolific water source cannot be substantiated from this data set for the area in and around the proposed Hume Coal Mine.
- Proximity to surface stream systems contribute to some of the highest flowing GWB flow rates in the area. It's noteworthy that the database shows that some of the highest flowing GWB are the shallowest in the database. Conversely, some of the deepest GWB are very low yielding.

While no-one would argue that the Government's water bore database is without faults, it is the most significant and detailed set of data regarding water bores in NSW and certainly in the local area.

Attempts were made to determine why some GWB have more significant flows than others. While depth plays a role this was found not to be the most significant factor. There appears to be a connection between surface stream paths and higher flow rates. In fact, as noted in Table 1 below some of the shallowest bores have high flow rates.

| Bore ID | Depth | Flow Rate l/s |
|---|---|---|
| GW102775 | 16.0 | 13.25 |
| GW056827 | 23.0 | 12.60 |
| GW047117 | 33.5 | 20.21 |
| GW060199 | 37.0 | 20.00 |
| GW031527 | 39.6 | 16.30 |

**Table 1. Five Shallow Ground Water Bores and their Respective Flow Rates.**

According to the database some 36 of the GWB in the A349 area intersect the Wongawilli Seam (WWSM). To reach the WWSM, a GWB has to drill through the entire HBSS present, including the basal section. Meaning that all these 36 GWB would intersect what Mr John Lee describes as the 'best part of the aquifer, where the hydraulic conductivity (Kh and Kv) is highest immediately above the coal seam to be mined'. Despite their depths, only 40% of these GWB achieve greater than average flow rates. This clearly highlights that the basal section of the HBSS is not the most prolific of aquifers for this area.

Approximately 75% of the GWB achieve less than average flow rates. So what makes the other 25% better flowing GWB?

- A correlation with predicted geological structures (faults and dykes) was undertaken, but did not show a high correlation with higher flowing GWB. In contrast there appears to be a stronger correlation for high flowing GWB with surface stream patterns.
- Estimations of strata thickness for GWB was undertaken using the Hume Coal Geological Model to predict depths and thicknesses of the various stratigraphic horizons. Thus allowing a definition of the strata present within the GWB (which is not accurately provided in the NOW database), specifically identifying GWB with the basal HBSS in them. Which according to Paragraph 140, high flowing water bores should be associated with the basal portion of the HBSS, which was found not to be the case. Where GWB have greater than 75m of HBSS in them (i.e. intersect the basal quarter of the HBSS), only 40% have flow rates greater than average flows (6 l/s).
- One thing not recorded in the data base is the diameter of the GWB, yet we know that some of the best flowing GWB have larger diameters than the norm. Of the GWB designed (or licenced) to be "irrigation bores" approximately half have flows rates less than 7.5l/s. (The refuted assumption being that irrigation GWB may have larger diameters and therefore have more influence on having high flow rates.)
- The database does not provide any evidence on the potential for GWB to have fracture permeability. However, the author considers this to be the most significant factor in achieving high flow rates in whatever stratigraphic horizon the geological structure is present.

The five (5) highest flowing bores in order are respectively the 19th, 44th, 13th, 46th and the 32nd deepest GWB in the data set. Of the 50 deepest GWB only half achieve flow rates greater than average. Which strongly suggests that depth of the GWB and proximity to the Wongawilli Seam have little to do with high flow rates. Fracture permeability is not restricted to any particular horizon in the existing strata.

(It should be noted that the report on GWB was completed before Dr Brian Jones (Sedpet Services) undertook his work that highlights why the strata immediately above the WWSM is not as permeable as other sections of the HBSS strata. It was also undertaken before Mr Scott Thomson (Coalbed Energy Consultants) undertook his investigation into geophysical logs.)

**Report 2 -** ***"Log Analysis Study For Hume Coal Pty Limited." Coalbed Energy Consultants***
The Coalbed report assessed the porosity of the HBSS Formation, in 8 exploration boreholes across the A349 area. All of these exploration bores intersect the Wongawilli Seam (WWSM) and therefore have the full sequence of HBSS available at the site. The holes were primarily selected to cover the general proposed mining area in an east-west and a north-south section as shown in Figure 1 below.

They achieved this assessment by undertaking geophysical log analysis with a special focus on the quantitative porosity of the HBSS. Observing the location where in the stratigraphic column was cleanest and where the most porous sandstones occur.

Hume Coal have used an Industry wide recognised and reputable logging company (Weatherford, previously BPB etc) to undertake logging of all their boreholes. Weatherford collects relevant data suitable for detailed log analysis pertinent to the estimation of porosity among other aspects associated with geological investigations.

Log analysis conducted across the Hume Coal Project area show that the HBSS has discrete clean sand intervals which cannot be correlated with confidence between neighbouring boreholes, nor generally across the area. Coalbed found that the presence of fine-grained low porosity units occurs throughout the stratigraphic interval and are not isolated to any particular stratigraphic horizon. This is an important finding as it supports the understanding of the environment of deposition, where various beds within the HBSS have limited channel width and thickness, which also act to restrict the lateral extent of permeability among its various horizons.

In short Coalbed's findings state that, ***"There is no evidence to suggest that the highest porosity intervals are closest to the coal seam. They seem to be irregularly distributed throughout the stratigraphic column."***

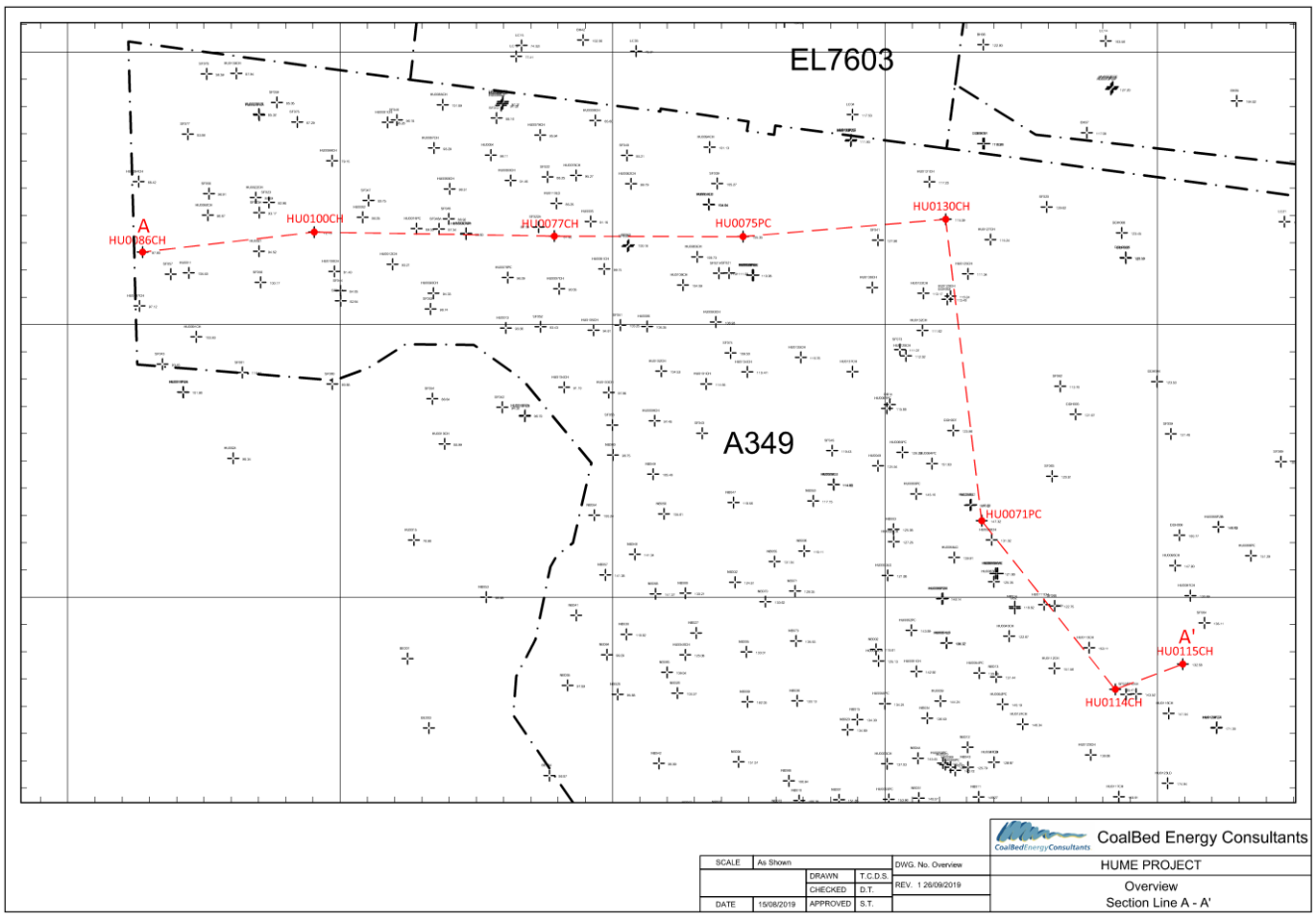



**Figure 1. Location of Exploration Bores (in red) used as part of the Geophysical Log Assessment.**

These two reports demonstrate that the strata immediately overlying the Wongawilli Seam, is not the most permeable strata. The facts demonstrate that the opposite is the case, that the strata overlying the WWSM (the Interburden and basal HBSS) has low permeability in contrast to the opponents to the Projects and the disbelief of the DPIE Water. Current permeability testing is confirming the conclusions previously drawn by the Hume Coal consultants demonstrating that the vertical permeability is much lower than the general clean porous horizons where they are present within the HBSS.

### *Report 3 - "Analysis of the Wongawilli Coal to Hawkesbury Sandstone succession in the Hume Coal Project area." Sedpet Services Dr Brian G Jones*

Dr Brian G Jones, has prepared a detailed report which address the layers of strata described by Hume Coal as the Interburden. In addition, he has gone to greater lengths and greater detail than has previously been undertaken in describing the stratigraphy. He has also indicated the presence of the Burragorang Claystone and the Eckersley Formation (Upper and Lower) where they are preserved within A349. By identifying the presence of these units, Dr Jones corrects the previous classification of strata by Hume Coal and expands on the work of others in this area (e.g. Bamberry references noted in the Jones report 1991 & 1995). Jones' interpretation follows on from several site inspections in and around A349 and careful investigations of core photographs and geological logs. As a result of this investigation Jones describes strata that was always present within A349, but did not have its stratigraphy properly described before.

Primarily Jones confirms the presence of, the interburden as defined by Hume Coal at A349, but with additional subdivisions. This redefined, revised stratigraphy is shown below in Table 2. Jones reinterpretation of the strata at the base of the Hawkesbury Sandstone better reflects the true nature of the rocks present.

| Interburden | Formation | Member | Previously Described | Rock Type | Typical Thick | Thick Range |
|---|---|---|---|---|---|---|
| No | Hawkesbury Sandstone | | Yes | Sandstone | 100 | 80-110 |
| Yes | Upper Eckersley Formation | | No | Sandstone and mudstone | 1.7 | 0-4.8 |
| | | Burragorang Claystone | No | Tuffaceous Claystone | 2.1 | 0-7.9 |
| | Lower Eckersely Formation | | No | Sandsstone and mudstone | 1.3 | 1-4.5 |
| | | Unnamed Member No 3 | Yes | Carbonaceous Shale and Mudstone | 1.8 | 0-7.7 |
| | Wongawilli R Ply | | Yes | Coal and bands | 0.4 | 0-1.3 |
| | | Farmborough Claystone | Yes | Tuffaceous Claystone | 0.64 | 0-2.5 |
| No | Wongawilli Coal Plies A to J | | Yes | Coal and bands | 6 | 0-8.0 |

**Table 2. Revised Stratigraphy between the Wongawilli Coal and the Hawkesbury Sandstone.**

**Hawkesbury Sandstone (HBSS)**

Jones notes that, 'Distinguishing the base of the Hawkesbury Sandstone in the Hume Coal Project area is difficult because of the underlying clastic successions of the Illawarra Coal Measures and possible Narrabeen Group equivalents, which have been derived from the same Lachlan Fold Belt source area as the Hawkesbury Sandstone." Further he adds that these sediments, "represent a distinctly finer-grained facies, that would have much lower porosity and permeability than the main part of the Hawkesbury Sandstone.

In defining the behaviour of the deposition of the Hawkesbury Sandstone, Jones notes that the Hawkesbury Sandstone is considerably thinner in the A349 area (nominally 100m) than compared to the unit in the central portion of the Sydney Basin, where it reaches up to 250m in thickness. "Since the (HBSS) formation is thinner in the southwestern area the tripartite subdivision in the Hawkesbury Sandstone recognised by Lee (2009) in the central and western parts of the basin may not be as recognisable or apparent in the southern part of the basin." See Figure 2 below, which is a 3D image of the Sydney Basin and highlights the location of the Hume Coal Project area at the south western margin of the Sydney Basin. In this figure the blue and green colours represent the deeper portions of the central part of the basin, while the red represents the much shallower marginal portions where the Hume Coal Project area is located. The figure was prepared by the Division of Resources and Geoscience in 2018.

Jones states that, "the Hawkesbury Sandstone varies considerably in the Hume Coal Project area and can be subdivide into two main facies. A central, more active channel facies, which trends northeast ….. which is parallel to the main channel flow direction indicated by the cross-bedding in outcrop." In describing some of the cores reviewed and that are presented in the report, Jones notes that in the area of the Hume Coal Project, "well cemented portions of the Hawkesbury Sandstone occur and result in local permeability barriers". That is, the lower HBSS strata in the Hume Coal area is well cemented and has lower permeability that other portions of the HBSS.

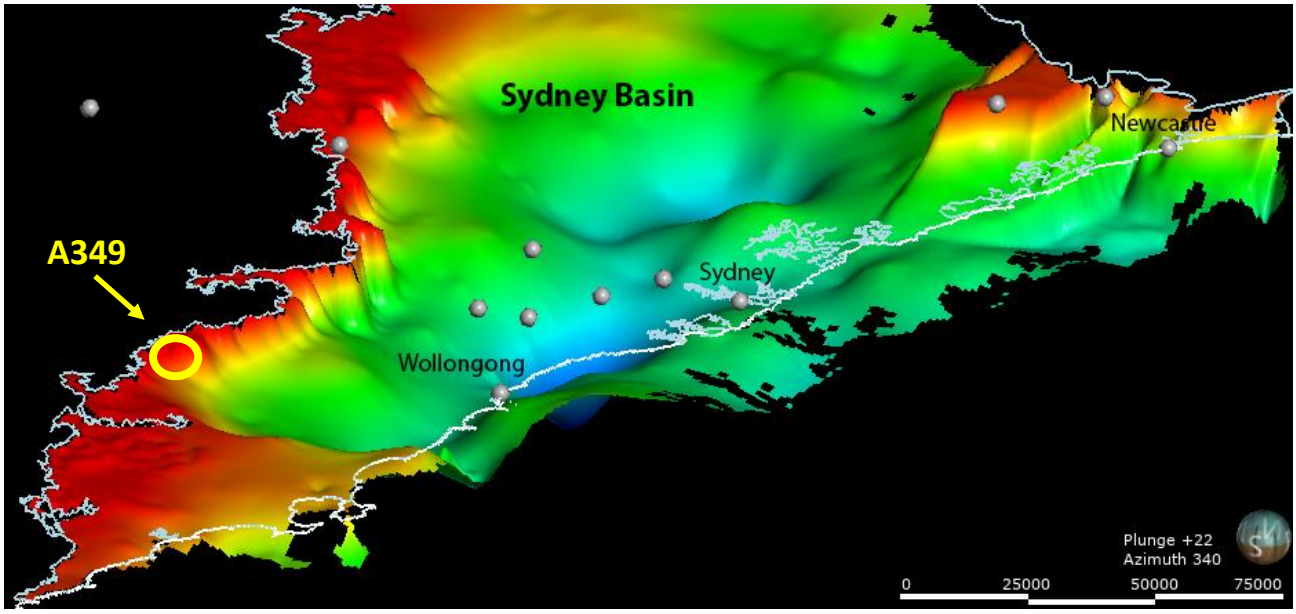



**Figure 2. A 3D image of the Sydney Basin highlighting its depth and size and the location of A349. (Source. NSW Division of Resources and Geosciences.)**

In bore HU0130CH, Jones recognises that the lowest portion of the HBSS (Lee's A horizon) 'contains numerous thin carbonaceous and silty laminae on bedding planes that would locally reduce vertical permeability. (The Coalbed report also shows this particular hole as part of its study.)

With regard to permeability, Jones also notes the presence of thick overbank mudstones which form good permeability barriers and may cover a moderately large lateral area. Jones concludes that, "The north-western and south-eastern portions of the project area are characterised by deposition by smaller river systems and contain numerous low permeability fine-grained floodplain deposits that provide at least local vertical permeability barriers to groundwater movement."

**Upper Eckersley Formation (UEFM)**

Underlying the HBSS is the Upper Eckersley Formation, which Jones notes is comprised mostly of fine to medium grained sandstone sequence which fines upwards and is topped with carbonaceous mudstones. Distinguishing between this unit and the Lower Eckersley Formation is difficult if the Burragorang Claystone is absent. These finer grained sequences were deposited by small rivers that are atypical of the HBSS. (Previously this unit was interpreted by Hume Coal to be part of the HBSS.)

**Burragorang Claystone (BGCS**

Overlying the Lower Eckersley Formation is the BGCS, a volcanic tuff deposit that has been reworked in places. Jones notes that this unit "is very fine-grained consisting predominantly of clay'. This unit is similar in its appearance and behaviour to the Farmborough Claystone and has a very low permeability. This is reinforced by recent permeability testing of the unit.

The abundant presence of the Burragorang Claystone in the Project area is demonstrated by Jones, who identifies it as a very fine grained massive to weakly laminated tuffaceous deposit. Where it is

present, it clearly shows that the Hawkesbury Sandstone hasn't eroded down to the Wongawilli Seam. (Previously this unit was interpreted by Hume Coal to be part of the HBSS.)

**Lower Eckersley Formation (LEFM)**

Jones notes that the LEFM unit in A349 is 'compositional different to the typical unit elsewhere in the basin because it has come from a local Lachlan Fold Belt source to the west and/or southwest of the basin. It is similar in appearance to the Upper Eckersley Formation. (Previously this unit was interpreted by Hume Coal to be part of the HBSS.)

**Unnamed Member No 3 (UNM3)**

The Unnamed Member No 3 is a continuation of the Illawarra Coal Measure Strata and consists of Carbonaceous Mudstones and shales. It is a very fine-grained unit above the Wongawilli Seam. Beneath the UNM3 the WWR coal ply sits overlying the Farmborough Claystone.

**Farmborough Claystone (FCS)**

The FCS is another volcanic ashfall deposit similar to the Burragorang Claystone. It covers most of the northern part of A349. It is very fine-grained white claystone with very low permeability. In the south it is absent as the seam is reduced in thickness by erosion.

**A comment on the borehole data publicly available regarding the Interburden between the Farmborough Claystone and the base of the Hawkesbury Sandstone.**

In the IPC meeting transcript with CFSH (11/02/2019) Mr Lindsay claimed that his opposition group examined some 200 boreholes and weren't able to identify any interburden. (Line 22-29 on page 35.)

*"What they've called interburden and it's up to 10 metres thickness and it corresponds nicely with the proposed mine plan that they've got this layer. So, I mean, when I read this, I, sort of, chuckled to myself and said, "Look, they've found their Borde Hill claystone (sic – actually the Bald Hill Claystone) to save themselves. That, we looked at – there's over 200 boreholes in there. And we looked at them and we could find – in most of them there was hard contact between the Hawkesbury Sandstone and the coal regions. <u>So we didn't find any evidence to support this extra layer</u> in our model and we didn't put it in, based on the evidence."*

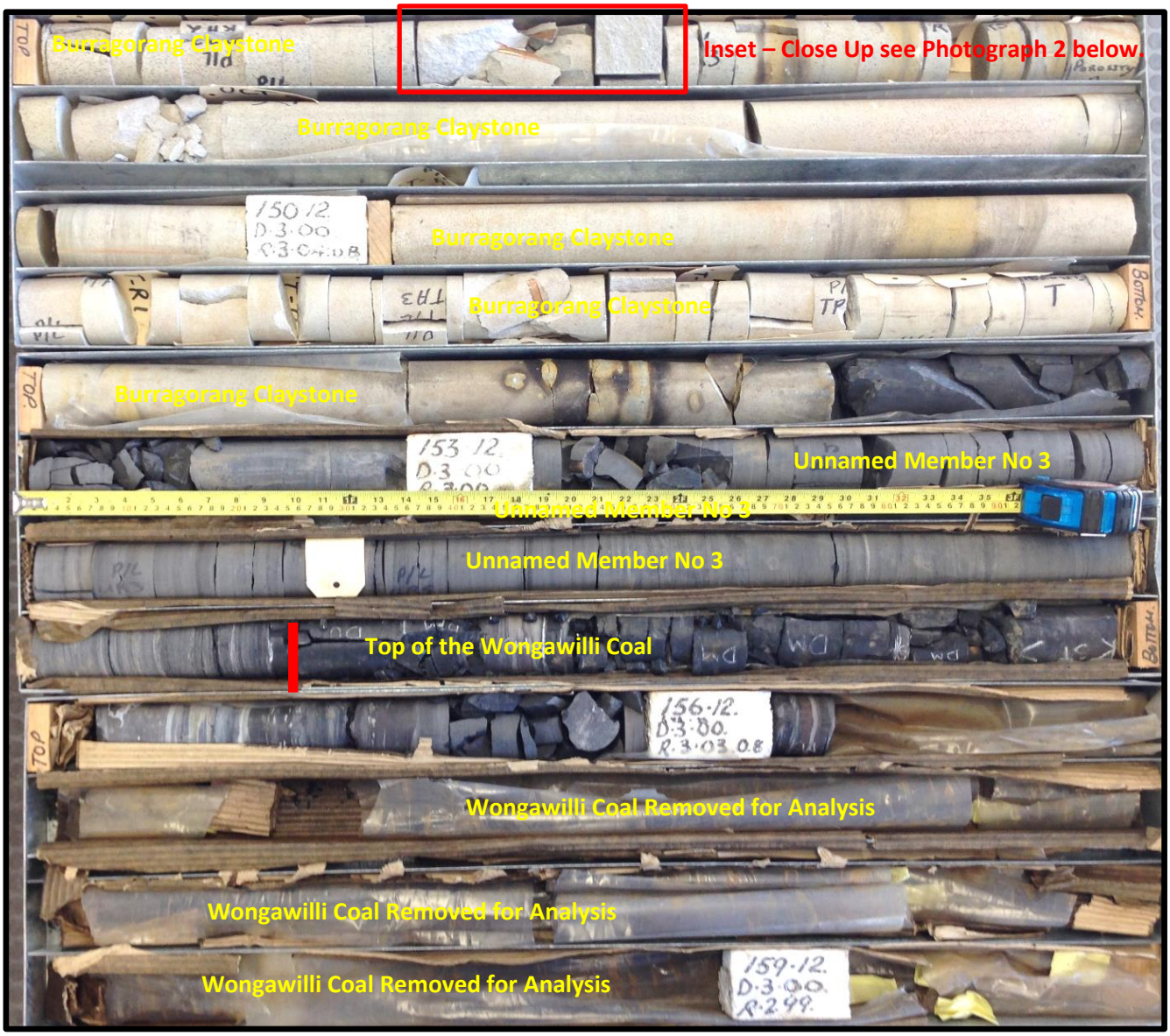
As Lindsay notes, they **'<u>didn't locate any evidence'</u>** of the Interburden among the boreholes and as a result didn't put any interburden in their water model. While Hume Coal cannot vouch for the quality of the search that was undertaken by Mr Lindsay and the opposition group/s (SHCAG & CFSH), the information presented below proves that the Interburden strata is present. Both as Jones has outlined in his report and also shown in the core photos below.

The example of the bore DDH6 drilled adjacent to Golden Vale Road/Carters Lane, highlights the presence of the Interburden as do a great many of the exploration holes in the area, including both

historic holes (publicly available) as well as Hume Coal bores. DDH6 is a historic hole (circa 1989), core from this hole resides in the NSW Governments WB Clarke Core Library at Londonderry and is available for the public to inspect. Core photographs from bores DDH 1A, 3, 4, 5, 5R, 6 ,7 & 8 are also presented to highlight the amount of evidence available. See locations of bores in Photograph 1.

**Photograph 1. Location of DDH series holes in the North of A349. Mount Gingenbullen to right.**

In Figure 3 below a graphical representation of the DDH6 borelog is presented. It identifies the Base of the HBSS (*base Hss* - circled in red) some 4 metres above the top of coal from the WWSM. It also describes a horizon of about 1 metres thickness as '*cream tuff f sdst*' between the WWSM and the HBSS, also circled in red, which is a reference to the volcanic ash (tuff) of the BGCS unit.




**Photograph 2. Core from DDH6 (WB Clarke Core Library) Strata Overlying the Wongawilli Seam. Note the red square in the top row - is shown as a close up in Photograph 2 below.**

**Photograph 3. A close up of the Burragorang Claystone – a tuffaceous ash fall deposit.**

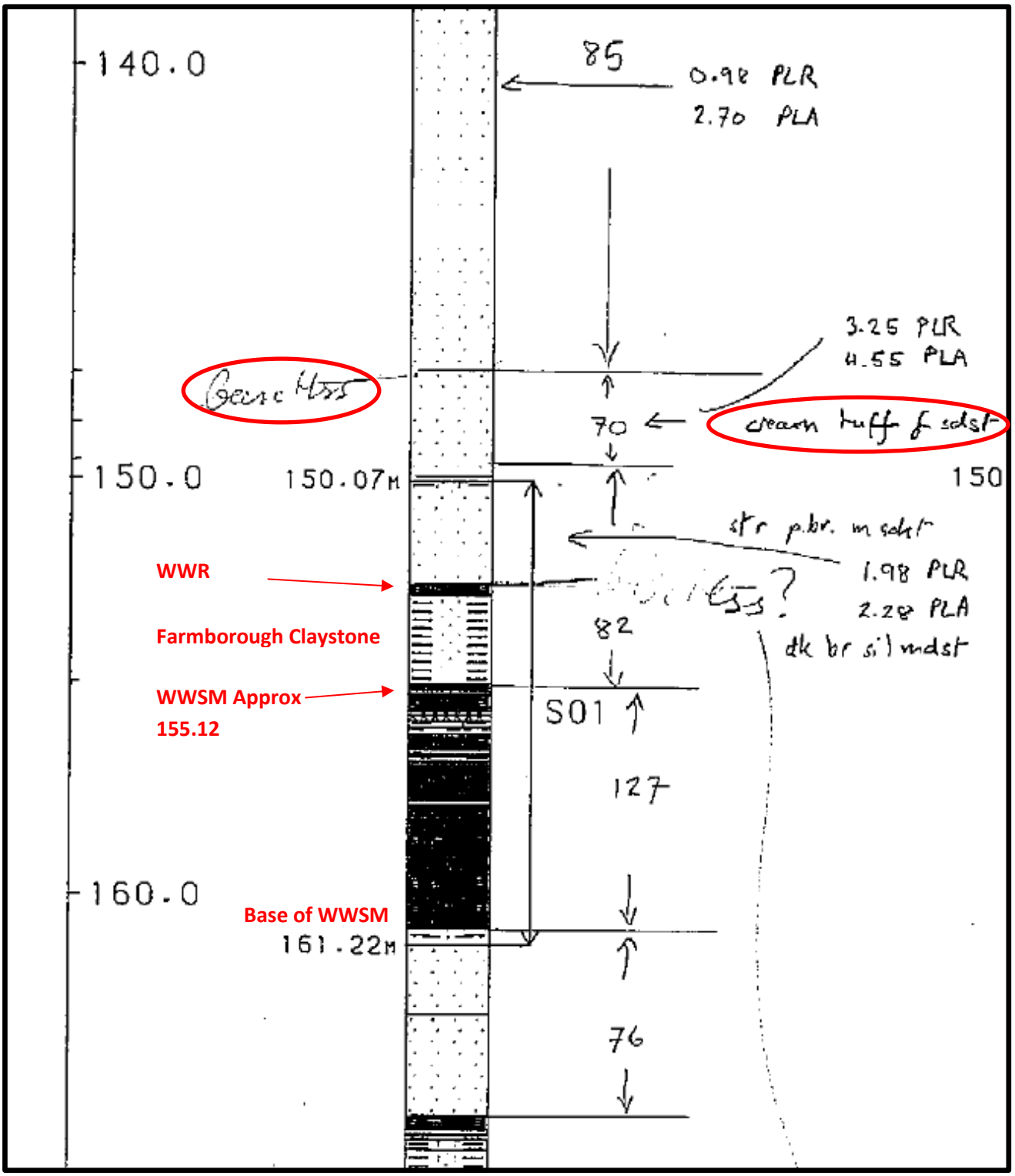



**Figure 3. Section prepared for DDH6 by McElroy Bryan Geological Services (MBGS circa 1989). Highlighting the Wongawilli Seam and the "Cream Tuff" acting as a portion of the Interburden between the Wongawilli Seam and the Base of the Hawkesbury Sandstone (base Hss). The red circles and text have been added to assist the reader.**

**Photograph 4. DDH1A Boxes 7. 8 & 9. Hawkesbury Sandstone at top. Underlain by Burragorang Claystone. Underlain by the Unnamed Member No 3 (UNM3) top at about 109.70m base at about 110.80m. Top of Wongawilli Seam (WWSM) with Farmborough Claystone Member present.**

**Photograph 5. DDH3 Boxes 6, 7 & 8 Wongawilli Coal at base. Approx. 0.4m of Lower Eckersley present. It is overlain by the Burragorang Claystone, which in turn is overlain by the Hawkesbury Sandstone.**

**Photograph 6. DDH4 Boxes 4, 5 & 6 Hawkesbury Sandstone top 2 boxes also see next photograph for the continuation of this bores core.**

**Photograph 7. DDH4 Boxes 7, 8 & 9 Burragorang Claystone top 2 rows + Underlain by UNM3 which grades into top of Wongawilli Coal with small section of Farmborough Claystone present in row 4 of top box.**

**Photograph 8. DDH5 Boxes 5, 6 & 7 Some 5.5m of Burragorang Claystone present in hole – showing about 4.2m here in the top box +. Directly overlying the top of Wongawilli Coal.**

**Photograph 9. DDH5R (Redrill) Boxes 1, 2 & 3. Thick Burragorang Claystone at top. Directly overlying the top of the Wongawilli Coal.**

**Photograph 10. DDH6 Boxes 37, 38 & 39. Approx. 5.0m of Burragorang Claystone throughout top box +. Underlain by the UNM3 which grades into the top of Wongawilli Coal.**

**Photograph 11. DDH7 Boxes 6, 7 & 8 Hawkesbury Sandstone at top, underlain by Upper Eckersley Formation. Small section of Burragorang Claystone present - reworked. It is underlain by the Lower Eckersley Formation. UNM3 from 116.70m to about 118.25m. Which overlies the Top of Wongawilli Coal.**

**Photograph 12. DDH8 Boxes 7, 8 & 9 Hawkesbury Sandstone present at top. With Upper Eckersley Formation present. Five metre thick section of Burragorang Claystone is present. No UNM3 present. Burragorang overlying the top of Wongawilli Coal.**

## 2020 Permeability Data

Following the Jones report a more detailed testing program was undertaken of core from the Interburden. The testing provided Vertical Permeability and Porosity data. That data is presented below in Figure 4 which highlights the recently tested permeability data (2020) to support the Ground Water Model. The red squares shown below show the Hume exploration bore data with the recent focus being on the Interburden horizon. The data provides strong evidence to support the conclusions previously reached that permeability decreases with depth. This data is presented to address the Paragraph 123 presented in the IPC Report.

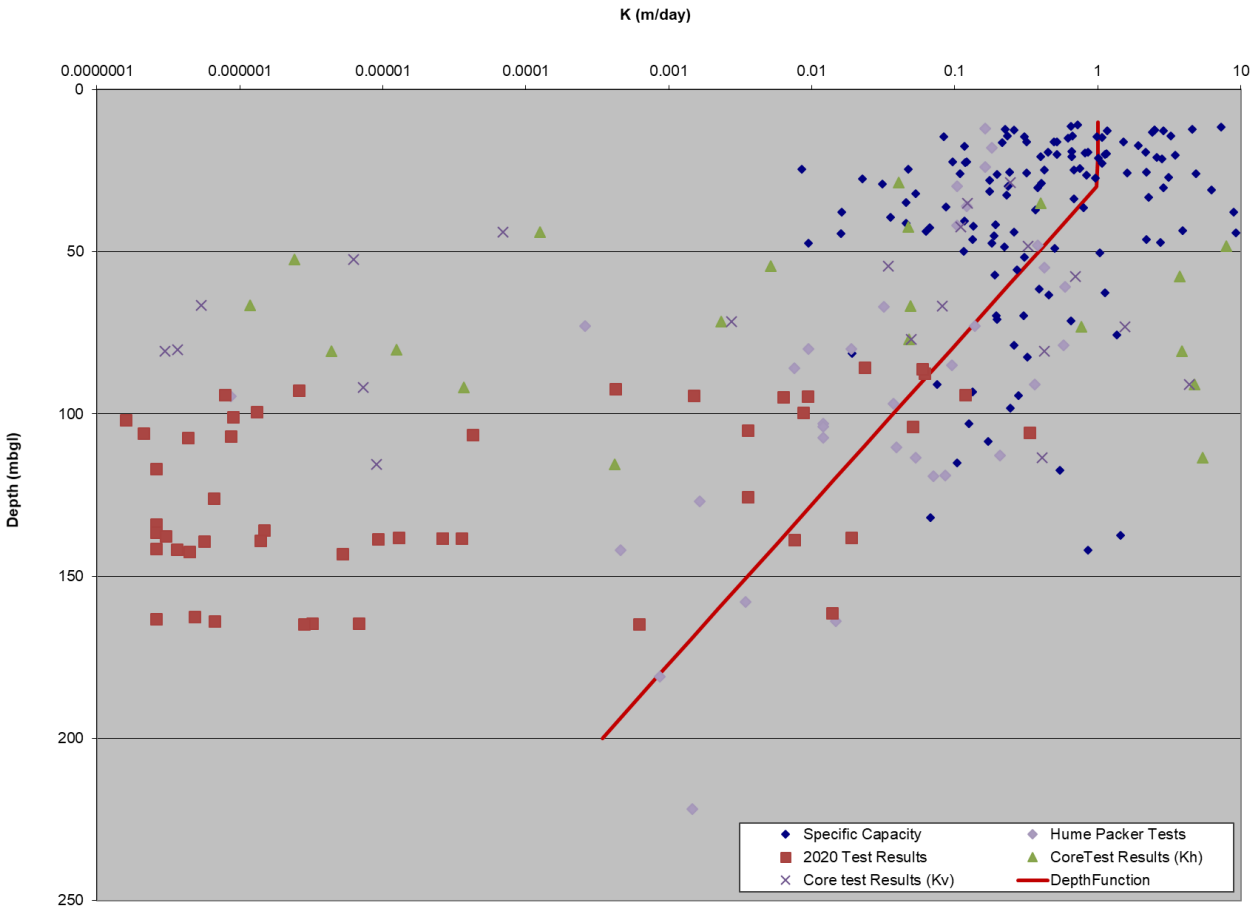



**Figure 4. Permeability data for Hume Coal including Recent 2020 Results (Red Squares).**

The permeability data and porosity data is presented in Table 3, where over 50 additional results are presented. Note that the samples were taken from various units within the Interburden. Those units include the Burragorang Claystone, the Unnamed Member No 3, the Upper and Lower Eckersley Formation and the basal Hawkesbury Sandstone.

| STS Lab # | Bore ID | From | To | Thick | Unit | Rocktype | Porosity | Dry RD | Perm m/day |
|---|---|---|---|---|---|---|---|---|---|
| 3881-01A | HU088PZB | 133.93 | 134.11 | 0.18 | BCS | Claystone very fine grained silty sideritic dark grey | 3.09 | 2.617 | 2.60E-07 |
| 3881-03E | | 135.86 | 136.03 | 0.17 | BCS | Claystone, very fine grained light grey reworked | 10.15 | 2.365 | 1.49E-06 |
| 3881-02E | | 136.44 | 136.63 | 0.19 | BCS | Claystone, very fine grained sideritic light grey reworked | 8.15 | 2.43 | 2.60E-07 |
| 3881-04A | | 137.61 | 137.91 | 0.30 | BCS | Claystone, very fine grained light grey reworked | 6.34 | 2.479 | 3.05E-07 |
| 3881-05A | | 138.21 | 138.27 | 0.06 | BCS | Claystone, very fined grained white reworked | 12.58 | 2.224 | 1.29E-05 |
| 3881-31A | | 138.35 | 138.41 | 0.06 | BCS | Claystone, very fined grained white reworked | 14.45 | 2.197 | 2.60E-05 |
| 3881-32A | | 138.45 | 138.52 | 0.07 | BCS | Claystone, very fined grained white reworked | 15.82 | 2.197 | 3.54E-05 |
| 3881-06B | | 138.53 | 138.60 | 0.39 | BCS | Claystone, very fine grained white reworked | 12.05 | 2.212 | 9.24E-06 |
| 3881-07A | HU085CH | 94.18 | 94.34 | 0.16 | BCS | Claystone, sandy fine grained grey white pebbly | 23.14 | 1.974 | 1.18E-01 |
| 3881-08A | | 94.34 | 94.49 | 0.15 | BCS | Claystone, sandy fine grained grey white pebbly | 23.18 | 2.013 | 1.50E-03 |
| 3881-09A | | 94.49 | 94.71 | 0.22 | BCS | Claystone, sandy fine grained grey white pebbly | 19.89 | 2.073 | 9.42E-03 |
| 3881-10A | | 94.71 | 94.96 | 0.25 | BCS | Claystone, sandy fine grained grey white pebbly | 18.95 | 2.111 | 6.32E-03 |
| 3881-11A | HU095CH | 139.13 | 139.37 | 0.24 | BCS | Claystone, well layered and graded vfg grey white | 5.25 | 2.495 | 1.40E-06 |
| 3881-12A | | 139.92 | 140.15 | 0.23 | BCS | Claystone, vfg, sandy, grey white | 7.37 | 2.425 | 1.14E-06 |
| 3881-13B | | 140.82 | 141.09 | 0.27 | BCS | Claystone vfg light grey - white | 10.09 | 2.374 | 3.80E-07 |
| 3881-14B | | 141.50 | 141.80 | 0.30 | BCS | Claystone, vfg grey white | 8.00 | 2.427 | 2.60E-07 |
| 3881-16B | HU114CH | 127.61 | 127.70 | 0.09 | BCS | Claystone, minor siderite grains o/w vfg grey white | 6.04 | 2.462 | 4.70E-07 |
| 3881-17A | | 127.80 | 127.90 | 0.10 | BCS | Claystone, minor siderite grains o/w vfg grey white | 6.33 | 2.462 | 2.27E-06 |
| 3881-18A | HU111CH | 116.97 | 117.14 | 0.17 | UNM3 | I/B shale+ mudstone, carbonaceous, dark grey-black vfg | 2.16 | 2.287 | 2.60E-07 |
| 3881-19A | HU129PZA | 161.18 | 161.39 | 0.21 | UEF | Sandstone, fg, grey white in colour | 20.29 | 2.058 | 4.27E-02 |
| 3881-20A | | 161.39 | 161.64 | 0.25 | UEF | Sandstone, fg, grey white in colour | 19.8 | 2.093 | 1.39E-02 |
| 3881-21A | | 162.55 | 162.88 | 0.33 | BCS | Claystone, fg, grey | 3.84 | 2.533 | 4.83E-07 |
| 3881-22A | | 163.26 | 163.51 | 0.25 | BCS | Claystone, grey - looks indurated, disturbed bedding. | 6.6 | 2.801 | 2.60E-07 |
| 3881-23A | | 163.88 | 164.08 | 0.20 | BCS | Claystone, grey indurated | 5.68 | 2.505 | 6.70E-07 |
| 3881-24A | | 164.53 | 164.60 | 0.07 | BCS | Claystone, reworked banded grey | 12.88 | 2.277 | 6.77E-06 |
| 3881-33A | | 164.66 | 164.72 | 0.06 | BCS | Claystone, reworked banded grey | 14.31 | 2.222 | 3.22E-06 |
| 3881-34A | | 164.73 | 164.80 | 0.07 | BCS | Claystone, reworked banded grey | 13.48 | 2.273 | 2.82E-06 |
| 3881-25A | | 164.85 | 164.92 | 0.39 | BCS | Claystone reworked banded grey vfg | 12.82 | 2.272 | 6.22E-04 |
| 3881-26A | HU035CH | 138.17 | 138.37 | 0.20 | BCS | Claystone, sandy white - orange in colour fg | 22.39 | 2.023 | 1.88E-02 |
| 3881-27A | | 138.81 | 139.03 | 0.22 | BCS | Claystone, sandy white fg | 15.83 | 2.201 | 7.58E-03 |
| 3881-28A | | 139.32 | 139.64 | 0.32 | UNM3 | Mudstone silty banded some minor dip | 1.82 | 2.305 | 5.61E-07 |
| 3881-29A | HU061CH | 125.66 | 126.80 | 1.14 | BCS | Claystone, vfg white. | 20.65 | 2.046 | 3.59E-03 |
| 3881-30A | | 126.11 | 126.29 | 0.18 | BCS | Claystone, vfg white. | 17.53 | 2.043 | 6.57E-07 |
| 3881-31A | | 138.35 | 138.41 | 0.06 | BCS | Claystone, vfg white. | 14.45 | 2.197 | 2.60E-05 |
| 3905-01 | HU064 | 141.71 | 141.94 | 0.23 | BGS | Claystone Sandy sideritic, light grey | 2.64 | 2.59 | 3.65E-07 |
| 3905-02 | | 142.47 | 142.59 | 0.12 | BGS | Claystone very fine grained dark grey | 1.95 | 2.561 | 4.46E-07 |
| 3905-03 | | 143.19 | 143.27 | 0.08 | BGS | Claystone vfg light grey | 10.11 | 2.357 | 5.25E-06 |
| 3905-04 | HU079 | 87.58 | 87.73 | 0.15 | LEF | Sandstone med-coarse grained orangy in colour and weathered | 23.06 | 2.001 | 6.16E-02 |
| 3905-05 | | 86.22 | 86.31 | 0.09 | LEF | Sandstoone fine grained well cemented | 21.93 | 2.047 | 5.90E-02 |
| 3905-06 | | 85.68 | 85.90 | 0.22 | LEF | med-coarse well cemented orangy and quartzose | 16.73 | 2.145 | 2.35E-02 |
| 3905-07 | HU029 | 107.26 | 107.58 | 0.32 | UNM3 | Carbonaceous silt/mudstone dark grey-black | 2.64 | 2.459 | 4.36E-07 |
| 3905-08 | | 105.98 | 106.22 | 0.24 | UNM3 | Carbonaceous silt/mudstone dark grey-black | 3.34 | 2.276 | 2.12E-07 |
| 3905-09 | HU083 | 103.81 | 103.89 | 0.08 | UNM3 | Carbonaceous silt/mudstone dark grey-black | 14.41 | 2.077 | 5.10E-02 |
| 3905-10 | | 101.88 | 101.97 | 0.09 | UNM3 | Carbonaceous silt/mudstone dark grey-black | 3.65 | 2.619 | 1.60E-07 |
| 3905-11 | | 100.85 | 101.00 | 0.15 | HBSS | Sandstone med-coarse grained pebbly | 3.42 | 2.586 | 9.00E-07 |
| 3905-12 | HU093 | 99.36 | 99.49 | 0.13 | EF | Silt/mudstone med grey in colour | 12.34 | 2.389 | 1.31E-06 |
| 3905-13 | | 99.49 | 99.72 | 0.36 | BCS | Sandstone fine grained light grey | 19.46 | 2.060 | 8.73E-03 |
| 3905-14 | HU094 | 92.28 | 92.47 | 0.19 | EF | Sandstone fine grained well cemented | 15.77 | 2.285 | 4.21E-04 |
| 3905-15 | | 92.81 | 92.98 | 0.17 | EF | Sandstone fine grained well cemented, silty whisp layers | 9.42 | 2.402 | 2.58E-06 |
| 3905-16 | | 94.10 | 94.22 | 0.12 | EF | Silt/mudstone dark grey to black | 2.6 | 2.545 | 7.86E-07 |
| 3905-17 | HU0130 | 106.87 | 107.05 | 0.18 | EF | Sandstone fine grained well sorted and cemented | 1.5 | 2.356 | 8.67E-07 |
| 3905-18 | | 104.96 | 105.19 | 0.23 | HBSS | Conglomerate med coarse grained sandstone | 18.16 | 2.151 | 3.57E-03 |
| 3905-19 | | 105.70 | 105.90 | 0.20 | HBSS | Sandstone fine grained light grey | 18.66 | 2.061 | 3.32E-01 |
| 3905-20 | | 106.46 | 106.60 | 0.14 | UNM3 | Mud/siltstone dark grey to black - overlain by coal. | 10.5 | 2.369 | 4.27E-05 |
| STS Lab # | Bore ID | From | To | Thick | Unit | Description | Porosity | Dry RD | Perm m/day |

**Table 3. Permeability and Porosity Data (2020).**

**Conclusions**

A review of the DPIE-W database of Ground Water Bores (GWB) indicates that the flow rates of the GWB gives a good indication of how permeable the Hawkesbury Sandstone (HBSS) is and where the high flows emanate from within this unit. These results go towards responding to the Independent Planning Commissions (IPC) concerns, re: hydraulic conductivity (Paragraphs 123 and 140).

A review of the ground water bores and their yields in and around A349 clearly indicate that the deepest holes in the area are not the most productive. There is only a 50% chance of ground water bores which intersect the entire HBSS sequence having better than average flow rates. This in itself casts significant doubt on the argument that the best aquifer is closest to the WWSM.

Coupled together with the assessment of several geophysical logs across A349 which clearly identify that the location of clean and porous sands indicating higher permeability layers in the HBSS are not situated in the immediate vicinity of the WWSM. This work when combined refutes the likelihood of broad scale high permeability horizons being adjacent to the Wongawilli Seam.

The work undertaken by Dr Brian Jones identifies less permeable strata at and below the base of the HBSS which covers about 75% of the proposed mine foot print. The identification of the Burragorang Claystone means that there are two significant tuffaceous ash fall deposits in the "Interburden" both of which are effectively impermeable. Together with other horizons that are also low in permeability, including the Unnamed Member No 3 and the Upper and Lower Eckersley Formation.

A program of laboratory testing to measure permeability and porosity is being undertaken to establish the exact permeability for the strata in the 'Interburden' – between the WWSM and the HBSS. Results from 2020 are presented in figures and tables in this document and show exceptional low permeability values.

Report 1 Ground Water Bore Report to be Appended

Report 2 Coalbed Report on Geophysics to be Appended.

Report 3 Sedpet Report on Interburden Strata to be Appended.

Report 4 Summary of Geology of A349 to be Appended.

# Commentary on the
# NSW Office of Water Groundwater Bore Database
# In and Around Authorisation A349.

***Wongonbra 24*7 Pump Test – Irrigating water 28/06/2014***

**Executive Summary**

A review of the New South Wales WaterNSW database for groundwater bores (GWB) in and around the A349 Authorisation has been conducted. The main findings of this study can be summarised as follows:-

- The Ground Water Bore database in and around A349 has been investigated. Data is extensive, it is specific and it is local to the A349 area. That is, the data reflects the local site-specific conditions of the aquifers.
- In general, the uppermost rocks in the local stratigraphy, the Wianamatta Shale and Robertson Basalt only provide a small water contribution to GWB.
- The Hawkesbury Sandstone (HBSS) contributes water to GWB primarily through the strata in layered beds and secondarily, through contributions via geological structures, jointing or fracture permeability.
- This study shows that the GWB flow rates of the uppermost portion of the HBSS tend to contribute more water than others horizons within the HBSS.
- The assertion that the lowest portion of the HBSS. i.e. the sandstone closest to the Wongawilli Coal seam is the most prolific water source cannot be substantiated.
- The surface stream systems contribute to some of the highest flowing GWB in the area. Its noteworthy that the database shows that some of the highest flowing GWB are also the shallowest in the database.

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**Introduction**

In May 2019 the NSW Governments' Independent Planning Commission (IPC) issued a Report on the Hume Coal and Berrima Rail Projects. The IPC raised two concerns that relate to the 'hydraulic conductivity' of the Hawkesbury Sandstone, the relevant paragraphs are copied below. (The bolding is the author's emphasis.)

> *No 123 – With regard to hydraulic conductivity (permeability) decreasing with depth, DOI-Water stated that, "In summary,* ***we do not believe that the data presented by the proponent demonstrates clear field evidence for the assertion that hydraulic conductivity decreases with depth****."*
>
> *No 140 –* ***Of particular interest to the Commission is the possibility that the Hawkesbury Sandstone's hydraulic conductivity (Kh and Kv) is highest immediately above the coal seam to be mined.*** *There was no representation of this in the model realisations, despite apparently being requested by DOI-Water at a previous modelling meeting. This work would have been useful to check the possibility of larger water inflows to the mine. Likewise, a larger range of drainage conductance values could have been modelled to eliminate the speculation about the interburden layer acting as a bottleneck to flow.*

The purpose of this report is to address these issues using data directly available from the NSW Government. This report is seen as one part of an overall assessment to refute the belief that, "the hydraulic conductivity is enhanced at depth where the Hawkesbury Sandstone is in proximity to the Wongawilli Seam". This study strongly suggests that this belief is incorrect.

The New South Wales Department of Planning, Industry and Environment (DPIE) through its Water Office (DPIE-W) collects and records groundwater bore (GWB) data. In this report the water database information has been interrogated in an attempt to better understand the behaviour of the aquifers in and around A349. Locations of the GWBs of interest to the Hume Coal Project are shown in Figure 1. Relevant GWB data is presented in the Appendix.

Each GWB is identifiable with an individual GW number and a Licence Number. The area of interest to Hume Coal is the area within A349 and its immediate surrounds. There are some 248 GWB in total which cover the entire area of the original A349 area (pre-relinquishment) including an area, for the most part, about 1km outside the Authorisation boundary.

Figure 1 also shows both the relinquished (light red dotted outline) and current boundary areas (darker and bolder solid red outline) of the Authorisation (A349). The blue dots represent the GWB. (Note, in this study the terms, water yield and flow rate are treated as the same thing.)

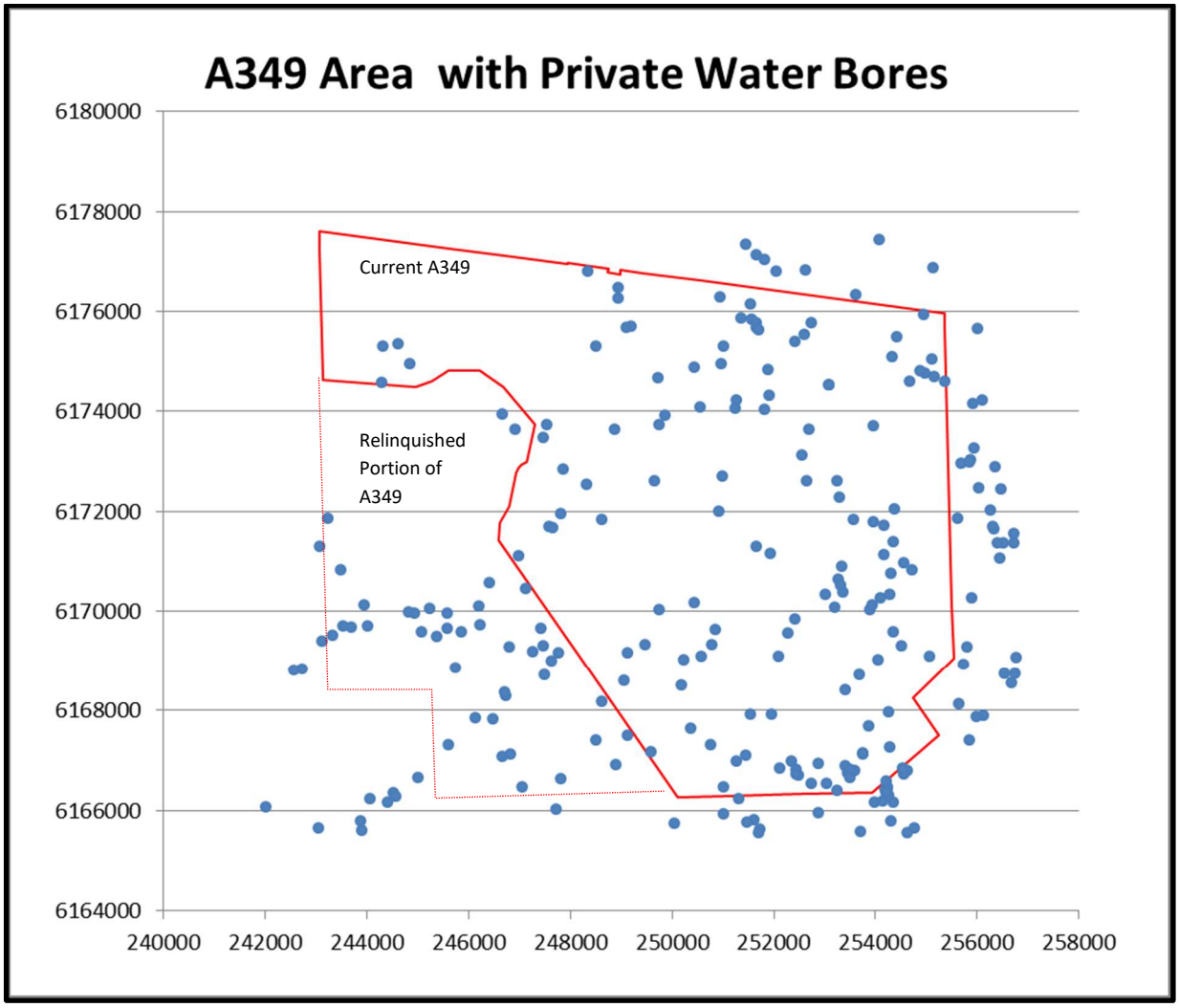


**Figure 1. Plan of GWB Locations from the GWB Database.**

**Data Range for Flow Rates**

The GWB flow rates range from having no available information (38 bores) i.e. zero to a reported bore with 149 litres/second (l/s) flow (GW028832). This high value is believed to be an error, possibly litres/minute (est. 2.5 l/s), or it may be missing a decimal place (e.g. 14.9 l/s). Because this value is some 4 times larger than the next largest value, the entry has been ignored. It is also considered to be a totally impractical flow and was removed from this study until its status can be confirmed. Below in Table 1 are the basic flow statistics of the available GWB, (ignoring the 38 nulls and 1 anomalously high 149 l/s value).

| | | |
|---|---|---|
| **Min** | **=** | **0.08 l/s** |
| **Max** | **=** | **40.02 l/s** |
| **Average** | **=** | **6.04 l/s** |
| **Standard Deviation** | **=** | **6.97 l/s** |
| **Count** | **=** | **209 (248 Total less nulls etc)** |

**Table 1. Basic Flow Rate Statistics for of the GWB Data Base relative to A349.**

All GWB flow data is shown in the Frequency plot below (Figure 2). The data essentially fits into a bell-shaped curve. With the data falling neatly into 5 groups with a total number of data points being 209 GWB.

1. From the lowest flow (0.08 l/s) to the average flow (6 l/s) there are 147 GWB (70%).
2. From 6 l/s to 13 l/s the number of GWB is 33 - totalling 180, i.e. from the avg flow (6 l/s) to 1 Standard Deviation (SD) above the average - 13 l/s (Combined 86%).
3. From 13 and 20 l/s there are 16 GWB, i.e. between 1SD and 2SD above avg (94%).
4. From 20 and 27 l/s there are 8 GWB i.e. between 2SD and 3SD above avg (98%).
5. There are 5 values above the 3 Standard Deviation value of 27 l/s. (100%)

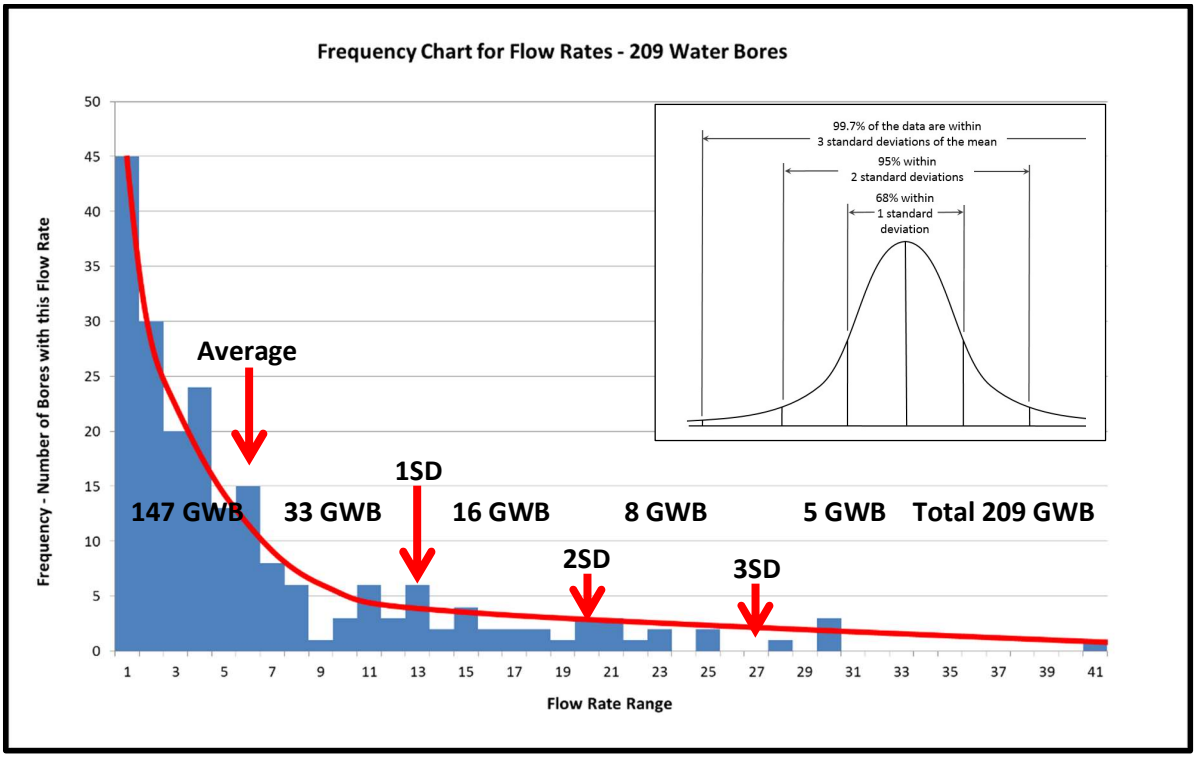


**Figure 2. Frequency of Flow Rates of GWB.**

Figure 3 presents the GWB locations shown as graduated flow rates, that is, the larger the coloured marker the higher the flow rate. There are 5 categories and while the values for these categories are selected arbitrarily, the red bores are described as having very high yields or flow rates, i.e. they are greater than 3 standard deviations above the average. GWB shown as large red circles have flow rates greater than 27.5 l/s. GWB with flow rates of > 10 l/s, but < 27.5 l/s are shown as slightly smaller blue circles, etc as per the legend.

**Overview of Data – Source Quality Reliability**

Reliability of the data is generally thought to be satisfactory, but should be verified as it relies on numerous drilling contractors of varying experience. Hume Coal's decision to undertake testing of some of these wells (as part of its 'Make Good Policy') is commensurate with a sensible approach to establishing the veracity of the data.

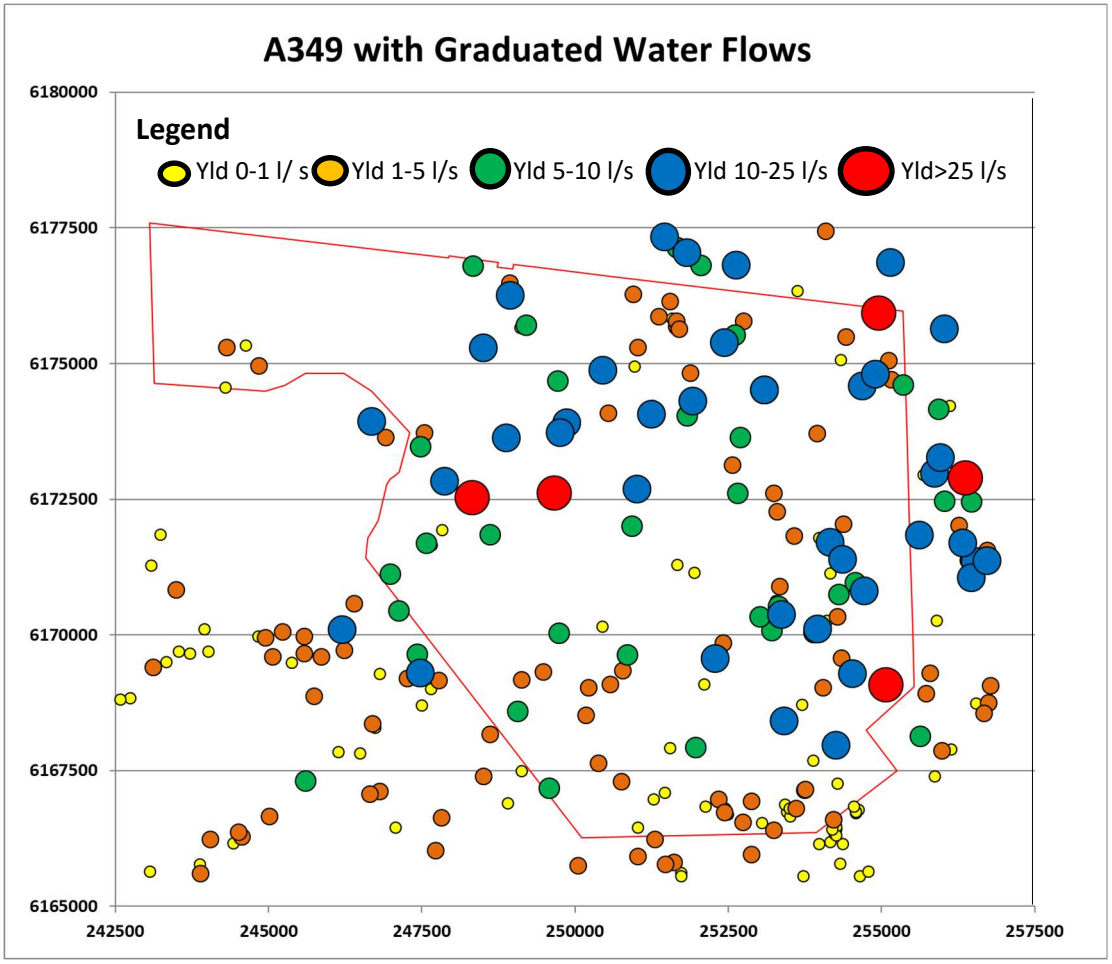


**Figure 3. Plan of GWB Locations Highlighting Flow Rates Categories.**

Some of the data is believed to be invalid, for example:

- Some data for casing depth is negative (2 data points), which indicates metres above ground level rather than depth or length of casing, which the rest of the data is assumed to be.
- Two bores near Exeter (in the south-east of the area) have Standing Water Levels (SWL) of greater than 160m depth, which is three standard deviations greater than the average SWL value and would seem to be anomalous especially when considering that the average SWL data in and around Exeter is 28m. These SWL may have been read before the water level settled, or the data may have been incorrectly entered into the database.
- One bore was identified as being 673m deep, which seems likely to be an error and may have omitted a decimal place. (The GWB data used in this study is presented in the appendix.)
- From discussions with landowners, Hume Coal is aware that some of the survey co-ordinates of the GWB are also in error. Two GWB have the same survey co-ordinates recorded. The use of Google Earth also identifies some errors with GWB location.

- In contrast to the above, two extensive pumping tests (on GW07535 and GW108194) accurately confirm the flow rates from this GWB with the data from the DPIE-W database.

The Wongonbra 24/7 test pump on GW108194 (Hume Coal June 2014) has a consistent flow rate of 20 l/s, comparable to 21 l/s in the DPIE-W database. Photograph 1 below shows the water being pumped from the GWB. The water was then irrigated to the surface land (see cover photograph). A GWB on an adjacent property (Rosedale) is recorded as producing 40 l/s (GWB database) and is confirmed by Hydroilex (Hume Coal Major Projects submission dated 30/06/2017) as having similar results. These two results add a degree of certainty to the data in the DPIE-W database.

While Hume Coal is aware of the deficiencies of the database, it is nevertheless an extraordinary volume of data that reflects very specific aspects of the groundwater behaviour in the aquifers present in the locality. The WaterNSW database is noteworthy and considering its level of detail, is vital to any review about the presence and performance of the aquifers and its contribution of water to GWB in the area associated with A349. Its abundance of evidence is formidable and when contrasted with anecdotal commentary cannot be dismissed.

**Photograph 1. Water Pumped from GW108194 during a 24*7 Pump Out Test.**

**Strata Intersected**

The major strata horizons present in the area of A349 are well established from surface mapping and from exploration drilling. A349 exists within the Southern Coalfield of the Sydney Basin. However, the stratigraphy in A349 is different from the normal stratigraphy of the Basin. For a start, the Narrabeen Group (NG) and a significant portion of the Illawarra Coal Measures (ICM) are absent.

| SYDNEY BASIN STRATIGRAPHY | | | |
|---|---|---|---|
| TYPICAL STRATIGRAPHY | | | A349 STRATIGRAPHY |
| | | Robertson Basalt | Present |
| TRIASSIC | | Wianamatta Group | Present |
| | | Hawkesbury Sandstone | Present |
| | NARRABEEN GROUP | Newport Formation | Absent |
| | | Bald Hill Claystone | |
| | | Bulgo Sandstone | |
| | | Stanwell Park Claystone | |
| | | Scarborough Sandstone | |
| | | Wombarra Claystone | |
| | | Coalcliff Sandstone | |
| PERMIAN | ILLAWARRA COAL MEASURES | Bulli Coal | Absent |
| | | Loddon Sandstone | |
| | | Balgownie Coal | |
| | | Lawrence Sandstone | |
| | | Cape Horn Coal Member | |
| | | Hargrave Coal Member | |
| | | Woronora Coal Member | |
| | | Upper Eckersley | Present |
| | | Burragorang Claystone | |
| | | Lower Eckersley | |
| | | Wongawilli R Ply | |
| | | Farmborough Claystone | |
| | | Wongawilli Coal | |
| | | Kembla Sandstone | |
| | | American Creek Coal Member | |
| | | Darkes Forest Sandstone | |
| | | Tongarra Coal | |
| | | Wilton Formation | |
| | | Erins Vale Formation | |
| | | Pheasants Nest Formation | |
| | Shoalhaven Group | | Present |
| | Talaterang Group | | Present |

**Table 2. Stratigraphic Table Comparison of Sydney Basin to A349 Area. Hume Coal Interburden is shown highlighted in light blue.**

A stratigraphic table is presented in Table 2 above to highlight the strata present and absent. The major influence on the stratigraphy is either:-

a) the Hawkesbury Sandstone Formation (HBSS)/Eckersley Formation has eroded down through the missing strata (i.e. the NG and significant portion of the ICM) to the top of the Wongawilli Seam (WWSM) and in some places removed the entire WWSM, or considered more likely,

b) that this 'missing strata'(i.e. the NG and significant portion of the ICM) was never deposited in this environment i.e. close to the south western corner of and in this elevated position within the Sydney Basin.

Interburden is present from the Farmborough Claystone and the base of the HBSS. The recent report by Dr Jones has also identified additional layering from the Eckersley Formation and the Burragorang Claystone. This slightly increases the thickness of the interburden and acts to reduce permeability.

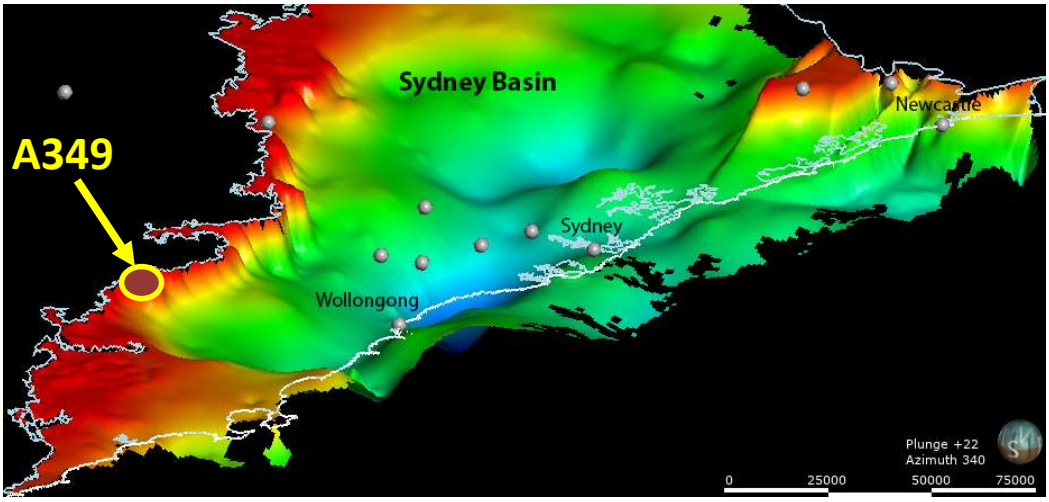


**Figure 4. Location of A349 as part of the Sydney Basin.**

The HBSS represents the main focus of the water supply present within the area. On average the HBSS attains a thickness of about 100m. This is significantly different to most of the Sydney Basin, in particular where it reaches its maximum thickness of about 250m in and around Sydney itself. Other strata of interest includes; the Robertson Basalt (as surface basalt flows), the Wianamatta Shales and the Wongawilli Seam itself. These units also contain and contribute minor amounts of water of varying quality and flow rates.

GWB to the west of the Hume Highway, within A349 are likely to start in sandy soils or straight into the HBSS. Whereas to the east of the Hume Highway, GWB will more commonly commence in the Wianamatta Shales or Robertson Basalt. Then as the GWB achieve greater depth they progress into the HBSS. Some 44 GWB are recorded as having the Robertson Basalt unit within them. The basalt generally occurs as ridgelines in the area.

Of the GWB that intersected the Robertson Basalt (44):

- 7 did not have flow data (16%),
- 18 had less than 1 l/s (41%),
- 7 had flows of between 1 and 2 l/s (16%),
- 8 had flows between 2 and 5 l/s (18%), and
- only 4 of the bores had values greater than 5 l/s (9%).

For GWBs intersecting basalt, very few have attained even an average flow rate (6 l/s). Increasing depth only sees one GWB improve its flow rate well above the average flow rate. A conclusion to be drawn regarding GWB intersecting basalt is that they do not achieve high flow rates. The GWB intersecting basalt are shown in Figure 5 below, with flow rates plotted against depth of bore.

Also shown in Figure 5 are some 36 GWB (black circles) that intersect coal from the Wongawilli seam. Of these GWB which intersected coal all have flow data;

- 5 GWB had less than 1 l/s (14%),
- 7 GWB had flows between 1 and 2 l/s (19%),
- 8 GWB had flows between 2 and 5 l/s (22%),
- 10 GWB had values of between 5 and 10 l/s (28%), and
- 6 GWB had values of 10 l/s or greater (17%).

Generally, the coal seam is intersected at depths greater than 85m, indicating that the GWB that intersect coal are deep. **It is important to understand that the all GWB intersecting the Wongawilli Coal will have the entire available sequence of the HBSS in them, i.e. from top to bottom.** Despite having all the HBSS, including the basal unit, 60% (more than half) of these GWB have less than the average flow rate (<6 l/s). Further 83% of the GWB intersecting coal have flow rates less than 10 l/s. All these GWB intersect the lowest part of the HBSS and clearly is not the most productive portion of the HBSS aquifer. This evidence **strongly contradicts** the assertion that the HBSS immediately overlying the WWSM has the highest hydraulic conductivity.

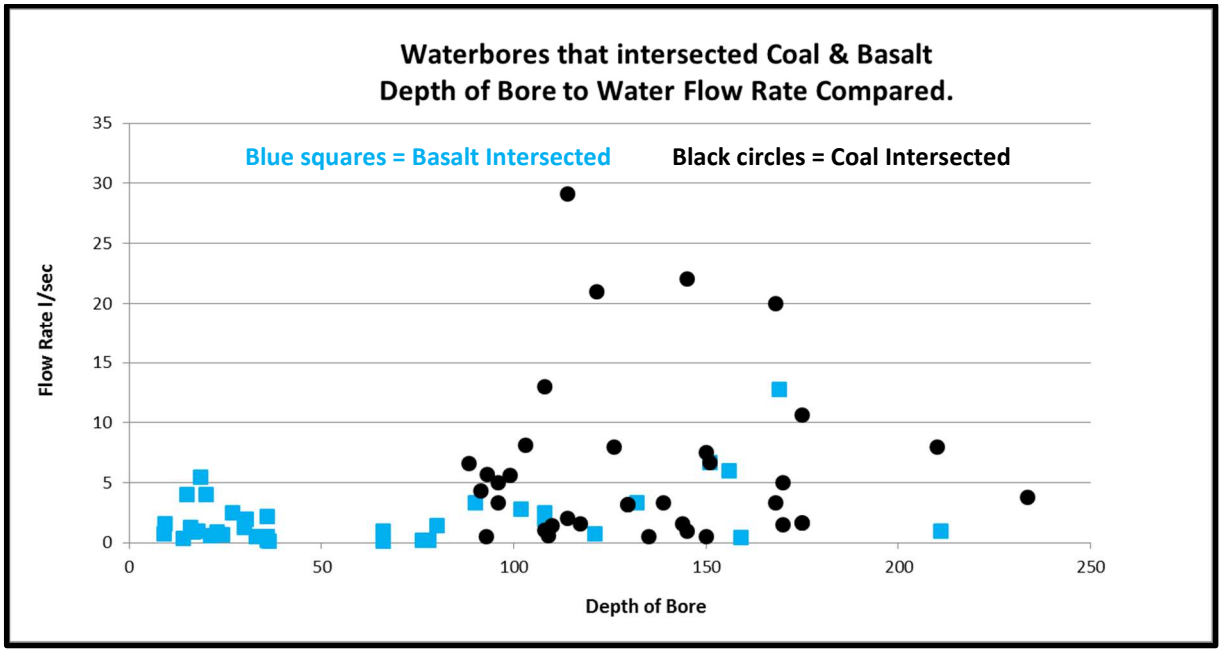


**Figure 5. All GWB that have Intersected Basalt or Coal compared to Flow Rates & Depth.**

With more than half of the GWB in this grouping having less than average flow rates, it clearly demonstrates that the lower portion of the HBSS does not make a significant contribution to the total water make in GWB. That is, the hydraulic conductivity of the basal HBSS (and the Eckersley Formation and Burragorang Claystone) is clearly not highest near the coal. In fact, evidence suggests that the near surface and upper most section of the HBSS are the best contributors to GWB. Overall these findings support the conclusion that the permeability actually decreases with depth as per the Hume Coal water model.

In Figure 6 below, the depth of every GWB database is compared to their respective flow rates. There is a distinct lack of correlation between flow rates and the depth of the hole. It does seem counter intuitive, but **some of the deepest GWB have some of the lowest flow values while many shallow GWB have high flow rates.**

About 75% of all GWB have flow values less than 7.5 l/s with the remaining 25% being greater than 7.5 l/s. Given the large proportion of GWB with flow rates lower than 7.5 l/s at all depths, it seems reasonable to conclude that there are additional influences impacting upon the remaining 25% of GWB which contribute to their having greater flow rates. For example, do the higher flowing GWB experience geological influences such as; jointing, increased fracture permeability, faulting, borehole breakout or changes in sedimentary rock behaviour e.g. porosity, grain size, lack of cement, or other engineering designs such as the diameter of the GWB etc?

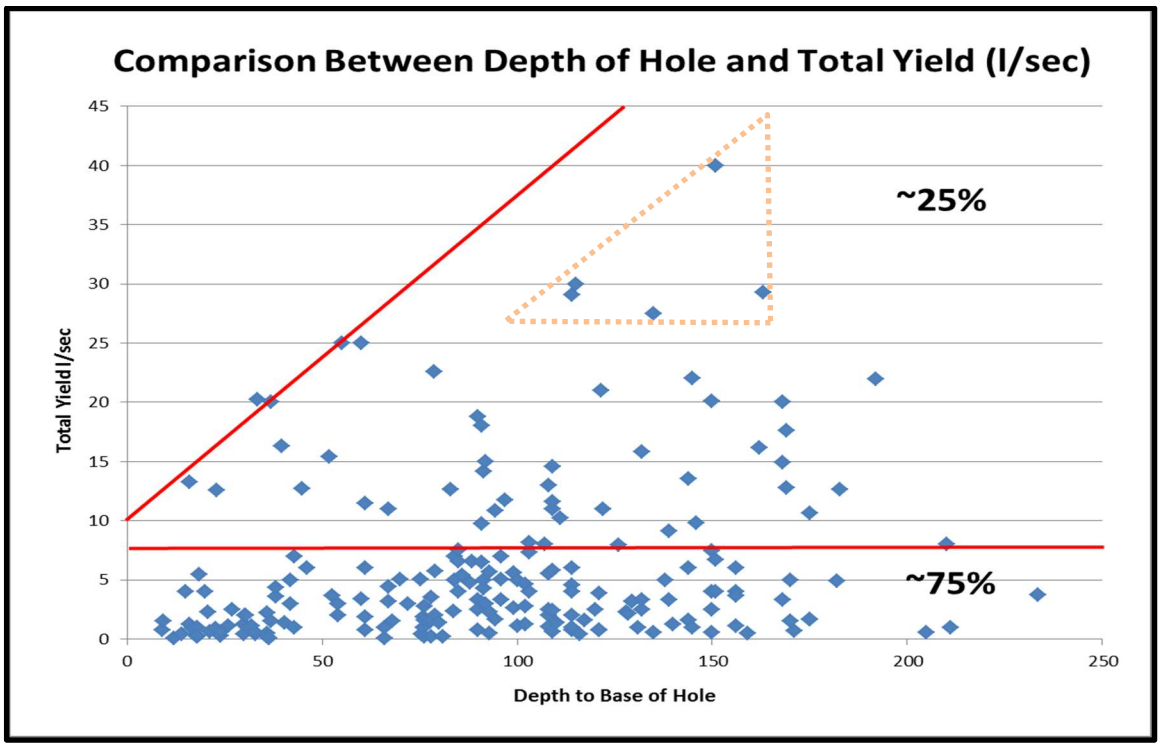


**Figure 6. GWB Flow Rates (Yields) plotted against Total Borehole Depth. Highlighting the percentage of GWB, 75% with <7.5 l/s flow irrespective of depth.**

With the exception of the 5 GWB in Figure 6 above with values greater than 25 l/s (in the orange dotted triangle), the rest of the GWB with >7.5 l/s to 25 l/s are fairly evenly distributed across the full range of depths. There is certainly no large bias of deep GWB to have high flow rates. If you ignore the 5 anomalously high values the only reasonable conclusion you could draw from this graph is that depth is not a factor in obtaining high flow rates.

**Diameter of GWB**

The database does not provide information regarding hole diameter, which would clearly have an influence on water flow rates and is therefore important in reviewing the behaviour of the GWB and the aquifer. An increase in the diameter of a GWB will see an increase in the circumference of the hole and therefore increase the potential for water to inflow at greater rates into the GWB and increase the potential for improving flow from the GWB. Some holes are known to be larger in their diameter, for example the holes on Wongonbra (GW108194), and Rosedale (GW07535), but for the vast majority of GWB information regarding GWB diameter is not available.

**Bore Purpose**

There are 220 GWB that provide categories indicating the **'purpose'** of the GWB. These GWB can be divided into six main categories, they are:-

Domestic/Stock = 111 (50%)
Domestic = 17 (7.7%)
Monitoring = 4 (<2%)
Irrigation (including 5 variations) = 75 (34%)
Stock = 10 (4.6%)
Industrial = 3 (>1%)

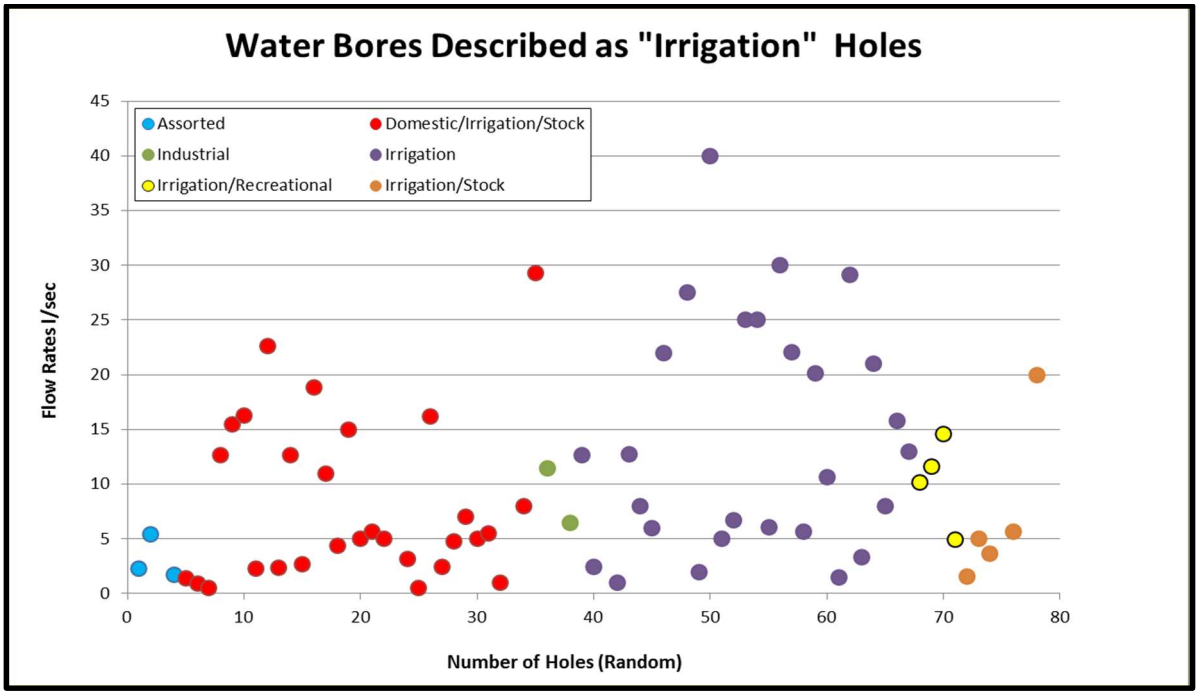


**Figure 7. Graphical Representation of Irrigation GWB.**

It is considered likely that the GWB designated as 'Irrigation' are more likely than not to have larger diameters and therefore be biased towards higher flows. Although there is no evidence to confirm this. Nevertheless, an examination of the data was plotted above in Figure 7 to consider the result. This category of GWB certainly has several high flowing GWB, but surprisingly this category of 'irrigation' GWB have a significant number that are low flowing. With more than half the Irrigation GWB having less than average flow rates.

**Correlations with Geological Structure**

In an attempt to identify possible contributions to high or anomalous flow rates an examination of some of the possible influences upon flow rates has been undertaken. Two aspects in particular seem relevant, they are:- potential geological structures and the proximity of GWB to existing creeks and their near surface water systems.

The GWB on Wongonbra (GW108194) is considered to have a geological fault of approximately 5m throw within the GWB, this was the site of the 24*7 pump test. Nearby exploration holes also have joint zones identified in them. The confidence of this predicted geological feature is of a moderate level.

In Figure 8 above the location of GWB is shown as graduated circles indicating their flow rates. This is shown with an overlay of the predicted geological structure i.e. faults and dykes. While the concept of high flow rates being associated with geological structures would seem logical, apart from the odd few bores there does not appear to be a good correlation between the high flowing GWB and the predicted geological structure. (N.B. in the above geological structural interpretation faults and dykes are included, but it does not take joint zones into account.)

Note that in Figure 8 geological structures have not been predicted to the south of the Illawarra Highway, which roughly equates to the southern boundary of the proposed mine. Overall there does not appear to be a good correlation between geological structures and high flowing water bores. However, this is acknowledged as being an arbitrary assessment.

**Correlations with Surface Stream Systems**

As an alternate consideration to geological structures, it was decided to overlay a plot of streams and creeks on a plan with GWB (see Figure 9). There appears, to be a modest correlation between the surface location of creeks and streams with the location of high flowing GWB. Nearly every high flowing GWB is located in the near vicinity to a water course and towards the upper reaches of these water courses. This suggests that the high flow rates have a correlation to the near surface stream system rather than the thicker and deeper HBSS aquifer.

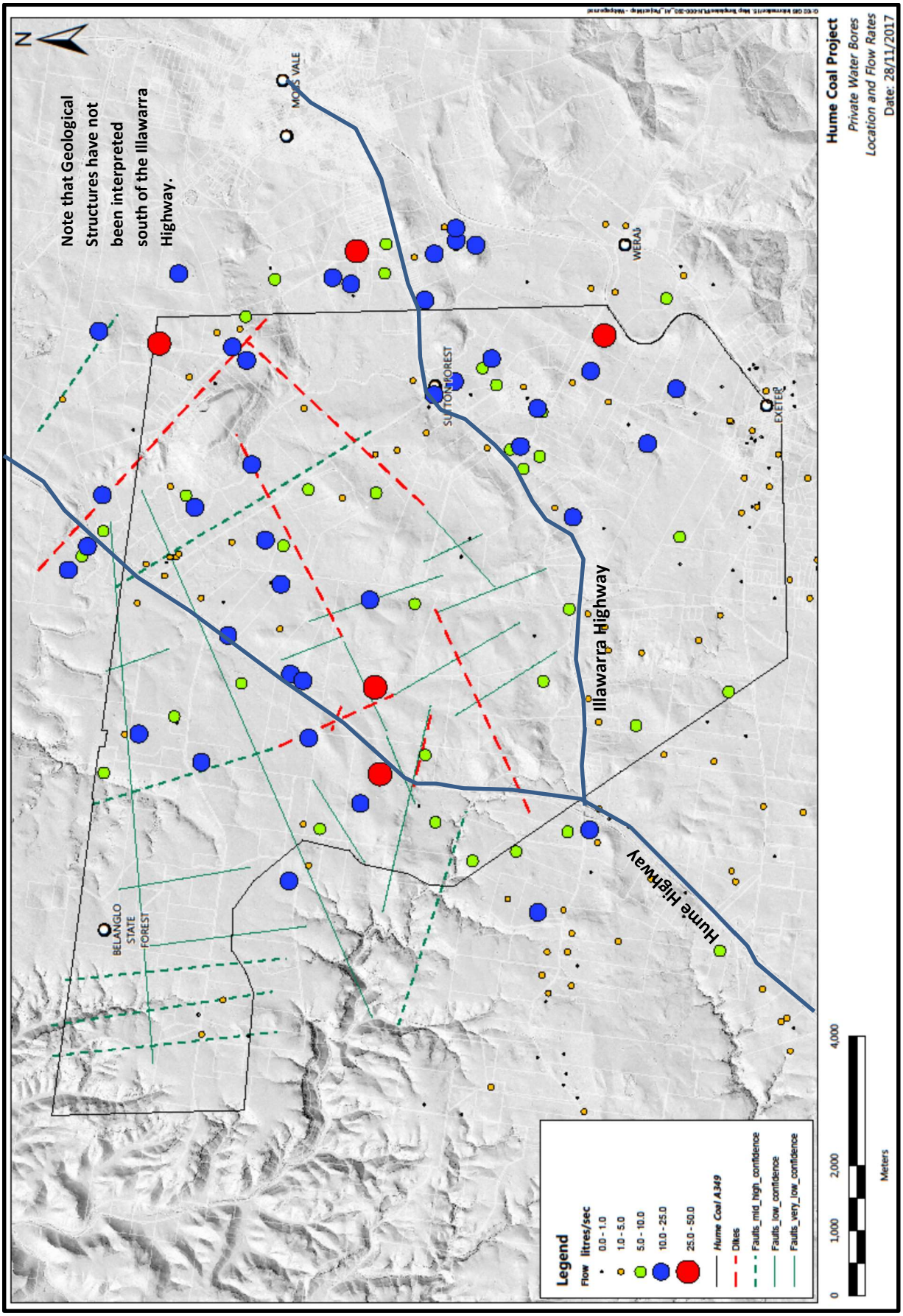


**Figure 8. Location of GWB in relation to Predicted Geology.**

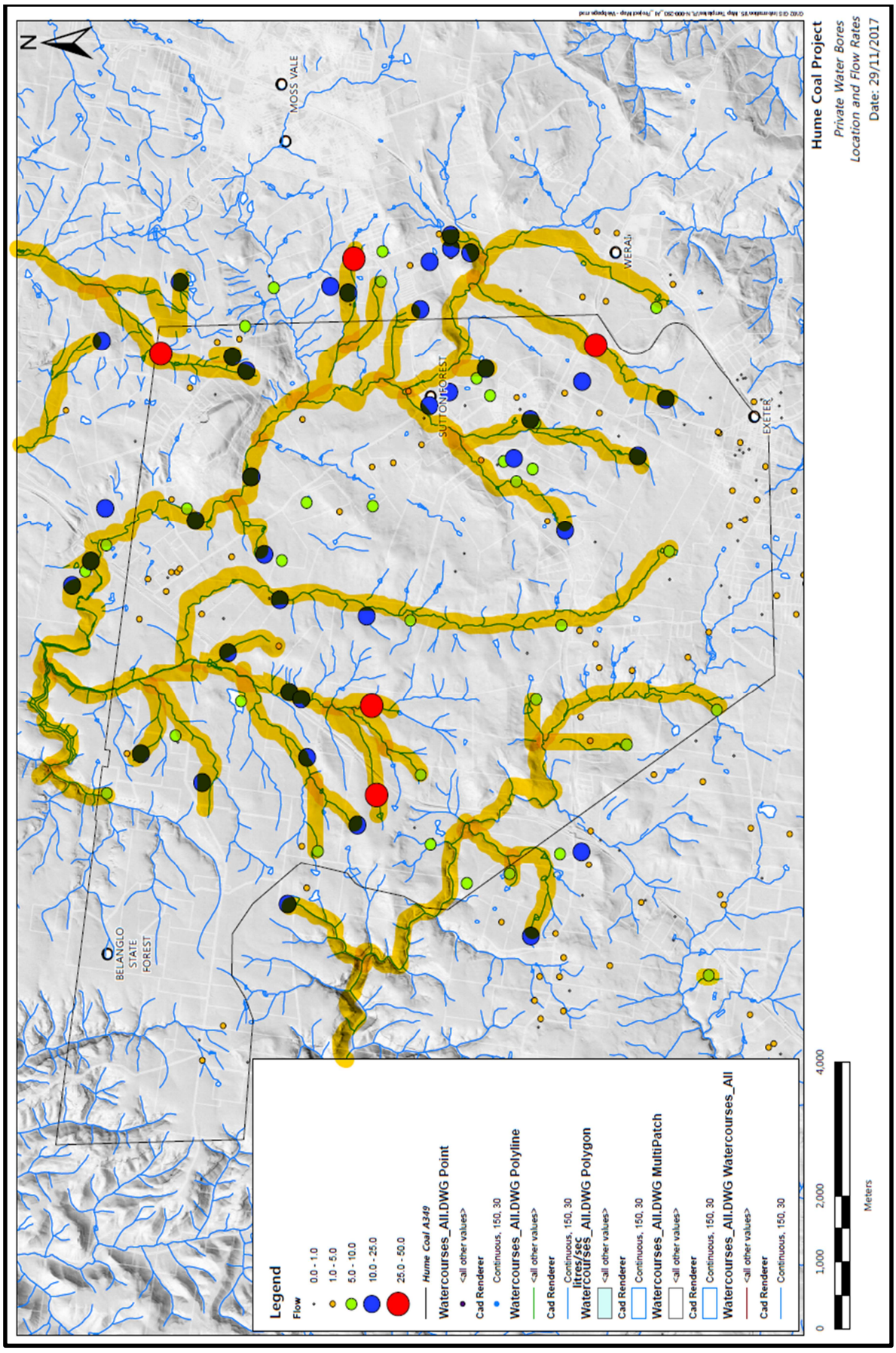


**Figure 9. Location of GWB Relative to the Surface Drainage Pattern.**

**GWB Depths and Strata**

Figure 10 below shows every GWB present (163) within the boundary of the Hume Coal geological model. Every column in the figure represents an individual GWB and highlights the modelled strata thickness. The purpose of this figure is to allow a comparison of flow rates in every GWB while examining the strata present. Specifically, how much HBSS is present within each bore and how much of the basal portion of the HBSS is present? Flow rates are also shown as small red squares plotted on the secondary Y axis (RHS).

Figure 10 tests the assertion, 'that the lowest portion of the HBSS has the highest hydraulic conductivity' – i.e. has the highest flow rates. Figure 10 also goes toward providing evidence that dispels DOI-W disbelief that permeability does not decrease with depth. Assuming that hydraulic conductivity/permeability is reasonable represented by flow rates.

The stratigraphic unit thicknesses were not available from the GWB database. To progress estimating strata thicknesses the actual survey co-ordinates of the GWB were used to determine a 'predicted log' at those locations.

The predicted logs are taken from the Hume Coal geological model (Minex). A predicted log is a determination of strata present at any point within an existing geological model. This procedure is common practice within the exploration industry and has a high degree of accuracy.

In Figure 10, the Robertson Basalt (RBBT) and Wianamatta Shale (WMSH) have been combined and are shown as an olive grey colour i.e. they have not been distinguished from one another in this plot. The Hawkesbury Sandstone (HBSS) is shown as yellow and the Illawarra Coal Measures strata (ICM) is shown in black.

The x axis shows the shallowest GWB at left and deepest at right. The left y-axis depicts the depth of GWB with its respective strata. The right y-axis depicts the GWB flow rates. It is of significance that some of the bores with significant flows are comparatively shallow. These shallow bores are important to consider as they typically do not extend into the basal half of the Hawkesbury Sandstone.

It is clear that the 5 highest flowing GWB shown in Figure 10 (**green circle**) are 'some of' the deepest holes with 3 of these holes having a near or full sequence of HBSS. But interestingly these highest flowing bores are not **the** deepest holes, indicating that greater depth does not necessarily correspond to greater flows. Clearly pointing to the fact that flow rates depend on much more than just depth of the GWB or the amount of HBSS present or the proximity to the coal seam.

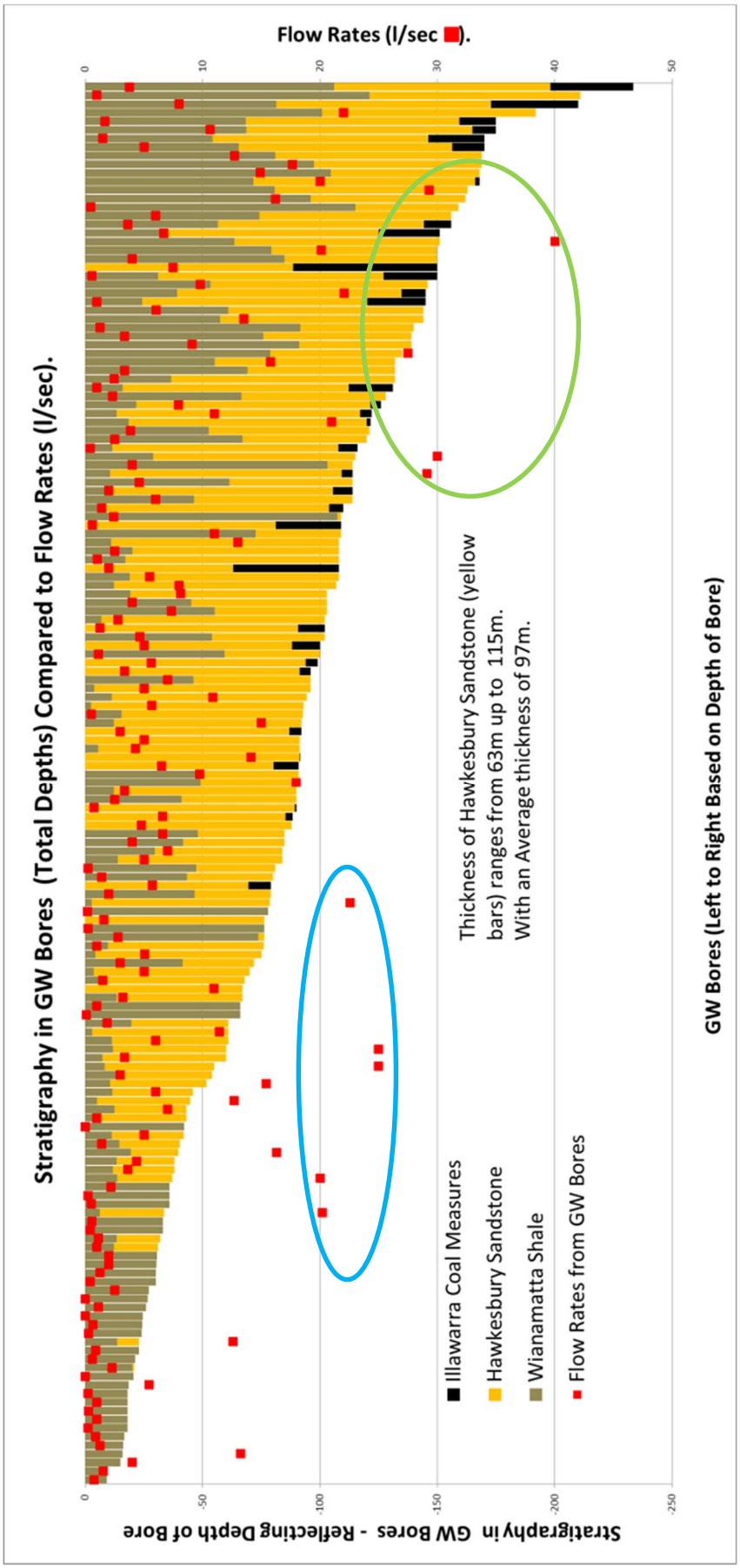


**Figure 10. Depth of GWB (with Stratigraphy) Shown Against Flow Rates.**

Continuing with this issue of depth, the highest flowing bore (40 l/s) is the 19th deepest hole, it has approximately 80m thickness of HBSS in it and was not recorded as having hit coal. The next highest flowing bore (30 l/s) is the 44th deepest hole, (it also has approx. 80m of HBSS in it and did not intersect coal) the next highest flowing bore (29.3 l/s) is the 13th deepest hole, (it has approx. 80m of HBSS in it and did not intersect coal) the next highest flowing bore (29.1 l/s) is the 46th deepest hole (it has approx. 100m of HBSS in it and intersected the Wongawilli Seam), and the fifth highest flowing bore (27.5 l/sec) is the 32nd deepest hole (it has approx. 55m of HBSS in it and did not intersect coal). It appears that the high flowing GWB are not directly correlated to depth. In contrast the five GWB shown within the **blue circle** have some high flow rates (>20 l/s), but are comparatively shallow and have generally less than 50% of the HBSS Formation present i.e. nowhere near coal or the base of the HBSS.

Out of the 209 GWB there were only 163 GWB located within the area covered by the geological model of Hume Coal. The other 46 holes are outside the boundary of the geological model covering A349 and therefore predicted logs were not estimated. Of the 163 GWB, 4 GWB are monitoring bores and did not record flow data hence giving 159 (see highlighted section on page 32).

Of the 10 deepest GWB in this data set 6 intersect the Wongawilli Coal and 5 have less than average flow rates. All ten GWB intersect a significant portion of the HBSS. Only 1 GWB has greater than 20 l/s.

The number of GWB used in different parts of this report is shown in Table 3 below. The table has been prepared to provide an explanation as to why and when the number of GWB varies.

| GWB # | Explanation | GWB Changes |
|---|---|---|
| 248 | As shown in Fig 1. | No changes. |
| 209 | Number of GWB with flow rate data - Figure 2 etc. | 38 GWB have no flow data, 1 anomalously high (39). |
| 163 | GWB with Geo Model Coverage - Fig 10. | 46 GWB are outside Geo Model area. |
| 159 | As shown in Table 3 and Fig 11 & 12. | 4 GWB don't have flow data. |

**Table 3. Number of GWB used in this report.**

The two-part table below (Table 4) considers average flow rates of GWB with various proportions of HBSS within the GWB. Note, in the table on the left-hand side (LHS) the ranges all extend from 0m while on the right-hand side (RHS), the ranges are confined to layers, typically 25m thick. For example, on the LHS the HBSS with depths from 0 to 25m (highlighted in yellow) has 45 GWB that fall within that layer and has a very low average flow rate of 2.5 l/sec. But on the RHS the range from 10 to 25m only has 6 GWB and they have a much greater average of 7.8 l/sec. The aim of this analysis is to identify which horizon/s contribute the greater water inflows.

| From | To | No. GWB | Avg l/sec | | From | To | No. GWB | Avg l/sec |
|---|---|---|---|---|---|---|---|---|
| 0 | 10 | 39 | 1.7 | | 0 | 10 | 39 | 1.7 |
| 0 | 25 | 45 | 2.5 | | 10 | 25 | 6 | 7.8 |
| 0 | 50 | 76 | 4.4 | | 25 | 50 | 31 | 7.2 |
| 0 | 75 | 102 | 5.2 | | 50 | 75 | 26 | 7.4 |
| 0 | 100 | 163 | 6.4 | | 75 | 100 | 61 | 8.5 |

**Table 4. HBSS Layers (Cumulative and Singular) Compared to Flow Rates.**

Below, Figure 11 (LHS of Table 4) and Figure 12 (RHS of Table 4) represent the two halves of Table 4. Despite minor fluctuation the LHS data, Figure 11 shows a consistent increase of flow with percentage of HBSS present, which is comparable to depth. While the RHS data (Figure 12) shows a rapid increase in flow from 10-25% of HBSS and then from there it basically flat lines. There is clearly no radical high increase with depth and proximity to the coal.

Overall the data suggest that the best flow rates and permeability is actually in the top 25m of the HBSS unit and not at the base or the bottom half of the HBSS. This result contrasts directly with Mr John Lee's submission to the IPC and the Opposition Groups claim 'that the highest permeability is immediately adjacent to the coal seam', neither claim can be corroborated. Clearly their assertions do not stack up against the large local database provided by the WaterNSW and a rigorous review.

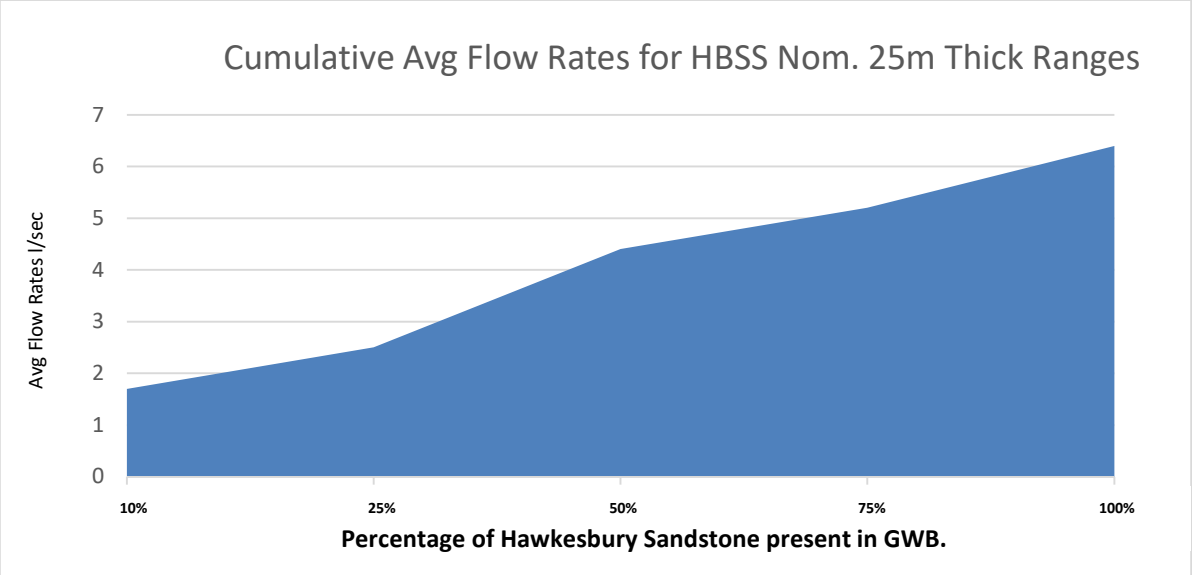


**Figure 11. Cumulative Flow Rates for Proportion of Hawkesbury Sandstone present.**

If the assertion that the 'hydraulic conductivity (Kh and Kv) is highest immediately above the coal seam' is correct then its most likely that high flowing bores intersect this basal HBSS zone. That is, high flowing GWB intersect the basal 75 to 100m of the HBSS. A review of the data clearly indicates that this is not the case. High flowing bores exist at various depths

within the HBSS. (This is clearly shown not to be the case in Figure 5, with the GWB's that intersect the Wongawilli seam and have full sequences of the HBSS.

In addition, two GWB have flow rates of about 25 l/s, but have shallow depths of about 60m and are therefore nowhere near the lowest portion of the HBSS. In the deepest 50 GWB, only 18 holes (36%) have flow rates greater than 10 l/s and approximately half of the deepest GWB have flow rates of less than the average flow rate of 6 l/s. The assertion that, 'the flow rates in the aquifer are much greater near the coal seam', cannot be supported.

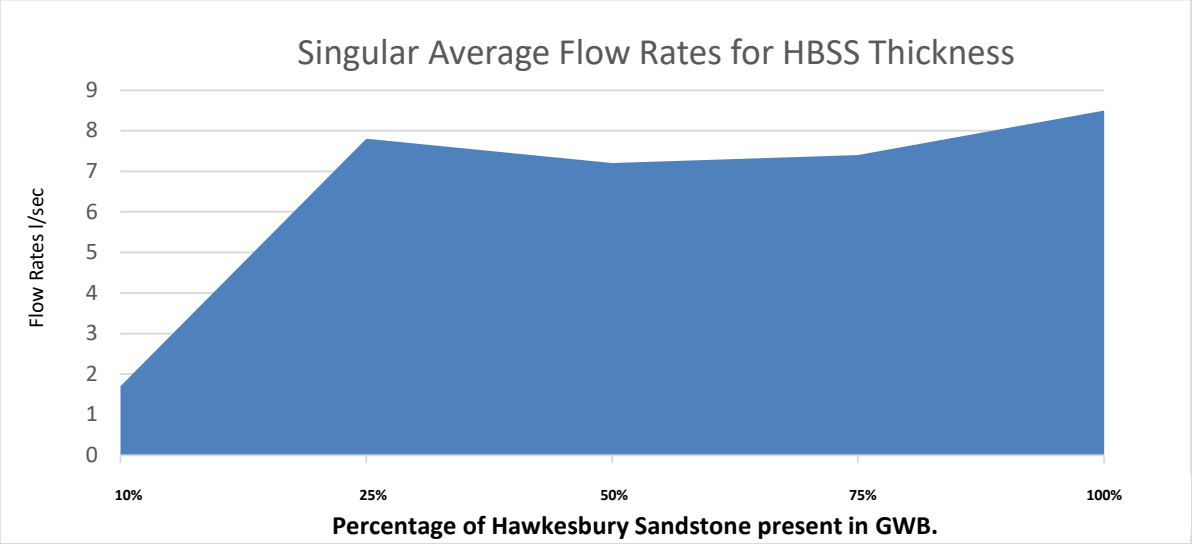


**Figure 12. Singular Flow Rates for Proportion of Hawkesbury Sandstone present.**

In Figure 13 below, the plot area is shown divided into four numbered quadrants (1 to 4). The red lines drawn are used to define the quadrants, the horizontal line is based on the average flow rate for all these bores (6 l/s for the 159 modelled GWB) while the vertical line is drawn where the thickness of HBSS achieves 50m (or approximately 50%). The two halves of the X axis are based on, firstly the **thinness of the HBSS** - LHS **<**50% (i.e. 0 to 50m thickness) and secondly where it is **thicker** - RHS **>**50% (i.e. 50m to 100m thick). While the two halves of the Y axis are based on **above average flow rates** (upper portion, i.e. >6 l/s) or **below average flow rates** (lower portion, i.e. <6 l/s). In summary, the quadrants represent:

**1)** Thick HBSS – High Flow; Top Right Hand Side
**2)** Thick HBSS – Low Flow; Bottom Right Hand Side
**3)** Thin HBSS – High Flow; Top Left Hand Side
**4)** Thin HBSS – Low Flow; Bottom Left Hand Side

In Figure 13, the Thick HBSS-High Flow (Category **1**) only represents 41% (36 GWB) of the total 87 GWB in the "Thick HBSS", therefore less than half of the high flowing bores are in "Thick HBSS". Whilst, nearly 60% of GWB in the "Thick HBSS" strata section have less than average flow rates (Category **2**).

If only the basal 25m section of the HBSS is examined, i.e. if the vertical axis is shifted to the 75m mark (as shown with the orange-dashed line in Figure 13), then the results are a little more balanced. With the number of GWB increasing for the "Thick HBSS-High Flow" (Category **1**) to 46% - but still less than half. If > 50% of GWB have less than the average flow rate, the concept that the highest flow rates are in this basal section renders the 'assertion', that the lower part of the HBSS has higher permeability or hydraulic conductivity, sterile. See Table 5 below which shows the number of GWB in the various categories.

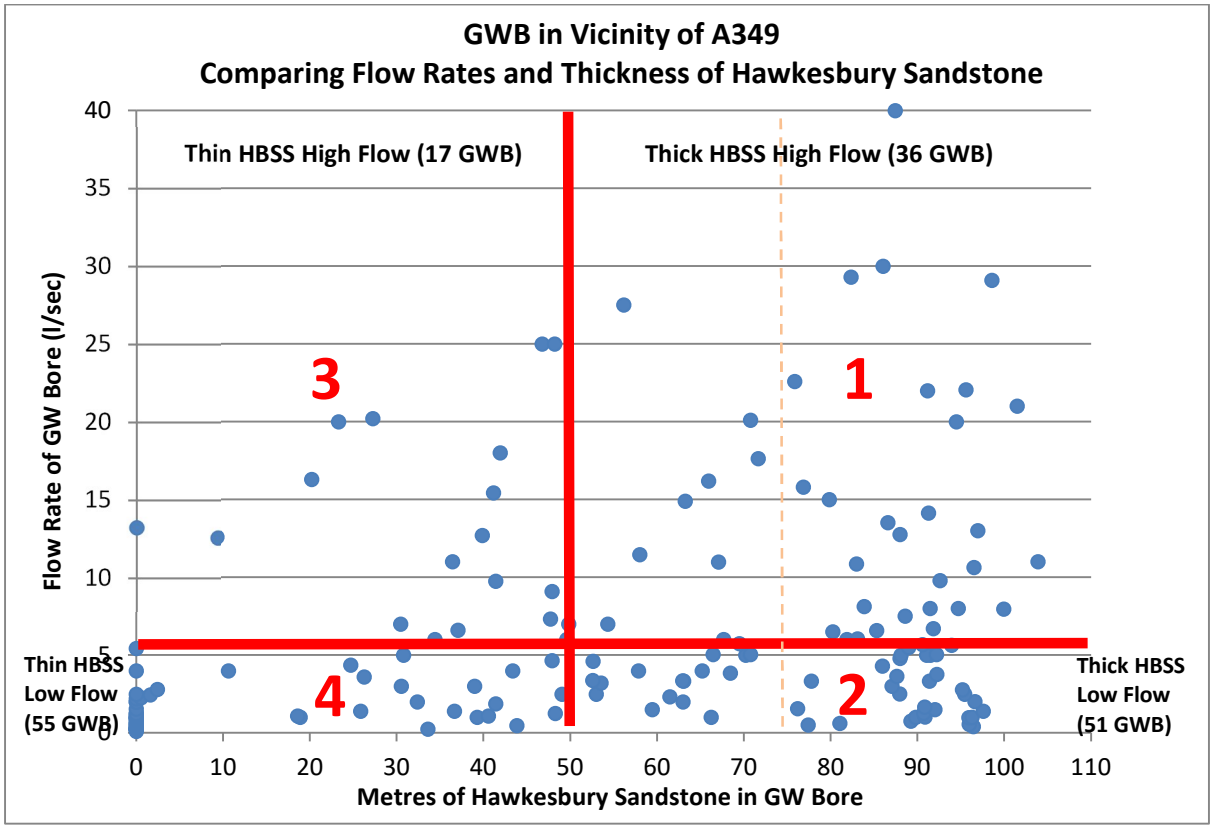


**Figure 13. Compares GWB Flow Rates with the Thickness of the HBSS.**

| Cut Off Based on Thickness of Hawkesbury Sandstone | Low Flow Thin | Low Flow Thick | High Flow Thin | High Flow Thick | No data available | Total GWB |
|---|---|---|---|---|---|---|
| 50m HBSS Thick | 55 | 51 | 17 | 36 | 4 | 163 |
| 75m HBSS Thick | 73 | 33 | 25 | 28 | 4 | 163 |

**Table 5. Number of GWB in the various quadrants of Figure 13.**

Figure 14 below compares the thickness of the HBSS (Y axis – LHS - Yellow Circles) and Flow Rates (Y axis – RHS – Blue Circles) against the total depth of the GWB. Note that each blue circle (GWB) has a corresponding partner in yellow. Some points of note are as follows:-

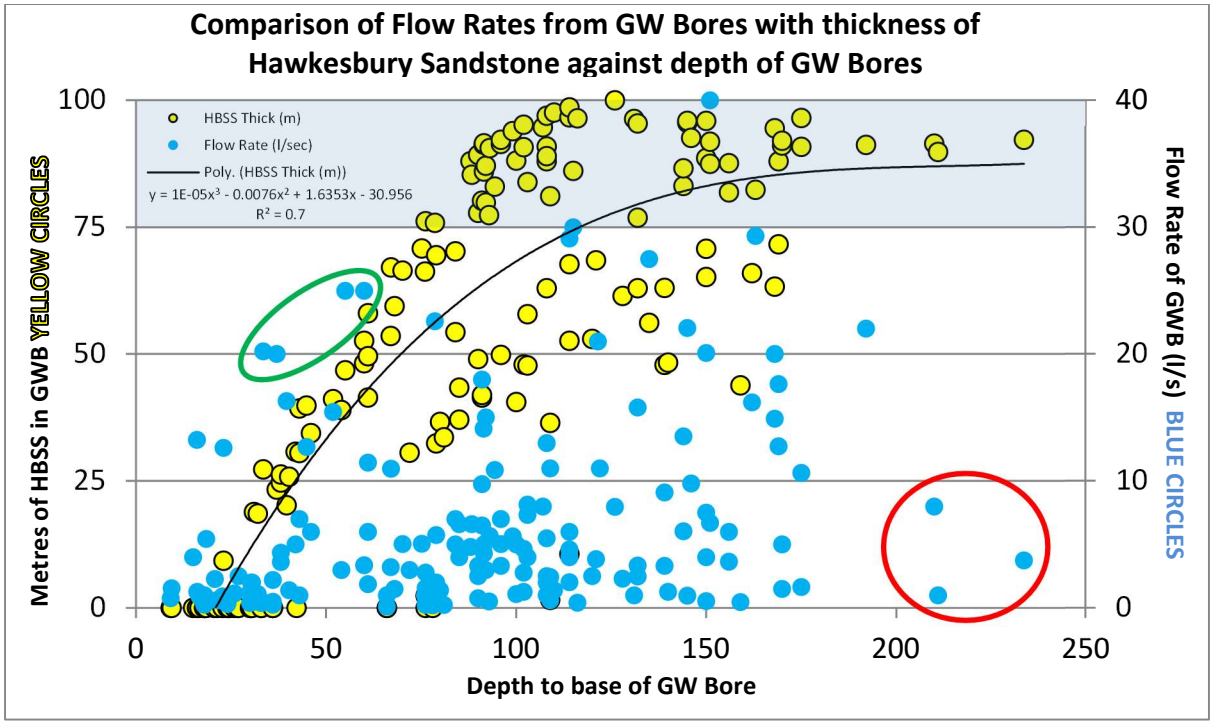


**Figure 14. Compares Flow Rates and HBSS Thickness to the depth of the GWB.**

1) About half of the 159 GWB (87 GWB) have greater than 50m of HBSS in them, but only 12 GWB (14%) of the 87 GWB have very high flow rates >20 l/s.

   **THICK HBSS - HIGH FLOW ∴ Contradicts assertion.**

2) The three deepest GWB (red circle) have the entire HBSS unit present, yet have comparatively low flows (<8 l/s).

   **THICK HBSS - LOW FLOW ∴ Contradicts assertion.**

3) 36 GWB intersect coal (see Figure 5 above) and these have all the available HBSS in them. According to DOI-Water, Mr John Lee and others, these GWB should have the greatest permeability and therefore have the highest flow rates. Of these 36 GWB, only 6 (17%) have flow rates greater than 10 l/sec. Another 10 GWB (28%) have flow rates in the range of 5-10 l/sec. The remaining 20 GWB (nearly 60%) have flow rates of <5 l/sec. i.e. 60% of these GW bores have less than the average flow.

   **THICK HBSS - LOW FLOW ∴ Contradicts assertion.**

4) Some GWB (green oval in Figure 14) are at relatively shallow depths of about 50-60m and therefore have only about 50% of HBSS present in them, but nevertheless have very high flows >20 l/sec. The 'thin' HBSS sections point to the fact that the basal HBSS and the Wongawilli Seam is some considerable distance deeper, some 40-50m from the base of these GWB.

   **THIN HBSS - HIGH FLOW ∴ Contradicts assertion.**

Based on the government's own GWB database, the flow rates give a clear indication that the most permeable (i.e. highest flow rates) GWB do not follow a simple rule of 'closest to

the coal seam has the greater permeability' (IPC Report May 2019, Paragraph 140). Based on all the available data from the GWB database that assertion is refuted. This overall assessment clearly supports the opposite conclusion that permeability actually decreases with depth. This agrees with the permeability data presented in Hume Coals' EIS and RTS and provides an opposite view to what the IPC Report states at Paragraph 123.

The results presented suggest that the permeability is built upon by a comparatively uniform baseload flow rate (permeability) from the HBSS rock mass which decreases with depth. In places it is elevated due to other controlling factors such as: fracture permeability, geological structures, randomness of depositional behaviour, grain size, cementation and surface stream contributions or GWB diameter; rather than to attribute a specific behaviour to the HBSS based on depth or proximity to the Wongawilli seam. (Note Thomson's geophysical assessment report identifying clean sandstone horizons which have higher porosity and permeability potential throughout the HBSS not just at the base of the HBSS.)

**Standing Water Level**

Standing Water Levels (SWLs) from the GWB database were gridded using the Minex geological modelling software and is shown in Figure 15 below. When the output was examined it appeared reasonably consistent, i.e. comparatively few bulls eyes.

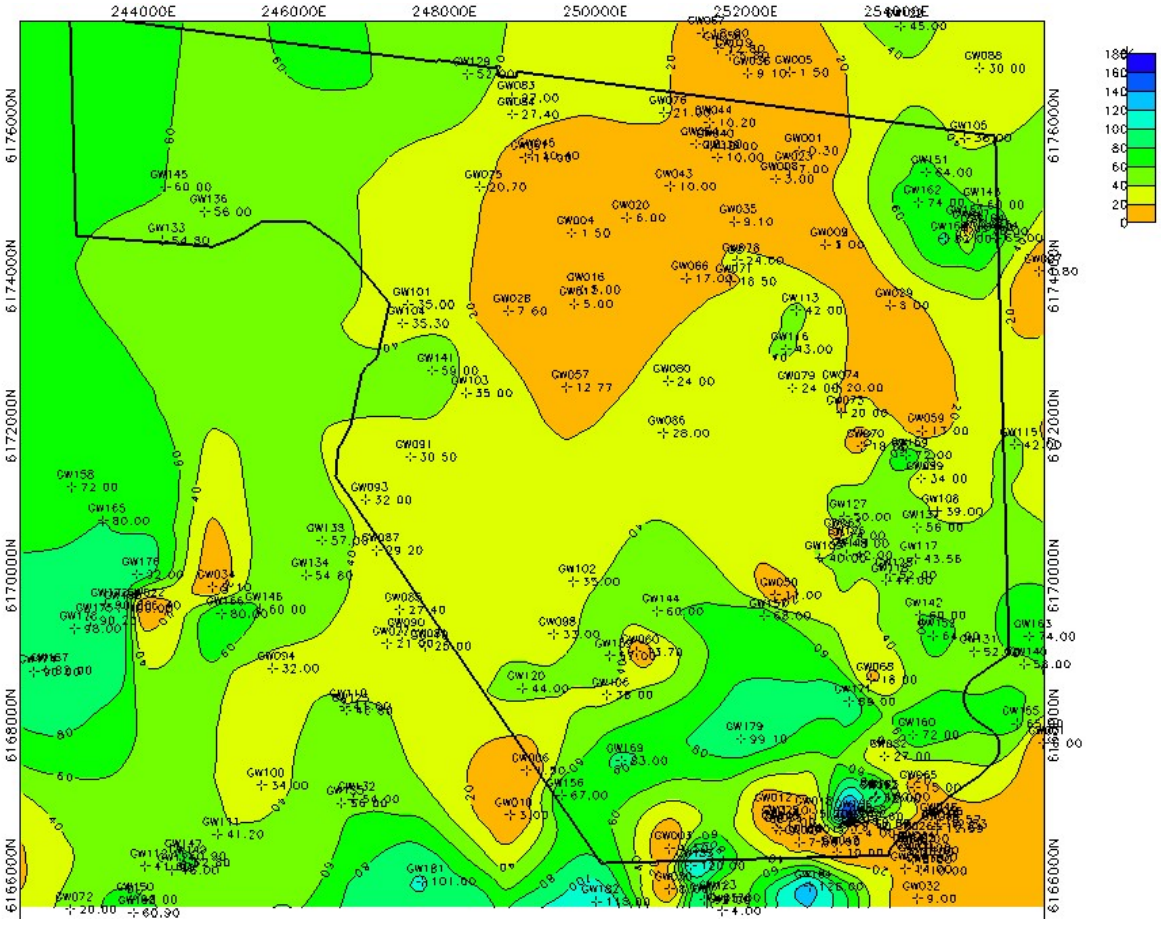


**Figure 15. Showing Gridded Standing Water Level Data.**

Some of these bulls eyes occur near Exeter in the basalt, but the majority of the plot appears to be reasonable uniform. In addition to the GWB database, SWL measurements from the Hume Coal piezometers were also compared to see how well the data sits in the with the GWB plot. A good correlation exists with the piezometer data complimenting the GWB data.

Figure 16 below shows SWL plotted against total depth of the GWB. A correlation is provided, the $R^2$ for the 'straight line' has a value of 0.6199 which indicates that there is a fair correlation. Overall shallow GWB tend to have a low range in SWL depths, while deeper holes range in depth of SWL by up to 100m.

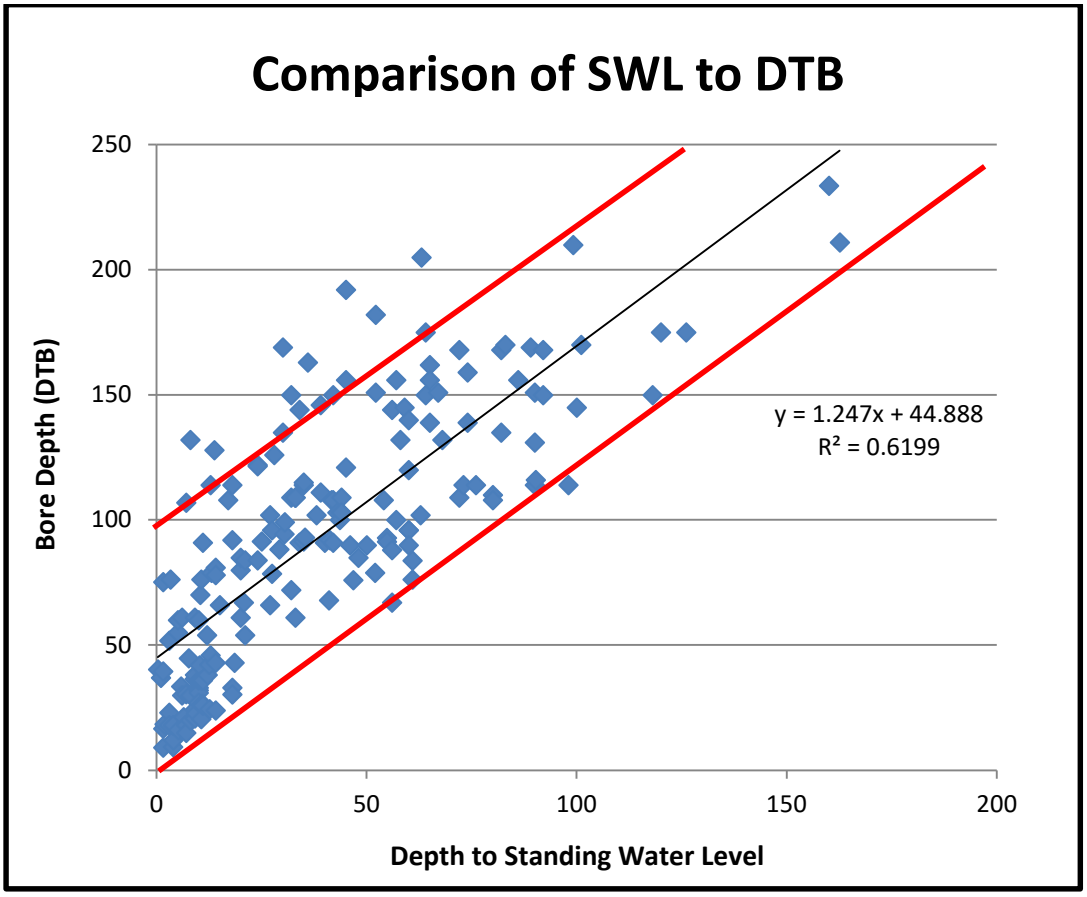


**Figure 16. Comparison of Standing Water Level to Depth to Base of GWB.**

Ultimately SWL are a reasonable indicator for assisting with determining how deep a GWB should be drilled – dependant on the needs of the landowner. Drilling to the greatest depth or to the base of the HBSS is no guarantee of securing the highest or even high flow rates. The surface water system is a strong indicator of high flow rates particular with elevated SWL.

**Lee Subdivision of the HBSS.**

In the Southern Highland Coal Action Group (SHCAG) groundwater study it refers to John Lee having sub-divided the Hawkesbury Sandstone into three layers – A, B & C. With the A layer being the basal layer nearest to the Wongawilli Seam; B the central layer and the C layer being the upper most layer.

A quote from page 6 of the SHCAG report states, "The assumed permeability in the break-up of the Hawkesbury Sandstone layer is based on the well logs and the pumping tests that Mr Lee had undertaken on these bores which consistently showed that the primary aquifers in the Hawkesbury Sandstone resided within the section just above the coal seam, i.e. the A layer of the Hawkesbury Sandstone."

The report goes on to state that the A layer represents 25% of the total HBSS thickness. With Layer B being 45% and Layer C being 30% of total thickness. (However, these thicknesses or proportions seem to vary in different source documents.)

A list of boreholes is provided by Lee, although with the exception of the Hume Coal holes there are no specifics about where these other holes were actually drilled and over how extensive an area they occupy. It becomes apparent that the bores used by Lee cover a more extensive area than the A349 local area and therefore are not directly correlated to the Hume Coal zone. The holes include:-

- 28 groundwater bores installed, logged and tested by Hydroilex.
- 82 selected groundwater bores on the NSW Office of Water database. (DPIE-W)
- 7 boreholes in the Belanglo area drilled by Hume Coal.

The report also states that Permeability values for the Hawkesbury Sandstone were referenced against data from the Southern Coalfield and include tunnelling projects in the Greater Sydney region. The relevance of either of these sites to the Hume Coal proposed mining area was not established and is seen as being irrelevant to the area around A349. It's important to keep in mind that the Hawkesbury Sandstone is on average more than twice as thick in the Central portion of the Sydney Basin (maximum thickness approx. 250m), compared to A349 (maximum thickness approx. 110m).

The data reviewed for A349 by this review, makes two significant conclusions:-

1) That the main source of some of the highest flow rates is related to some of the shallowest bores and not as Lee claims to be from the lowest 25% + of the basal Hawkesbury Sandstone adjacent to the Wongawilli Seam.
2) That GWB with high flow rates are very likely to have elevated flow rates due to the influence of geological structures that enhance flow paths and fracture permeability. As well as having larger diameter bores.

**Conclusions**

A review of the Ground Water Bore (GWB) database indicates that the flow rates give a very good indication of how permeable the Hawkesbury Sandstone (HBSS) is and where the high flows emanate from. These results go towards responding to the Independent Planning Commissions (IPC) concerns, re: hydraulic conductivity (Paragraphs 123 and 140).

The GWB database provides a good local site-specific coverage with some 209 GWB with defined locations in and around A349. Frequency charts show the large range of flows, some of which are clearly anomalously high.

- Overall there appears to be a reasonable correlation with the surface stream systems and shallow GWB which have high flow rates. Data shows that significant water is made from these near surface systems in preference to the deeper portions of the Hawkesbury Sandstone.
- There doesn't appear to be a strong correlation between Hume's predicted geological structure and high flowing GWB.
- There appears to be a high proportion (75%) of GWB with nominally average flow rates (<7.5 l/s), which are considered to be 'normal background permeability levels'.
- GWB with greater rates of flow are likely to be explained by additional factors that contribute to increasing their flow rates. Examples of these contributions could be; increased permeability due to porosity changes, cementation, geological structures that enhance flow paths and fracture permeability, proximity to surface water drainage patterns, larger diameter GWB etc.
- Average flow rates are elevated due to some very high flowing anomalous GWB.
- Where GWB have intersected coal (36 GWB), i.e. where it is certain the maximum depth of HBSS is present, some 60% of GWB have lower than average flow rates.
- The main source rocks of some of the highest flow rates are related to some of the shallowest bores and not as Mr John Lee claims to be the strata immediately above the Wongawilli Seam. Therefore, his assertion is strongly refuted. This review also provides evidence to enlighten the DOI-W 'disbelief' regarding decreasing permeability with depth.

Rod Doyle
Exploration Manager - Hume Coal

# APPENDIX – GWB DATA

| WELL_ID | LICENCE | END DATE | STATUS | PURPOSE | PROPERTY_NAME | LOT/DP | EASTING | NORTHING | CASING | CASING_ | SWL | DTB | COMMENTS | ROCK | FLOW RATE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW011227 | 10BL004391 | 1/08/1955 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | OLDBURY FARM | 62/DP1986732 | 252755 | 6175769 | STEEL | 11.50 | 0.30 | 40.30 | FREE FLOWING | | 1.39 |
| GW011262 | 10BL004525 | 1/12/1955 | CANCELLED | IRRIGATION, STOCK | N/A | 21/DPPT21 | 252352 | 6166970 | STEEL | 9.10 | 3.90 | 9.40 | INTERSECTS BASALT/VOLCANIC ROCK | BASALT | 1.55 |
| GW014121 | 10BL006063 | 1/12/1956 | ACTIVE | STOCK | TARANDI | 21/DPPT21 | 252487 | 6166696 | UNKNOWN | 19.60 | 9.10 | 24.30 | INTERSECTS VOLCANIC ROCK/BASALT | BASALT | 0.64 |
| GW014491 | 10BL005982 | 1/11/1956 | ACTIVE | DOMESTIC | COOEEYANA | 21/DP4751289 | 253454 | 6166753 | STEEL | 22.40 | 9.40 | 22.80 | INTERSECTS BASALT | BASALT | 0.91 |
| GW015061 | 10BL005944 | 1/12/1956 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | SANDERS | 30243688/DP30243688 | 251024 | 6166459 | STEEL | 16.70 | 1.50 | 16.70 | INTERSECTS BASALT | BASALT | 0.91 |
| GW015689 | 10BL006488 | N/A | ACTIVE | DOMESTIC | OLDBADAH FARM | 32/DP10861916 | 243332 | 6169500 | UNKNOWN | -0.70 | 90.20 | 116.10 | | | 0.41 |
| GW017295 | 10BL007943 | 1/01/1958 | ACTIVE | DOMESTIC, STOCK | EAGLEROO | 51/DPPT51751253 | 256273 | 6172008 | STEEL | 57.60 | 3.30 | 76.20 | | | 2.79 |
| GW021686 | 10BL014166 | 1/11/1963 | ACTIVE | DOMESTIC, STOCK | LANTERN HILL | 102/DPB751289 | 255859 | 6167403 | STEEL | 12.10 | N/A | 14.00 | INTERSECTS VOLCANIC ROCK | BASALT | 0.39 |
| GW021817 | 10BL600083 | 1/06/1963 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | MEREDITH PARK | 5711048/DP5711048 | 244293 | 6174569 | STEEL | 6.10 | 54.80 | 92.90 | ENDS IN COAL | COAL | 0.51 |
| GW023033 | 10BL016419 | 1/02/1966 | ACTIVE | DOMESTIC, STOCK | NOVAK | 41/DP1741965 | 256784 | 6169061 | STEEL | 7.60 | N/A | 128.60 | | | 2.15 |
| GW023322 | 10BL017081 | 1/10/1965 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | CHERRY TREE HILL | 8/DP1124496 | 248882 | 6173630 | STEEL | 6.70 | 7.60 | 44.80 | | | 12.69 |
| GW023519 | 10BL015312 | 1/07/1965 | CANCELLED | CONSERVATION OF WATER, IRRIGA | BROWLEY | 59/DP59 | 255936 | 6174158 | STEEL | 7.10 | 1.80 | 18.50 | GRANITE/PORPHYRY | BASALT | 5.43 |
| GW024339 | 10BL018435 | 1/10/1965 | ACTIVE | STOCK | FELI | 10/DP411045309 | 250763 | 6167297 | UNKNOWN | 6.40 | N/A | 143.80 | ENDS IN COAL | COAL | 1.59 |
| GW024688 | 10BL019148 | N/A | ACTIVE | IRRIGATION, STOCK | GLENDALE | 8/DP10705789 | 249722 | 6174670 | STEEL | 12.30 | 1.50 | 75.20 | | | 5.05 |
| GW025571 | 10BL015313 | N/A | ACTIVE | STOCK | BROWLEY | 34/DP34 | 256113 | 6174224 | | | | 57.90 | NO WATER BEARING ZONES DETAILS FOUND | | |
| GW025808 | 10BL023335 | 1/09/1965 | CANCELLED | CONSERVATION OF WATER, FARMI | WHITNASH | 10/DP2751289 | 250587 | 6169081 | STEEL | 17.30 | 13.70 | 128.00 | | | 2.32 |
| GW026136 | 10BL016479 | N/A | ACTIVE | IRRIGATION, STOCK | RAVENSWOOD | 9/DP29262738 | 250554 | 6174076 | UNKNOWN | 52.70 | N/A | 52.70 | | | 3.64 |
| GW026805 | 10BL017107 | 1/04/1966 | ACTIVE | IRRIGATION | CHERRY TREE HILL | 44/DP122751251 | 246680 | 6173940 | UNKNOWN | 2.70 | N/A | 82.90 | | | 12.63 |
| GW028511 | 10BL020687 | 1/01/1966 | CANCELLED | DOMESTIC, FARMING, IRRIGATION, | WEST-A-WAY | 18/DPPT18 | 252126 | 6166841 | UNKNOWN | 12.50 | N/A | 47.20 | NO WATER BEARING ZONES FOUND | | |
| GW028687 | 10BL022901 | 1/09/1968 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | OLDBURY FARM | L29(62)/DP31046976 | 252433 | 6175391 | STEEL | 7.60 | 3.00 | 51.80 | | | 15.43 |
| GW028832 | 10BL160106 | 10/04/2001 | ACTIVE | IRRIGATION | KENMORE | 188227/DP188227 | 253958 | 6173704 | STEEL | 40.00 | 8.00 | 132.00 | HIGH SALINITY/ PUMP TEST DURING CONSTRUCTION. F/R WAS 149l/sec | | 2.48 |
| GW031041 | N/A | 1/04/1968 | N/A | N/A | N/A | 30 | 247063 | 6166457 | PVC | 5.60 | N/A | 75.50 | | | 0.44 |
| GW031074 | 10BL022698 | 1/06/1968 | ACTIVE | DOMESTIC, STOCK | ANDYBOW | 42/DP42 | 244015 | 6169704 | STEEL | 21.30 | 6.40 | 21.30 | INTERSECTS VOLCANIC ROCK | BASALT | 0.61 |
| GW031527 | 10BL125096 | 1/12/1968 | LAPSED | DOMESTIC, IRRIGATION, STOCK | N/A | L17DP238719(63)/DPLT17DP2 | 252625 | 6176814 | STEEL | 5.70 | 1.50 | 39.60 | | | 16.30 |
| GW032319 | 10BL024735 | 1/01/1970 | ACTIVE | DOMESTIC, STOCK | N/A | 35/DP33751253 | 251374 | 6175856 | STEEL | 18.90 | 12.10 | 38.10 | | | 3.61 |
| GW033778 | 10BL164298 | N/A | ACTIVE | DOMESTIC, IRRIGATION, STOCK | BRIDGEWATER | 221049146/DP231095888 | 244953 | 6169945 | STEEL | 6.40 | 9.10 | 20.70 | NO STRAT LOG - PREVIOUS LICENCE No: 10BL029712 | | 2.27 |
| GW034245 | 10BL027261 | N/A | ACTIVE | DOMESTIC, STOCK | ROBINWOOD COTTAGE | 98/DP8A751289 | 251281 | 6166972 | IRON/UNKNOV | 3.90 | N/A | 4.00 | | | |
| GW03246 | 10BL027260 | N/A | ACTIVE | DOMESTIC, STOCK | ROBINWOOD COTTAGE | 98/DP8A751289 | 251456 | 6167100 | STEEL | -1.20 | N/A | 91.40 | | | |
| GW034701 | 10BL027926 | 1/03/1968 | ACTIVE | DOMESTIC, STOCK | ECCLESTON PARK | 55/DP9805624 | 245590 | 6169963 | UNKNOWN | 1.90 | N/A | 92.90 | QUARTZITE | | 2.27 |
| GW034742 | 10BL027256 | 1/01/1972 | ACTIVE | STOCK | HIGHFIELD | 17/DP33751253 | 254976 | 6174749 | STEEL/SLOTS | 42.60 | 10.60 | 76.20 | INTERSECTS BASALT | BASALT | 0.23 |
| GW035062 | 10BL028443 | 1/03/1973 | ACTIVE | DOMESTIC, STOCK | YARRABIN | 24/DP239258 | 246664 | 6167063 | STEEL | 16.10 | 56.00 | 67.00 | | | 3.22 |
| GW035423 | 10BL161938 | 28/02/1983 | ACTIVE | DOMESTIC, STOCK | CARDRONA | 1//1081472/DPPT50751253 | 256334 | 6171640 | UNKNOWN | 71.40 | N/A | 71.40 | NO STRAT LOG - PREVIOUS LICENCE No: 10BL028935 | | |
| GW035429 | 10BL029074 | 1/01/1940 | ACTIVE | DOMESTIC, STOCK | WATERLOO | 8/DPPT8 | 246807 | 6169287 | NIL | NIL | NIL | 60.30 | | | |
| GW035590 | 10BL029395 | N/A | ACTIVE | DOMESTIC, STOCK | N/A | 10/DP10 | 247831 | 6171936 | UNKNOWN | 1.80 | N/A | 33.50 | | | |
| GW035924 | 10BL029181 | 1/06/1973 | ACTIVE | DOMESTIC, STOCK | BRIDGEWATER | 2//253435/DP100 | 244516 | 6166356 | STEEL | 2.40 | 60.90 | 76.20 | | | 1.57 |
| GW037077 | N/A | 1/11/1973 | N/A | N/A | N/A | 46 | 247133 | 6170437 | STEEL | 11.70 | 29.20 | 88.30 | INTERSECTS COAL - THICKNESS 0.31 | COAL | 6.59 |
| GW037851 | 10BL030789 | 1/05/1973 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | WERONA | LT1DP746773/DP11093425 | 248939 | 6176253 | STEEL | 2.40 | 27.40 | 78.60 | INTERSECTS IRONSTONE | | 22.59 |
| GW037960 | 10BL109498 | 1/12/1973 | ACTIVE | DOMESTIC, STOCK | WATERLOO | 9/DPP+PORT8 | 247470 | 6169305 | STEEL/PRESSUR | 24.00 | 30.40 | 94.40 | | | 10.87 |
| GW037967 | 10BL031244 | 1/11/1973 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | DANELLEN | L12(103)/DP12241054 | 243900 | 6165599 | STEEL | 5.70 | 60.90 | 83.80 | INTERSECTS IRONSTONE | | 2.33 |
| GW038008 | 10BL030810 | 1/01/1967 | CANCELLED | IRRIGATION, STOCK | THE CHASE | 32/DP32 | 255889 | 6173016 | STEEL | 0.00 | N/A | 87.70 | | | |
| GW042640 | 10BL030812 | 1/01/1971 | CANCELLED | DOMESTIC, IRRIGATION, STOCK | THE CHASE | 32/DP32 | 255959 | 6173264 | N/A | N/A | N/A | 182.80 | | | 12.63 |
| GW042641 | 10BL030811 | 1/01/1971 | CANCELLED | IRRIGATION, STOCK | THE CHASE | 5//614362/DP32 | 256031 | 6172464 | N/A | N/A | N/A | N/A | | | 5.68 |
| GW042642 | 10BL031425 | 1/01/1971 | CANCELLED | IRRIGATION, STOCK | THE CHASE | 32/DP32 | 255687 | 6172949 | STEEL | 0.00 | N/A | 68.50 | | | |
| GW042926 | 10BL159960 | 1/05/1977 | ACTIVE | DOMESTIC, STOCK | N/A | 7//546153/DP7546153 | 247823 | 6166632 | STEEL | 12.80 | N/A | 117.40 | INTERSECTS IRONSTONE/ENDS IN COAL | COAL | 1.58 |
| GW043282 | 10BL029775 | 1/08/1974 | ACTIVE | STOCK | N/A | 94/DPLOT465 | 246198 | 6170103 | STEEL | 1.70 | 54.80 | 91.40 | INTERSECTS IRONSTONE | | 14.13 |
| GW044058 | 10BL100296 | 1/04/1974 | ACTIVE | DOMESTIC, STOCK | N/A | 10/DPP+PORT10 | 249125 | 6167500 | STEEL | 0.10 | 1.50 | 9.10 | INTERSECTS BASALT BOULDERS | BASALT | 0.76 |
| GW045708 | 10BL029128 | 1/01/1974 | ACTIVE | DOMESTIC, STOCK | BORA | L4DP243199(24)/DPL4DP2431 | 246490 | 6167829 | STEEL | 4.30 | N/A | 54.90 | NO WATER BEARING ZONES DETAILS FOUND | | |
| GW045709 | 10BL100269 | 1/01/1973 | ACTIVE | N/A | BORA | L4DP243199(24)/DPL4DP2431 | 246132 | 6167850 | N/A | N/A | N/A | 111.30 | | | |
| GW047003 | 10BL106906 | 1/10/1977 | CANCELLED | DOMESTIC, IRRIGATION, STOCK | N/A | 44/DP44 | 246918 | 6173638 | N/A | N/A | N/A | 99.00 | INTERSECTS IRONSTONE | | 2.66 |
| GW047076 | 10BL107468 | 1/03/1978 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | MACMADAM | 2844621/DP2844621 | 254720 | 6170814 | STEEL | 5.80 | N/A | 89.90 | INTERSECTS FISSURE -THICKNESS 0.30 | | 18.82 |
| GW047117 | 10BL107723 | 1/04/1978 | LAPSED | STOCK | N/A | 61/DPP+PORT61 | 251827 | 6177040 | STEEL/PRESSUR | 4.90 | 5.80 | 33.50 | INTERSECTS IRONSTONE/ INTERSECTS CAVITY - THICKNESS 0.31 | | 20.21 |
| GW047157 | 10BL108548 | 1/10/1973 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | OLD PIG FARM | 8/DP12553 | 248506 | 6175285 | STEEL | 5.80 | 20.70 | 67.10 | | | 10.98 |
| GW047406 | 10BL128859 | 1/09/1979 | ACTIVE | DOMESTIC, STOCK | SOUTHLANDS | 9/DP9 | 247780 | 6169159 | STEEL | 19.00 | 25.00 | 91.50 | INTERSECTS COAL - THICKNESS 2.70 | COAL | 4.30 |
| GW047443 | 10BL110924 | 1/11/1979 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | MOOSE WOOD FARM | L3DP250747(10)/DP3250747 | 249131 | 6169165 | PVC | 24.40 | N/A | 67.10 | | | 4.40 |
| GW048345 | 10BL105846 | 1/01/1976 | ACTIVE | DOMESTIC, STOCK | MARTIN | L2DP249175(36)/DP6829835 | 251887 | 6174821 | STEEL/PRESSUR | 25.30 | 9.10 | 38.10 | | | 4.36 |
| GW049172 | 10BL108851 | 1/12/1978 | ACTIVE | DOMESTIC, STOCK | N/A | 7/DPP+PORT68789 | 249209 | 6175705 | STEEL | 25.00 | 10.40 | 70.10 | | | 5.04 |
| GW049231 | 10BL107892 | 1/01/1978 | ACTIVE | DOMESTIC, STOCK | WYOMING | 44/DPP+PORT44 | 245373 | 6169494 | N/A | N/A | N/A | 30.00 | | | |
| GW050251 | 10BL109722 | 1/02/1979 | ACTIVE | DOMESTIC | EVERTON GRANGE | 68/DP+PORT68 | 252889 | 6166923 | STEEL | 14.30 | 5.20 | 16.10 | INTERSECTS BASALT | BASALT | 1.26 |
| GW050583 | 10BL115165 | 1/07/1980 | CANCELLED | DOMESTIC, STOCK | N/A | 10/DP1554129 | 248623 | 6168165 | STEEL | 18.30 | N/A | 129.60 | INTERSECTS COAL - THICKNESS 1.6 | COAL | 3.20 |
| GW051450 | 10BL116811 | 1/10/1980 | ACTIVE | DOMESTIC, STOCK | OLIVE GROVE | L4(41)/DP4239391 | 242025 | 6166071 | STEEL | 6.40 | 12.00 | 54.00 | | | 2.00 |
| GW051537 | 10BL111068 | 1/10/1980 | ACTIVE | DOMESTIC | N/A | L1(100)/DPL1 | 245018 | 6166647 | STEEL | 25.70 | 41.20 | 92.00 | | | 3.00 |
| GW052538 | 10BL117065 | N/A | ACTIVE | DOMESTIC, STOCK | ROCKLEA FARM | 65/DP64751251 | 244625 | 6175333 | STEEL | 6.60 | N/A | 88.00 | | | |

| WELL_ID | LICENCE | END DATE | STATUS | PURPOSE | PROPERTY_NAME | LOT/DP | EASTING | NORTHING | CASING | CASING_ | SWL | DTB | COMMENTS | ROCK | FLOW RATE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW053019 | 10BL134345 | 1/10/1980 | ACTIVE | DOMESTIC, STOCK | N/A | L2DP243199(8)/DPLT2DP2431 | 246732 | 6168298 | PVC | 9.10 | 46.80 | 76.00 | | | 1.00 |
| GW053272 | 10BL135249 | 1/01/1981 | ACTIVE | DOMESTIC, STOCK | DRUMDERRY | 6718101/DP6718101 | 247435 | 6169643 | STEEL | 39.00 | 27.40 | 96.00 | INTERSECTS COAL - THICKNESS 0.60 | COAL | 5.04 |
| GW053331 | 10BL120574 | 1/08/1980 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | MEREWORTH | 200839314/DP200839314 | 251462 | 6177338 | STEEL | 6.40 | 18.00 | 92.00 | INTERSECTS ROCK CLAY | | 15.00 |
| GW053793 | 10BL117377 | 1/10/1980 | LAPSED | DOMESTIC, IRRIGATION, STOCK | N/A | 44/N/A | 247553 | 6173717 | STEEL | 20.00 | 35.00 | 91.50 | | | 5.00 |
| GW053801 | 10BL122407 | 1/09/1981 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | COMFORT HILL | 1744544/DP1744544 | 247583 | 6171683 | STEEL | 75.40 | 30.50 | 99.10 | INTERSECTS COAL - THICKNESS 3.90 | COAL | 5.63 |
| GW054137 | 10BL113601 | 1/08/1980 | ACTIVE | DOMESTIC, STOCK | WILLOWS END | 61/DP7703937 | 251672 | 6177128 | STEEL | 6.40 | 12.80 | 46.00 | | | 6.00 |
| GW056829 | 10BL123793 | 1/02/1983 | ACTIVE | STOCK | GOLDEN VALLEY | 73/DP73 | 253094 | 6174514 | STEEL | 6.00 | 3.00 | 23.00 | | | 12.60 |
| GW057287 | 10BL124876 | 1/05/1982 | ACTIVE | DOMESTIC, STOCK | GREENMOUNT | L6DP243199(8)/DPL6DP24319 | 246705 | 6168359 | STEEL | 10.00 | 41.00 | 68.00 | | | 1.50 |
| GW057683 | 10BL126421 | 1/12/1982 | ACTIVE | DOMESTIC, STOCK | N/A | L10DP244195(35)/DPL10DP24 | 252063 | 6176799 | STEEL | 6.10 | 9.10 | 61.00 | | | 6.00 |
| GW057687 | 10BL126432 | 1/03/1983 | ACTIVE | DOMESTIC, STOCK | N/A | L3(100)/DPL3(P+PORT100) | 244419 | 6166168 | STEEL | 23.00 | 46.00 | 90.00 | | | 0.76 |
| GW057906 | 10BL125123 | 1/04/1983 | ACTIVE | INDUSTRIAL | RTA-MITTAGONG WORKS | L2DP247919(9)/DP30262738 | 250456 | 6174875 | STEEL | 6.00 | 6.00 | 61.00 | | | 11.45 |
| GW057908 | 10BL125146 | 1/02/1983 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | EVANDALE | 21009075/DP21009075 | 250955 | 6176276 | STEEL | 6.00 | 21.00 | 84.00 | | | 5.00 |
| GW057943 | 10BL140853 | 1/03/1983 | ACTIVE | DOMESTIC, STOCK | ROTHERWOOD | 16/DP11068950 | 252428 | 6169840 | STEEL | 25.90 | 11.00 | 25.90 | | | 1.14 |
| GW060067 | 10BL137608 | 1/02/1983 | ACTIVE | DOMESTIC, STOCK | N/A | L3(17)/DPLT3PT17 | 254057 | 6169020 | PVC | 6.00 | N/A | 76.00 | | | 1.89 |
| GW060125 | 10BL131271 | N/A | ACTIVE | FARMING, IRRIGATION, STOCK | OLDBURY | LT1DP986732/DP1986732 | 252618 | 6175525 | STEEL | 6.00 | 7.00 | 107.00 | | | 8.00 |
| GW060199 | 10BL140888 | 1/08/1984 | ACTIVE | DOMESTIC, STOCK | N/A | 73/DP73 | 253094 | 6174514 | STEEL | 21.40 | 1.00 | 37.00 | | | 20.00 |
| GW061330 | 10BL133406 | 1/10/1985 | ACTIVE | DOMESTIC | N/A | L2DP1002(31)/LT2DP1002PT31 | 256537 | 6168746 | PVC | 6.00 | 73.00 | 114.00 | | | 0.80 |
| GW062326 | 10BL138136 | 1/11/1988 | ACTIVE | DOMESTIC, IRRIGATION | BRIGADOON | 10/DP2587064 | 250784 | 6169333 | STEEL | 15.20 | N/A | 94.50 | | | 1.69 |
| GW064613 | 10BL136819 | 1/03/1988 | ACTIVE | DOMESTIC | N/A | L2DP746778(99)/DPLT2DP746 | 249108 | 6175671 | STEEL | 6.50 | 14.00 | 43.00 | | | 1.00 |
| GW065191 | 10BL137688 | 1/04/1988 | ACTIVE | DOMESTIC | HEALEY | 52714321/DP52714321 | 248904 | 6166904 | STEEL | 15.20 | 3.00 | 18.00 | | | 0.25 |
| GW066749 | N/A | 13/05/1992 | N/A | N/A | N/A | 37//243688 | 251725 | 6165627 | PVC | 12.00 | 4.00 | 12.00 | | | 0.08 |
| GW066761 | N/A | 16/10/1992 | N/A | N/A | N/A | 3//1084219 | 253508 | 6166662 | STEEL | 18.00 | 4.00 | 18.00 | | | 1.00 |
| GW066764 | N/A | N/A | N/A | N/A | N/A | 11//1083391 | 254253 | 6166435 | STEEL | 24.00 | 14.00 | 24.00 | | | 0.30 |
| GW066769 | N/A | N/A | N/A | N/A | N/A | 12//1083391 | 254252 | 6166466 | STEEL | 24.00 | 7.00 | 18.00 | | | 0.30 |
| GW066770 | N/A | N/A | N/A | N/A | N/A | 642//717065 | 254362 | 6166160 | PVC | 33.00 | 10.00 | 33.00 | | | 0.40 |
| GW066775 | N/A | 21/08/1991 | N/A | N/A | N/A | 4//243528 | 253213 | 6170077 | PVC | 6.00 | N/A | 86.00 | | | 5.40 |
| GW066798 | N/A | 16/02/1989 | N/A | N/A | N/A | 4//244195 | 251660 | 6175678 | PVC/STEEL | 10.00 | 10.00 | 32.00 | | | 1.10 |
| GW066800 | N/A | 26/11/1989 | N/A | N/A | N/A | 1/803085 | 253274 | 6170634 | PVC | 45.50 | 14.00 | 81.00 | | | 0.24 |
| GW067303 | N/A | 27/06/1990 | N/A | N/A | N/A | 1//744544 | 247661 | 6171654 | STEEL | 100.00 | N/A | 100.00 | | | |
| GW067305 | N/A | 7/01/1991 | N/A | N/A | N/A | 31//262738 | 250965 | 6174950 | UNKNOWN | 6.00 | N/A | 15.00 | NO WATER BEARING ZONES DETAILS FOUND | | |
| GW067319 | N/A | 17/12/1989 | N/A | N/A | N/A | 6//806772 | 251579 | 6175830 | PVC | 10.00 | 10.00 | 31.00 | | | 1.00 |
| GW067521 | N/A | 28/01/1992 | N/A | N/A | N/A | L17DP533513 | 253702 | 6168715 | PVC | 33.00 | 18.00 | 33.00 | INTERSECTS BASALT | BASALT | 0.55 |
| GW068253 | N/A | 5/09/1994 | N/A | N/A | N/A | L46DP243731 | 251723 | 6165562 | N/A | N/A | N/A | 170.70 | | | |
| GW068481 | N/A | 16/05/1990 | N/A | N/A | N/A | L2DP718101 | 247646 | 6169005 | UNKNOWN | 51.00 | N/A | 51.00 | | | |
| GW068897 | N/A | 27/08/1990 | N/A | N/A | N/A | L9DP241054 | 243063 | 6165644 | STEEL | 2.50 | 20.00 | 61.00 | | | 0.74 |
| GW068965 | N/A | 16/10/1991 | N/A | N/A | N/A | L5DP244195 | 251659 | 6175774 | PVC | 8.00 | N/A | 37.00 | | | 1.50 |
| GW069007 | N/A | 4/11/1991 | N/A | N/A | N/A | L54DP14140 | 254188 | 6166419 | PVC | 36.00 | 10.00 | 36.00 | ENDS IN BASALT | BASALT | 0.50 |
| GW069072 | N/A | 4/11/1991 | N/A | N/A | N/A | L19DP554041 | 254350 | 6169571 | PVC | 99.00 | 60.00 | 120.00 | | | 2.50 |
| GW069118 | N/A | 25/02/1991 | N/A | N/A | N/A | L1DP379482 | 253610 | 6166800 | PVC | 18.00 | 18.00 | 30.30 | ENDS IN BASALT | BASALT | 2.00 |
| GW071741 | 10BL150015 | 18/03/1992 | ACTIVE | DOMESTIC, STOCK | GREENACRES | 3806934/DP3806934 | 248620 | 6171839 | PVC | 12.00 | N/A | 85.00 | | | 7.51 |
| GW072154 | N/A | 17/01/1994 | N/A | N/A | N/A | L2DP709635 | 253249 | 6166401 | STEEL | 13.00 | 10.00 | 27.00 | INTERSECTS BASALT CLAYS/ENDS IN BASALT | BASALT | 2.50 |
| GW072179 | 10BL153970 | 9/02/1994 | ACTIVE | IRRIGATION, RECREATION (GROUN | MT BROUGHTON COUNTR | 1236285/DP1236285 | 256531 | 6171363 | STEEL, UNKNOV | 110.00 | 39.00 | 111.00 | INTERSECTS QUARTZ | | 10.20 |
| GW072207 | N/A | 15/02/1993 | N/A | N/A | N/A | LPT50DP751253 | 256328 | 6171699 | STEEL, PVC | 109.00 | 33.00 | 109.00 | INTERSECTS QUARTZ | | 11.00 |
| GW072245 | N/A | 24/02/1994 | N/A | N/A | N/A | L1DP516824 | 243532 | 6169705 | STEEL | 30.00 | 90.00 | 131.00 | | | 1.00 |
| GW072273 | N/A | 31/01/1992 | N/A | N/A | N/A | L3DP549063 | 253044 | 6166546 | STEEL | 18.00 | 4.00 | 18.00 | ENDS IN DECOMPOSED BASALT | BASALT | 1.00 |
| GW072320 | 10BL155153 | 10/02/1994 | ACTIVE | IRRIGATION, RECREATION (GROUN | MT BROUGHTON GOLF CL | 234589902/DP234589902 | 256462 | 6171059 | STEEL, PVC | 109.00 | 33.00 | 109.00 | INTERSECTS QUARTZ | | 11.60 |
| GW072321 | 10BL155154 | 12/02/1994 | ACTIVE | IRRIGATION, RECREATION (GROUN | MT BROUGHTON GOLF CL | 234589902/DP234589902 | 256725 | 6171367 | STEEL, PVC | 109.00 | 33.00 | 109.00 | INTERSECTS QUARTZ | | 14.60 |
| GW072341 | 10BL155467 | 16/05/1990 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | SOUTHLANDS | 2718101/DP2718101 | 247491 | 6168706 | UNKNOWN | 0.00 | N/A | 51.00 | | | |
| GW072416 | N/A | 24/11/1994 | N/A | N/A | N/A | L11DP802737 | 252451 | 6166806 | STEEL | 17.00 | 7.00 | 18.00 | | | 0.25 |
| GW072672 | 10BL154540 | 10/05/1994 | CANCELLED | DOMESTIC, STOCK | MARTIN | 6829385/DP6829385 | 251924 | 6174305 | STEEL | 12.00 | 24.00 | 122.00 | | | 11.00 |
| GW075036 | N/A | 15/11/1998 | N/A | N/A | N/A | 13/6/758938 | 254286 | 6170324 | STEEL, PVC | 85.00 | 43.56 | 100.00 | | | 1.10 |
| GW100147 | 10BL143028 | 26/05/1991 | ACTIVE | DOMESTIC, STOCK | N/A | 4826337 | 253307 | 6172269 | STEEL | 6.00 | 20.00 | 80.00 | INTERSECTS BASALT | BASALT | 1.40 |
| GW100153 | 10BL143169 | 18/03/1992 | ACTIVE | DOMESTIC, FARMING, STOCK | N/A | LT2DP249175 | 253247 | 6172606 | STEEL | 12.00 | 20.00 | 85.00 | | | 4.00 |
| GW100252 | 10BL601486 | 5/08/1993 | ACTIVE | DOMESTIC | WILLIAMWAY | 3735722/DP3735722 | 256758 | 6168748 | PVC | 0.72 | 86.00 | 156.00 | | | 4.00 |
| GW100253 | 10BL152848 | 3/05/1993 | ACTIVE | DOMESTIC, STOCK | N/A | 31//243688/DP41 | 251027 | 6165917 | PVC | 20.00 | 8.00 | 20.00 | INTERSECTS WEATHERED BASALT/ENDS IN BASALT | BASALT | 4.00 |
| GW100256 | 10BL152878 | 10/08/1993 | ACTIVE | DOMESTIC | N/A | 57//14140/DP5714140 | 254259 | 6166306 | PVC | 30.00 | 8.00 | 30.00 | INTERSECTS SOAPSTONE | | 0.40 |
| GW100257 | 10BL152881 | 12/08/1993 | ACTIVE | DOMESTIC, STOCK | N/A | 56//14140/DP5614140 | 254231 | 6166339 | PVC | 36.00 | 11.00 | 36.00 | INTERSECTS BROKEN BASALT | BASALT | 0.25 |
| GW100258 | 10BL152884 | 8/12/1993 | CANCELLED | DOMESTIC, STOCK | MISTY LODGE | 24//580989/DP24580989 | 254644 | 6165561 | PVC | 12.00 | N/A | 15.00 | ENDS IN BROKEN BASALT | BASALT | |
| GW100370 | 10BL157664 | 12/06/1996 | ACTIVE | DOMESTIC | N/A | 10//800596/DP10800596 | 255142 | 6176868 | PVC | 108.00 | 30.00 | 169.00 | ONLY DRILLED DEPTH AVAILABLE | | 17.63 |
| GW100720 | 10BL157759 | 20/10/1996 | ACTIVE | DOMESTIC | N/A | 3//60330/DP360330 | 253419 | 6166882 | STEEL | 126.00 | 162.60 | 211.00 | BASALT SOIL/INTERSECTS BASALT | BASALT | 1.00 |
| GW101108 | 10BL158164 | 30/07/1997 | ACTIVE | DOMESTIC, STOCK | N/A | 5//708386/DP5708386 | 246406 | 6170565 | PVC | 99.00 | 57.00 | 100.00 | | | 5.00 |
| GW101324 | 10BL156976 | 26/09/1995 | ACTIVE | DOMESTIC | N/A | LOT5SEC3FP978852 | 254223 | 6166588 | PVC | 15.00 | 7.00 | 15.00 | ENDS IN FRACTURED BASALT | BASALT | 4.00 |

| WELL_ID | LICENCE | END DATE | STATUS | PURPOSE | PROPERTY_NAME | LOT/DP | EASTING | NORTHING | CASING | CASING_ | SWL | DTB | COMMENTS | ROCK | FLOW RATE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW101421 | 10BL157496 | 13/03/1996 | ACTIVE | DOMESTIC | N/A | 15239341 | 254321 | 6165789 | PVC | 19.50 | 9.00 | 36.50 | ENDS IN BASALT | BASALT | 0.10 |
| GW101500 | 10BL161010 | 6/10/1992 | ACTIVE | DOMESTIC, STOCK | N/A | LT999DP818282/DP999818282 | 243230 | 6171854 | UNKNOWN | 7.00 | N/A | 171.00 | INTERSECTS QUARTZ | | 0.70 |
| GW101502 | 10BL158657 | 1/07/1980 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | THE WOODS | 1554129/DP1554129 | 248516 | 6167391 | STEEL | 18.30 | N/A | 129.60 | INTERSECTS COAL - THICKNESS 1.60 | | 3.20 |
| GW101856 | 10BL158969 | 1/01/1991 | ACTIVE | DOMESTIC | N/A | 2513527 | 253980 | 6166150 | PVC | 30.00 | N/A | 30.00 | | | |
| GW101872 | 10BL157463 | 13/02/1996 | ACTIVE | DOMESTIC, STOCK | N/A | 4//253435/DP4253435 | 243873 | 6165776 | PVC | 42.00 | 63.00 | 205.00 | | | 0.57 |
| GW101890 | 10BL158956 | 1/01/1988 | ACTIVE | DOMESTIC | N/A | 2//626008/DP2626008 | 256133 | 6167902 | PVC | 19.00 | N/A | 19.00 | | | |
| GW101925 | 10BL159517 | 26/02/1998 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | FOXGROVE | 3//805624/DP3805624 | 243951 | 6170114 | PVC | 36.00 | 92.00 | 150.00 | INTERSECTS BASALT/INTERSECTS COAL - THICKNESS 2.00 | COAL | 0.55 |
| GW101984 | 10BL160900 | 17/01/1998 | ACTIVE | FARMING, IRRIGATION, STOCK | BRAEBROOK | 8800596/DP8800596 | 254951 | 6175936 | STEEL | 78.00 | 36.00 | 163.00 | | | 29.30 |
| GW102064 | 10BL158998 | 26/11/1998 | ACTIVE | DOMESTIC, STOCK | N/A | 26//751251/DP26751251 | 243081 | 6171279 | PVC | 109.00 | 72.00 | 109.00 | INTERSCTS COAL WITH SILTSTONE BANDS - THICKNESS 12.00 | COAL | 0.62 |
| GW102269 | 10BL159082 | 13/11/1998 | ACTIVE | DOMESTIC, STOCK | THE CHASE | 3//614362/DP3614362 | 255865 | 6172984 | N/A | N/A | N/A | 97.00 | | | 11.75 |
| GW102309 | 10BL159095 | 1/01/1987 | ACTIVE | IRRIGATION | MONTROSE | 2//620221/DP2620221 | 254109 | 6170271 | PVC | 0.00 | N/A | 67.00 | | | |
| GW102350 | 10BL604146 | 1/05/2010 | ACTIVE | IRRIGATION | HARMONY FARM | 2516824/DP2516824 | 243710 | 6169664 | STEEL, PVC | 145.00 | 100.00 | 145.00 | INTERSECTS BASALT/ENDS IN COAL WITH SHALE BANDS | COAL | 0.98 |
| GW102371 | 10BL159646 | 6/03/1999 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | HIGHFIELD | 159375/DP159375 | 254898 | 6174809 | STEEL | 102.00 | 65.00 | 162.00 | | | 16.20 |
| GW102401 | 10BL157841 | 20/12/1996 | ACTIVE | DOMESTIC, STOCK | N/A | LOT1DP14140 | 254158 | 6166186 | PVC | 31.00 | 14.00 | 78.00 | INTERSECTS WEATHERED BASALT | BASALT | 0.20 |
| GW102442 | 10BL159260 | 1/03/1999 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | WHARE TAU | 1858547/DP1858547 | 253750 | 6167131 | PVC | 5.50 | 32.00 | 109.00 | | | 2.44 |
| GW102516 | 10BL139746 | 31/07/1989 | ACTIVE | STOCK | N/A | 233589902 | 256418 | 6171364 | PVC | 14.00 | 11.00 | 91.00 | | | 3.10 |
| GW102567 | 10BL159313 | 1/01/1993 | CANCELLED | INDUSTRIAL | MISTY LODGE | 11013343 | 254784 | 6165647 | N/A | N/A | N/A | 1.00 | | | |
| GW102588 | 10BL159645 | 11/08/1999 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | BELANGLO HOLDINGS | 3711048/DP3711048 | 244853 | 6174954 | PVC | 42.00 | 56.00 | 88.00 | | | 4.80 |
| GW102589 | 10BL159343 | 30/07/1999 | ACTIVE | DOMESTIC, STOCK | N/A | 4979138 | 255363 | 6174605 | STEEL | 84.00 | 65.00 | 139.00 | | | 9.10 |
| GW102621 | 10BL158855 | 11/12/1998 | ACTIVE | MONITORING BORE | N/A | 1732123 | 254577 | 6166721 | PVC | 16.99 | 12.59 | 24.50 | INTERSECTS WEATHERED BASALT/BASALT AMIGDALOIDAL/IRONSTONE | BASALT | N/A |
| GW102622 | 10BL158855 | 13/11/1998 | ACTIVE | MONITORING BORE | N/A | LOT1DP732123/DP1732123 | 254626 | 6166784 | PVC | 23.10 | 12.53 | 42.20 | BASALT FRACTURED/BASALT ALTERED/BASALT/ENDS IN BASALT MASSIVE | BASALT | N/A |
| GW102623 | 10BL158855 | 15/11/1998 | ACTIVE | MONITORING BORE | N/A | LOT1DP732123/DP1732123 | 254576 | 6166752 | PVC | 0.00 | 10.81 | 26.60 | BASALT MASSIVE/BASALT AMYGDALOIDAL/ENDS IN BASALT MASSIVE | BASALT | N/A |
| GW102624 | 10BL158855 | 18/11/1999 | ACTIVE | MONITORING BORE | N/A | LOT1DP732123/DP1732123 | 254548 | 6166844 | PVC | 14.50 | 10.57 | 20.55 | BASALT AMYGDALOIDAL/ZEOLITE/BASALT ALTERED/ENDS IN ZEOLITE | BASALT | N/A |
| GW102689 | 10BL159119 | 25/11/1999 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | KOLTAI | LO12DP1004339/DP121004339 | 252658 | 6172598 | STEEL, PVC | 36.00 | 24.00 | 84.00 | | | 7.00 |
| GW102694 | 10BL159368 | 1/09/1999 | ACTIVE | IRRIGATION | CAPMA | 2502895/DP2502895 | 253410 | 6168417 | STEEL | 96.00 | 89.00 | 169.00 | INTERSECTS SOIL AND WEATHERED BASALT | BASALT | 12.75 |
| GW102705 | 10BL159159 | 29/01/1999 | ACTIVE | DOMESTIC, STOCK | N/A | 1550645 | 246987 | 6171111 | PVC | 105.00 | 32.00 | 150.00 | INTERSECTS COAL - THICKNESS 1.00 /INTERSECTS UNSTABLE PEBBLES | COAL | 7.50 |
| GW102713 | 10BL159444 | 4/06/1999 | ACTIVE | DOMESTIC, STOCK | N/A | 17705790 | 251032 | 6175292 | PVC | 12.00 | 10.00 | 60.00 | INTERSECTS IRONSTONE GRAVEL | | 3.37 |
| GW102756 | 10BL603303 | 7/05/1999 | ACTIVE | DOMESTIC, STOCK | COBBADAH | 21060378/DP21060378 | 243500 | 6170830 | PVC | 110.00 | 80.00 | 110.00 | INTERSECTS COAL - THICKNESS 3.00 | COAL | 1.40 |
| GW102757 | 10BL159080 | 5/05/1999 | ACTIVE | IRRIGATION | KULOOMBA | 1579931/DP1579931 | 251971 | 6167918 | STEEL | 210.00 | 99.10 | 210.00 | INTERSECTS COAL - THICKNESS 3.50 | COAL | 8.00 |
| GW102759 | 10BL159371 | 27/04/1999 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | ECCLESTON PARK | 8805624/DP8805624 | 245230 | 6170045 | PVC | 117.00 | N/A | 138.00 | | | 5.00 |
| GW102775 | 10BL159513 | 8/12/1999 | ACTIVE | DOMESTIC, STOCK | N/A | 111004339 | 254164 | 6171706 | PVC | 59.00 | 72.00 | 16.00 | | | 13.25 |
| GW102777 | 10BL159462 | 16/12/1999 | ACTIVE | DOMESTIC, STOCK | N/A | LOT10DP758938 | 253902 | 6170034 | STEEL | 59.00 | 44.00 | 103.00 | | | 7.33 |
| GW102916 | 10BL159425 | 3/06/1999 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | BURROWS | 8//883697/DP8883697 | 252708 | 6173638 | PVC | 48.00 | 42.00 | 108.00 | | | 5.50 |
| GW102964 | 10BL159634 | 1/01/1956 | ACTIVE | DOMESTIC, STOCK | N/A | 403//1076207/DP466297 | 253499 | 6166812 | STEEL | 0.00 | N/A | 23.00 | | | |
| GW103108 | 10BL164662 | 22/06/2000 | ACTIVE | IRRIGATION | ROSEDALE | 6//250743/DP6250743 | 249748 | 6170021 | STEEL, PVC | 59.60 | 35.00 | 114.00 | INTERSECTS IRONSTONE GRAVEL/IRON OXIDE | | 6.00 |
| GW103201 | 10BL159576 | 20/10/1999 | ACTIVE | IRRIGATION | CHARLESTON | 1215782/DP1215782 | 256024 | 6175640 | STEEL | 84.00 | 45.00 | 192.00 | | | 22.00 |
| GW103342 | 10BL161945 | 26/10/2000 | ACTIVE | DOMESTIC, STOCK | COBBADAH | 7//857831/DP7857831 | 243123 | 6169392 | PVC | 36.00 | 98.00 | 114.00 | INTERSECTS COAL - THICKNESS 2.00 | COAL | 2.02 |
| GW103516 | 10BL603302 | 3/01/1996 | ACTIVE | DOMESTIC, STOCK | COBBADAH | 13861916/DP13861916 | 242739 | 6168835 | PVC | 135.00 | 82.00 | 135.00 | INTERSECTS COAL - THICKNESS 6.00 | COAL | 0.53 |
| GW103597 | 10BL159588 | 22/06/2000 | ACTIVE | DOMESTIC, STOCK | N/A | 16//2715/DP162715 | 253347 | 6170885 | PVC | 6.00 | 50.00 | 90.00 | | | 2.50 |
| GW103692 | 10BL160074 | 15/01/2001 | ACTIVE | IRRIGATION | MOUNT BROUGHTON | 233//589902/DP233589902 | 255893 | 6170270 | STEEL | 78.50 | N/A | 152.00 | INTERSECTS BASALT/NO WATER BEARING ZONES DETAILS FOUND | BASALT | |
| GW104110 | 10BL160212 | 23/10/2001 | ACTIVE | DOMESTIC, STOCK | N/A | LT2DP506784/DP250784 | 255121 | 6175050 | PVC | 90.70 | 60.00 | 140.00 | | | 1.26 |
| GW104116 | 10BL160333 | 31/10/2001 | ACTIVE | DOMESTIC, STOCK | N/A | LT3DP708386/DP3708386 | 246237 | 6169711 | PVC | 78.00 | N/A | 78.00 | | | 3.50 |
| GW104193 | 10BL160461 | 13/02/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT1DP626008/DP1626008 | 255989 | 6167862 | PVC | 30.00 | 6.00 | 30.00 | INTERSECTS BASALT | BASALT | 1.25 |
| GW104198 | 10BL160474 | 5/02/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT6DP843367/DP6843367 | 252443 | 6166728 | PVC | 36.00 | 10.60 | 36.00 | INTERSECTS GRANITE/BASALT | BASALT | 2.20 |
| GW104213 | 10BL160524 | 8/03/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT5DP857597/DP5857597 | 254367 | 6171392 | STEEL | 84.00 | 34.00 | 144.00 | | | 13.51 |
| GW104229 | 10BL160309 | 1/12/2001 | ACTIVE | IRRIGATION | SOUTHERN HIGHLAND W | PT1DP10658/DP110658 | 256369 | 6172893 | STEEL | 72.00 | 30.00 | 135.00 | | | 27.50 |
| GW104317 | 10BL160075 | 24/02/2001 | ACTIVE | IRRIGATION, RECREATION (GROUN | MOUNT BROUGHTON CO | LT234DP589902/DP234589902 | 256737 | 6171550 | STEEL | 80.00 | 52.10 | 182.00 | | | 4.90 |
| GW104404 | 10BL160766 | 21/08/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT4DP245007/DP4245007 | 254332 | 6175078 | PVC | 126.00 | 74.00 | 159.00 | INTERSECTS BASALT | BASALT | 0.47 |
| GW104421 | 10BL160635 | 19/08/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT3DP244195/DP3244195 | 251708 | 6175634 | PVC | 42.00 | N/A | 42.00 | | | 3.00 |
| GW104468 | 10BL160924 | 18/10/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT9DP1040207/DP91040207 | 252574 | 6173120 | PVC | 103.00 | 43.00 | 103.00 | | | 4.00 |
| GW104486 | 10BL161022 | 11/11/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT7DP874965/DP7874965 | 251831 | 6174027 | PVC | 42.00 | 18.50 | 43.00 | | | 7.00 |
| GW104523 | 10BL160991 | 21/11/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT1DP703669/DP1703669 | 253372 | 6170373 | STEEL, PVC | 91.00 | 42.00 | 91.00 | | | 18.00 |
| GW104526 | 10BL161000 | 14/11/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT102DP749283/DP102749283 | 249484 | 6169317 | PVC | 61.00 | 33.00 | 61.00 | | | 1.87 |
| GW104642 | 10BL161230 | 11/01/2003 | ACTIVE | DOMESTIC, STOCK | N/A | LT13DP800596/DP13800596 | 254092 | 6177430 | PVC | 121.00 | 45.00 | 121.00 | | | 3.85 |
| GW104684 | 10BL161456 | 27/01/2003 | ACTIVE | DOMESTIC, STOCK | N/A | LT103DP1021005/DP10310210 | 250231 | 6169027 | PVC | 66.00 | 57.00 | 156.00 | | | 3.65 |
| GW104727 | 10BL161333 | 25/03/2003 | ACTIVE | DOMESTIC, STOCK | FOREST RIDGE | LT234DP808954/DP31095423 | 252108 | 6169089 | STEEL | 103.50 | N/A | 175.00 | DECOMPOSED BASALT/FRACTURED/NO WATER BEARING ZONES FOUND | BASALT | |
| GW104728 | 10BL161397 | 17/03/2003 | ACTIVE | DOMESTIC, STOCK | N/A | LT18DP32/DP1832 | 254382 | 6172032 | PVC | 79.00 | 13.00 | 79.00 | | | 2.00 |
| GW104745 | 10BL161546 | 15/07/2003 | ACTIVE | DOMESTIC, STOCK | RAVENSWOOD | LT30DP262738/DP29262738 | 251266 | 6174225 | STEEL | 0.00 | N/A | N/A | | | |
| GW104765 | 10BL161862 | 8/05/2003 | ACTIVE | IRRIGATION | SITECAT PTY LTD | 4253435/DP4253435 | 244057 | 6166221 | STEEL, PVC | 72.00 | 41.60 | 108.00 | INTERSECTS DACITE (TONALITE) - DAM WALL FILL | BASALT | 2.00 |
| GW104874 | 10BL161514 | 1/01/1950 | ACTIVE | DOMESTIC, STOCK | N/A | LT1DP995642/DP1995642 | 253974 | 6171788 | STEEL | 0.00 | N/A | 35.00 | | | |
| GW104911 | 10BL160872 | 21/10/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT13DP1033996/DP131033996 | 251616 | 6165801 | PVC | 6.00 | 45.00 | 156.00 | | | 1.13 |
| GW104917 | 10BL161065 | 28/11/2002 | ACTIVE | DOMESTIC, STOCK | N/A | LT1DP722988/DP1722988 | 255641 | 6168126 | STEEL | 101.00 | 65.00 | 156.00 | INTERSECTS BASALT | BASALT | 6.00 |

| WELL_ID | LICENCE | END DATE | STATUS | PURPOSE | PROPERTY_NAME | LOT/DP | EASTING | NORTHING | CASING | CASING_ | SWL | DTB | COMMENTS | ROCK | FLOW RATE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW105068 | 10BL157465 | 4/05/1995 | ACTIVE | DOMESTIC, STOCK | N/A | LT3DP243528/DP3243528 | 253025 | 6170333 | PVC | 91.00 | 40.00 | 91.00 | | | 9.75 |
| GW105079 | 10BL162003 | 25/09/2003 | ACTIVE | DOMESTIC, STOCK | COAD | LT1DP995642/DP1995642 | 253578 | 6171823 | PVC | 60.00 | 18.00 | 114.00 | | | 4.60 |
| GW105082 | 10BL161903 | 22/09/2003 | ACTIVE | DOMESTIC, STOCK | KANTOR | LT421DP1028898/DP42110288 | 250190 | 6168508 | STEEL | 30.00 | 38.00 | 102.00 | | | 4.65 |
| GW105092 | 10BL162439 | 11/11/2003 | ACTIVE | DOMESTIC, STOCK | WESTLANDS | LT3DP239258/DP3239258 | 246820 | 6167116 | PVC | 60.00 | 54.00 | 108.00 | INTERSECTS COAL AND SANDSTONE - THICKNESS 12.00 | COAL | 1.03 |
| GW105093 | 10BL162446 | 19/11/2003 | ACTIVE | DOMESTIC, STOCK | SHILLINGFORD | LT12DP1034680/DP121034680 | 252884 | 6165950 | PVC | 120.00 | 126.00 | 175.00 | INTERSECTS COAL - THICKNESS 3.00 / ENDS IN PERMIAN | COAL | 1.66 |
| GW105097 | 10BL161918 | 31/10/2003 | ACTIVE | DOMESTIC, STOCK | WHARE TAU | LT1DP858547/DP1858547 | 253767 | 6167150 | PVC | 90.00 | 160.00 | 233.60 | INTERSECTS COAL, THICK 4.00 / ENDS IN SANDSTONE WITH COAL FLECKS | COAL | 3.76 |
| GW105102 | 10BL161825 | 1/03/2003 | ACTIVE | IRRIGATION | ELGIN | 11838706/DP11838706 | 255075 | 6169083 | STEEL | 97.00 | 52.10 | 151.00 | | | 40.02 |
| GW105308 | 10BL160336 | 1/03/2002 | ACTIVE | IRRIGATION | YURUGA | 401045309/DP401045309 | 250384 | 6167628 | STEEL | 90.00 | 83.00 | 170.00 | BASALT/SANDSTONE, BLACK COAL SEAMS THICK - 17.00/COAL - THICK 4.00 | COAL | 5.00 |
| GW105396 | 10BL162097 | 12/09/2003 | ACTIVE | DOMESTIC, STOCK | WELLS COTTAGE | 1875422/DP1875422 | 250860 | 6169623 | STEEL | 79.00 | 60.00 | 96.00 | | | 7.00 |
| GW105744 | 10BL162857 | 4/02/2004 | ACTIVE | DOMESTIC, STOCK | CAMPBELL | 1/3/758938/DP1758938 | 253955 | 6170109 | STEEL, PVC | 67.00 | 52.00 | | (Was stated as being 673m! - Data omitted.) | | 19.65 |
| GW105950 | 10BL162306 | 1/01/2004 | ACTIVE | IRRIGATION, STOCK | SUMMER DELL FARM | 4609857/DP4609857 | 254257 | 6167973 | STEEL | 79.50 | 72.00 | 168.00 | INTERSECTS COAL - THICKNESS 6.00 | COAL | 20.00 |
| GW105989 | 10BL162707 | 13/01/2004 | ACTIVE | DOMESTIC, STOCK | DUNOLLIE | 6175478/DP254433 | 254433 | 6175478 | STEEL | 97.00 | 64.00 | 150.00 | | | 4.00 |
| GW106103 | 10BL162492 | 27/02/2004 | ACTIVE | DOMESTIC, STOCK | KILLARNEY | 2//801103/DP2801103 | 253879 | 6167685 | PVC | 66.00 | 27.00 | 66.00 | INTERSECTS BASALT | BASALT | 0.10 |
| GW106245 | 10BL163833 | 1/08/2004 | ACTIVE | DOMESTIC, STOCK | KARALEE PARK | 21//549149/DP21549149 | 255801 | 6169286 | PVC | 139.00 | 74.00 | 139.00 | INTERSECTS COAL - THICKNESS 1.00 | COAL | 3.33 |
| GW106246 | 10BL163823 | 30/07/2004 | ACTIVE | DOMESTIC, STOCK | SMETHURST | 100//1078294/DP11602830 | 256676 | 6168550 | PVC | 79.00 | 90.00 | 151.00 | | | 4.00 |
| GW106255 | 10BL161936 | 24/06/2003 | ACTIVE | DOMESTIC, STOCK | WILLOW WOOD | 1//998244/DP1998244 | 256480 | 6172441 | PVC | 84.00 | 44.00 | 109.00 | | | 5.80 |
| GW106311 | 10BL162758 | 1/09/2004 | ACTIVE | INDUSTRIAL (MINERAL WATER EXTR | SUTTON FOREST ESTATE V | 6660349/DP6660349 | 245608 | 6167299 | PVC | 91.00 | 34.00 | 91.00 | INTERSECTS IRONSTONE | | 6.50 |
| GW106342 | 10BL162876 | 19/03/2004 | ACTIVE | IRRIGATION | BADGERY'S CREEK | 611053915/DP611053915 | 249588 | 6167168 | PVC | 114.00 | 67.00 | 151.00 | INTERSECTS BASALT SOIL/COAL THICKNESS - 5.00/ COAL THICKNESS - 8.00 | COAL | 6.70 |
| GW106489 | 10BL165601 | 1/06/2005 | ACTIVE | IRRIGATION | HARTFIELD | 22262737/DP22262737 | 249862 | 6173914 | PVC | 55.00 | 5.00 | 55.00 | | | 25.00 |
| GW106491 | 10BL165600 | 1/06/2005 | ACTIVE | IRRIGATION | CARLISLE DOWNS | 21262737/DP21262737 | 249758 | 6173724 | PVC | 60.00 | 5.00 | 60.00 | | | 25.00 |
| GW106517 | 10BL162362 | 1/06/2004 | ACTIVE | IRRIGATION | TRAFFORD PARK | 23574059/DP23574059 | 254312 | 6170743 | STEEL | 88.00 | 56.00 | 144.00 | | | 6.05 |
| GW106589 | 10BL163098 | 1/01/1940 | ACTIVE | STOCK | MANX PARK | 1//788262/DP1788262 | 253626 | 6176337 | PVC | 0.00 | N/A | 120.00 | | | |
| GW106710 | 10BL165975 | 1/06/2005 | ACTIVE | IRRIGATION | COMFORT HILL | 1744544/DP1744544 | 248321 | 6172535 | STEEL | 109.00 | 35.00 | 115.00 | | | 30.00 |
| GW106711 | 10BL165976 | 1/06/2005 | ACTIVE | IRRIGATION | COMFORT HILL | 1744544/DP1744544 | 247871 | 6172835 | STEEL | 60.00 | 59.00 | 145.00 | INTERSECTS COAL - THICKNESS 6.00 | COAL | 22.06 |
| GW106718 | 10BL163281 | 1/10/1980 | ACTIVE | IRRIGATION | CHERRY TREE HILL | 10262736/DP10262736 | 247480 | 6173463 | STEEL | 19.80 | 35.30 | 93.00 | ENDS IN COAL | COAL | 5.67 |
| GW106855 | 10BL163149 | 28/06/2004 | ACTIVE | DOMESTIC, STOCK | MYSTIC PARK | 4//857597/DP4857597 | 254574 | 6170957 | PVC | 59.00 | 39.00 | 146.00 | | | 9.80 |
| GW106906 | 10BL163126 | 24/12/2004 | ACTIVE | IRRIGATION | SUMMERLEES | 158843/DP158843 | 255615 | 6171846 | STEEL | 72.00 | 42.00 | 150.00 | | | 20.09 |
| GW106958 | 10BL164720 | 11/03/2005 | ACTIVE | DOMESTIC, STOCK | FROST | 2//867224/DP2867224 | 254688 | 6174591 | STEEL | 138.00 | 82.00 | 168.00 | | | 14.90 |
| GW107006 | 10BL164549 | 29/10/2004 | ACTIVE | IRRIGATION | ELGIN | 10838706/DP10838706 | 254526 | 6169294 | STEEL | 90.00 | 64.00 | 175.00 | INTERSECTS COAL - THICKNESS 8.00 | COAL | 10.63 |
| GW107082 | 10BL164551 | 24/12/2004 | ACTIVE | IRRIGATION | HALL | 4807066/DP4807066 | 247735 | 6166020 | PVC | 170.00 | 101.00 | 170.00 | INTERSECTS COAL,SHALE,SANDSTONE - THICKNESS 9.00 | COAL | 1.50 |
| GW107120 | 10BL164831 | 17/03/2005 | ACTIVE | DOMESTIC, STOCK | BROWN | 4//1077545/DP41077545 | 255737 | 6168916 | STEEL | 85.00 | 58.00 | 132.00 | INTERSECTS BASALT | BASALT | 3.35 |
| GW107240 | 10BL164836 | 18/08/2005 | ACTIVE | DOMESTIC, STOCK | TOD | 7806772/DP7806772 | 251555 | 6176142 | PVC | 14.00 | 10.20 | 42.00 | | | 5.00 |
| GW107427 | 10BL165088 | 29/04/2005 | ACTIVE | DOMESTIC, STOCK | WATERLOO | 1//1141890/DP11548621 | 245752 | 6168860 | STEEL, PVC | 72.00 | 32.00 | 72.00 | | | 3.00 |
| GW107434 | 10BL165091 | 2/05/2005 | ACTIVE | DOMESTIC, STOCK | CHARMSEAT P/L | 2217895/DP2217895 | 245872 | 6169586 | PVC | 78.30 | N/A | 78.00 | | | 1.50 |
| GW107435 | 10BL165090 | 5/05/2005 | ACTIVE | DOMESTIC, STOCK | CHARMSEAT P/L | 3718101/DP31141890 | 247272 | 6169190 | STEEL, PVC | 54.00 | 21.00 | 54.00 | | | 3.00 |
| GW107469 | 10BL165729 | 18/10/2005 | ACTIVE | DOMESTIC, STOCK | ROBINSON | 1//527078/DP1527078 | 245070 | 6169590 | STEEL, PVC | 108.00 | 80.00 | 108.00 | INTERSECTS BASALT | | 2.52 |
| GW107535 | 10BL164661 | 1/03/2005 | ACTIVE | IRRIGATION | ROSEDALE | 19262737/DP19262737 | 249655 | 6172612 | STEEL | 58.00 | 12.77 | 114.00 | ENDS IN COAL | COAL | 29.10 |
| GW107625 | 10BL165509 | 15/11/2005 | ACTIVE | DOMESTIC, STOCK | COTTONWOOD | 32//1014368/DP321014368 | 252749 | 6166539 | STEEL | 30.00 | 7.00 | 30.50 | BASALT | BASALT | 2.00 |
| GW107677 | 10BL160762 | 9/09/2002 | ACTIVE | STOCK | N/A | 101//739673/DP101739673 | 249069 | 6168592 | PVC | 103.00 | 44.00 | 103.00 | ENDS IN COAL | COAL | 8.13 |
| GW107679 | 10BL164300 | 27/08/2001 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | BRIDGEWATER | 21053805/DP241095888 | 242579 | 6168814 | PVC | 114.00 | 90.00 | 114.00 | | | 1.00 |
| GW107807 | 10BL164522 | 2/03/2005 | ACTIVE | DOMESTIC, STOCK | SUTTON PARK | 1//112008/DP1112008 | 251666 | 6171294 | STEEL, PVC | 121.00 | N/A | 121.00 | INTERSECTS BASALT | BASALT | 0.76 |
| GW107964 | 10BL600275 | 1/01/2006 | ACTIVE | IRRIGATION | HIGHLANDER | 1711048/DP1711048 | 244325 | 6175286 | PVC | 96.00 | 60.00 | 96.00 | INTERSECTS COAL - THICKNESS 4.00 / ENDS IN GRANITE | COAL | 3.33 |
| GW108004 | 10BL165038 | 2/03/2005 | ACTIVE | DOMESTIC, STOCK | SUTTON PARK | 1112008/DP1112008 | 251939 | 6171152 | STEEL, PVC | 121.00 | N/A | 121.00 | | | 0.76 |
| GW108058 | 10BL600352 | 2/08/2006 | ACTIVE | DOMESTIC, STOCK | BRIDGEWATER LODGE | 2253435/DP2253435 | 244574 | 6166272 | PVC | 66.00 | 62.80 | 102.00 | | | 1.28 |
| GW108108 | 10BL600267 | 10/05/2007 | ACTIVE | DOMESTIC, STOCK | NORMANDIE FARM | 2814974/DP2814974 | 251549 | 6167917 | N/A | N/A | N/A | N/A | | | |
| GW108194 | 10BL600325 | 1/12/2005 | ACTIVE | IRRIGATION | WONGONBRA | 311147/DP311147 | 251005 | 6172692 | STEEL | 42.00 | 24.00 | 121.50 | INTERSECTS COAL - THICKNESS 3.50 | COAL | 21.00 |
| GW108195 | 10BL600326 | 1/12/2005 | ACTIVE | IRRIGATION | WONGONBRA | 311147/DP311147 | 250939 | 6172001 | STEEL | 42.00 | 28.00 | 126.00 | INTERSECTS COAL - THICKNESS 5.00 | COAL | 7.96 |
| GW108223 | 10BL600417 | 1/07/2006 | ACTIVE | DOMESTIC, STOCK | WYOMING | 10548621/DP10548621 | 245584 | 6169650 | PVC | 90.00 | 60.00 | 90.00 | INTERSECTS BASALT/IRONSTONE | BASALT | 3.33 |
| GW108271 | 10BL600340 | 26/08/2006 | ACTIVE | DOMESTIC, STOCK | VINE LODGE | 1596495/DP1596495 | 254281 | 6167270 | PVC | 66.00 | 15.00 | 66.00 | INTERSECTS BASALT/SOAPSTONE | BASALT | 1.00 |
| GW108425 | 10BL600854 | 21/11/2006 | ACTIVE | DOMESTIC, STOCK | MIHAJLOV | 34//243688/DP34243688 | 251487 | 6165771 | PVC | 126.00 | 92.00 | 168.00 | INTERSECTS COAL - THICKNESS 3.00/COAL - THICKNESS 3.00 | COAL | 3.30 |
| GW108469 | 10BL601907 | 31/08/2007 | ACTIVE | DOMESTIC, STOCK | BONHEUR | 5//979138/DP5979138 | 255171 | 6174696 | ABS, PVC | 114.00 | 76.00 | 114.00 | | | 4.00 |
| GW108825 | 10BL164774 | 27/03/2007 | ACTIVE | DOMESTIC, STOCK | COOK | 1//718830/DP1718830 | 248345 | 6176790 | PVC | 12.00 | 52.00 | 79.00 | | | 5.74 |
| GW108833 | 10BL601276 | 1/04/2007 | ACTIVE | DOMESTIC, STOCK | KIRKAM MANOR | 2//803085/DP2803085 | 253326 | 6170528 | STEEL, PVC | 85.00 | 48.00 | 85.00 | | | 6.60 |
| GW108868 | 10BL164299 | 12/05/2008 | ACTIVE | DOMESTIC, IRRIGATION, STOCK | JAMASA PARK | 21//1049146/DP211049146 | 244830 | 6169981 | N/A | N/A | N/A | 20.70 | | | |
| GW109039 | 10BL165129 | 14/07/2008 | ACTIVE | DOMESTIC, STOCK | CORLETTE | 22//574059/DP22574059 | 254164 | 6171137 | N/A | N/A | N/A | 120.00 | | | |
| GW109084 | 10BL162162 | 18/07/2008 | ACTIVE | DOMESTIC, STOCK | WONGONBRA | 7//250743/DP7250743 | 250446 | 6170161 | N/A | N/A | N/A | 139.00 | | | |
| GW109249 | 10BL602575 | 20/08/2008 | ACTIVE | DOMESTIC | INVERGOWRIE | 1//522290/DP1522290 | 253724 | 6165567 | N/A | N/A | N/A | 3.00 | | | |
| GW109323 | 10BL600507 | 11/09/2008 | ACTIVE | IRRIGATION | ROTHERWOOD | 1//1068950/DP11068950 | 252286 | 6169562 | STEEL | 72.00 | 68.00 | 132.00 | | | 15.80 |
| GW109918 | 10BL602838 | 19/02/2009 | ACTIVE | DOMESTIC, STOCK | YALLAMBEE | 2//1093425/DP21093425 | 248938 | 6176472 | PVC | 24.00 | 27.00 | 102.00 | INTERSECTS BASALT | BASALT | 2.78 |
| GW110236 | 10BL600494 | 1/05/2006 | ACTIVE | IRRIGATION | RAVENSWOOD | 30262738/DP30262738 | 251246 | 6174064 | STEEL | 72.00 | 17.00 | 108.00 | INTERSECTS COAL - THICKNESS 2.00 | COAL | 13.00 |
| GW110529 | 10BL603404 | 29/10/2009 | ACTIVE | DOMESTIC, STOCK | WILLIAMSON | 1//1031819/DP41018748 | 251309 | 6166226 | PVC | 139.00 | 120.00 | 175.00 | INTERSECTS COAL - THICKNESS 12.00 | COAL | 1.66 |
| GW110782 | 10BL603557 | 15/12/2009 | ACTIVE | DOMESTIC, STOCK | COLE | 1877253/DP1877253 | 250054 | 6165748 | PVC | 150.00 | 118.00 | 150.00 | | | 2.50 |

# LOG ANALYSIS

STUDY FOR
**HUME COAL Pty LIMITED**
HUME PROJECT

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# LOG ANALYSIS

*for*

## HUME COAL PTY LIMITED

## REPORT PREPARED BY:

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## EXECUTIVE SUMMARY:

This report is primarily designed to assess the porosity of the Hawkesbury Sandstone Formation, which overlies the target Wongawilli coal seam in the Hume Coal Project area. Objectives include:

a) Undertake routine log analysis pertinent to the quantitative porosity values of the Hawkesbury Sandstone Formation interval.
b) Make general observations relevant to the extent that individual clean sandstones can be correlated throughout the area.
c) Determine where in the stratigraphic column the cleanest, most porous sandstones occur.
d) Address whether there is any evidence of gas-filled pore space in the sandstones above the Wongawilli Seam.

The methodology employed in this study follows standard procedure pertinent to detailed log analysis, namely:

1. Select log traces of interest from the borehole LAS file provided by logging contractor.
2. Set up template suitable for visual analysis.
3. Review indicative bulk porosity of clean intervals within the sandstone.
4. Check for areas of neutron/density crossover indicating gas-filled pore space.
5. Present in log form, with appropriate annotations.

Eight (8) individual boreholes were investigated constituting a representative section through the Hume Coal Project area.

The work undertaken indicated the following:

1. Log analysis carried out on boreholes of the Hume Coal project shows that the Hawkesbury Sandstone interval has discrete clean sand intervals that cannot be correlated with confidence between neighbouring boreholes and generally across the area.
2. Bulk porosity for the clean sand intervals reaches a maximum of 25% but is more commonly in the range of 10-20%.
3. The presence of fine-grained low porosity units occurs throughout the stratigraphic interval.
4. There is no evidence to suggest that the highest porosity intervals are closest to the coal seam. They seem to be irregularly distributed throughout the stratigraphic column.
5. Only one borehole showed any evidence of a density/neutron crossover, thereby indicating a possible gas-filled interval. That borehole was HU114CH from 104.5-109.5m. This appears to be a very isolated occurrence as the same unit cannot be observed in the neighbouring borehole HU115CH, or any other borehole investigated. The evidence suggests that the pore space of the Hawkesbury Sandstone Formation is water-filled.

# 1. INTRODUCTION

Hume Coal propose an underground coal mine southwest of Berrima in the Southern Highlands area of NSW (Figure 1).

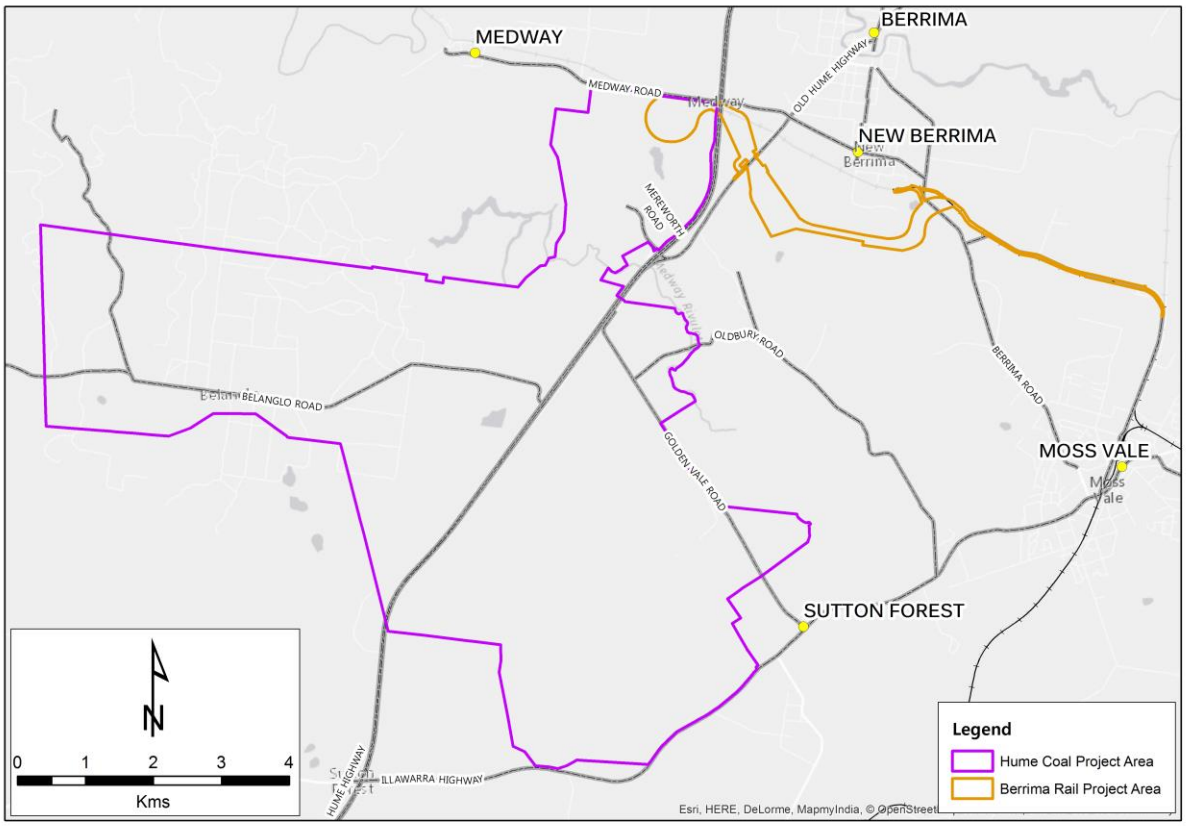



***Figure 1:** General location of Hume Coal Project Area.*

This report is primarily designed to assess the porosity of the Hawkesbury Sandstone Formation, which overlies the target Wongawilli coal seam. This work is supplementary to other work currently being undertaken by Hume Coal and its consultants, including a fugitive emissions assessment by CoalBed Energy Consultants Pty Limited (CoalBed), and an Independent Review of the Sedimentology of the Hawkesbury Sandstone in the Hume Coal Project area by Professor Brian Jones.

The main objectives of this project include:

1. Undertake routine log analysis pertinent to the quantitative porosity values of this interval.
2. Make general inferences relevant to the extent that individual clean sandstones can be correlated throughout the area.

3. Determine where in the stratigraphic column the cleanest, most porous sandstones occur.
4. Address whether there is any evidence of gas-filled pore space in the sandstones above the Wongawilli Seam.

CoalBed is experienced in the provision of general geological/geophysical services and has been engaged in gas-related consulting since 1998.

## 2. METHOD

Hume Coal sub-contracted a recognised logging company (Weatherford) to log all their boreholes. Weatherford collects relevant data suitable for detailed log analysis pertinent to the estimation of porosity including:

- Gamma (GRDE)
- Caliper (CADE)
- Density Porosity (DPRS)
- Neutron porosity (RPRS), and
- Resistivity (FE1 & FE2).

The methodology employed in this study is as follows:

1. Select log traces of interest from the borehole LAS file provided by Weatherford.
2. Set up a template suitable for visual analysis.
3. Review indicative bulk porosity of clean intervals within the sandstone.
4. Check for areas of neutron/density crossover indicating gas-filled pore space.
5. Present in log form, with appropriate annotations.

Eight (8) individual boreholes were investigated, constituting a representative section through the Hume Coal Project area (Figure 2).

Formation evaluation through log analysis works on the assumption that in the cleanest sandstone units the unit is comprised of essentially two (2) elements, quartz and pore space. This is reasonable first approximation for the Hawkesbury Sandstone Formation, which contains only very minor non-quartz minerals (e.g. feldspar, lithic grains, and clays). Log analysis is the most useful methodology for bulk porosity analysis of geological units. Additional observations:

- Crossplots of density porosity versus gamma show that in the formations studied, the shale correction to the density porosity log is quite small (i.e. 100% shale density is very close to 100% sandstone (and both are ~ 2.65 gm/cc). This implies that in a porous zone with low shale content, the density porosity log is a good approximation to real formation porosity without the need for any additional shale correction *provided the pores are water-filled.*

- This observation does not apply to the neutron porosity log, which will only read the actual formation porosity in an absolutely clean unit. Thus, as shale content increases, the neutron porosity log requires increasing shale correction. This is why, when the neutron and density logs are plotted on compatible scales (as in this report), there is in general a gap between them reflecting the shale content of the unit in question.
- The above points are valid in zones with only three (3) components (sandstone, shale, and water in the pore space). If other fluids (gas for example) partially (or totally) fill the pore space, these departures provide evidence of gas indicators. A porosity estimate for such zones can be determined by using an arithmetic average of the density and neutron curves.

At the shallow depths the Hawkesbury Sandstone is encountered in the Hume Coal Project area the expectation would be that the interval would be reasonably porous and water-filled (as evidenced by the number of agricultural water bores in the area). Prior to this log analysis, it was not known whether individual clean sand intervals could be correlated, where they appeared in the stratigraphic column, and how persistent they are laterally.

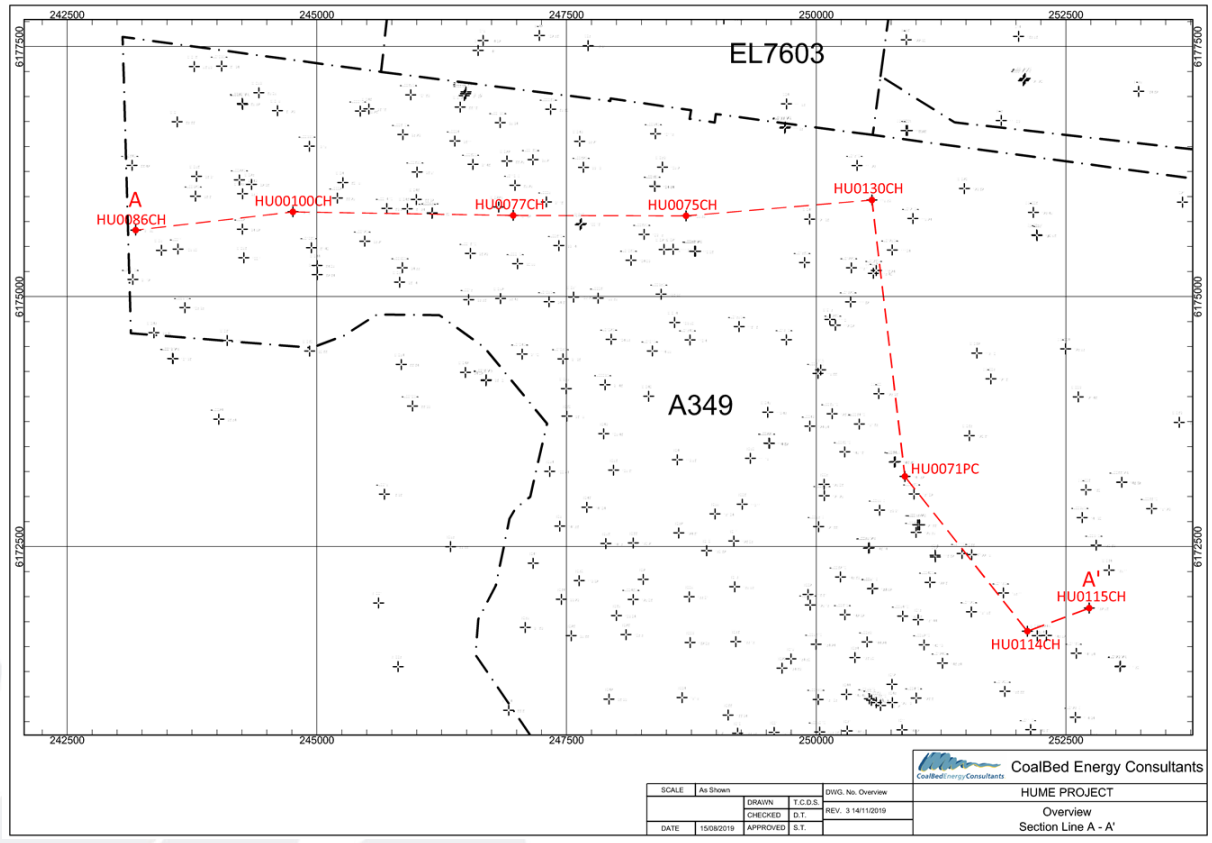



***Figure 2:* Location of boreholes selected for analysis.**

# 3. CHARACTER OF THE HAWKESBURY SANDSTONE

The Hawkesbury Sandstone mineralogy is primarily quartz, with some clays, feldpars and lithic fragments. The formation is usually medium to coarse-grained. Primary porosity (~0-16.5%) is more common than secondary porosity (up to 4.3%) (Gahtani, 2017[1]). The sandstones medium and coarse-grained units have moderate to good groundwater storage and flow potential. Fine-grained deposits represented by impermeable shale and siltstone units are potential confining layers and these provide local vertical permeability seals in the Hawkesbury Sandstone. More detail on the environment of deposition, sedimentology and character of the Hawkesbury Sandstone will be provided in the Independent Review of Sedimentology currently being conducted by Professor Brian Jones (in press).

# 4. RESULTS - LOG ANALYSIS

Log analysis of individual boreholes appears in Figures 3 – 10. A representative section is provided in Figure 11. A detailed copy of the section and the individual borehole files have been provided separately in a DWG file.

The following geophysical properties have been analysed (left to right):

- Gamma (GRDE), green trace and shading.
- Caliper (CADE), red trace and shading.
- Density (DPRS), blue trace.
- Neutron (RPRS), green trace, neutron-density crossovers blue shading.
- Resistivity (FE1 and FE2), red and green trace.

Photographs (where available) of the relevant intervals are contained in the Appendix.

[1] Al Gahtani F (2017) Petrology, Diagenesis and Reservoir Quality in the Hawkesbury Sandstone, Southern Sydney Basin, Australia. J Geol Geophys 6: 283. doi:10.4172/2381-8719.1000283

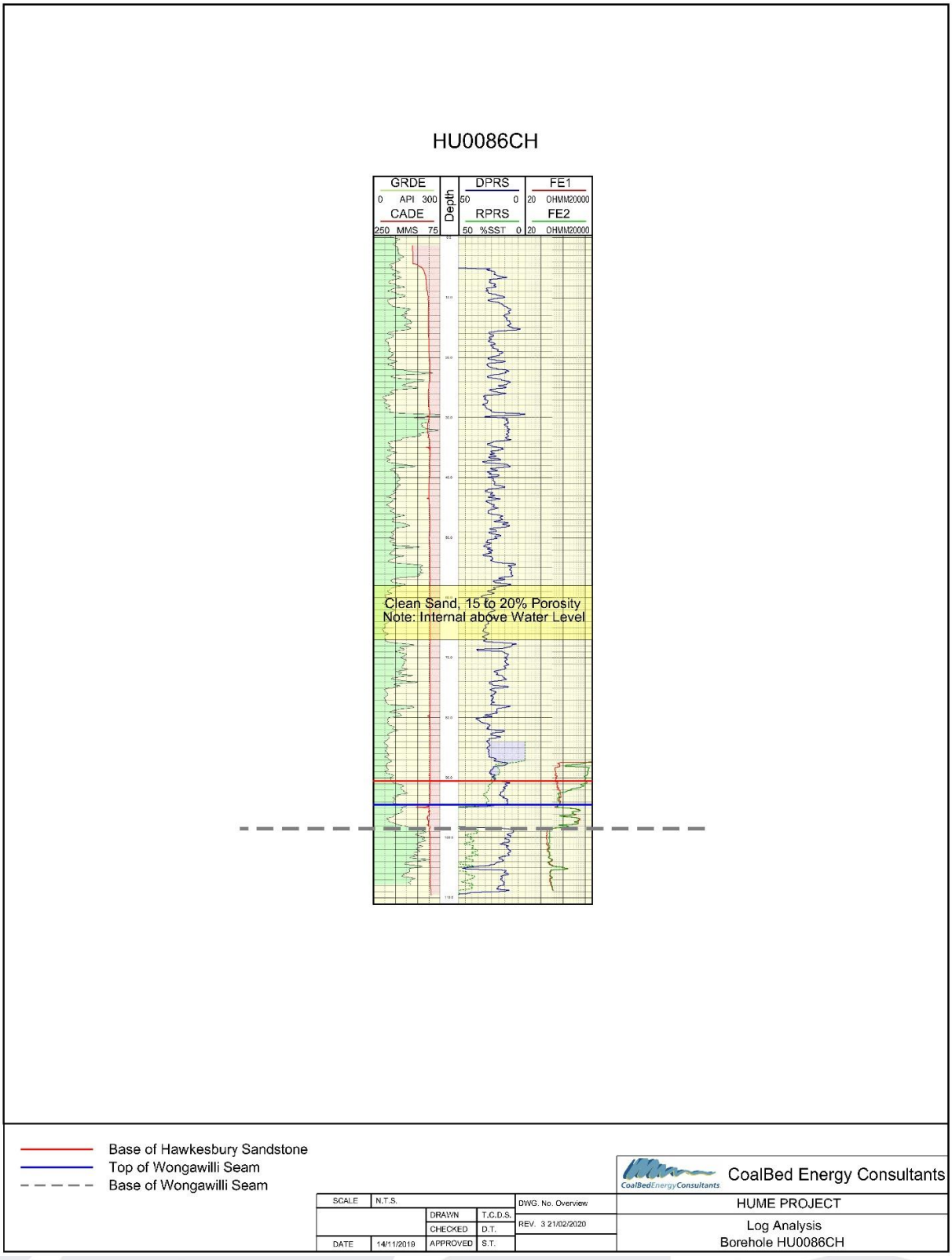



***Figure 3:** Log analysis, borehole HU0086CH.*

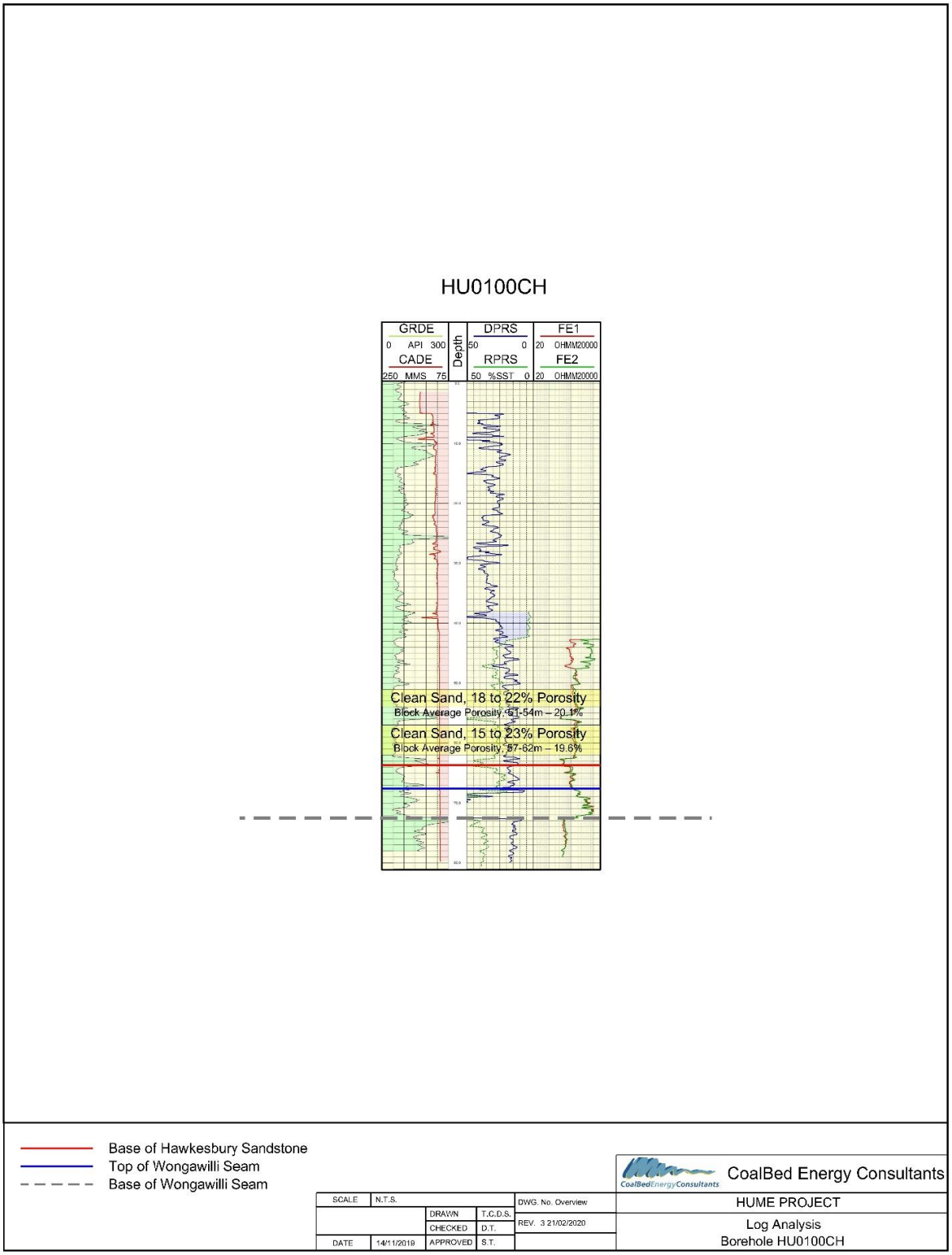



***Figure 4:** Log analysis, borehole HU0100CH.*

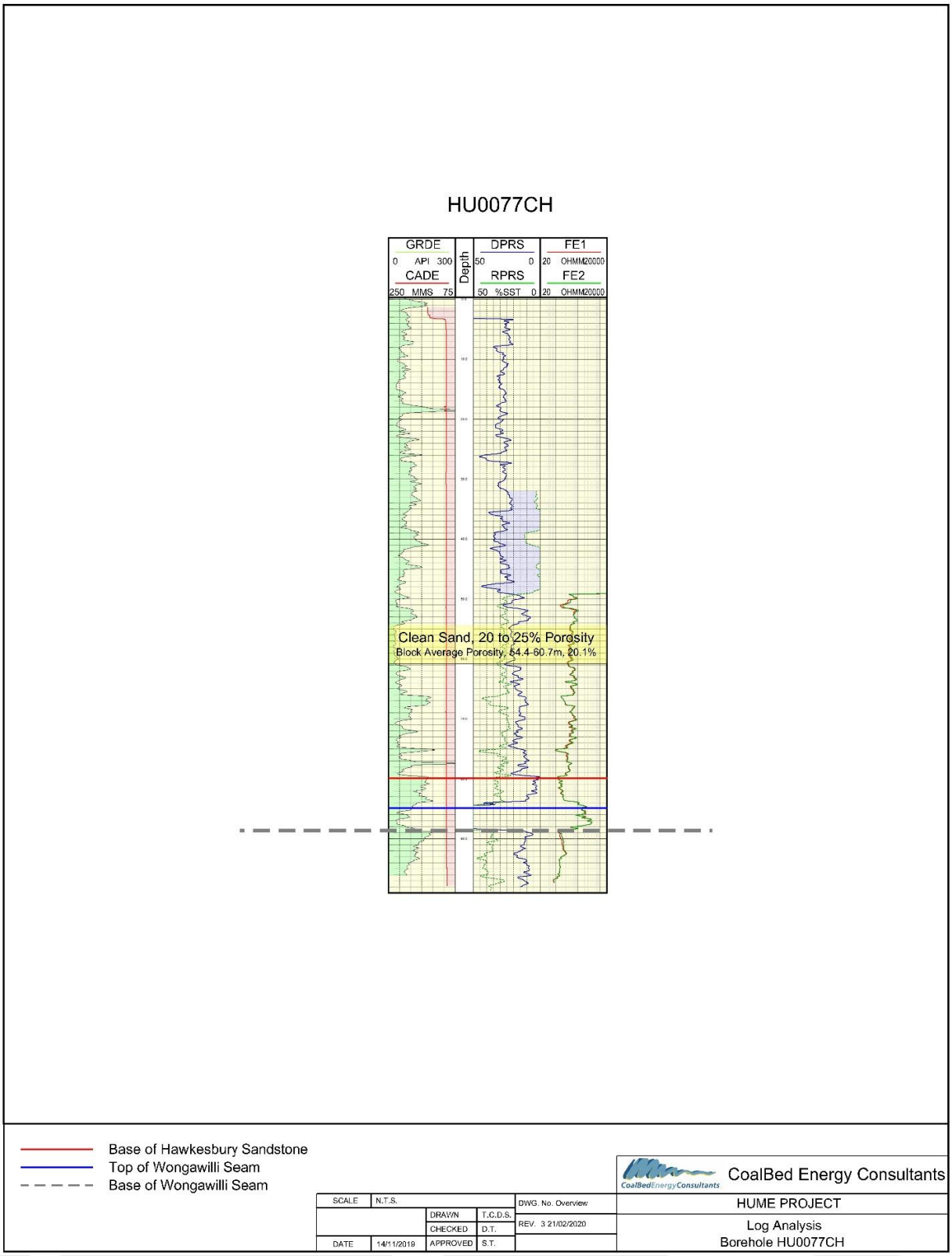



***Figure 5:** Log analysis, borehole HU0077CH.*

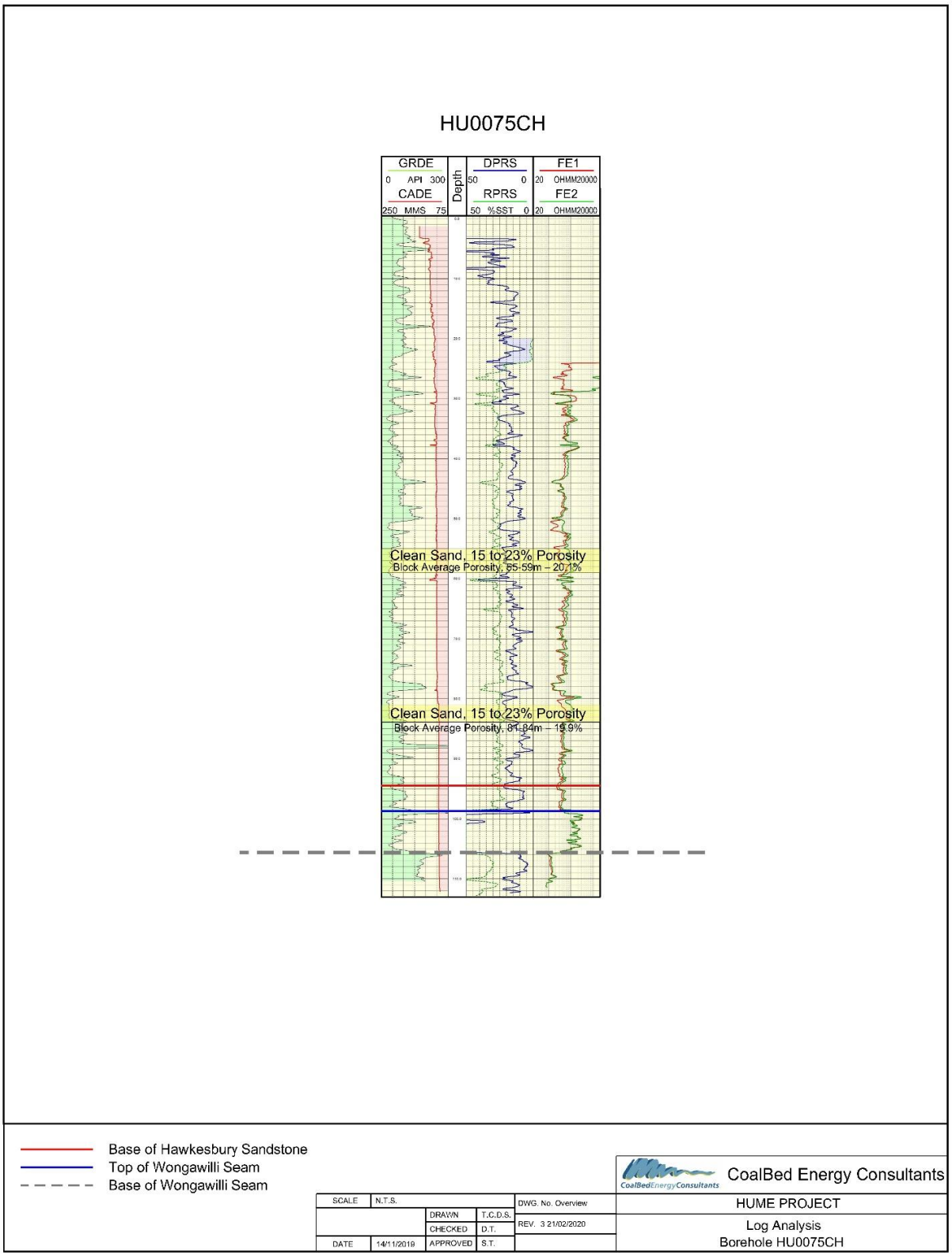



***Figure 6:** Log analysis, borehole HU0075CH.*

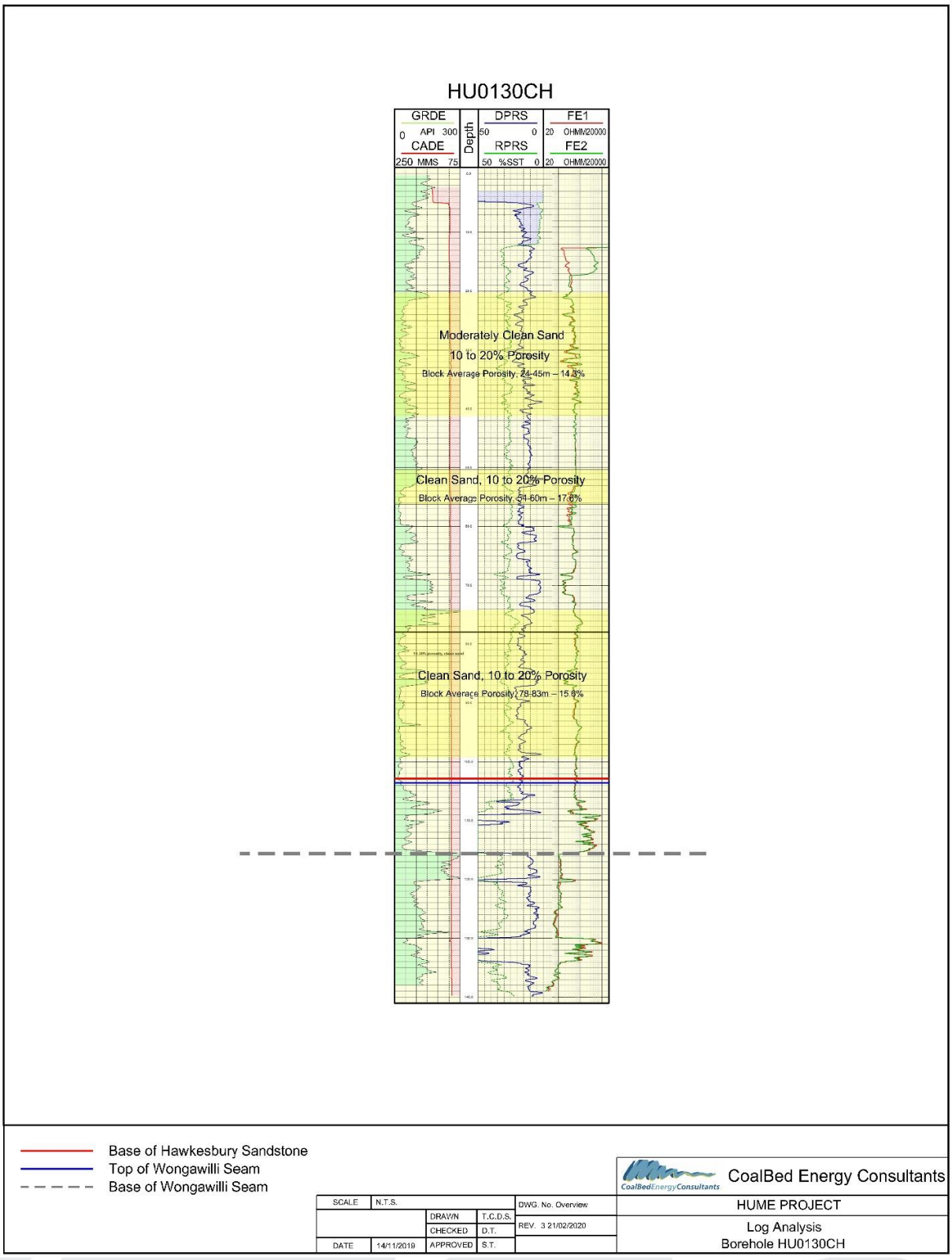



***Figure 7:** Log analysis, borehole HU0130CH.*

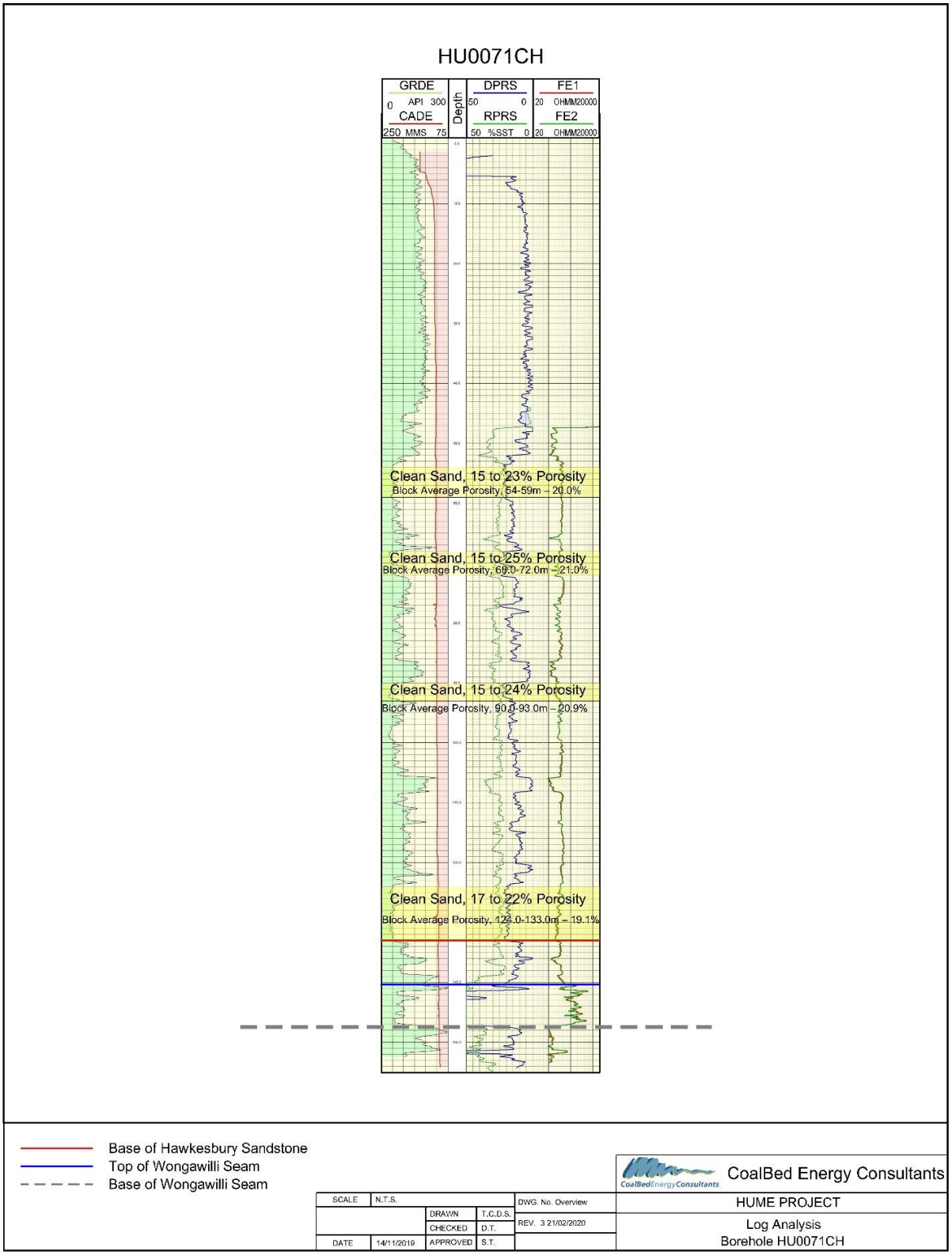



***Figure 8:** Log analysis, borehole HU0071CH.*

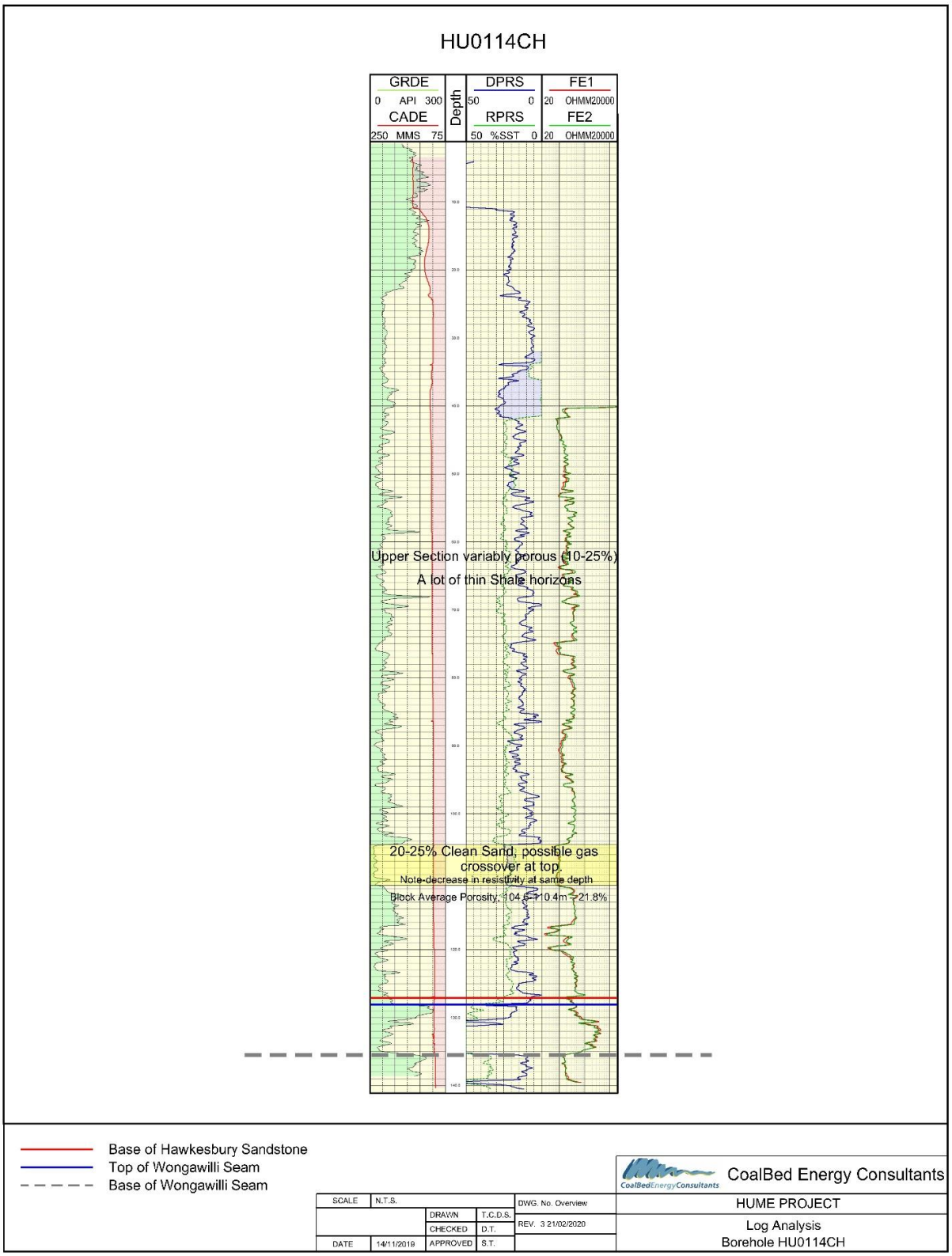



***Figure 9:*** ***Log analysis, borehole HU0114CH.***

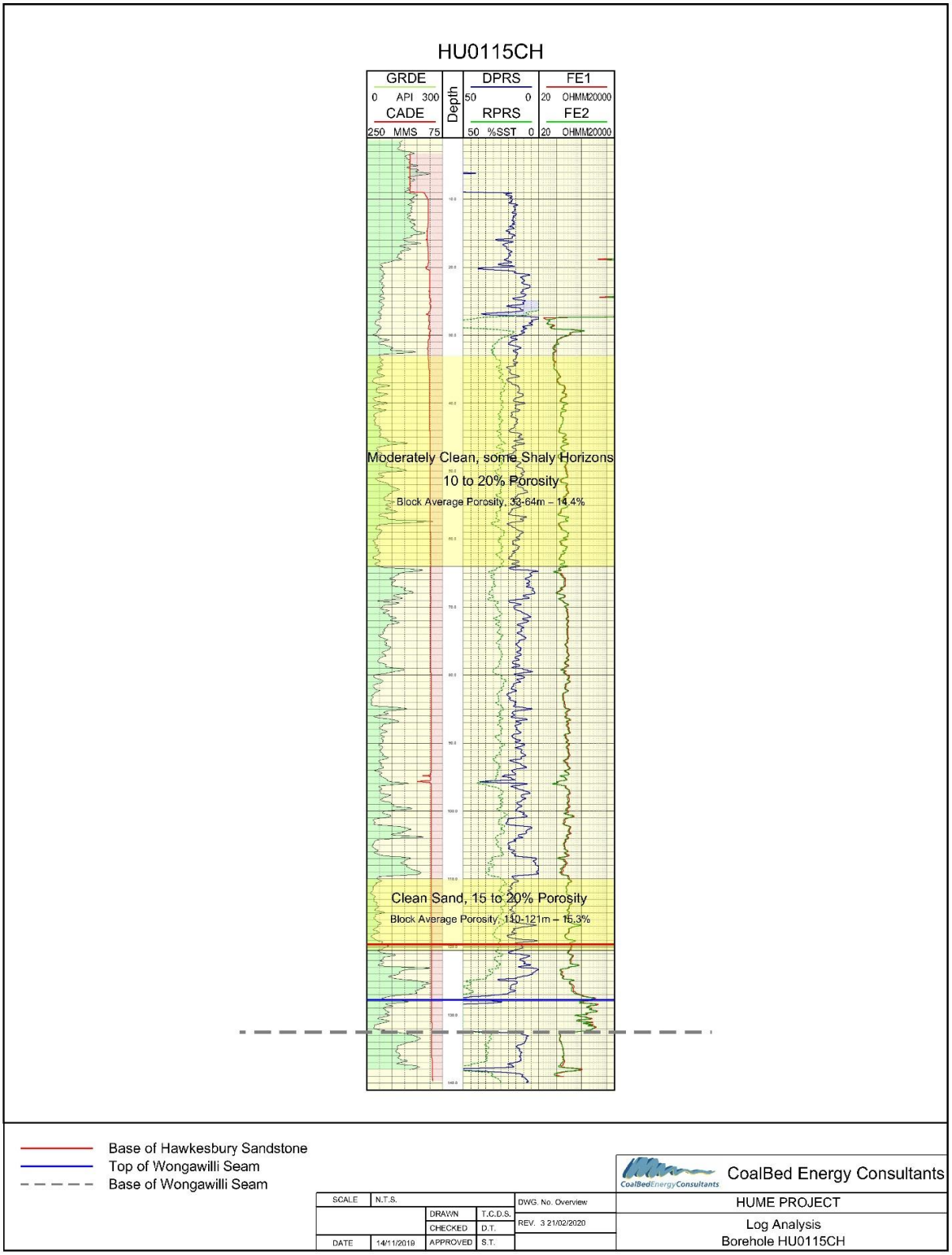
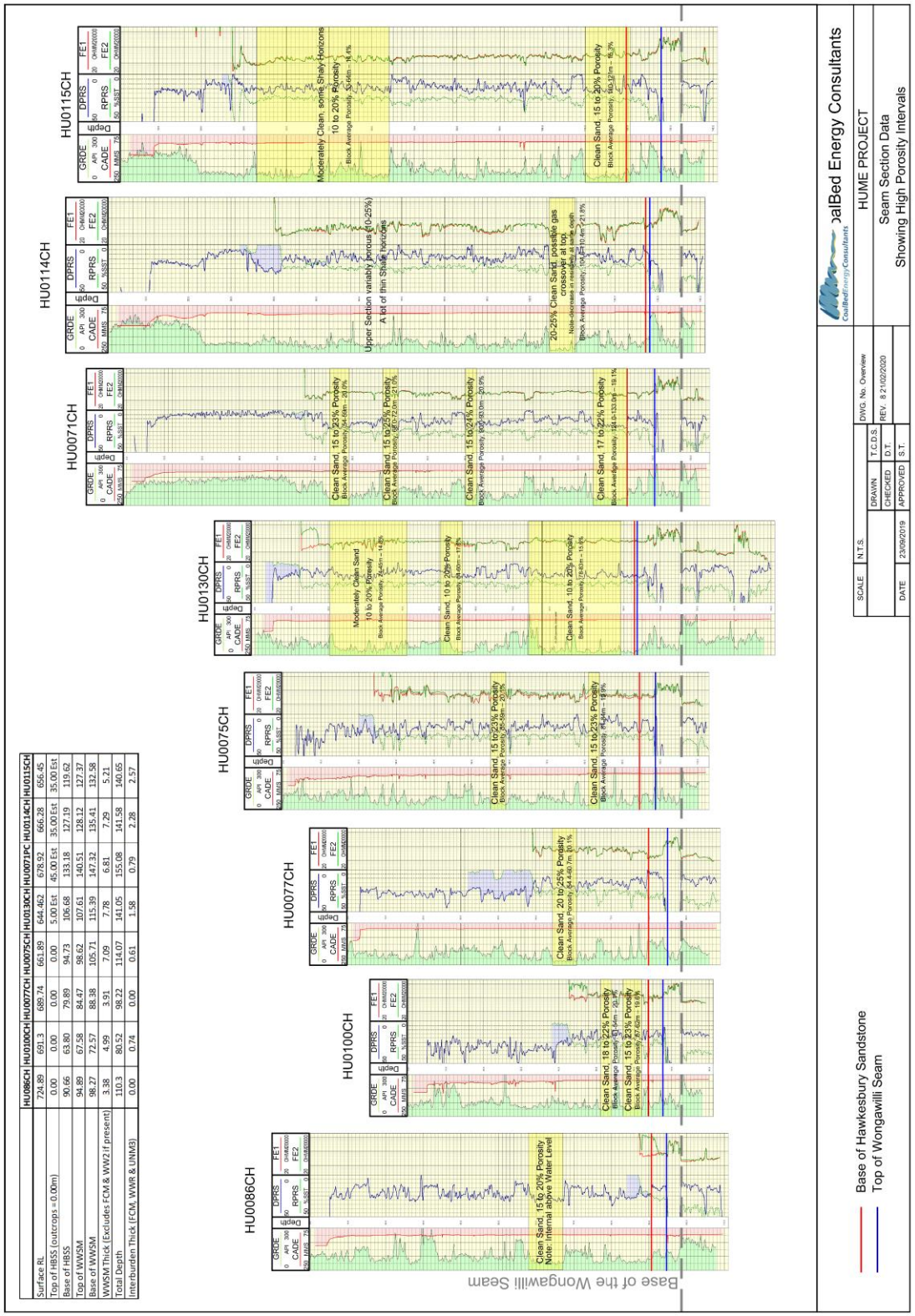



***Figure 10:** Log analysis, borehole HU0115CH.*




| | HU086CH | HU0100CH | HU0077CH | HU0075CH | HU0130CH | HU0071PC | HU0114CH | HU0115CH |
|---|---|---|---|---|---|---|---|---|
| Surface RL | 724.89 | 691.3 | 689.74 | 661.89 | 644.462 | 678.92 | 666.28 | 656.45 |
| Top of HBSS (outcrops = 0.00m) | 0.00 | 0.00 | 0.00 | 0.00 | 5.00 Est | 45.00 Est | 35.00 Est | 35.00 Est |
| Base of HBSS | 90.66 | 63.80 | 79.89 | 94.73 | 106.68 | 133.18 | 127.19 | 119.62 |
| Top of WWSM | 94.89 | 67.58 | 84.47 | 98.62 | 107.61 | 140.51 | 128.12 | 127.37 |
| Base of WWSM | 98.27 | 72.57 | 88.38 | 105.71 | 115.39 | 147.32 | 135.41 | 132.58 |
| WWSM Thick (Excludes FCM & WW2 if present) | 3.38 | 4.99 | 3.91 | 7.09 | 7.78 | 6.81 | 7.29 | 5.21 |
| Total Depth | 110.3 | 80.52 | 98.22 | 114.07 | 141.05 | 155.08 | 141.58 | 140.65 |
| Interburden Thick (FCM, WWR & UNM3) | 0.00 | 0.74 | 0.00 | 0.61 | 1.58 | 0.79 | 2.28 | 2.57 |

***Figure 11:** Summary section of boreholes studied.*

# 5. CONCLUSIONS AND RECOMMENDATIONS

1. Log analysis carried out on boreholes of the Hume Coal project shows that the Hawkesbury Sandstone Formation has discrete clean sand intervals that cannot be correlated with confidence between neighbouring boreholes and generally across the area.
2. Bulk porosity for the clean sand intervals reaches a maximum of 25% but is more commonly in the range of 10-20%.
3. The presence of fine-grained low porosity units occurs throughout the stratigraphic interval.
4. There is no evidence to suggest that the highest porosity intervals are closest to the coal seam. They seem to be irregularly distributed throughout the stratigraphic column.
5. Only one borehole showed any evidence of a density/neutron crossover, thereby indicating a possible gas-filled interval. That borehole was HU114CH from 104.5-109.5m. This appears to be a very isolated occurrence as the same unit cannot be observed in the neighbouring borehole HU115CH, or any other borehole investigated. The evidence suggests that the pore space of the Hawkesbury Sandstone Formation is water-filled.

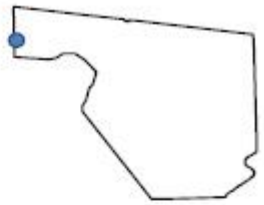
**Scott Thomson**
**Managing Director**
**CoalBed Energy Consultants Pty Limited**

# APPENDIX

HUMECOAL

# BORE ID HU0086CH

**Site Layout ID:** HP135PC
**Location:** Belanglo State Forest
**Survey Details:**
*Easting* 243188.00
*Northing* 6175664.05
**Surface RL:** 724.89
**Total Depth:** 110.30
**Drilled:** *Start* 15/05/2013
*End* 21/05/2013



A349 Boundary - Borehole Location

## Stratigraphy Summary:

Fully cored hole from 5.00m starts in the HBSS. Sub-vertical joints at 7, 8, 19, 30, 50, and infilled at 94.5m. Shales at 30-33m and 54-56m, large cobble/dropstone (missing at 68m). Minor core loss at base of HBSS at 94.68m, which is erosional into roof of WWSM. Broken and cobbled coal at top. Base of WWSM at 98.17m.

## Wongawilli Seam Description:

| Ply Thickness | |
|---|---|
| WWR | - |
| FCM | - |
| WWA | - |
| WWB | - |
| WWC | - |
| WWD | - |
| WWE | 0.79 |
| WWF | 0.23 |
| WWG | 0.55 |
| WWH | 0.30 |
| WWI | 1.23 |
| WWJ | 0.28 |
| Total | 3.38 |

**Coal Quality Data (July 2016)**

[redacted]

| | |
|---|---|
| Top WWSM | 94.89 |
| Base WWSM | 98.27 |
| | 3.38 |

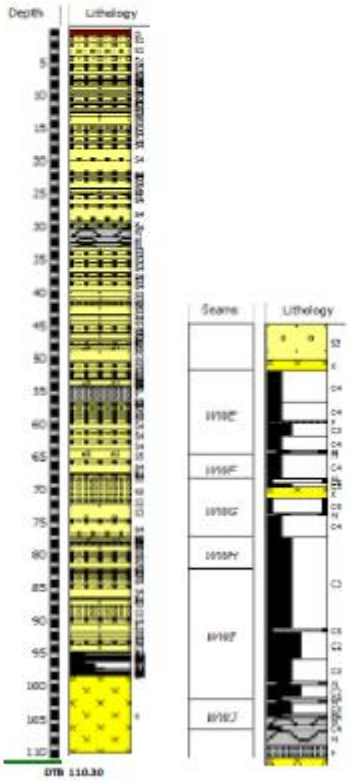
## Geological Structures noted:

No structures interpreted or observed.

## Comments:

Fully Cored Hole
Nil gas observed during drilling operations. No gas testing undertaken of hole during drilling. No coal samples taken for gas.

## Sections




**Geophysical Logs Available**

Density, Caliper, Sonic, Resitivity, Neutron, ATV, Verticality, PDF, & Hardcopies are Available.

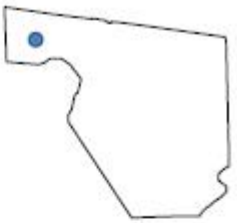
**HU0086CH**

**Clean Sand 15-20% Porosity N.B Interval above Standing Water Level. Interval from 58 to 67m.**

HUMECOAL

# BORE ID HU0100CH

**Site Layout ID:** HP125PC
**Location:** Belanglo State Forest
**Survey Details:**
*Easting* 244762.29
*Northing* 6175847.48
**Surface RL:** 691.30
**Total Depth:** 80.52
**Drilled:** *Start* 15/08/2013 *End* 20/08/2013



A349 Boundary - Borehole Location

## Stratigraphy Summary:

Coring starts at 53.50m in the HBSS. Sub-vertical joints at 49, 56, 66m. HBSS sits unconformably on top of WWSM at 67.47m. Sub-vertical joint/fault present in seam near roof through conglomerate. No FCM. Core loss at 71.48-71.88m. Floor of WWSM at 72.38m. Sub-vertical joint at 75m. Generally OK. WWSM a little broken - small fault?

## Wongawilli Seam Description:

| Ply Thickness | |
|---|---|
| WWR | 0.17 |
| FCM | 0.57 |
| WWA | 0.00 |
| WWB | 0.33 |
| WWC | 0.40 |
| WWD | 0.34 |
| WWE | 0.40 |
| WWF | 0.11 |
| WWG | 0.43 |
| WWH | 0.41 |
| WWI | 1.44 |
| WWJ | 0.39 |
| Total | 4.99 |

| Coal Quality Data (July 2016) | |
|---|---|
| Section Thickness (m) | 3.13 |
| Raw Ash% | [redacted] |
| CC Yld % | |
| CC Ash % | |
| Thermal Yld % | |
| Thermal Ash % | |
| Culm Yld % | |

| | |
|---|---|
| Top WWSM | 68.32 |
| Base WWSM | 72.57 |
| | 4.25 |

Excludes WWR & FCM

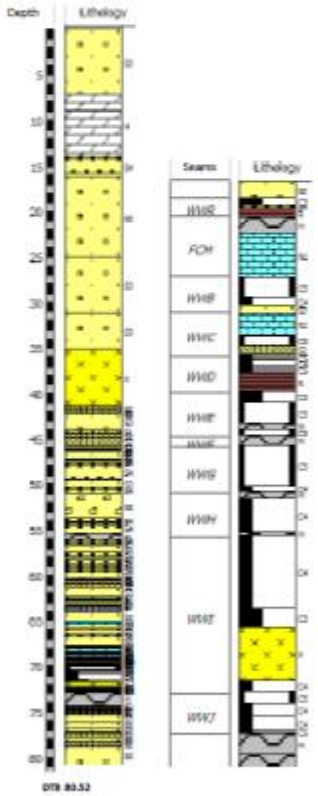
## Geological Structures noted:

Core loss, jointing and minor faulting.

## Comments:

Partially Cored Hole
Nil gas observed during drilling operations. No gas testing undertaken of hole during drilling. No coal samples taken for gas.

## Sections



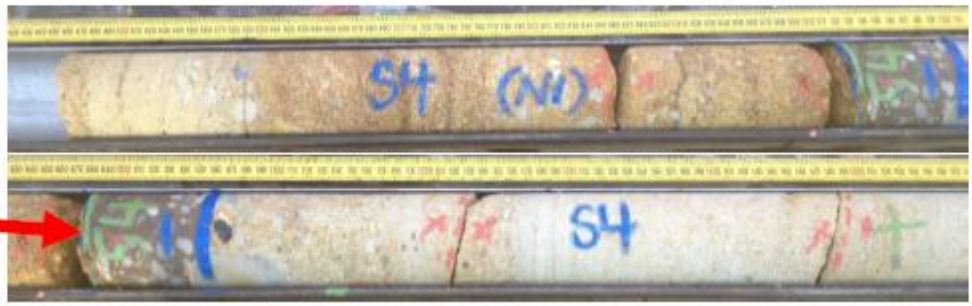

**Geophysical Logs Available**

Density, Caliper, Sonic, Resitivity, Neutron, ATV, Verticality, PDF, & Hardcopies are Available.

HU0100CH

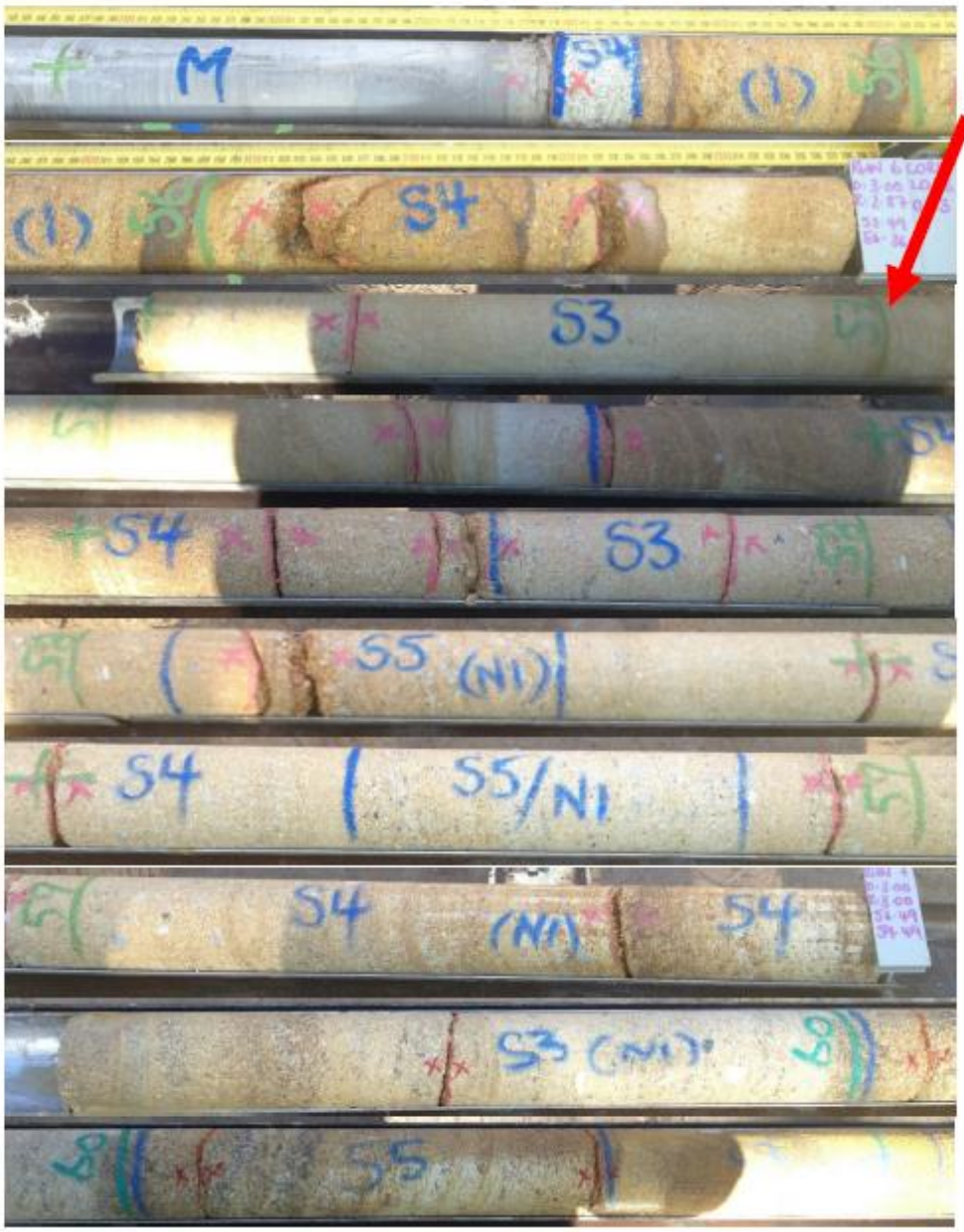
Clean Sand 18-22% Porosity. Block Average Porosity 20.1%. Interval A from 51 to 54m.

Coring commenced at 53.5m.



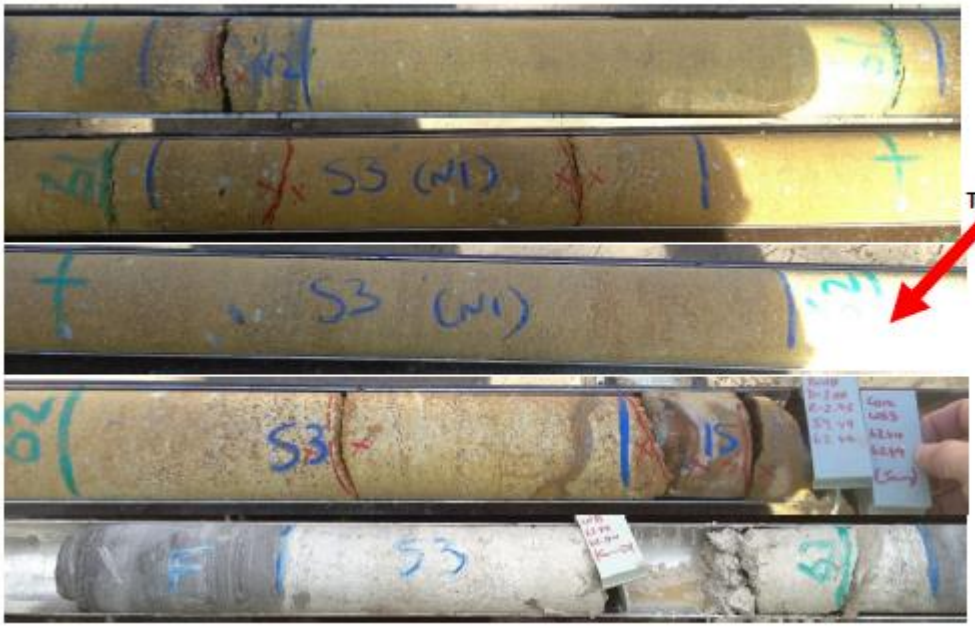

To 54.00

Interval B from 57 to 62m. Clean Sand 15-23% Porosity BAP = 19.6%.




From 57.00

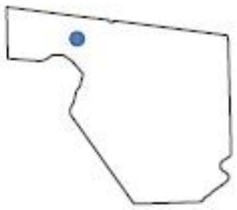
Interval B from 57 to 62m. Clean Sand 15-23% Porosity BAP = 19.6%.



HUMECOAL

# BORE ID HU0077CH

**Site Layout ID:** HP142CH
**Location:** Belanglo State Forest
**Survey Details:** *Easting* 246966.28
*Northing* 6175811.07
**Surface RL:** 689.74
**Total Depth:** 98.22
**Drilled:** *Start* 28/03/2013
*End* 4/04/2013



A349 Boundary - Borehole Location

## Stratigraphy Summary:

Fully cored hole starting from 2.85m. In HBSS. Weathered bedding plane joints. A sub-vertical joint at 17.8m. An weathered/alteration zone associated with a sub-vertical joints (infilled) from 28m to 40m. Weak and broken core throughout. More sub-vertical joints 50.5, 51, 52 and 53m. Faulted at 63.5m, uncertain displacement (>1m). Contains a shale horizon at 65.5-67.5m. Broken and jointed sandstone core at 68m. Joints at 72m & 73.5m. Erosive HBSS into WWSM, roof at approx 83.90m. Well rounded white cobbles at base. Base of WWSM at approx 87.78. Minor sub-vertical joints at 96.5 & 98.0m.

## Wongawilli Seam Description:

| Ply Thickness | |
|---|---|
| WWR | - |
| FCM | - |
| WWA | - |
| WWB | - |
| WWC | - |
| WWD | - |
| WWE | 0.46 |
| WWF | 0.25 |
| WWG | 0.93 |
| WWH | 0.36 |
| WWI | 1.45 |
| WWJ | 0.46 |
| Total | 3.91 |

| Coal Quality Data (July 2016) | |
|---|---|
| Section Thickness (m) | 3.35 |
| Raw Ash% | [redacted] |
| CC Yld % | |
| CC Ash % | |
| Thermal Yld % | |
| Thermal Ash % | |
| Culm Yld % | |

| | |
|---|---|
| Top WWSM | 84.47 |
| Base WWSM | 88.38 |
| | 3.91 |

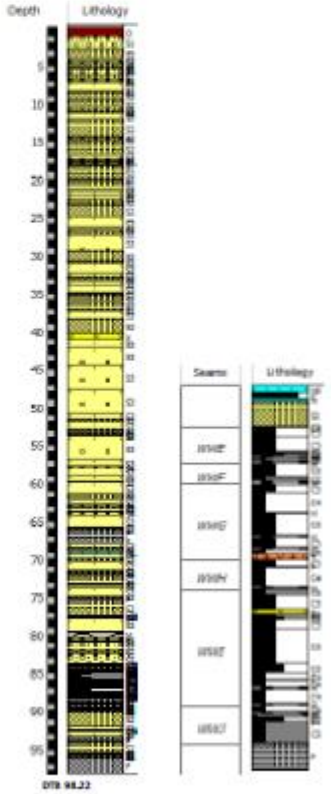
## Geological Structures noted:

Jointed, broken and faulted.

## Comments:

Fully Cored Hole
Nil gas observed during drilling operations. No gas testing undertaken of hole during drilling. No coal samples taken for gas.

## Sections

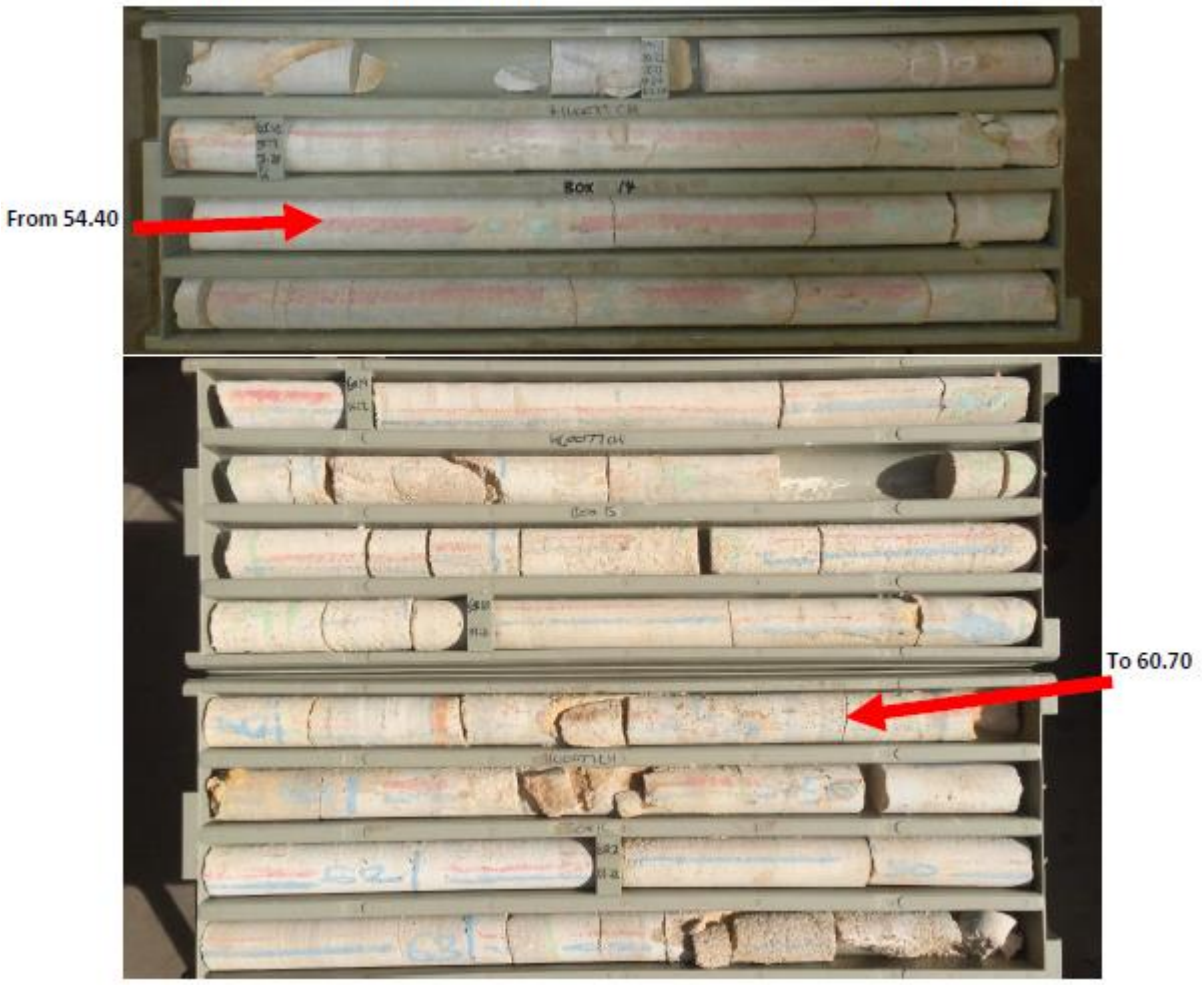



**Geophysical Logs Available - Groundsearch Aust**

Density, Caliper, Sonic, Resitivity, Neutron, ATV, Verticality, PDF, & Hardcopies are Available.

HU0077CH

Clean Sand 20-25% Porosity. Block Average Porosity 20.1%. Interval A from 54.4 to 60.7m.



HUMECOAL

# BORE ID HU0075PC

**Site Layout ID:** HP157PC
**Location:** Belanglo State Forest
**Survey Details:**
*Easting* 248697.47
*Northing* 6175806.69
**Surface RL:** 661.89
**Total Depth:** 114.07
**Drilled:** *Start* 18/03/2013
*End* 27/03/2013

A349 Boundary - Borehole Location

## Stratigraphy Summary:

HBSS at surface, coring starts at 80.40m in the HBSS. The HBSS completely erodes the UNM3 but all the WWSM at 98.55m is present including the FCM & WWR. Base of WWSM at 105.65m approx.

## Wongawilli Seam Description:

| Ply Thickness | |
|---|---|
| WWR | 0.21 |
| FCM | 0.40 |
| WWA | 0.50 |
| WWB | 0.57 |
| WWC | 0.50 |
| WWD | 0.65 |
| WWE | 1.01 |
| WWF | 0.27 |
| WWG | 1.03 |
| WWH | 0.30 |
| WWI | 1.29 |
| WWJ | 0.36 |
| Total | 7.09 |

| Coal Quality Data (July 2016) | |
|---|---|
| Section Thickness (m) | 3.35 |
| Raw Ash% | [redacted] |
| CC Yld % | |
| CC Ash % | |
| Thermal Yld % | |
| Thermal Ash % | |
| Culm Yld % | |

| | |
|---|---|
| Top WWSM | 99.23 |
| Base WWSM | 105.71 |
| | 6.48 |

Ignores WWR & FCM

## Geological Structures noted:

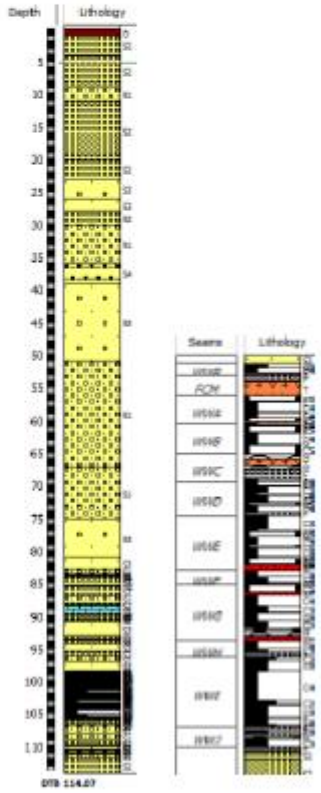
No structures interpreted or observed.

## Comments:

Partially Cored Hole

Nil gas observed during drilling operations. No gas testing undertaken of hole during drilling. No coal samples taken for gas.

## Sections




**Geophysical Logs Available**

Density, Caliper, Sonic, Resitivity, Neutron, Verticality, PDF, & Hardcopies are Available.

HU0075CH

Clean Sand 15-23% Porosity. Block Average Porosity 20.1%. Interval A from 55.0 to 59m. No core.

Clean Sand 15-23% Porosity. Block Average Porosity 19.9%. Interval A from 81.0 to 84m.

Coring commenced at 80.90m.

From 81.00

To 84.00

HUMECOAL

# BORE ID HU0130CH

**Site Layout ID:** HP201
**Location:** Evandale
**Survey Details:** *Easting* 250557.35
*Northing* 6175964.96
**Surface RL:** 644.46
**Total Depth:** 141.05
**Drilled:** *Start* 4/03/2014
*End* 14/03/2014

A349 Boundary - Borehole Location

## Stratigraphy Summary:

Fully cored hole starting at 5.00m in the HBSS. Shale 69-71m, Base of HBSS at 106.60. Coal ply underlain by shale. Top of WWSM at approx 107.97m. FCM is present (0.65m thick). Base of WWSM at approx 115.54m.
ACSM present. TGSM present - jointed in places. Hole cemented and cored due to loss of water at 60.0m mark. Appears to be an open void in strata. Initial rice hulls didn't work so grouted with 600 litres and then cored through section 51-62.6m.

## Wongawilli Seam Description:

| Ply Thickness | |
|---|---|
| WWR | 0.66 |
| FCM | 0.68 |
| WWA | 0.54 |
| WWB | 0.68 |
| WWC | 0.56 |
| WWD | 0.51 |
| WWE | 1.17 |
| WWF | 0.31 |
| WWG | 0.80 |
| WWH | 0.13 |
| WWI | 1.74 |
| WWJ | 0.24 |
| Total | 8.02 |

| Coal Quality Data (July 2016) | |
|---|---|
| Section Thickness (m) | 3.35 |
| Raw Ash% | [redacted] |
| CC Yld % | |
| CC Ash % | |
| Thermal Yld % | |
| Thermal Ash % | |
| Culm Yld % | |

| | |
|---|---|
| Top WWSM | 108.95 |
| Base WWSM | 115.39 |
| | 6.44 |

Excludes WWR, FCM & WWJ Plies.

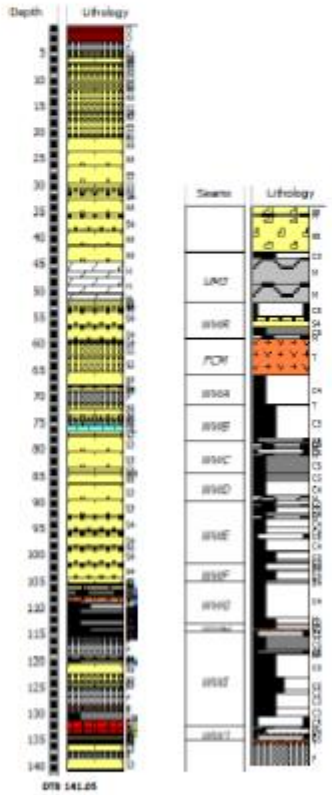
## Geological Structures noted:

No structures interpreted or observed.

## Comments:

Fully Cored Hole
Nil gas observed during drilling operations. 3 WWSM gas samples tested, low contents and high CO2%. 1 ACSM sample taken.

## Sections




**Geophysical Logs Available**

Density, Caliper, Sonic, Resitivity, Neutron, ATV, Verticality, PDF, & Hardcopies are Available.

**HU0130CH Moderately Clean Sand 10-20% Porosity. Block Average Porosity 17.6%.**

**Interval A from 24.45 to 45.0m.**

HU0130CH Clean Sand 10-20% Porosity. Block Average Porosity 17.6%.

Interval B from 54.00 to 60.00m.

HU0130CH Clean Sand 10-20% Porosity. Block Average Porosity 15.6%.

Interval C from 78.00 to 103.00m.

To 103.00

HUMECOAL

# BORE ID HU0071PC

**Site Layout ID:** HP262PZ
**Location:** Wongonbra
**Survey Details:** Easting 250888.00
Northing 6173200.94
**Surface RL:** 678.92
**Total Depth:** 155.08
**Drilled:** Start 18/02/2013
End 20/02/2013

A349 Boundary - Borehole Location

## Stratigraphy Summary:

WMSH at surface down to nearly 45m. Coring starts at 120.05m in HBSS. A couple of sub-vertical joints at 128, 132.5, 133.5. Base of HBSS at 138.77m. A K sample taken at this depth by PB. UNM3 present - two IT samples taken from Box 6. Top of WWSM at approx 140.50m, base at 146.92m. A couple more sub-vertical joints at 149.5m, 151m. ACSM present.

## Wongawilli Seam Description:

| Ply | Thickness |
|---|---|
| WWR | 0.21 |
| FCM | 0.58 |
| WWA | 0.50 |
| WWB | 0.52 |
| WWC | 0.50 |
| WWD | 0.64 |
| WWE | 1.00 |
| WWF | 0.34 |
| WWG | 0.80 |
| WWH | 0.35 |
| WWI | 1.37 |
| WWJ | 0.00 |
| Total | 6.81 |

**Coal Quality Data (July 2016)**

| | |
|---|---|
| Section Thickness (m) | 3.35 |
| Raw Ash% | |
| CC Yld % | |
| CC Ash % | |
| Thermal Yld % | |
| Thermal Ash % | |
| Culm Yld % | |

| | |
|---|---|
| Top WWSM | 141.30 |
| Base WWSM | 147.32 |
| | 6.02 |

Excludes WWR & FCM

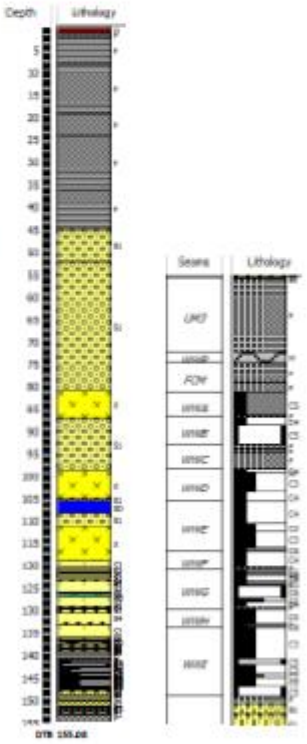
## Geological Structures noted:

No structures interpreted or observed.

## Comments:

Partially Cored Hole
Nil gas observed during drilling operations. No gas testing undertaken of hole during drilling. No coal samples taken for gas.

## Sections




**Geophysical Logs Available**

Density, Caliper, Sonic, Resitivity, Neutron, Verticality, PDF, & Hardcopies are Available.

**HU0071PC Clean Sand 17-22% Porosity. Block Average Porosity 19.1%.**

**Interval D from 124.00 to 133.00m.**

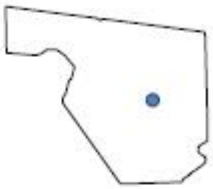
**Coring starts at 120.05m.**

HU0114CH Clean Sand 20-25% Porosity. Block Average Porosity 21.8%.
Interval A from 124.00 to 133.00m. No core in this interval. No photographs.
Coring starts at 120.00m.

HUMECOAL

# BORE ID HU0114CH

**Site Layout ID:** HP246
**Location:** Sutton Park
**Survey Details:** *Easting* 252113.31
*Northing* 6171654.32
**Surface RL:** 666.28
**Total Depth:** 141.58
**Drilled:** *Start* 16/12/2013
*End* 15/01/2014



A349 Boundary - Borehole Location

## Stratigraphy Summary:

WMSH at surface about 23m thick underlain by basalt about 15m thick. Coring starts at 120.00m in the HBSS. Sub-vertical joint at 121m, Calcite infilled sub-vertical joint at 124.50m. Healed fault zone (high angle) at 126.20m. Puggy zone reworked? at 127m. HBSS sits on to pof a full sequence of WWSM at 128.19m. Coal at roof angled and broken. 128-130m heavily fractured/jointed - faulted. High angle structural feature in thick shale lens at 129m. Coal recommences at 130.48m. Base of WWSM at 135.51m. 45 degree joint/fault at 136m. Healed micro faults at 138.50m, soft sediment deformation. ACSM present. Sub-Vertical joint at 141.30m.

## Sections

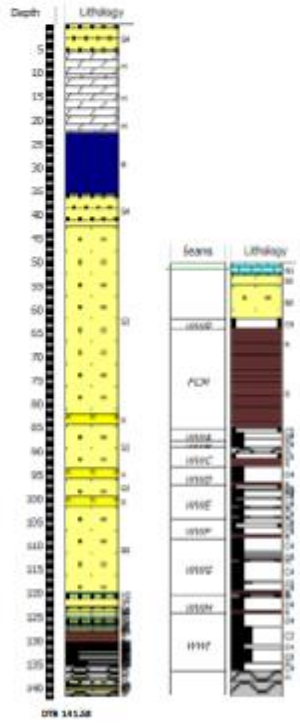
## Wongawilli Seam Description:

| Ply Thickness | |
|---|---|
| WWR | 0.22 |
| FCM | 2.06 |
| WWA | 0.23 |
| WWB | 0.16 |
| WWC | 0.39 |
| WWD | 0.39 |
| WWE | 0.68 |
| WWF | 0.40 |
| WWG | 1.20 |
| WWH | 0.36 |
| WWI | 1.20 |
| WWJ | 0.00 |
| Total | 7.29 |

| Coal Quality Data (July 2016) | |
|---|---|
| Section Thickness (m) | 3.35 |
| Raw Ash% | |
| CC Yld % | |
| CC Ash % | |
| Thermal Yld % | |
| Thermal Ash % | |
| Culm Yld % | |

| | |
|---|---|
| Top WWSM | 130.40 |
| Base WWSM | 135.41 |
| | 5.01 |

Excludes WWR & FCM




## Geological Structures noted:

Healed fault zones, puggy zone, fractured or faulted in places.
FCM is not a tuff - all mudstone and likely to be faulted and abnormal. But has coal overlying it and below it. It is possible that the upper coal could be from the Cape Horn or Hargrave and the mudstone is an Unnamed Member.

## Comments:

Partially Cored Hole
Nil gas observed during drilling operations. No gas testing undertaken of hole during drilling. No coal samples taken for gas.

**Geophysical Logs Available**

Density, Caliper, Sonic, Resitivity, Neutron, ATV, Verticality, PDF, & Hardcopies are Available.

HUMECOAL

# BORE ID HU0115CH

**Site Layout ID:** HP235
**Location:** Sutton Park
**Survey Details:** *Easting* 252732.94
*Northing* 6171885.79
**Surface RL:** 656.45
**Total Depth:** 140.65
**Drilled:** *Start* 17/12/2013
*End* 15/01/2014

A349 Boundary - Borehole Location

## Stratigraphy Summary:

WMSH at surface about 20m thick and about 15m of basalt layer underlying it on to pof HBSS. Coring starts at 116.30m in the HBSS. Base of HBSS (sandstone) at 121.70m. Shale unit (HBSS equivalent?) overlies WWSM at 124.27m approx. WWSM floor at 129.47m. Jointing in a scissor shape pattern at 120.60 and 136.50m. Sub-vertical joints at 121.40m, 136.3m & 137.20m.

## Wongawilli Seam Description:

| Ply Thickness | |
|---|---|
| WWR | 0.09 |
| FCM | 2.48 |
| WWA | 0.30 |
| WWB | 0.21 |
| WWC | 0.45 |
| WWD | 0.40 |
| WWE | 1.07 |
| WWF | 0.38 |
| WWG | 0.78 |
| WWH | 0.34 |
| WWI | 1.28 |
| WWJ | 0.00 |
| Total | 7.78 |

| Coal Quality Data (July 2016) | |
|---|---|
| Section Thickness (m) | 3.35 |
| Raw Ash% | |
| CC Yld % | |
| CC Ash % | |
| Thermal Yld % | |
| Thermal Ash % | |
| Culm Yld % | |

| | |
|---|---|
| Top WWSM | 124.80 |
| Base WWSM | 132.58 |
| | 7.78 |

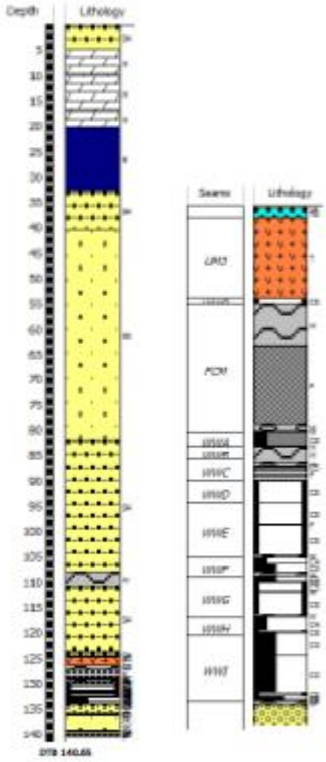
## Geological Structures noted:

No structures interpreted or observed. Approx 15m of basalt below WMSH and near surface (above HBSS).

## Comments:

Partially Cored Hole
Nil gas observed during drilling operations. No gas testing undertaken of hole during drilling. No coal samples taken for gas.

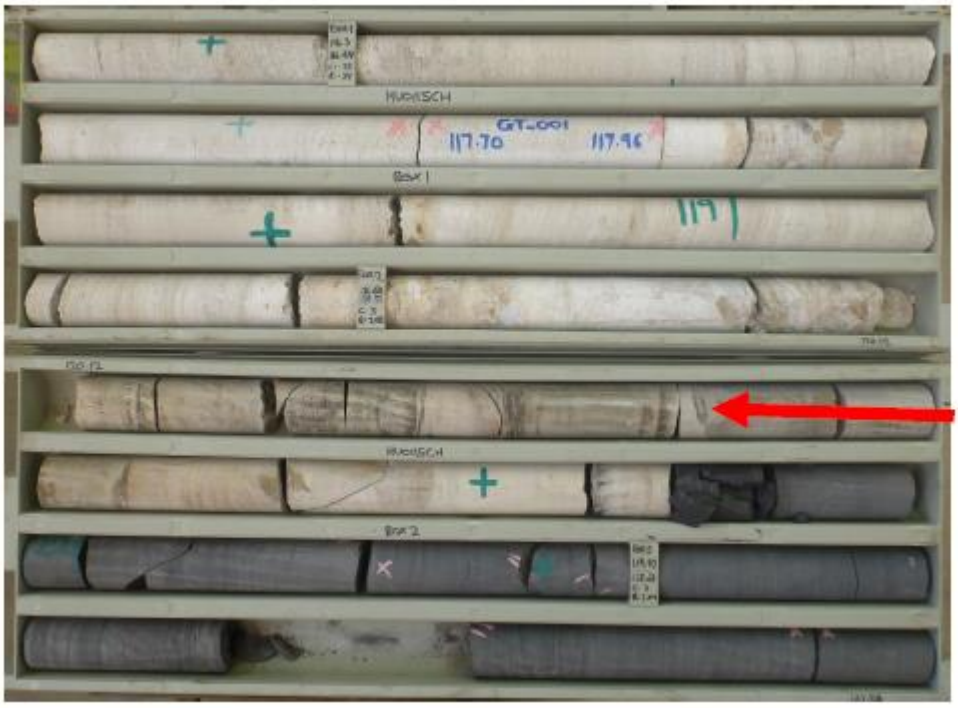
## Sections




**Geophysical Logs Available**

Density, Caliper, Sonic, Resitivity, Neutron, ATV, Verticality, PDF, & Hardcopies are Available.

**HU0115CH Clean Sand 20-25% Porosity. Block Average Porosity 21.8%.**
**Interval B from 110.00 to 121.00m.**
**Coring starts at 116.30m.**



# Analysis of the Wongawilli Coal to Hawkesbury Sandstone succession in the Hume Coal Project area.

**Brian G. Jones, PhD**

**Sedpet Services**

**January 2020**

## EXECUTIVE SUMMARY

Portions of the Eckersley Formation and the Burragorang Claystone are present to varying extents and locations across A349. Hume Coal interpreted these units as part of the Hawkesbury Sandstone Formation. However, the complex nature of the depositional environment here at the southwestern edge of the Sydney Basin has contributed to this misunderstanding. This report demonstrates the presence of the Burragorang Claystone and portions of the Eckersley Formation and their influence on the behavioural aspects of the Hawkesbury Sandstone aquifer and their permeability properties with regard to Hume Coal's proposed mine.

The presence of these finer grained units (up to 8 m thick) between the A Ply of the Wongawilli Coal and the Hawkesbury Sandstone are evident from both surface exposures in quarries to the west of A349 and in the abundant borehole detail from Hume Coal. It is clear from an examination of the Eckersley Formation and Burragorang Claystone that they have significantly lower permeability and porosity than the overlying Hawkesbury Sandstone. These two units are present between the actual Hawkesbury Sandstone and the "Interburden" horizon previously identified by Hume Coal.

Within the Hawkesbury Sandstone porosity and permeability are strongly linked to the sedimentary facies. A northeast-trending channel facies extends through the centre of A349 and contains thicker more porous and permeable sandstone units in the upper and lower Hawkesbury Sandstone. To the northwest and southeast of this channel facies the Hawkesbury Sandstone has common finer grained facies with porous sandstones only 2-5 m thick. These areas have much lower vertical permeability and even the lateral permeability is less likely to be interconnected.

## INTRODUCTION

This study was instigated to determine the characteristics of the lower Hawkesbury Sandstone where it overlies the Wongawilli Coal in the Hume Coal Project area. This study is primarily based on available photographic evidence of core from the Hume Coal drillholes and a few additional available drillholes. It was augmented by a brief field investigation of the local area to obtain stratigraphic and palaeocurrent data. The study was expanded to include all the units above the Farmborough Claystone Member of the Wongawilli Coal or, where this was absent, the youngest preserved ply in the Wongawilli Coal.

## GEOLOGICAL SETTING

The stratigraphic succession above the Wongawilli Coal in the southwestern Sydney Basin is poorly documented in the literature. In the area near and east of Bundanoon typical medium to coarse-grained Hawkesbury Sandstone lies disconformably above the Wongawilli Coal as seen at the Erith Coal Mine and at Meryla Pass (Trigg and Campbell, 2016). However, in the Hume Coal Project area in the Belanglo State Forest and around and to the west of Sutton Forest the stratigraphy has not been described in any detail (Fig. 1).

The contact between the Hawkesbury Sandstone and the Illawarra Coal Measures has been described as erosional by Bos (1988) with the amount of erosion increasing towards the southwest. This culminates in the Hawkesbury Sandstone directly overlying the Wongawilli Coal along the escarpment to the south of Moss Vale (Trigg and Campbell, 2016). However, there is no reported mention of the contact on the southwestern margin of the basin. Bamberry (1990) and Bamberry et al. (1995) show the southern limit of the Eckersley Formation that overlies the Wongawilli Coal within the main part of the Illawarra Coal Measures to lie just north of the Hume Coal Project area (Bamberry, 1991; fig.

26). Bamberry (1991; fig. 81) also shows the southwestern limit of the lower Eckersley Formation to lie northwest of Mittagong, and the southern limit of the Burragorang Claystone (fig. 30), which overlies the Cape Horn Coal Member, to be near Mount Jellore to the north of Mittagong. However, Bamberry (1991; fig 13b) shows the Burragorang Claystone beneath the Hawkesbury Sandstone on the Bunnigalore property in the Belanglo State Forest. Armstrong et al. (1995) noted that towards the southern and southwestern margins of the Southern Coalfield the lower Eckersley Formation merges with the upper Wongawilli Coal and, in places, the Burragorang Claystone directly overlies the Wongawilli Coal.

| GROUP | FORMATION | | MEMBER |
|---|---|---|---|
| **WIANA-MATTA** | ASHFIELD SHALE | | |
| | MITTAGONG FORMATION | | |
| | **HAWKESBURY SANDSTONE** | | |
| **NARABEEN GROUP** | NEWPORT | | |
| | BALD HILL CLAYSTONE | | |
| | BULGO SANDSTONE | | |
| | STANWELL PARK CLAYSTONE | | |
| | SCARBOROUGH SANDSTONE | | |
| | WOMBARRA CLAYSTONE | | |
| | COALCLIFF SANDSTONE | | |
| **SYDNEY SUB-GROUP** | BULLI COAL | | |
| | ECKERSLEY FORMATION | UPPER | LODDON SANDSTONE |
| | | | BALGOWNIE COAL |
| | | | LAWRENCE SANDSTONE |
| | | | BURRAGORANG CLAYSTONE |
| | | LOWER | CAPE HORN COAL |
| | | | UNM1 |
| | | | HARGRAVE COAL |
| | | | UNM2 |
| | | | WORONORA COAL |
| | | | NOVICE SANDSTONE |
| | | | UNM3 |
| | **WONGAWILLI COAL** | | FARMBOROUGH CLAYSTONE |
| | KEMBLA SANDSTONE | | |
| | ALLANS CREEK FORMATION | | |

Figure 1. Stratigraphic units recognised in the Hume Coal project area (units in red are either not recognised or not present).

The southwestern Sydney Basin is close to the depositional edge of the basin where subsidence rates were very low. During the deposition of the Illawarra Coal Measures and Narrabeen Group the major source for detritus in the Sydney Basin came from the New England Fold Belt to the north of the basin with minor contributions from the volcanic island arc to the east, especially during the early part of this depositional phase. Contributions from the Lachlan Fold Belt to the west of the basin are also known, such as the Marrangaroo Conglomerate, Wanganderry Sandstone Member and the Blackmans Flat Conglomerate which are most prominent in the lower part of the Illawarra Coal Measures when subsidence rates were slightly higher. Other quartz-rich sandstone units are present along the western margin of the basin but they have not been well documented. Hence the record of sedimentation and erosion over the 7 Ma (Metcalfe et al., 2015) between the deposition of the Wongawilli Coal and the Hawkesbury Sandstone is very poorly known, understood or documented in the southwestern Sydney

Basin area in any of the literature. This study investigates this interval and sheds more light on its understanding

**Outcrop Geology**

A few outcrops adjacent to the Hume Coal Project area were visited to get a feeling about the local stratigraphy. The most important sites were two small quarries 1 km to the northwest of the project area boundary. Together these quarries exposed the succession from beneath the Wongawilli Coal up into the lower Hawkesbury Sandstone.

In Quarry 2 at 56H 243623 m E 6178568 m S a thick succession of the Kembla Sandstone overlies a carbonaceous shale (possibly the Allens Creek Formation; Fig. 2a) and is overlain by an almost complete sequence of the Wongawilli Coal (including the Farmborough Claystone; Fig. 2b). The upper coal plies are overlain by a well-bedded unit equivalent to the lower Eckersley Formation between the coal and the Burragorang Claystone. The lowest outcrop of the Hawkesbury Sandstone above the Burragorang Claystone lies farther back from the quarry exposure.

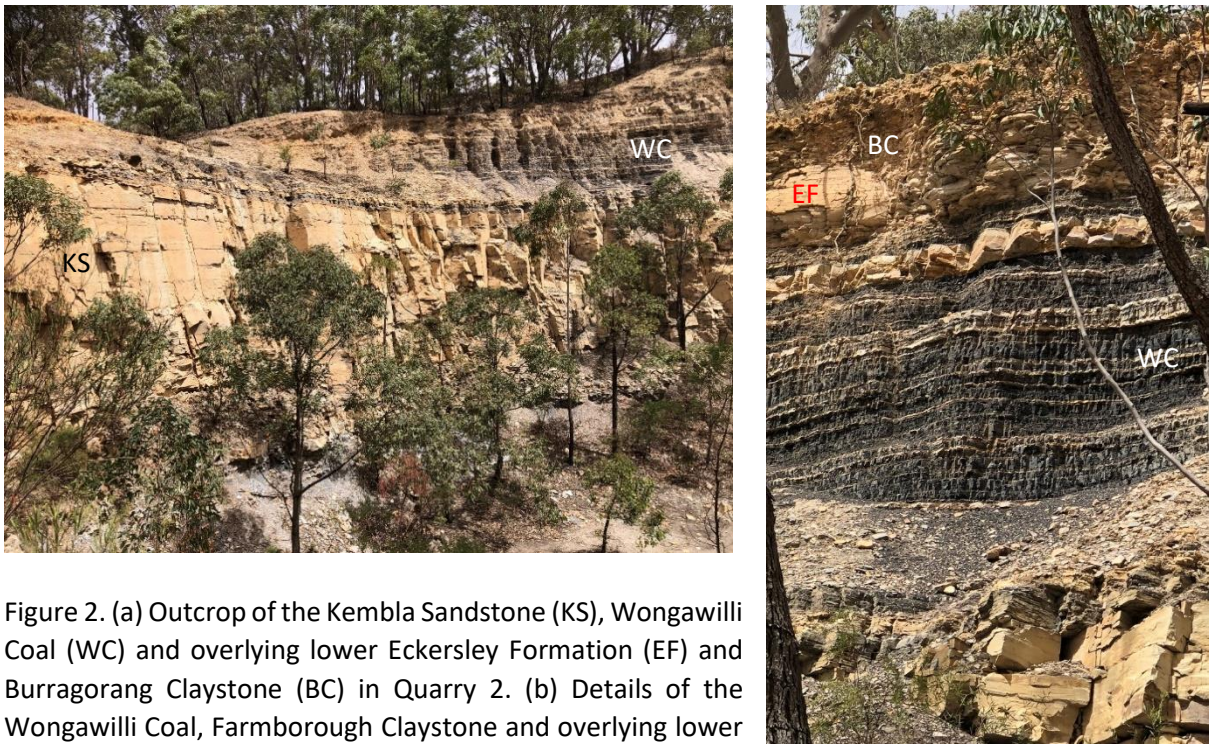



Figure 2. (a) Outcrop of the Kembla Sandstone (KS), Wongawilli Coal (WC) and overlying lower Eckersley Formation (EF) and Burragorang Claystone (BC) in Quarry 2. (b) Details of the Wongawilli Coal, Farmborough Claystone and overlying lower Eckersley Formation and Burragorang Claystone.

In Quarry 1 at 56H 243472 m E 6178825 m S the section through the upper Wongawilli Coal and Farmborough Claystone is separated from the overlying thick massive to weakly horizontally laminated Burragorang Claystone by a thin lensoidal carbonaceous clay and/or coal parting (Fig. 3a, b). The Burragorang Claystone exhibits a few bedding planes that represent at least two ash fall events and probably minor reworking of the ash especially towards the top of the outcrop. This is consistent with the findings reported by Bamberry et al. (1995) for the Burragorang Claystone from farther north along the western margin of the basin and indicates that the Burragorang Claystone is more widespread again south of its previously defined extent. In fact Bamberry (1991; fig. 13b) shows this quarry with the Burragorang Claystone identified. The widespread distribution is to be expected from volcanic eruptions that have formed tuff beds up to 16 m thick from probably more than one eruptive event.

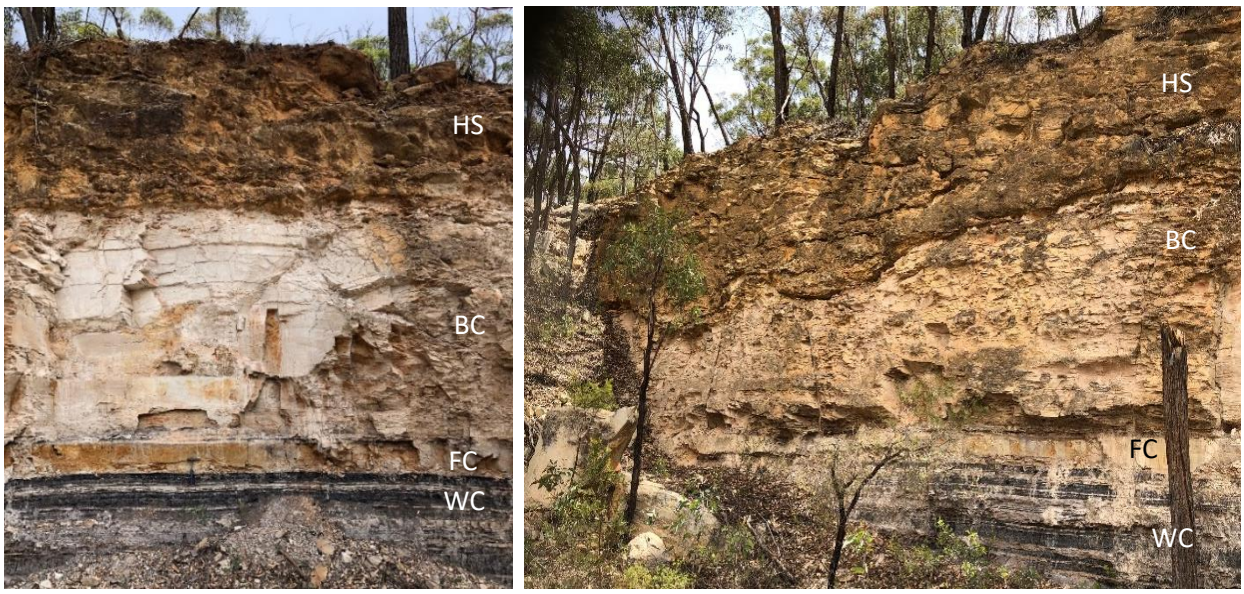



Figure 3. The Wongawilli Coal (WC) and Farmborough Claystone (FC) overlain by carbonaceous claystone and then disconformably by the weakly laminated Burragorang Claystone (BC) that is erosively overlain by the coarse-grained pebbly Hawkesbury Sandstone (HS) which shows some scours into the underlying claystone.

At Quarry 1 the Hawkesbury Sandstone directly overlies the Burragorang Claystone. The contact is sharp and ranges from disconformable in Figure3a to erosively scoured into the Burragorang Claystone (Figure 3b). The Hawkesbury Sandstone in Quarry 1 is coarse-grained with small pebbles (up to 6 cm) in lenses along the basal contact and on some scour surfaces within the sandstone. The sandstone is mainly trough cross-bedded but contains some horizontal bedding.

Outcrops of the lower Hawkesbury Sandstone about 2.5 m above the top of the Wongawilli Coal adit at 56H 244673 m E 6177243 m S show a palaeocurrent trend towards 061° based on 7 cross-bed readings (Fig. 4). Just above Quarry 2 outcrops of the Hawkesbury Sandstone are very weathered but about 60 m higher in the sequence at 56H 243863 m E 6177726 m S the unit is much better exposed and the palaeocurrent trend is towards 049° based on 11 cross-bed readings. An additional palaeocurrent trend of 052° (n=3) was obtained from large well-exposed cross-beds in Wells Creek on Evandale property (56H 250576 m E 6175680 m S; Fig. 5). These outcrops are about 100 m above the base of the Hawkesbury Sandstone in the adjacent holes HU0125 and HU0130 and are very near to the top of the formation at this location. Although these palaeocurrent readings are only from three outcrops they conform to the northeast palaeocurrent trend and gradient determined for the southwestern Sydney Basin by Standard (1969).

Figure 4. Outcrop of planar and trough cross-bedded medium- to coarse-grained pebbly sandstone at the base of the Hawkesbury Sandstone about 2.5 m above the top of the Wongawilli Coal adit.

Figure 5. Large scale planar cross-bedding in the upper Hawkesbury Sandstone in Wells Creek on the Evandale property.

**Drill hole data from the Hume Coal Project area**

The extent, thickness and number of plies recognised in the Wongawilli Coal has been defined in 146 Hume Coal drill holes, as well as previous drill holes including 15 NSW Geological Survey DDH drill holes, 76 New Berrima drill holes, 5 OB drill holes and 78 Sutton Forest drill holes (Fig. 6). These data are presented as three contour maps based on nearest neighbour interpolation in ArcGIS (Figs 7-9).

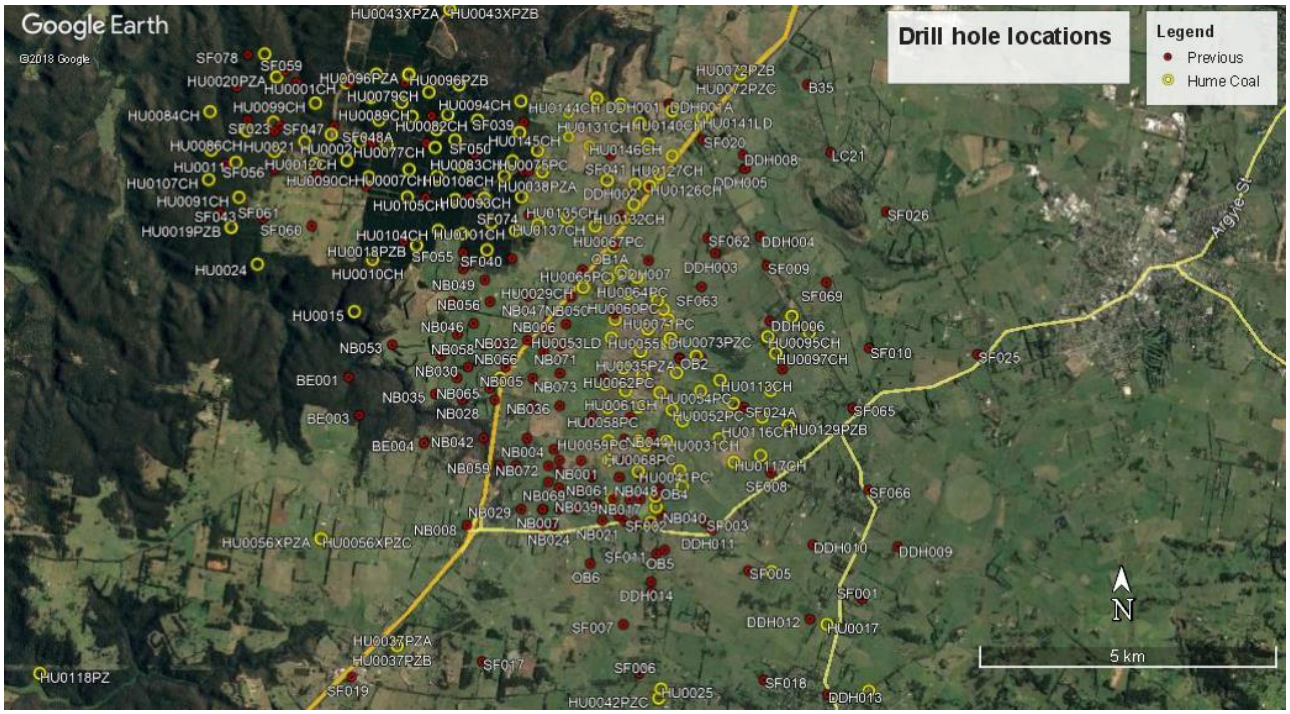



Figure 6. Location of the Hume Coal, NSW Geological Survey DDH, New Berrima, OB and Sutton Forest drill holes in and adjacent to the Hume Coal Project area.

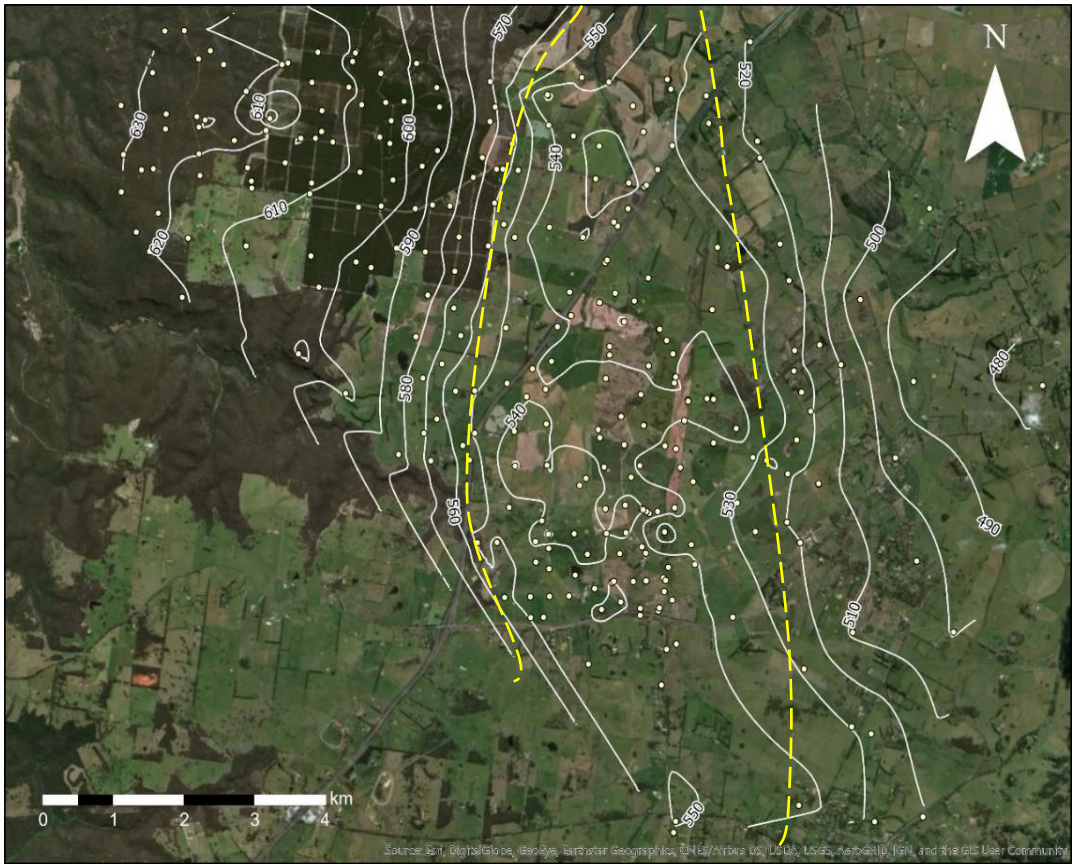



Figure 7. Interpolated contours on the base of the Farmborough Claystone (where present) or the top of the preserved Wongawilli Coal. Drill hole locations are indicated. A lower irregular gradient occurs between dashed yellow lines

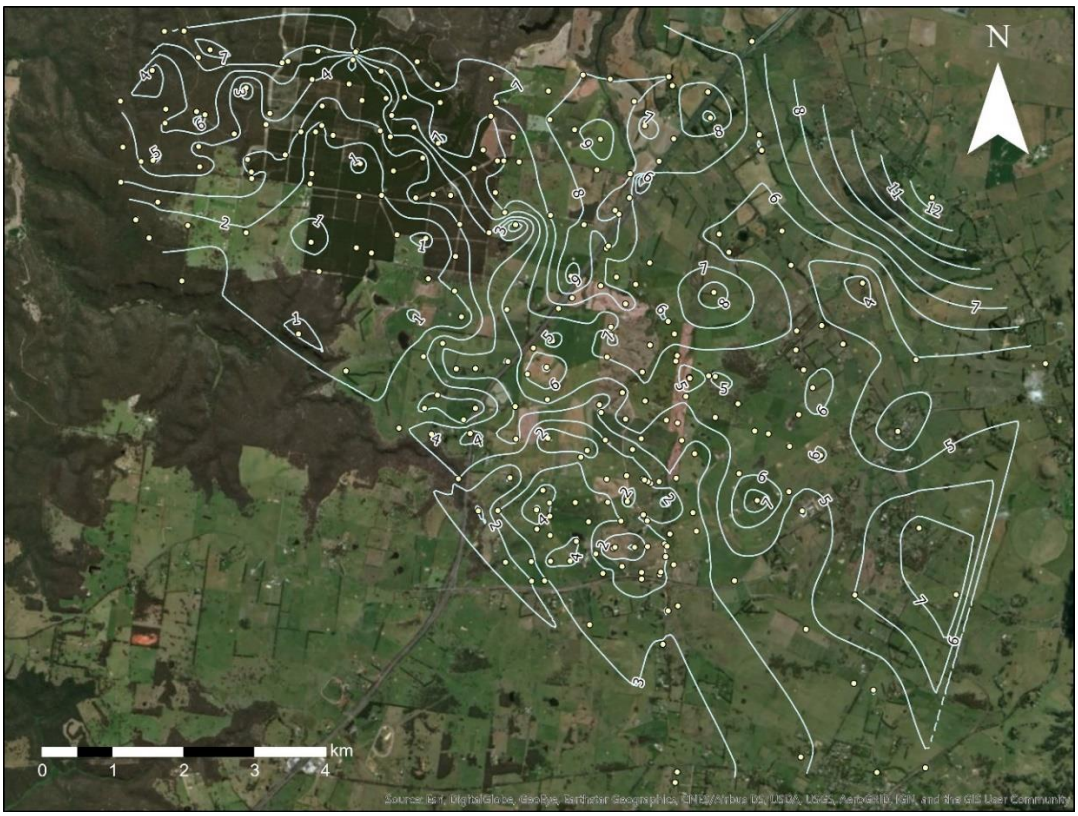



Figure 8. Interpolated contours showing the preserved thickness of the Wongawilli Coal.

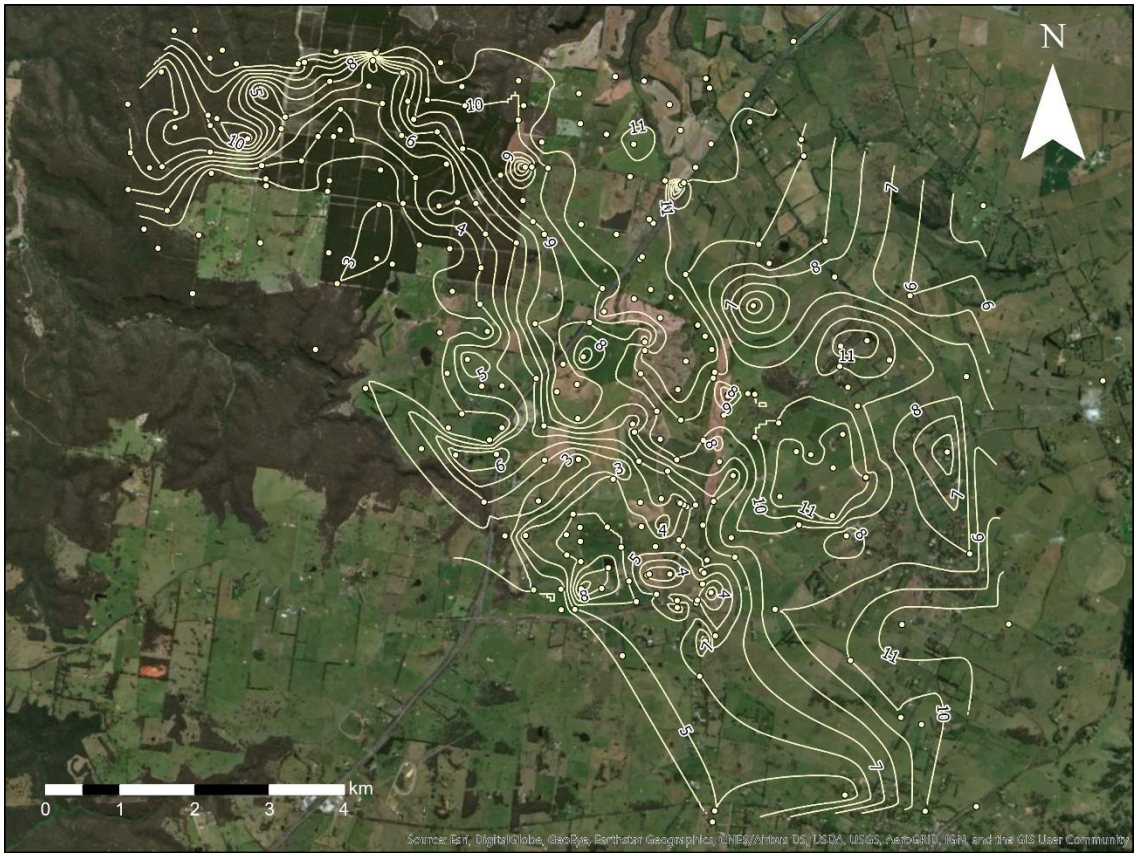



Figure 9. Interpolated contours showing the number of preserved plies (numbered from base to top) in the Wongawilli Coal. The Farmborough Claystone is included as ply 11.

**Wongawilli Coal**

The elevation of the workable section of the Wongawilli Coal (beneath the Farmborough Claystone, if present) rises from 480 m in the east to 630 m in the west (Fig. 7). A 2-4 km wide north-south zone in the central part of the Hume Coal Project area shows a much lower gradient probably due to faulting and diapiric intrusions. Hume Coal have also proposed faulting through this zone based on a variety of exploration techniques. The preserved thickness of the Wongawilli Coal (including the Farmborough Claystone and the roof plies; e.g. see Figs 13 and 15) shows a general increase from the southwest to the northeast (Fig. 8). This decrease in thickness in the west and southwest may be partly attributed to depositional thinning towards the margin of the basin but is probably mainly due to post-depositional erosion of the upper plies in the coal seam. Over most of the Hume Coal Project area the Wongawilli Coal shows local variations of several metres in seam thickness, but shows no clear evidence of broad river channel incision beneath the Hawkesbury Sandstone. Evidence for erosion in the western and southwestern parts of the Hume Coal Project area is also provided by the low number of coal plies preserved in this area (Fig. 8). In this area of thin Wongawilli Coal only the lowest 2 or 3 plies are preserved. The number of coal plies preserved increases both to the north and to the east where moderately extensive areas have the Farmborough Claystone (ply 11 in Fig. 9) preserved above the workable coal seam.

The interval overlying the highest preserved ply of the Wongawilli Coal (beneath the Farmborough Claystone where this is present, Figs 10-11) has been investigated in cores from one hundred and eleven Hume Coal drill holes, fifteen NSW Geological Survey DDH drill holes and three Sutton Forest drill holes. The preserved thickness of the Farmborough Claystone, roof ply and carbonaceous shale

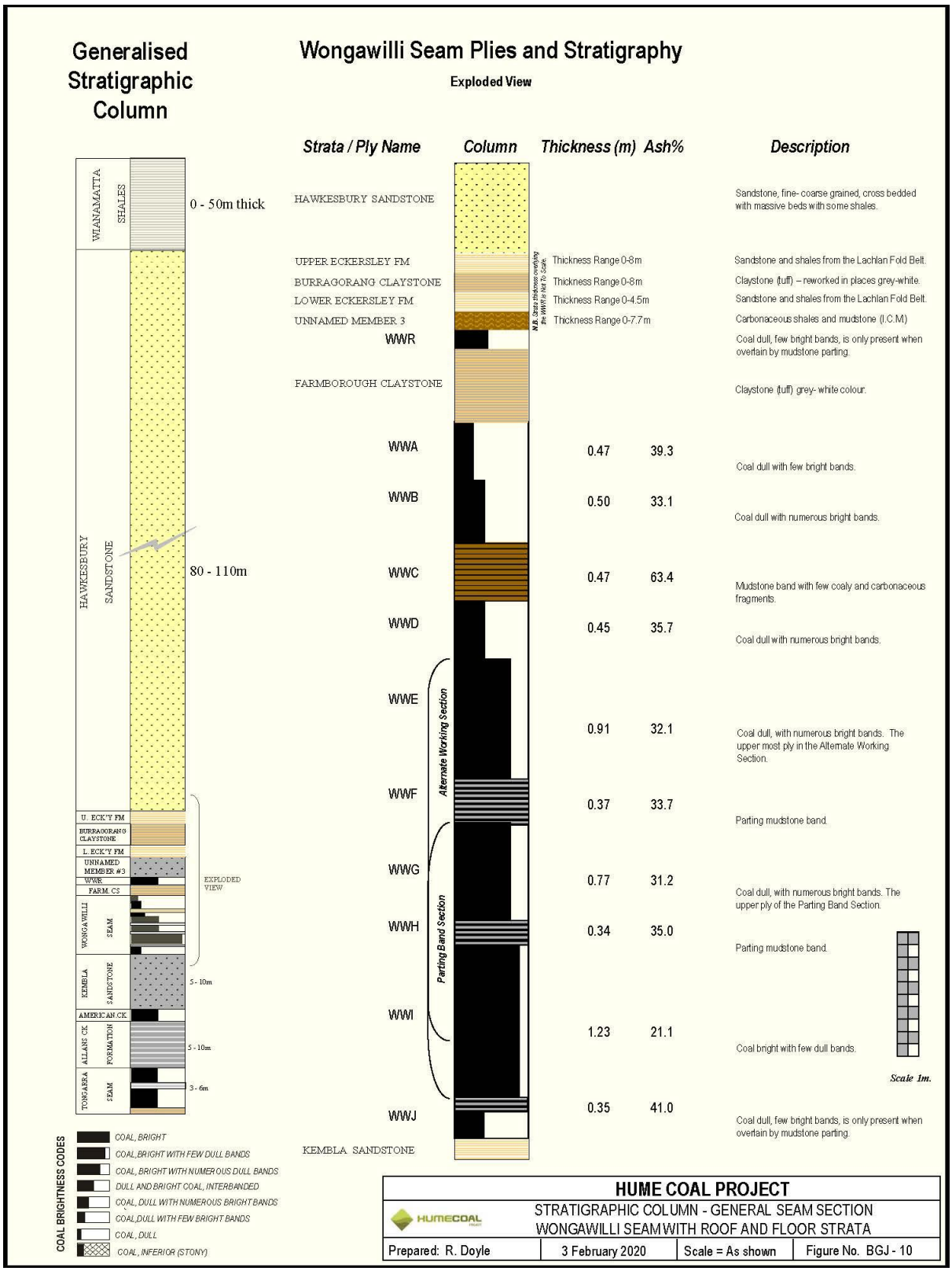



Figure 10. Stratigraphy of the Wongawilli Coal and associated strata.

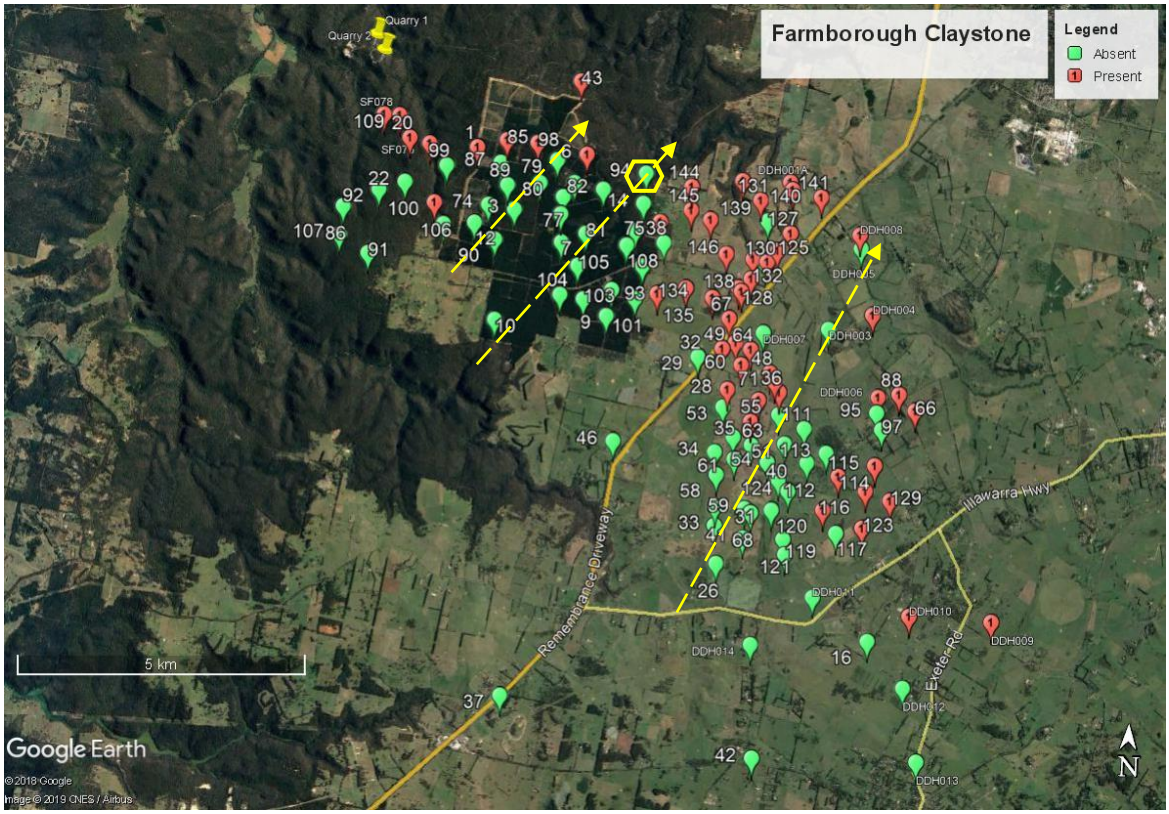



Figure 11. Location of preserved Farmborough Claystone showing possible channel locations

Figure 12. Thickness of the Farmborough Claystone and the overlying R ply of the Wongawilli Coal together with the carbonaceous shale of the Unnamed Member 3 (UNM3).

above the Wongawilli Coal is shown in Figure 12. The Farmborough Claystone is preserved along the northern and northeastern margins of the Hume Coal Project area but has been eroded over most of the southwestern portion of the project area (Fig. 11). One area around HU0094CH (yellow hexagon on Fig. 11) shows a narrow northeasterly zone of erosion of the Farmborough Claystone suggesting possible channel incision in this area. Possible channel incision is also suggested by the absence of upper Wongawilli Coal and overlying shale along a narrow belt extending north-northeast from HU0012CH in Figures 11 and 12. Figures 11 and 12 also illustrate a second northeast-trending zone with thinner preservation of the Farmborough Claystone and overlying shale from HU0034CH to DDH005. The R ply of the Wongawilli Coal was either never deposited or has been extensively eroded along the southern and southwestern portion of the Hume Coal Project area.

**Unnamed Member No. 3 (UNM3)**

The Unnamed Member 3 (UNM3) represents the basal unit of the Eckersley Formation recognised in the Hume Coal project area. This unit consists predominantly of carbonaceous mudstone or shale ranging from structureless to weakly or well laminated (Figures 13, 15-18). It is very similar in character to the shales in the underlying Wongawilli Coal. However, in places it contains thin sandstone interbeds at the base or within the unit representing higher energy pulses of deposition. The unit commonly ranges in thickness from 1-3 m but ranges up to 7.7 m in HU0082. It occurs above the A ply, Farmborough Claystone or R ply of the Wongawilli Coal in most areas where these units are present. The few areas where lower coal plies are overlain by thin carbonaceous mudstone it probably represents an intra-seam mudstone rather than the UNM3. The UNM3 contains very thin carbonaceous stringers on some of the laminae and in HU0132CH a 23 cm coal lens is present at the top of the unit (see Fig. 25). Rare thin very fine- to medium-grained sandy laminae are present in some drill holes (e.g. Fig. 14, 16, 20-23). Possible tuffaceous or reworked tuffaceous material is present in HU0082CH (Fig. 21). Figures 20 and 21 show that the upper plies in the Wongawilli Coal were eroded prior to the deposition of the UNM3 where the B or A ply is overlain by thin medium-grained sandstone lenses beneath the UNM3. The sandstone, and in places pebbly sandstone, lenses within and at the base of UNM3 are quartz-rich and represent detritus derived from the Lachlan Fold Belt to the west or southwest of the Sydney Basin (see Fig. 36). They would have been brought into the peat swamp or lake during drier periods as sheetflood or small stream deposits that must have entered the basin from the basin margin to the southwest. The presence of extensive shale in UNM3 over the northern and eastern parts of the Hume Coal Project area indicates that the whole area must have subsided and been occupied by a lake in which the carbonaceous shale accumulated under anoxic conditions. This lake must have been deep enough to drown the peat swamp in this southwestern part of the Sydney Basin, which was too far from the main axis of deposition of the Eckersley Formation from the north or east to receive sandy sediment from these sources.

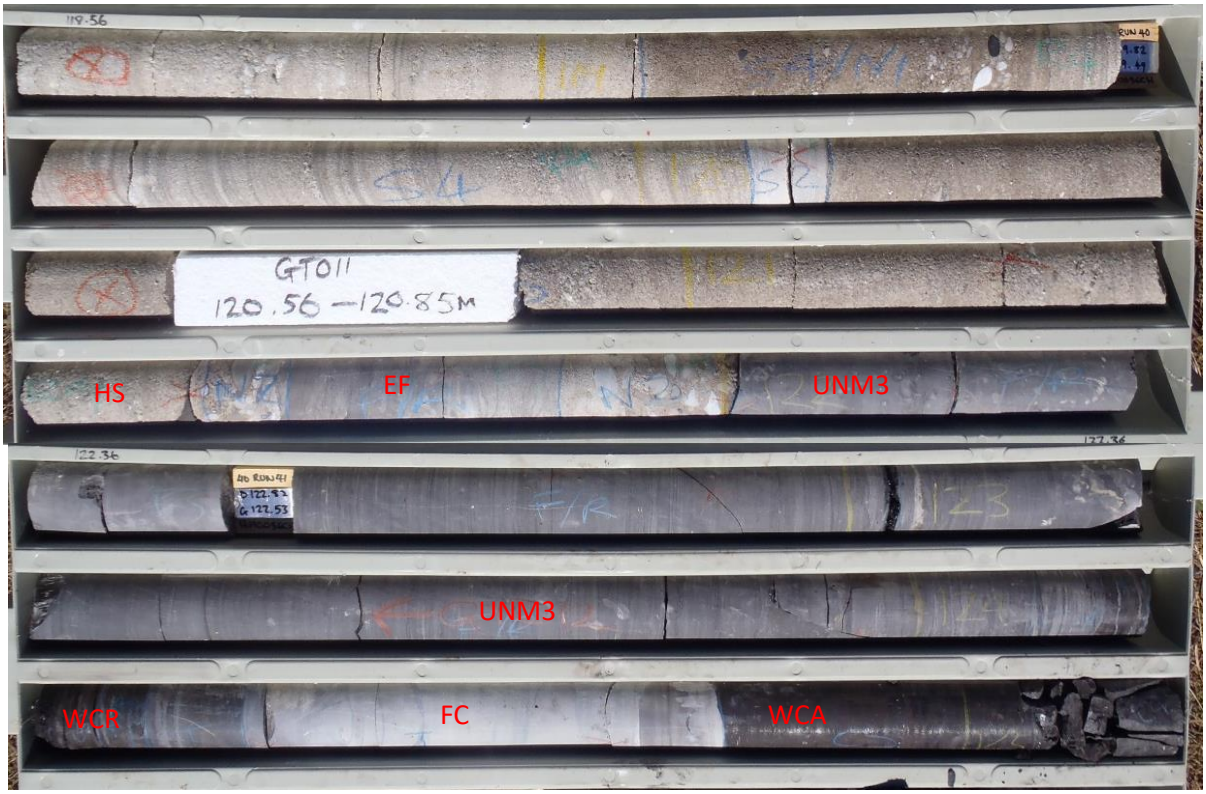



Figure 13. HU0036CH showing the Wongawilli Coal Ply A, Farmborough Claystone, Ply R, a thick UNM3, 38 cm of possible Eckersley Formation (pebble conglomerate passing up into sandy carbonaceous shale) sharply overlain at 121.63 m by coarse-grained Hawkesbury Sandstone with quartz pebbles near the base.

Figure 14. HU0038CH showing Wongawilli Coal ply A overlain successively by thin white remnant of Farmborough Claystone and about 1 m of UNM3 before being truncated at 102.78 m by the quartz-pebble-bearing Hawkesbury Sandstone.

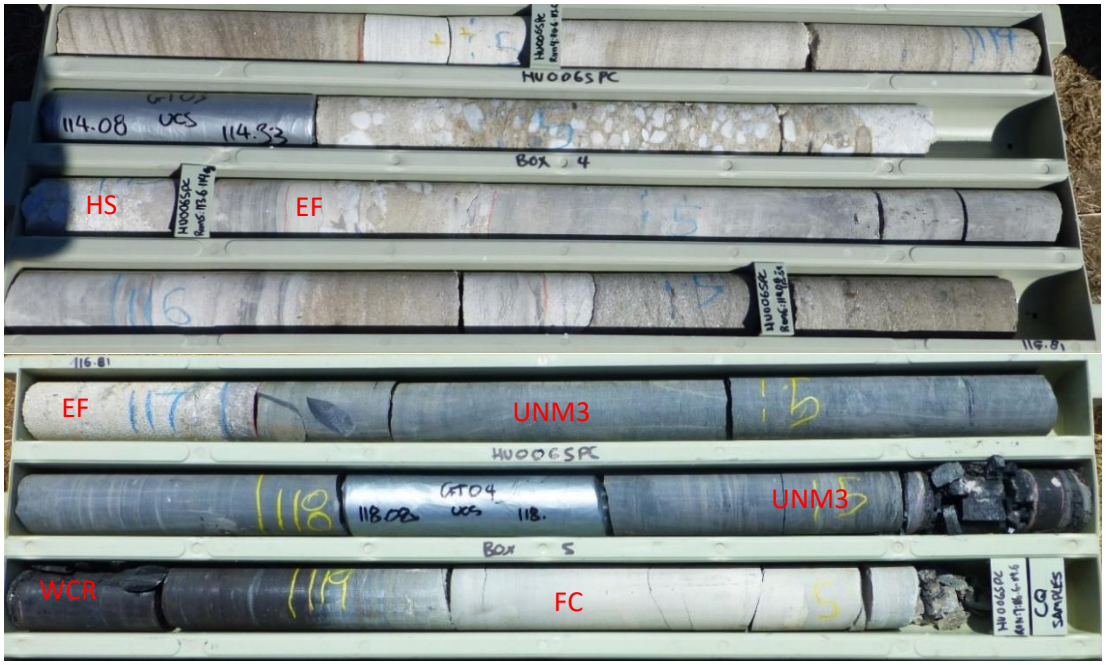



Figure 15. HU0065CH showing Farmborough Claystone, upper Wongawilli Coal Ply R and UNM3 disconformably overlain at 117.04 m by medium- to very fine-grained Eckersley Formation that is erosionally truncated by pebbly Hawkesbury Sandstone at 115.08 m.

Figure 16. HU0109CH showing Farmborough Claystone, upper Wongawilli Coal Ply R and UNM3 overlain by medium- to fine-grained lower Eckersley Formation, Burragorang Claystone and upper Eckersley Formation that grades up into another carbonaceous shale before being erosionally truncated by pebbly Hawkesbury Sandstone at 75.84 m.

Figure 17. HU0128CH showing UNM3 overlain by 0.36 m lower Eckersley Formation and Burragorang Claystone beneath the pebbly Hawkesbury Sandstone at 100.14 m. The top of the Burragorang Claystone is reworked and may represent 20 cm of upper Eckersley Formation (UEF?).

Figure 18. HU0144CH showing Farmborough Claystone, upper Wongawilli Coal and 48 cm of UNM3 overlain by very fine-grained lower Eckersley Formation and the Burragorang Claystone before being erosionally truncated by pebbly Hawkesbury Sandstone at 133.22 m.

Figure 19. HU0145CH showing Farmborough Claystone, upper Wongawilli Coal Ply R and UNM3 overlain by a thin sequence of medium- to coarse-grained lower Eckersley Formation, the Burragorang Claystone and medium to very fine-grained upper Eckersley Formation before being erosionally truncated by pebbly Hawkesbury Sandstone at 103.74 m.

Figure 20. HU0083CH shows Ply B (removed for analysis) of the Wongawilli Coal erosionally overlain by a thin medium-grained sandstone unit that passes up into 3 m of carbonaceous shale in UNM3 before being erosionally overlain by coarse-grained pebbly Hawkesbury Sandstone at 101.00 m.

Figure 21. HU0082CH showing the Farmborough Claystone overlain by a thick sequence of carbonaceous mudstone and shale with very fine-grained sandstone interbeds in UNM3 and with thin coarser sandstone interbeds at the top (probably lower) Eckersley Formation from 87.41 m before being truncated at 86.30 m by medium- to coarse-grained, moderately oxidised Hawkesbury Sandstone containing a few pebbles and mudclasts.

Figure 22. HU0094CH shows Ply A (removed for analysis) of the Wongawilli Coal erosionally overlain by a thin fine- to medium-grained sandstone unit (possibly reworked Farmborough Claystone) that passes up into 4 m of carbonaceous shale in UNM3 (and possibly a remnant of Burragorang Claystone). Possible Burragorang Claystone is overlain at 88.38 m by upward fining sequences of very fine- to medium-grained upper Eckersley Formation before being erosionally truncated by coarse-grained pebbly Hawkesbury Sandstone at 85.11 m.

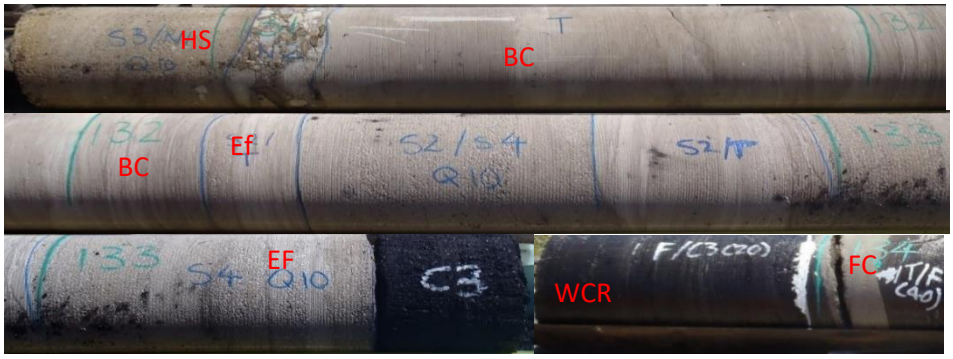



Figure 23. HU0055LD (200 mm core) showing a thin Farmborough Claystone overlain by the Ply R at the top of the Wongawilli Coal that is erosionally overlain by medium-grained sandstone of the lower Eckersley Formation and the massive Burragorang Claystone above 132.18 m. The latter is erosionally truncated beneath the pebbly base of the Hawkesbury Sandstone at 131.15 m.

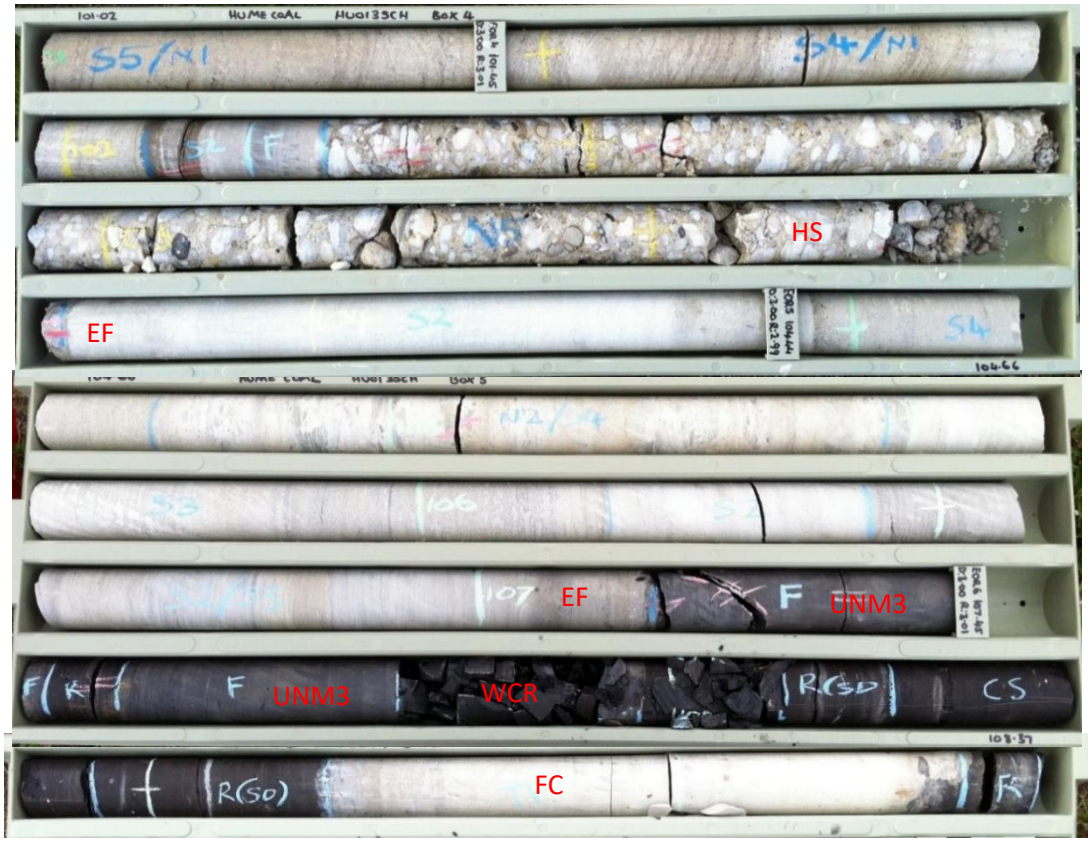



Figure 24. HU0135CH showing the Farmborough Claystone overlain by the upper R Ply of the Wongawilli Coal, the UNM3 and 3.34 m of fine- to medium-grained (probably lower) Eckersley Formation before being truncated by a quartz-pebble conglomerate at the base of the Hawkesbury Sandstone at 103.76 m.

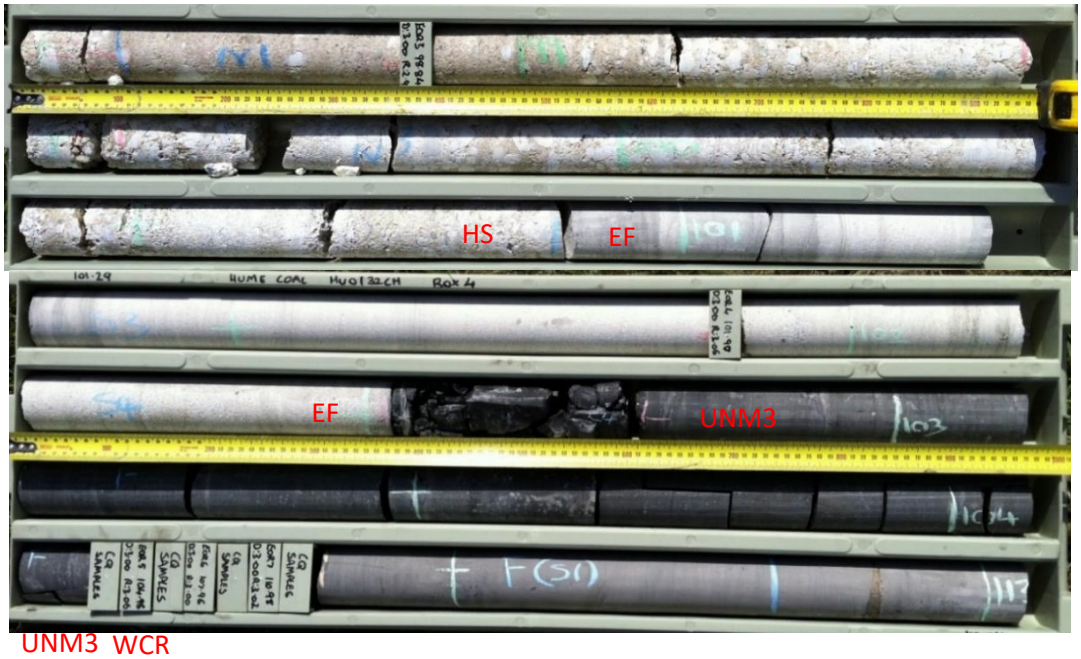



Figure 25. HU0132CH Showing the UNM3 above the R Ply (removed for analysis) of the Wongawilli Coal. The UNM3 has 23 cm of coal at the top (possibly the Woronora or Hargrave Coal Member) and is overlain by 1.64 m of fine- to medium-grained (lower or upper) Eckersley Formation before the erosional contact with the basal conglomeratic Hawkesbury Sandstone at 100.88 m.

**Lower Eckersley Formation**

The lower Eckersley Formation (Figs 15-17, 19, 21-25) includes all strata above the UNM3 and beneath the Burragorang Claystone. It is compositionally different to the typical unit elsewhere in the basin because it has come from a local Lachlan Fold Belt source to the west and/or southwest of the basin. Isopachs of the lower Eckersley Formation (Fig. 26) only record sequences beneath the Burragorang Claystone, but the sequence maybe more widespread where it cannot be differentiated from the overlying quartz-rich sandstone successions if the Burragorang Claystone is not present. The recorded thicknesses range from <1 m to 2.5 m where the Burragorang Claystone is present but may be up to 4.5 m where the claystone is not seen. The lower Eckersley Formation is a quartz-rich very fine- to medium-grained unit, locally containing coarser quartz up to quartz pebble conglomerate. Thus it is compositionally similar to the Hawkesbury Sandstone but the sandstone sequences in this unit are much thinner than those in the Hawkesbury Sandstone and they are commonly associated with fine-grained overbank deposits. They were probably deposited by much smaller, narrower stream systems than those of the Hawkesbury Sandstone, but these streams caused most of the erosion of the Wongawilli Coal over a time span of 1-2 Ma (deduced from Metcalfe et al., 2015) prior to the deposition of the Burragorang Claystone.

Figure 26. Thickness of the lower Eckersley Formation beneath the Burragorang Claystone.

**Burragorang Claystone**

An important stratigraphic marker in the Hume Coal Project area is the presence of the very fine-grained massive to weakly laminated tuffaceous deposits of the Burragorang Claystone (e.g. Figs 17-19, 23). The presence of this stratigraphic unit from the upper Illawarra Coal Measures clearly illustrates that the Hawkesbury Sandstone has not eroded down onto the Wongawilli Coal over much

of the Hume Coal Project area. The Burragorang Claystone is very fine-grained consisting predominantly of clay but with minor silt-sized quartz, feldspar and mica and may contain aligned carbonaceous fragments (Fig. 27). The Burragorang Claystone was probably deposited as airfall ash and probably represents at least two eruptive events. Some of the claystone may have been deposited into a lake where it appears carbonaceous and more laminated. Some of the ash also appears to have been reworked either subaerially or subaqueously. The Burragorang Claystone is typically less than 2 m thick but locally thickens to 6-8 m (Figs 28-29). The claystone is absent along a northeast trending zone from HU0101CH to HU0141CH (Fig. 29 between the dashed yellow lines) possibly representing an erosional trend beneath the Hawkesbury Sandstone. This trend is parallel to the palaeocurrent trend in the Hawkesbury Sandstone and its width of about 1 km is similar in dimension to the main channels in the Hawkesbury Sandstone (Miall and Jones, 2003).

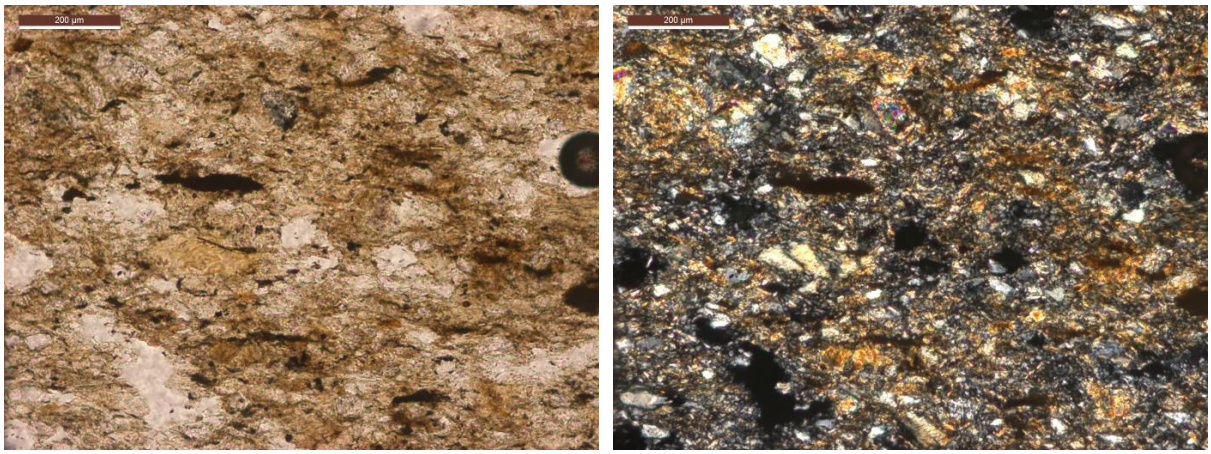



Figure 27. Thin section photomicrographs, in plain and cross-polarised light, of the Burragorang Claystone showing aligned organic matter and very fine crystal sizes. Scale bar is 200 microns.

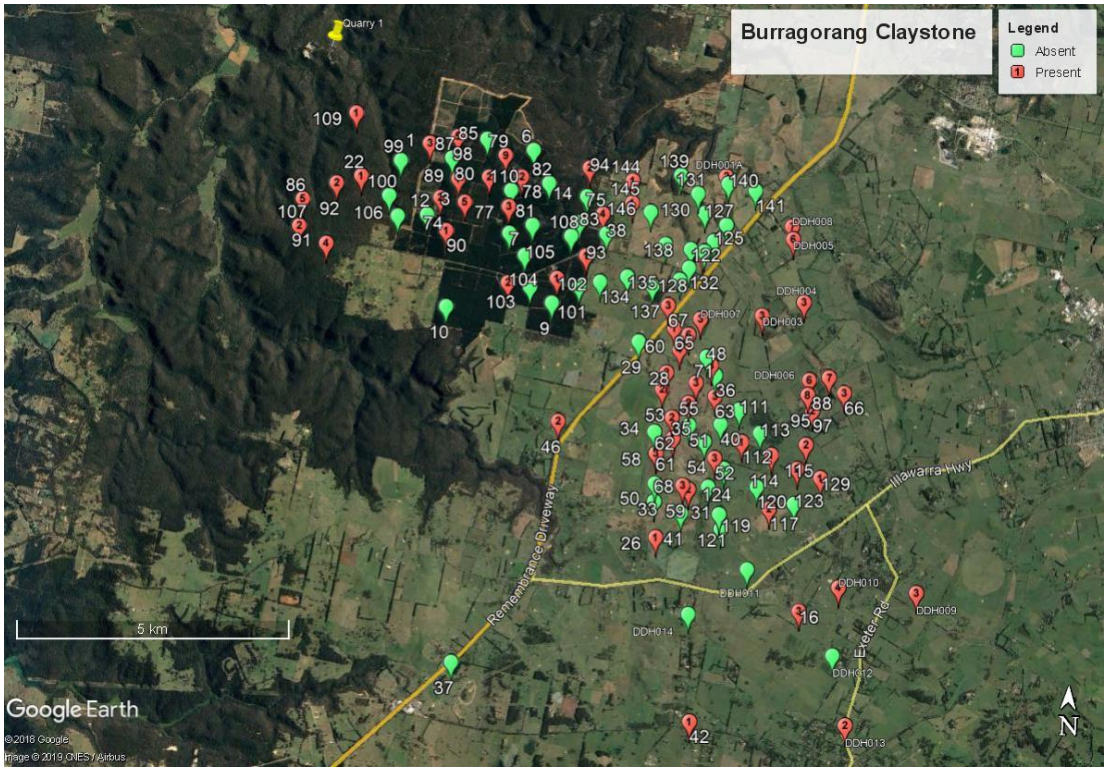



Figure 28. Distribution and (up-to) thickness (internal numbers) of the Burragorang Claystone plotted at bore sites (external numbers).

Figure 29. Isopachs of the preserved Burragorang Claystone, with the zone of low preservation between the dashed lines showing probably position of a larger erosional channel at the base of the Hawkesbury Sandstone.

**Upper Eckersley Formation**

In many drill holes the Burragorang Claystone is overlain by a variable thickness of mainly fine- to medium-grained sandstone forming small upward fining sequences that may end with carbonaceous or sideritic mudstone (Figs 30-34). In holes where the Burragorang Claystone is absent these fine-grained sequences cannot be distinguished from the lower Eckersley Formation (e.g. Figs 16, 19, 22, 24-25). These finer grained sequences (Figs 30-34) were deposited by small rivers that are atypical of the Hawkesbury Sandstone and probably represent deposits equivalent to the upper Eckersley Formation or even time equivalents of the Narrabeen Group which, in this part of the basin, would have also been derived from the Lachlan Fold Belt to the west and southwest. These deposits could have been laid down at any time over the 5 Ma period prior to the deposition of the coarse-grained Hawkesbury Sandstone. One interesting feature is that there is no evidence of significant periods of weathering and soil formation. However, the partly oxidised medium- to fine-grained quartz-rich sandstone showing flat and minor small-scale cross-bedding with carbonaceous laminae in the upper Eckersley Formation (Fig. 30) may represent weathering prior to the deposition of the Hawkesbury Sandstone. Similar partial oxidation of the mudstone at the top of the Eckersley Formation in Figure 33 may also represent weathering prior to the deposition of the Hawkesbury Sandstone. However at least a further 6 m of material would need to have been deposited above such sequences to allow incision of the main Hawkesbury Sandstone channels that would have been at least 6 m deep as seen elsewhere in the Sydney Basin (Miall and Jones, 2003).

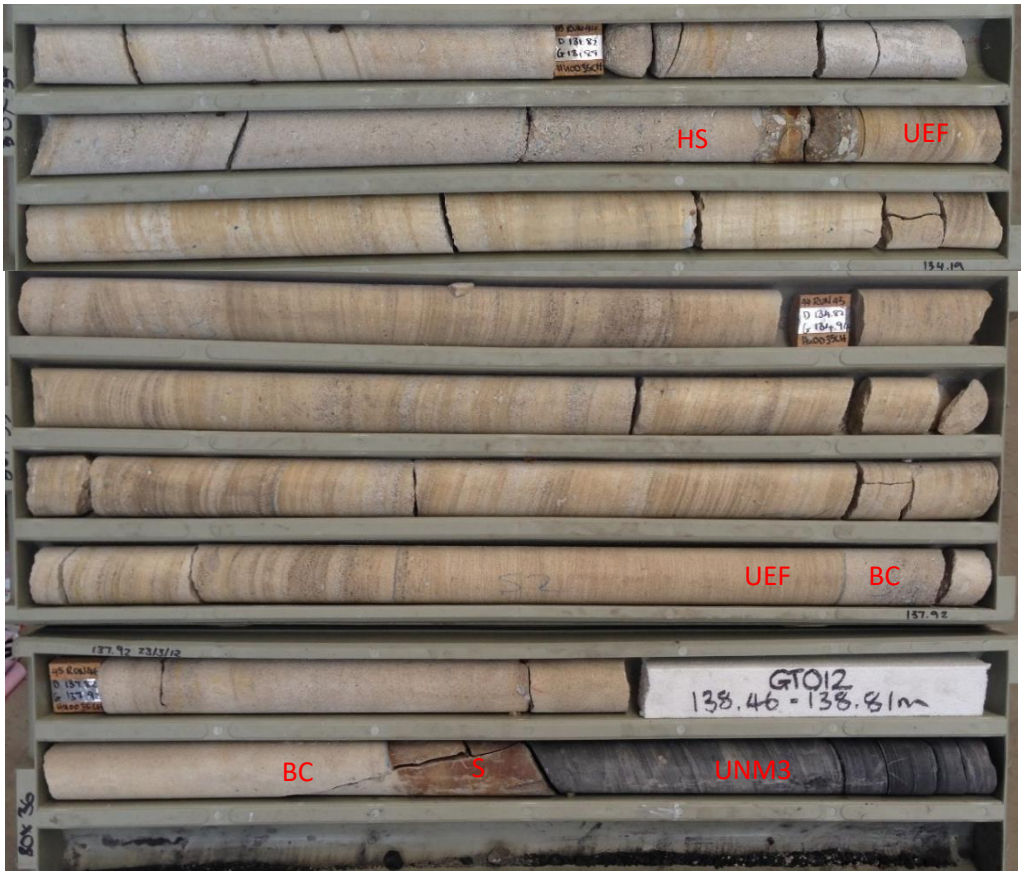



Figure 30. HU0035PZA Wongawilli Coal (removed for testing) overlain by UNM3 with weathered siderite cemented zone (S) at the top. This is directly overlain by 1.3 m of massive Burragorang Claystone and then by 4.75 m of partly oxidised medium to fine-grained quartz-rich sandstone showing flat and minor small-scale cross-bedding with carbonaceous laminae. This sequence represents the upper Eckersley Formation. This is erosively overlain at 133.14 m by medium- to coarse-grained typical Hawkesbury Sandstone with a thin basal pebble conglomerate.

Figure 31. HU0146CH showing the R Ply of the Wongawilli Coal directly overlain by the Eckersley Formation fine- to medium-grained sandstone with numerous thin shale beds.

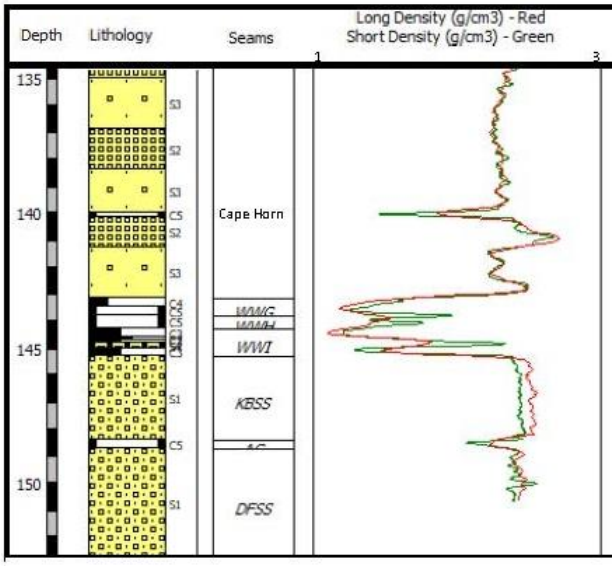


Figure 32. HU0059PC Cape Horn Coal, corresponding to a geophysical reduction spike in density (see above), overlain by Burragorang Claystone with the top 50 cm showing partial reworking. This is overlain by 6.65 m of mainly medium-grained quartz rich sandstone in the upper Eckersley Formation that fines upwards and ends in 20 cm of sideritic mudstone at 131.3 m. It is overlain by typical coarse-grained Hawkesbury Sandstone at 131.1 m with rip-up clasts at the base.

Figure 33. HU0097CH showing B Ply of the Wongawilli Coal overlain successively by a thin lower Eckersley Formation, the Burragorang Claystone and a predominantly fine- to medium-grained upper Eckersley Formation exhibiting thin upward fining cycles into oxidised carbonaceous mudstone before being overlain by coarse-grained Hawkesbury Sandstone at 113.47 m.

Figure 34. HU0138CH showing UNM3 erosionally overlain by very fine- to medium-grained Eckersley Formation before being truncated by the Hawkesbury Sandstone at 107.98 m.

Figure 35. Thickness of the interval between the top of the A Ply (or highest underlying ply) in the Wongawilli Coal and the base of the coarse-grained Hawkesbury Sandstone.

The total thickness of the interval between the top of the A or highest preserved ply in the Wongawilli Coal and the base of the coarse-grained Hawkesbury Sandstone is shown in Figure 35. The general trend is for thickening of this interval to the north and east with thinning or total erosion to the southwest. A notable embayment with very thin interval of preservation extends from the southwest towards the northeast (Fig. 35 between dashed orange lines) follows the same trend as the absence of the Burragorang Claystone (Figs 28-29). This suggests that a major axis of Hawkesbury Sandstone drainage may have eroded down into this area as shown by the Hawkesbury Sandstone directly overlying ply F of the Wongawilli Coal (Fig. 38). It also indicates that during the deposition of the Hawkesbury Sandstone the Sydney Basin was subsiding to the northeast producing a northeast dip in the Illawarra Coal Measures and providing accommodation space for deposition of the Balgownie and Bulli coal seams. Progressive erosion down through the Wongawilli Coal occurred on the non-subsiding or slightly uplifted southwestern margin of the Sydney Basin. Erosion of the Lachlan Fold Belt to the south and southwest of the Sydney Basin at this time contributed quartz-rich detritus to the southwestern portion of the basin during, and possibly after, the time of deposition of the northerly derived Eckersley Formation in the main part of the Sydney Basin. This accounts for the locally derived units deposited in the Hume Coal Project area between the Wongawilli Coal and Hawkesbury Sandstone. Schematic representations of the relationships between all these units both across and down the depositional slope are presented in Figures 36 and 37. Possibly the zone of inflexion of subsidence occurred in central the Hume Coal Project area resulting in tension that allowed the intrusion of diatremes.

**Hawkesbury Sandstone**

Distinguishing the base of the Hawkesbury Sandstone in the Hume Coal Project area is difficult because the underlying clastic successions in the Illawarra Coal Measures and possible Narrabeen Group equivalent have been derived from the same Lachlan Fold Belt source area as the Hawkesbury Sandstone. The main distinction is based on the grain size and depositional unit thicknesses which are both smaller beneath the Hawkesbury Sandstone. The base of the Hawkesbury Sandstone is therefore taken at the base of the first thick coarse-grained sandstone and/or conglomeratic unit that is typical of the Hawkesbury Sandstone (e.g. Fig. 38). Even if the underlying sandstone-shale successions are included in the Hawkesbury Sandstone they would represent a distinctly finer grained facies that would have much lower porosity and permeability than the main part of the Hawkesbury Sandstone.

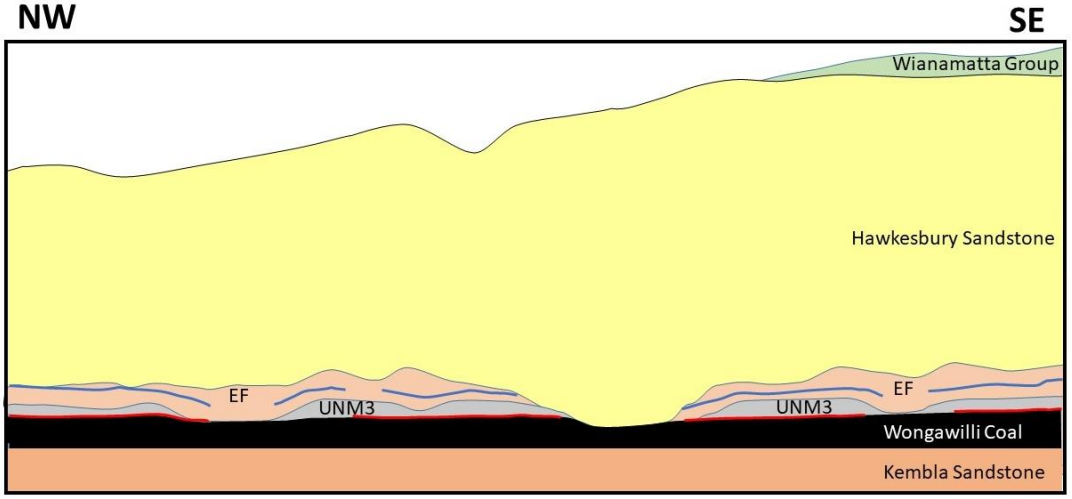



Figure 36. A schematic NW-SE section (not to scale) through the sequences from the Kembla Sandstone to the Wianamatta Group. EF = Eckersley Formation; blue line = Burragorang Claystone; red line = Farmborough Claystone.

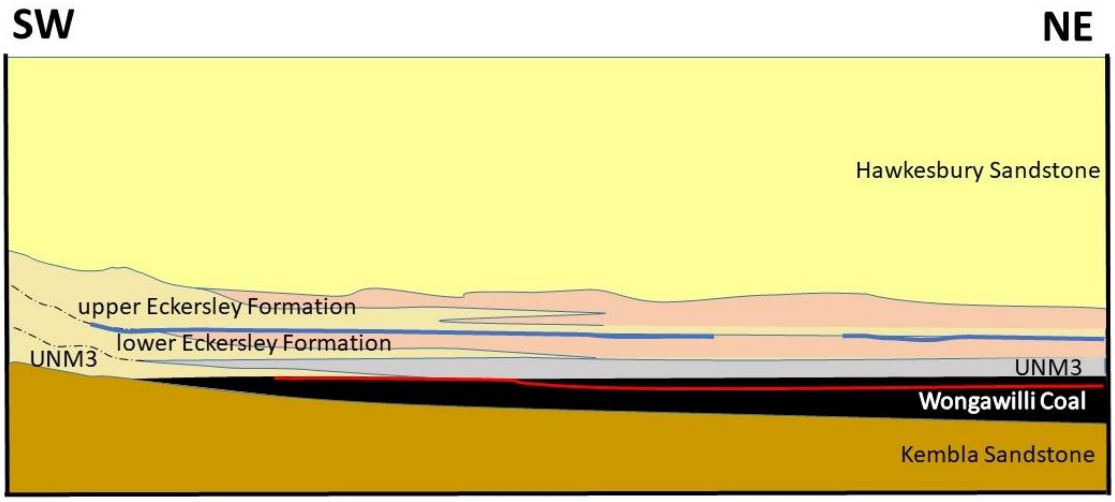



Figure 37. A schematic SW-NE section (not to scale) through the sequences from the Kembla Sandstone to the Wianamatta Group showing the interdigitation of coarser sediment (yellow) from the Lachlan Fold Belt source for all units above the Wongawilli Coal.

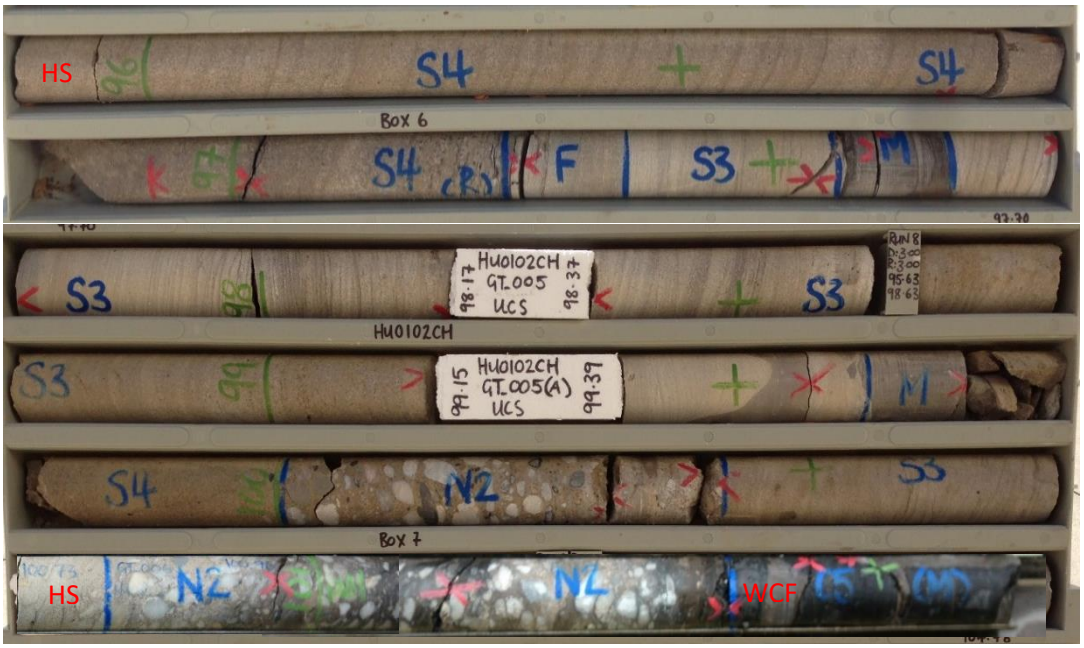



Figure 38. HU0102CH showing ply F of the Wongawilli Coal directly overlain by the conglomeratic base of the medium- to coarse-grained Hawkesbury Sandstone.

The elevation of the base of the coarse-grained Hawkesbury Sandstone shows a dip towards the east and east-northeast (Fig. 39) with a low dip zone in the central part of the Hume Coal Project area that is probably related to regional faulting and locally to diapiric intrusions. The thickness of the Hawkesbury Sandstone ranges from 80 to 110 m where it is overlain by the Wianamatta Group but it is thinner where it is exposed and partly eroded on the ground surface. This thickness is much less than in the central part of the basin (~250 m) where subsidence was greatest. The Hawkesbury Sandstone would be expected to be coarser grained in the more proximal southern and southwestern parts of the Sydney Basin. Since the formation is thinner in this southwestern area the tripartite subdivision in the Hawkesbury Sandstone recognised by Lee (2009) in the central and western parts of the Sydney Basin may not be as recognisable or apparent in this southern part of the basin.

Figure 39. Elevation of the base of the coarse-grained Hawkesbury Sandstone.

Figure 40. HU0086CH showing a carbonaceous shale unit in the middle of the coarse-grained Hawkesbury Sandstone.

Downhole logs, especially gamma and density (Fig. 40), show a common occurrence of thin fine-grained intervals throughout most of the Hawkesbury Sandstone with clean porous sandstone units generally less than 6 m thick except in HU0130CH where clean sandstone in both the lower and upper parts of the Hawkesbury Sandstone are up to 20 m thick (Thomson and Thomson, 2019).

The Hawkesbury Sandstone in the Hume Coal Project area varies considerably in character and can be subdivided into two main facies. A central, more active, channel facies trends northeast from about HU0101CH towards HU0130CH and is approximately 2-2.5 km wide (Fig. 35). This is parallel to the main channel flow direction indicated by the cross-bedding in outcrop. In this facies it may be possible to recognise the tripartite subdivision of the Hawkesbury Sandstone proposed by Lee (2009) as shown in the HU0130CH downhole logs (Fig. 40). In this hole the lowest 27 m (104-77 m) is predominantly porous (Unit A), overlain by Unit B from 77-45 m with a 6 m thick porous interval present in the middle (Fig. 41) and then by a porous sandstone forming the lower part of Unit C from 45-23 m. Unit A consists mainly of medium- to very coarse-grained sandstone but contains numerous thin carbonaceous and silty laminae on bedding planes that would locally reduce vertical permeability. The section above 53.7 m (Unit B) in HU0130CH is still mainly a clean sandstone but it is medium-grained, well sorted and well-cemented resulting in a higher density and lower porosity and permeability. Similar cemented portions of the Hawkesbury Sandstone occur sporadically throughout the Hume Coal Project area and result in local permeability barriers.

The second and more widespread facies in the Hawkesbury Sandstone contains common overbank material and occurs in both the northwest and southeast portions of the Hume Coal Project area (Fig. 35). It does not show the tripartite subdivisions of Lee (2009) but contains a few coarser grained porous intervals, usually less than 5 m thick, scattered through the formation. Individual channel depths appear to be smaller within this facies. Some channels near the active channel facies show an erosive base onto the Wongawilli Coal (Figs 40, 45) and may contain a basal conglomeratic unit. The sequence in Figure 45 shows rapid channel abandonment with the conglomerate overlain by a silty carbonaceous channel abandonment unit before being overlain by the next channel sandstone. The channels are commonly separated by small-scale bedding with common carbonaceous and silty laminae that would cause a reduction in vertical permeability (Fig. 43). Many of the small channels in this facies show upward fining to well laminated and ripple bedded very fine-grained sandstone and siltstone representing overbank deposits (Figs 40, 43). The finer grained sandstone beds tend to be more silty or cemented and would have a lower effective porosity.

**Oxidation in the Hawkesbury Sandstone**

One important feature in the Hawkesbury Sandstone is the presence of oxidised zones that represent areas of oxidised groundwater flow within the succession. Where the Hawkesbury Sandstone is exposed at the surface the upper part of the unit is usually strongly oxidised within the vadose zone. The depth of this zone is controlled by the grain size, porosity and permeability of the uppermost sequence in the Hawkesbury Sandstone, and by the presence of fractures and/or faults within the sequence. In general the coarser grained units tend to be more porous and permeable than the finer grained units (Fig. 44). Some of the fine- to medium-grained sandstone beds have higher densities and are cemented with secondary quartz and kaolinite which significantly reduces their permeability and also their porosity. Other fine-grained sandstone beds are simply poorly sorted with a higher silt content that also reduces their permeability. Some of the smaller cross-bed sets show variable flow conditions and may be interspersed with silty or carbonaceous laminae (e.g. Fig. 44).

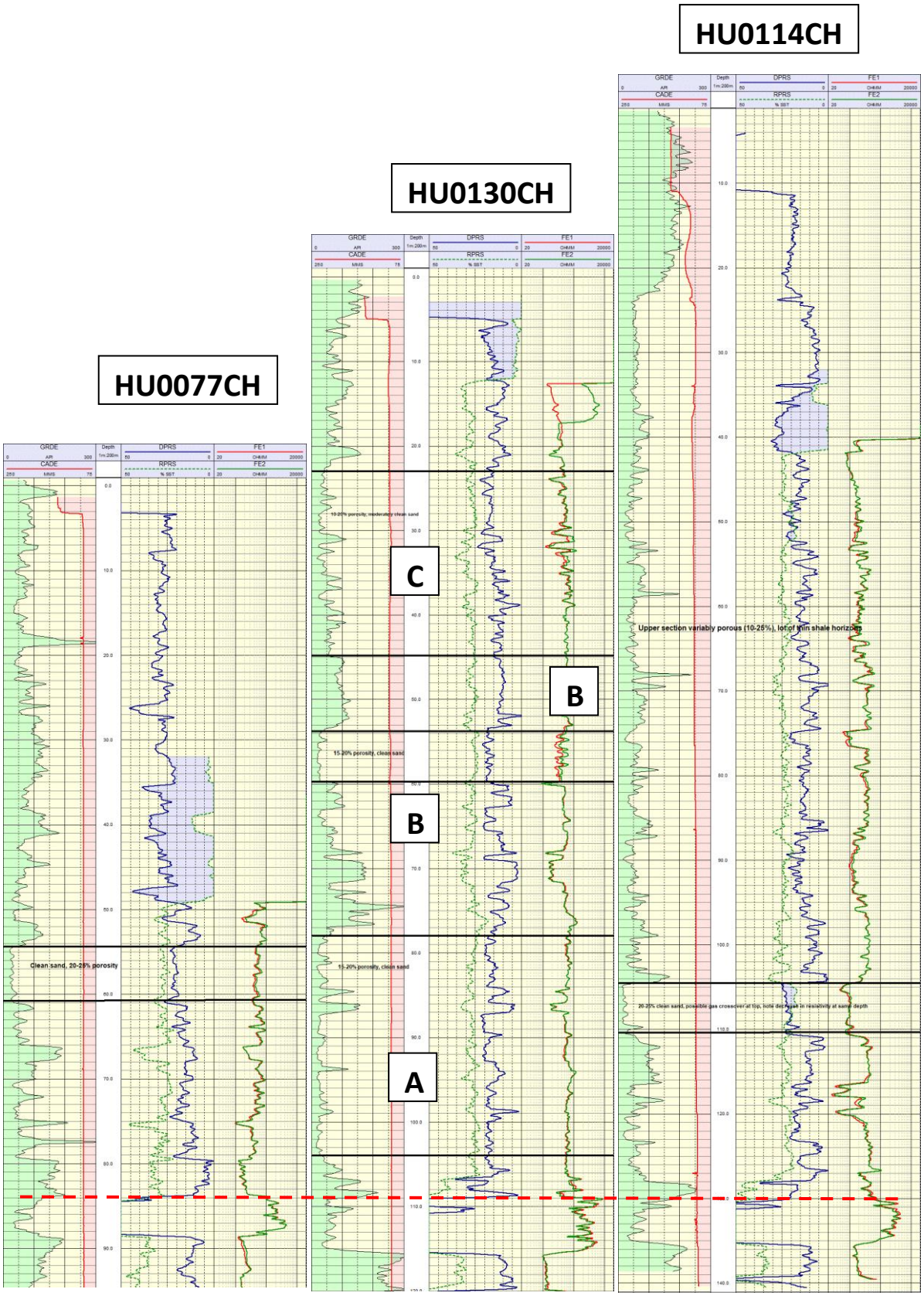



Figure 41. Northwest to southeast downhole log section through HU077CH, HU0130CH and HU0114CH showing the main porous intervals and the abundance of lower porosity silty and/or cemented sandstone intervals to both the northwest and southeast. The section datum is the top of the Wongawilli Coal (red dashed line). Possible subdivisions in the main channel area of the Hawkesbury Sandstone after Lee (2009) are indicated by the letters

Figure 42. HU0130CH showing a clean porous medium- to very coarse-grained sandstone between 53.7 m and 60 m overlying silty fine grained sandstone and overlain by clean well-cemented medium-grained sandstone with a higher density and relatively low porosity.

The distribution of oxidised zones within the Hawkesbury Sandstone is very variable. Where the Hawkesbury Sandstone is overlain by the carbonaceous Ashfield Shale at the base of the Wianamatta Group the Hawkesbury Sandstone tends to show fewer oxidised zones than where the formation is exposed at the surface. The Wianamatta Group mainly occurs in the eastern part of the Hume Coal Project area but since this is in the down-dip groundwater flow direction oxidised flows have still been recorded in this area (e.g. Fig. 46). However, in the western part of the project area where the Hawkesbury Sandstone is exposed at the surface oxidised intervals are more prevalent. There is no consistent pattern about the depth of the oxidised zones but they are more common in the upper half of the Hawkesbury Sandstone interval. The oxidised intervals are more common in the coarser grained channel facies that, although poorly sorted, tend to be more porous and permeable than the finer grained channel and overbank deposits (e.g. Fig. 46-49). The latter may be either well cemented with

Figure 43. HU0081CH shows the Hawkesbury Sandstone overlying the UNM3 that has eroded down onto the G Ply of the Wongawilli Coal. The basal Hawkesbury Sandstone conglomerate at 95.55 m represents deposition from a number of flood events before the channel was abandoned (probably by avulsion) and the abandoned channel filled with low permeability laminated carbonaceous siltstone and very fine-grained sandstone. This sequence was overlain by a more porous oxidised sandstone at the base of the next channel succession at 90.85 m (red arrow).

Figure 44. HU0040CH showing the common occurrence of carbonaceous and silty laminae on bedding planes on the smaller cross-beds in medium-grained sandstone in the Hawkesbury Sandstone.

Figure 45. HU0059CH shows a medium- to coarse-grained facies of the Hawkesbury Sandstone fining upwards to overbank succession of very fine-grained sandstone and siltstone.

Figure 46. HU0028CH shows a coarse-grained channel base deposit in the Hawkesbury Sandstone overlying (red arrow) a finer grained channel top or floodplain deposit that shows alternating low-permeability cemented zones and slightly more porous cross-bedded sandstone.

Figure 47. HU0006CH shows two oxidised coarse-grained channels in the Hawkesbury Sandstone separated by a low porosity and permeability fine-grained cemented sandstone and carbonaceous siltstone forming the overbank facies of the lower channel succession.

Figure 48. HU0007CH shows a poorly sorted medium- to very coarse-grained channel sandstone in the lower Hawkesbury Sandstone passes up into a silty fine-grained sandstone with low permeability. It is overlain by the next porous channel sandstone showing oxidation.

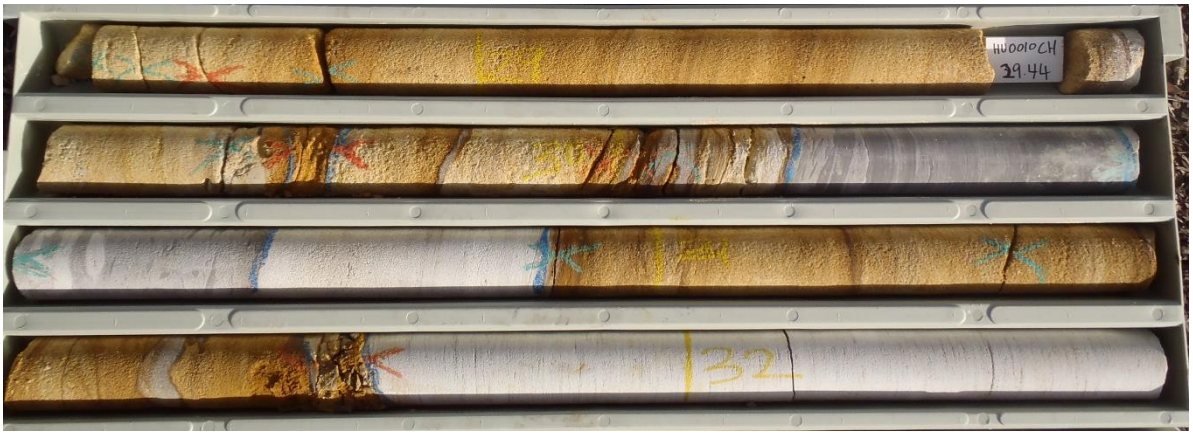



Figure 49. HU0010CH shows thin porous and oxidised channel sandstone units interbedded with low permeability fine-grained cemented sandstone and carbonaceous mudstone representing deposits from small streams in the finer grained facies of the Hawkesbury Sandstone.

Figure 50. HU0010CH shows fracture controlled (arrow) oxidation concentrated in a coarser sandstone in a predominantly fine-grained facies of the Hawkesbury Sandstone.

secondary quartz and kaolinite or be poorly sorted with a silty and carbonaceous matrix. The thicker overbank mudstones form good vertical permeability barriers and may cover a moderate lateral area. A good example of such a permeability barrier is seen in Figure 47 where a 3.6 m fine grained sandstone and overbank deposit forms a permeability barrier between one oxidised coarse-grained channel deposit and the underlying unoxidised channel sandstone. Similar permeability barriers in smaller channel systems are illustrated in Figure 49. The main water ingress to the deeper levels of the Hawkesbury Sandstone is probably through joints and faults (e.g. Fig. 50) that feed water down into the porous sandstone layers. This water would then move laterally through the porous sandstone in a down-dip direction to the east gradually becoming less oxidised as it interacts with the carbonaceous matter in the Hawkesbury Sandstone.

**Porosity and Permeability in the Hawkesbury Sandstone**

As noted by Lui et al. (1996), Al Gahtani (2012) and Zaid and Al Gahtani (2015), porosity variations in the Hawkesbury Sandstone are strongly linked to facies, with horizontal permeability being greater than vertical permeability. Porosity and permeability are greatest in the coarse-grained cross-bedded channel facies but even here permeability varies across each individual foreset lamina as a

consequence of grain size variation. In the finer grained facies in the Hawkesbury Sandstone both porosity and permeability are controlled by the quantity of fine-grained matrix and cement within the units and are especially low in any mudstone laminae and beds.

Within the Hume Coal Project area many of the drill holes were not fully cored through the Hawkesbury Sandstone interval and hence regional facies characteristics would need to be deduced from downhole geophysical logs augmented where possible with core data. Examples of this are presented in Figure 41 and in Thomson and Thomson (2019). Although all available data have not been analysed as yet, the geophysical characteristics confirm the facies subdivision with a central northeast-trending coarser channel facies separating two areas in the northwest and southeast that contain higher proportions of fine-grained facies.

In the central facies clean sandstone successions are up to 30 m thick and would have good porosity and permeability. Within these clean sandstone sequences minor cemented zones and accumulation of finer detritus parallel to bedding or on cross-laminae would provide lower permeability horizons especially in a vertical direction (e.g. Fig. 46). However, these clean sandstone intervals would have good aquifer characteristics both in the upper and lower Hawkesbury Sandstone. The middle of the Hawkesbury Sandstone contains thin clean sandstone units but these are separated from the upper and lower zones by finer grained units that would provide at least local low permeability zones to lateral, and especially vertical, groundwater movement (e.g. Fig. 42).

The finer grained facies to the east and west of the main channel have much thinner (2-5 m) clean sandstone units (e.g. Fig. 38) separated by higher proportions of finer grained or cemented sandstone and/or mudstone (e.g. Figs 40, 43-45, 47-49). The thinner clean sandstone beds are likely to have less lateral continuity than the one in the main channel facies since the rivers depositing them would have been smaller streams that would not have combed laterally across the whole area. Thus lateral permeability between the thin sandstone units could not be guaranteed unless they are intersected by structural features such as joints and faults (e.g. Fig. 50).

**Conclusions**

1. This study is based on both outcrop and photographic drillhole core and log data.
2. Along the southwestern margin of the Hume Coal Project area the top of the Wongawilli Coal has been removed by erosion that progressively decreases towards the northeast. This erosion started in the lower Eckersley Formation prior to the emplacement of the Burragorang Claystone. In the central part of the project area the Hawkesbury Sandstone has also eroded down onto the Wongawilli Coal along the southwestern margin.
3. The Wongawilli Coal is separated from the Hawkesbury Sandstone by a fine-grained succession including some or all of the Farmborough Claystone, UNM3, lower Eckersley Formation, Burragorang Claystone and upper Eckersley Formation (and possibly some Narrabeen Group equivalent) that ranges in thickness from 0-7.7 m.
4. The Eckersley Formation (and possibly Narrabeen Group equivalents) in this part of the Sydney Basin have also been derived from the Lachlan Fold Belt to the southwest and are lithologically similar to, but finer grained than, the Hawkesbury Sandstone.
5. A north-northeast trending zone about 2-2.5 km wide extends through the middle of the Hume Coal Project area and represents a major river axis of the Hawkesbury Sandstone. A tripartite subdivision of the Hawkesbury Sandstone may be apparent in this area.
6. The northwestern and southeastern portions of the project area and characterised by deposition by smaller river systems and contain numerous low permeability fine-grained floodplain deposits that provide at least local vertical permeability barriers to groundwater movement.

7. The irregular distribution of oxidised zones within the Hawkesbury Sandstone suggests that most oxidised groundwater ingress into the Hawkesbury Sandstone occurred through joints and faults rather than vertical percolation through the unit because of the presence of numerous thin vertical permeability barriers in the form of overbank deposits.

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**Explanatory Note**

This report was put together to assist with Hume Coal's response to the IPC. It represents a summary of the available Hume Coal Geological data.

Many submissions criticized the lack of geological data that was presented in both the Environmental Impact Statement (EIS) and the Reply to Submissions (RTS). While this was valid (in that the detailed geological data was not included in the EIS or RTS), it was neither fair nor reasonable criticism. There is an abundance of commercial in confidence geological data that has been compiled by Hume Coal over the last decade.

In the first instance Geological data was not requested either by the Department of Planning and Environment (DPE), nor in any of the Secretary's Environmental Assessment Requirements (SEARS), nor by any other department within the NSW Government. One critic bizarrely claimed that the Applicant "should have realized that the information" was wanted. The Applicant was submitting an "Environmental" impact Statement, its responsibility was to provide the information requested and not information that it thought might be relevant. A detailed geological assessment was never requested, never required and for the Applicant to be criticized for not providing something it wasn't asked for is inappropriate.

Despite criticism, Hume Coal Pty Limited has previously provided all of its geological data to the NSW government, in annual reports. Each year exploration geological reports are prepared by the Applicant and submitted to the Government for their approval. These reports outline the work undertaken and provides copies of geophysical logs, survey co-ordinates along with other geological data. Exploration and mining companies go to great lengths, as well as great expense to obtain their geological data, so the sensitivity of this data is critical. The Government in turn treats this data as confidential and does not release it to the public.

Secondly, Hume Coal provided all geological data to the NSW Government via the Department of Resources and Geoscience (DRG). That Department reviewed all the information and went on to confirm the data Hume Coal had gathered was suitable to confirm the Coal Resources. Their assessment report was sent from them by Ms Kylie Hargraves (DRG) and addressed to Mr Paul Freeman (DPE). Ms Hargraves notes that, "*the SEARS have been adequately addressed*", the assessment report undertaken establishes the Government's view on the Resource and Economic Assessment of the Hume Coal Project. That document is attached as well as the audit and the response provided to Government at that time.

Thirdly, Hume Coal has provided its geological data to the NSW government for a third time when it provided data following a data request in 2017 to assist with the 'Southern Coalfield Geological Data Request'. A copy of that letter from the DPE is also attached.

The Applicant considers the geological data it has gathered over the last decade is 'Commercial in Confidence' and that it is not required to make it public. Hume Coal does not wish its data to be disclosed to the public or its competitors.

The facts are:

1) If geological data was required for the EIS, it should have been requested.

2) Discussion with the DPE and other department in the NSW Government have been going on for many years as both Projects are State Significant Developments. It should have been clear to them if they had required geological information. Despite this, Hume Coal have provided its geological data base to the NSW Government on several occasions. How is Hume Coal at fault for not supplying confidential information (in the EIS) when that information was never requested at that time?
3) It appears that other Departments within the NSW Government (eg DOI-Water) were totally unaware that Hume Coal had previously provided geological information to the NSW Government.
4) A letter from the DRG (Ms Kylie Hargraves) to the DPE (Mr Paul Freeman) supports the level of geological information previously provided by Hume coal to the NSW Government.

Planning & Environment
Resources & Geoscience

OUT17/25104

Paul Freeman
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Dear Paul

**Hume Coal Project & Berrima Rail Project - Environmental Impact Statement Review**

Thank you for your correspondence of 31 March 2017 inviting the Division of Resources & Geoscience (the Division) to comment on the Environmental Impact Statement (EIS) for the Hume Coal Project & Berrima Rail Project (the Project) submitted by Hume Coal Pty Limited (the Proponent).

The Division has reviewed the EIS with regard to the *Mining Act 1992* (the Act) and economic benefits, resource recovery and utilisation of the proposal (**attachment A**).

The Project incorporates existing Authorisation 349 (Act 1973) held by the Proponent and applications MLA 527, MLA 528 and MLA 529 (Act 1992) have been submitted by the Proponent. Under the Act, these MLAs cannot be granted until development consent for the Project has been approved.

The Division views that the Secretary's Environmental Assessment Requirements (SEARs) have been adequately addressed and notes that the Project's rehabilitation outcome currently results in lower status land value, for 58 hectares, than that of pre-mining.

Therefore, the Division requires the Proponent to further address the following to demonstrate that sustainable rehabilitation outcomes can be achieved as a result of the project:

- The Proponent should provide further justification for the proposed reduction in Land and Soil Capability (LSC) for approximately 58 hectares of land subject to disturbance associated with establishment of surface facilities. Specifically, the identified 3 hectares of Class 3, 37 hectares of Class 4 and 18 hectares of Class 5 pre-mining land will be returned to lower quality Class 6 land at the end of the Project.

The Proponent should consider and assess options to increase the post mining LSC in the areas where this will decrease, as well as to assess any other options which will result in no net loss of agricultural land value as a result of the project. This may include consideration of offsets.

It is noted in the EIS that a biodiversity offset strategy will be submitted to DPE within 12 months of development consent being granted and this strategy will potentially include offset areas impacting on other resources (sterilisation). The Division requires consultation with the Proponent in development of the offset strategy prior to submitting offset plans to for approval.

Should you have any further questions in relation to this matter, please contact Zane West, Manager Royalties and Advisory Services on 02 4931 6771.

Yours sincerely

K Hargreaves

11.7.17

Kylie Hargreaves
**Deputy Secretary Resources & Geoscience**
Encl.
Addendum A – Resource and Economic Assessment – Hume Coal

INT17/75333

Planning & Environment
Resources & Geoscience

**Attachment A**

**Unit:** **Strategic Resource Assessment & Advice**

**Branch/Division:** **Geological Survey of NSW - Division of Resources & Geoscience**

**Subject:** **Hume Coal Project**
**Resource & Economic Assessment**

**Introduction**

State significant development is regulated under the Environmental Planning and Assessment Act 1979, which requires a proponent to apply to the Department of Planning and Environment for development consent, supported by an Environmental Impact Statement (EIS).

This Resource Assessment conducted for the Hume Coal Project (the Project) by the Division of Resources and Geoscience (DRG) is designed to review the resource/reserve estimates stated in a proponent's EIS and whether the Project will deliver significant social and economic benefits to NSW from the efficient development of the resource and that resource recovery is optimised and waste minimised. It is also to ensure an appropriate return to the State from developing the resource. As such DRG has conducted an independent calculation of the royalty to be generated over the life of the Project.

The objects of the *Mining Act 1992* (the Act) are to encourage and facilitate the discovery and efficient development of mineral resources in NSW. In particular, relevance to resource assessment;

Section 3A(a) "to recognise and foster the significant social and economic benefits to New South Wales that result from the efficient development of mineral resources", and Section 3A(d) "to ensure an appropriate return to the State from mineral resources".

The State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 Part 3, Clause 15: Resource Recovery requires that resource recovery is efficient, optimised and minimises waste.

The Project is owned by Pohang Iron and Steel Company (POSCO) Australia which is 100% owned by Pohang Iron and Steel Company, the fourth largest steel producer in the world. The Project is operated by Hume Coal Pty Ltd (the Proponent) a 100% owned subsidiary of POSCO. POSCO is also a joint venture partner in two coal operations in NSW, and therefore has a long historical association with the NSW coal industry.

The Project is located in the Southern Coalfield, on the south-western edge of the Permian-Triassic Sydney Basin near Berrima. The Southern Coalfield is one of the Sydney-Gunnedah Basin's five major coalfields and is the State's largest producer of high quality metallurgical coal (hard coking coal) used for steel production. There is a long history of underground coal mining in the Southern Coalfield, with five coal mines currently in operation and consistent total saleable production for the last five years of around 12 million tonnes per year. This represents around 6% of total NSW saleable production, making the Southern Coalfield the smallest producing coalfield in NSW.

**Size and quality of the resource**

The Division has verified that the Project will provide approximately 50 million tonnes (Mt) of Run-of-Mine (ROM) coal and approximately 40Mt of product coal over the project life. The Proponent has completed coal resource and reserve estimation for the Project in accordance with the Australasian Code for Reporting Exploration results, Mineral Resources and Ore Reserves "the JORC Code". The JORC Code is an industry-standard professional code of practice that sets minimum standards for public reporting of minerals exploration results, mineral resources and ore reserves.

The Project will be a new underground coal mine in the Southern Coalfield. A Coal Handling and Preparation Plant (CHPP) and all necessary infrastructure will be developed on-site to support the Project. Once operational, the life of the Project will be around 20 years. Approval is being sought to extract at a rate of up to 3.4 million tonnes per annum (Mtpa) of run-of mine (ROM) coal, which would provide up to 2.6 Mtpa of product coal.

There is a long history of underground coal mining in the Wongawilli Seam in the Southern Coalfield, such as at the adjacent Berrima Mine and from mines in the Illawarra (Dendrobium Mine and Wongawilli Colliery). The coking coal fraction of the Wongawilli Seam is typically blended with the Bulli Seam and is used locally for steel manufacture or sold to international coking coal markets. The Wongawilli Seam can be exported as a stand-alone product, but like most coking coal products is often blended with one or more products before utilisation. Approximately 90% of coal produced from the Southern Coalfield is sold into coking coal markets.

The Project will produce one semi-hard coking coal product (54%) and one thermal coal product. The export coking coal product will be an around 10% ash content semi-hard coking coal product. The remaining middlings product has potential to meet export thermal coal markets as a 22% ash content high ash product, or meet domestic cement/power generation market specifications. The remaining CHPP reject will be emplaced underground into mining voids. A review of available coal quality information suggests the proposed product quality, market split and yield is achievable. Raw ash levels necessitate all ROM coal to be processed by a CHPP to meet the proposed market specifications. DRG considers that a total of approximately 40Mt of product (saleable) coal from the Project is feasible.

**Resource Recovery**

A number of factors constrain the mine plan, extraction methodology and therefore the resource recovery at the Project. These include geological, mining and

environmental constraints. The Proponent has considered a large variety of underground mining techniques and mine plans for the Project.

Mining techniques assessed included first and second workings techniques such as longwalls, miniwalls (at varying widths), pillar pocketing and plunge mining. The pine-feather system of underground coal mining was selected by the Proponent to optimise economic extraction with due consideration of constraints at the Project. The pine-feather system is a first workings underground mining technique and as such will have lower resource recovery than secondary extraction techniques such as longwall mining. First workings are typically utilised in projects where no surface subsidence is permitted.

Berrima Colliery is the closest mine in the area, which lays adjacent and to the north of the Project. Workings from the Berrima Colliery are less than 5km from the Project. The Berrima Colliery, which ceased operation in 2013, mined the Wongawilli Seam using bord and pillar first workings with pillar extraction second workings techniques.

The Wongawilli Seam in the Southern Coalfield ranges up to ten metres in thickness, with the economically mineable section occurring towards the base. The working section extracted at the Berrima Colliery ranged from 2.2m to 2.5m with a raw ash content of 28% to 33%. The economic working section extracted at Berrima Colliery is similar to that proposed by the Project. The Project working section will range up to approximately 3.5m thickness. In some areas Triassic strata have eroded the top of the economic section and working section heights reduce to around 1.5m. Throughout the Southern Coalfield the basal section of the Wongawilli Seam is recognised as the only economic section of the Wongawilli Seam when extracted underground.

The Permian, Wongawilli Seam is the only viable seam to economically mine in the Project area. The Bulli Seam which has a long history of production as a coking coal across the Southern Coalfield, has been eroded during the deposition of Triassic sediments. The American Creek and Tongarra seams underlie the target Wongawilli Seam at the Project, however they are too thin and/or too high in ash content to be commercially viable.

The Project proposes to extract coal using the pine-feather technique. Given the constraints outlined in the Proponent's EIS, DRG Strategic Resource Assessment & Advice considers the Project mine plan for underground operations to adequately recover coal resources and provide an appropriate return to the State, within the mine footprint, giving due consideration to the particular constraints of the location.

**Subsidence impacts relating to pine-feather mining technique**

DRG acknowledges that the pine-feather system of mining is untested in both NSW and Australia, and notes the commissioning of an independent expert mining engineering advice relating to the Project. It is recommended that subsidence predictions and effects be a consideration of the advice sought in relation to this mining technique. Principally, the construct and placement of fill and claims by the Proponent that near zero subsidence would result from using this mining technique be addressed in the advice.

**Economic benefits of the resource**

Over the life of the Project, assuming production is sold on the export coking market (54%) and the remainder on either the export or domestic thermal markets, the value of the coal produced would be worth around $3.9 billion in current dollars. The net present value of this revenue stream has been estimated by DRG at approximately $1.6 billion.

Export income is vital for the health of both the NSW and Australian economy, export income contributes to the Nation's balance of trade which provides positive benefits to both the NSW and Australian credit rating. This additional export income will contribute to the around $13.2 billion (2015-16 total) of coal exports annually. Coal exports are by far the largest value export from NSW, representing around 25% of total NSW exports (both goods and services combined).

The Southern Coalfield is the smallest in NSW and as at June 2016 had five mines producing coal. In 2015-16 the Southern coalfield produced around 12 million tonnes of product coal, which was 6% of the State's total. The total number of mines in the Southern Coalfield has been in rapid decline over the past few decades and the region has not had a new green-field coal mine for many years.

If approved, the additional anticipated 50 million tonnes of ROM coal to be produced over 20 years from the Project would assist in ensuring the Southern Coalfield remains a part of the NSW coal industry.

In addition, the Project would contribute to the economic activity of the region through the expected creation of around 290 jobs at peak production. The majority of these roles are expected to be filled from Wingecarribee Shire and other surrounding areas.

Based on other mine projects, DRG believes the additional indirect employment within the region and in NSW as a whole from the Project could support a further 1200 positions. These would be roles in local businesses who supply the mining operations with a range of goods and services. Capital investment over the life of the Project could be of the order of $650 million.

DRG also notes from the Proponent's EIS, (specifically the Economic Impact Assessment Report prepared by BAEconomics) that the following net economic benefits would result from the Project:

- net value added/NSW gross state product would be a direct benefit of $295m
- net disposable income for the Southern Highlands region of $85m

DRG also notes from the local effects analysis in the BAEconomics Report that the following employment related benefits would flow from the Project:

- disposable income (NPV 2016) of $236m
- other, non-labour operating expenditure (NPV 2016) of $643m

**Coal royalty calculation**

The Project is a proposed underground mine and as such a royalty rate of 7.2% applies to all saleable production, this rate is applicable to the net disposal value. Net disposal value is the price received per tonne minus any allowable deductions. The main allowable deduction is for coal beneficiation which is either; $3.50 per tonne for coal subjected to a full washing cycle, or $2.00 per tonne for coal subjected to a simple washing process, or $0.50 per tonne for coal that is washed and screened. As all product coal from the Project will be subjected to a full washing cycle, a deduction of $3.50 per tonne from the value of coal produced applies. A deduction for levies also applies which would amount to no more than $1.00 per tonne. Hence allowable deductions for royalty for the Project would amount to $4.50 per tonne.

One of the most important assumptions in the calculation of future Royalty for a coal proposal is the estimate of a future coal price over the life of a project. Coal from the Project is expected to be sold into the export coking market (54%) and either the export or domestic thermal markets. A review of coal quality information by DRG suggests this is achievable.

Coal price forecasting is inherently difficult and over the long term. An average coal price of around A$120 per tonne over the life of the Project has been used for the export coking coal from the Project. An average price of around A$70 per tonne for the thermal coal from the Project has been used by DRG, as some of the thermal coal from the Project will be sold into the domestic market the overall price of thermal coal from the Project is lower than expected future export thermal coal prices.

Another important aspect of future royalty calculation for a proposed coal project is estimation of future annual production. DRG has estimated that if the Project is approved, around 40 million tonnes of product coal would be able to be economically mined from the Project area from 2020 to 2040. The maximum rate of extraction would be around 2.6 Mtpa of product coal.

Using the above parameters DRG has calculated that in a typical full production year the State will receive around $16 million per annum in royalty and $270 million over the life of the Project. The net present value of this royalty stream would be $110 million using a 7% real discount rate.

NSW GOVERNMENT | Planning & Environment

OUT17/46015

Mr Greig Duncan
Project Director
Hume Coal Project

Dear Greig

**Southern Coalfield Geological Data Request**

The Strategic Resource Assessment & Advice unit in the Geological Survey of NSW (GSNSW) is updating our geological and coal resource model of the Southern Coalfield.

This model assists the GSNSW in providing accurate advice to Government about the State's coal resources. This advice informs government in:

- land use planning,
- operational allocations for new coal exploration licences and
- strategic release of new coal exploration areas

To update our model the GSNSW is seeking the assistance of the coal mine operators in the Southern Coalfield. The assistance we are seeking is the provision of selected borehole and coal quality data in a digital format that can be readily imported into our modelling software to reduce the time required to update our model. We have six months to complete this project.

The GSNSW, as the custodian all geological data submitted under annual reporting requirements for prospecting and mining titles, have these data already. However, to extract these data from our DIGS system and reformat them will be time consuming.

The data we are seeking are:

- Collar data
- Lithological logs
- Pick files (ply-by-ply and working sections)
- Coal quality data – Raw (Ash, RD, Moisture, VM, FC, CSN, Sulphur, Romax), Washed (Ash, Yield)
- Geological features (sills, dykes, faulting, other geological features affecting coal resources)
- Geophysical logs

Any data submitted will fall under the confidentiality provisions that apply to geological data submitted with annual reports. As such any data provided will not be provided to any other party as it is deemed confidential. Any data and the media it that is provided on will be returned at the conclusion of the project.

Director- Strategic Resource Assessment & Advice
Geological Survey NSW
Division of Resources & Geoscience - NSW Planning & Environment
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The outputs of the project will be coal seam and indicative coal quality grids for the main economic seams in the Southern Coalfield. Maps based on the grids will be only made available for internal government use, if requested, and where provided will be masked for those areas under company title. These maps will not be published.

This modelling project is managed by Tully Matthews who can be contacted on 02 49316527 or via email tully.matthews@industry.nsw.gov.au.

Yours sincerely

16/11/17

Dr Kevin Ruming
**Director**
**Strategic Resource Assessment & Advice**
**Geological Survey of NSW**

**A Geological Overview of the Area around A349 – Sutton Forest.**

**Introduction**

The study of rocks and how they have been developed over time is known as Geology. In the area surrounding Sydney the geological strata are located in a trench like shape known as the Sydney Basin. The rocks present in the Sydney Basin are predominantly sedimentary rocks. That is, rocks deposited in water, either associated with rivers, swamps, foreshores and even deep ocean waters. Be they sandstones, shales or even coal seams. In addition to the sedimentary rocks there are several igneous rocks, mainly volcanic in nature, but some plutonic rocks are also known to be present.

**The Sydney Basin Geology**

The majority of the Sydney Basin rocks are either Permian or Triassic in age. That is the period of time when the sediments were originally laid down. The coal seams and coal measure strata are all Permian in age – approximately 250Ma of age with the Triassic being younger. Figure 1, below is a map which shows the rocks which outcrop (reach the surface) in the area. The central green colours represent the presence/outcrop and extent of the Hawkesbury Sandstone and the Wianamatta Group sediments. Both of which are present at the surface in the A349 area. Some igneous rocks are younger either flowing over the existing landform or being intruded into the strata and range in age from Jurassic to Tertiary.

https://resourcesandgeoscience.nsw.gov.au/__data/assets/image/0005/287204/Sydney_500k.jpg

What is difficult to get a sense of from Figure 1 is the 3D nature of the Basin, and a sense of the nature of those rocks lying beneath the surface. In Figure 2, an attempt to give a 3D image is provided in a diagram put together by the NSW Division of Resources and Geoscience.

Source https://www.resourcesandgeoscience.nsw.gov.au/__data/assets/image/0008/748646/3d-model-01.jpg

With the deeper blue identifying the deeper parts of the Basin. The majority of sediments in the Basin have been deposited by river systems from the north with erosion bringing sediments from the higher regions on either side of the Basin. The New England Fold Belt to the North-East and the Lachlan Fold Belt to the West and South. The RED arrow gives the approximate location of the A349 area, which is effectively at the South-Western edge of the Sydney Basin.

In contrast to this South-East trending deposition, sedimentation of the Hawkesbury Sandstone (HBSS) was brought in from the south and west, eroding landforms including the granites in the Snowy Mountains Region, a source rich in silica for the clean sands of the Hawkesbury Sandstone. Over time the sands turned into rock. Now the HBSS is a dominant rock in the Sydney Basin, as well as the local area around A349 where it is known.

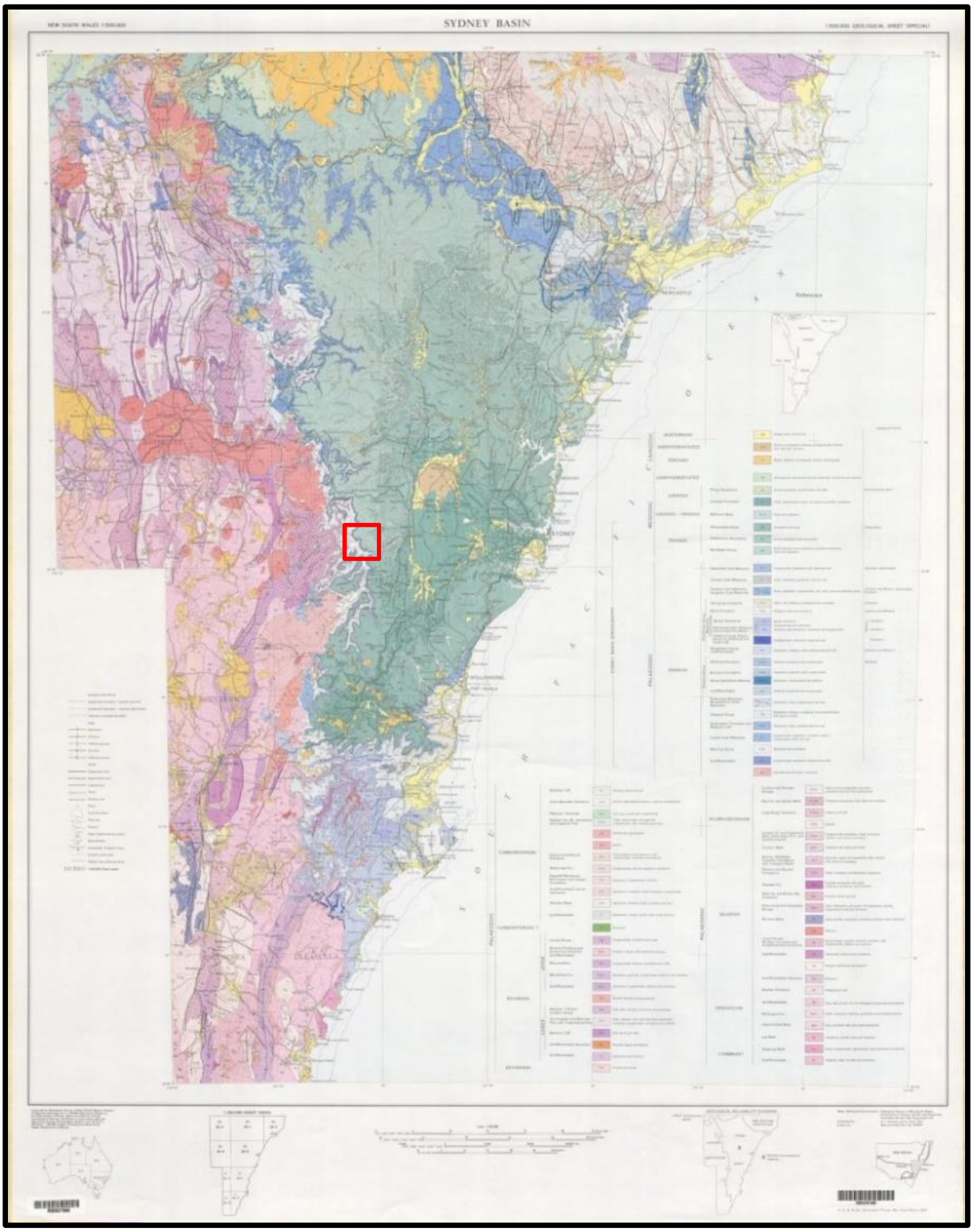



**Figure 1. The Sydney Basin Geological Map (Geological Survey of NSW).**

**Stratigraphy**

The Hawkesbury Sandstone (HBSS) is of major significance in the area around the potential mining area in A349. In this location the HBSS ranges between 80 to 110m in thickness. Whereas in deeper areas of the Basin (e.g. Central Sydney) the HBSS reaches a thickness of about 250m. In A349, the

HBSS sits unconformably on lower strata including in places the Wongawilli Seam – the coal seam proposed to be mined at the Hume Coal Project. The word 'unconformably' in a geological sense means that there may be a break between the two different units, a break in time, and or an angular difference between the two units and possibly a significant erosional break. The stratigraphy shown in Figure 3 represents the strata present in the area in and around A349. While in Figure 4 the strata shown represents typical rocks present over much of the central part of the Sydney Basin. The image is an outcrop near Wollongong and includes the Narrabeen Group.

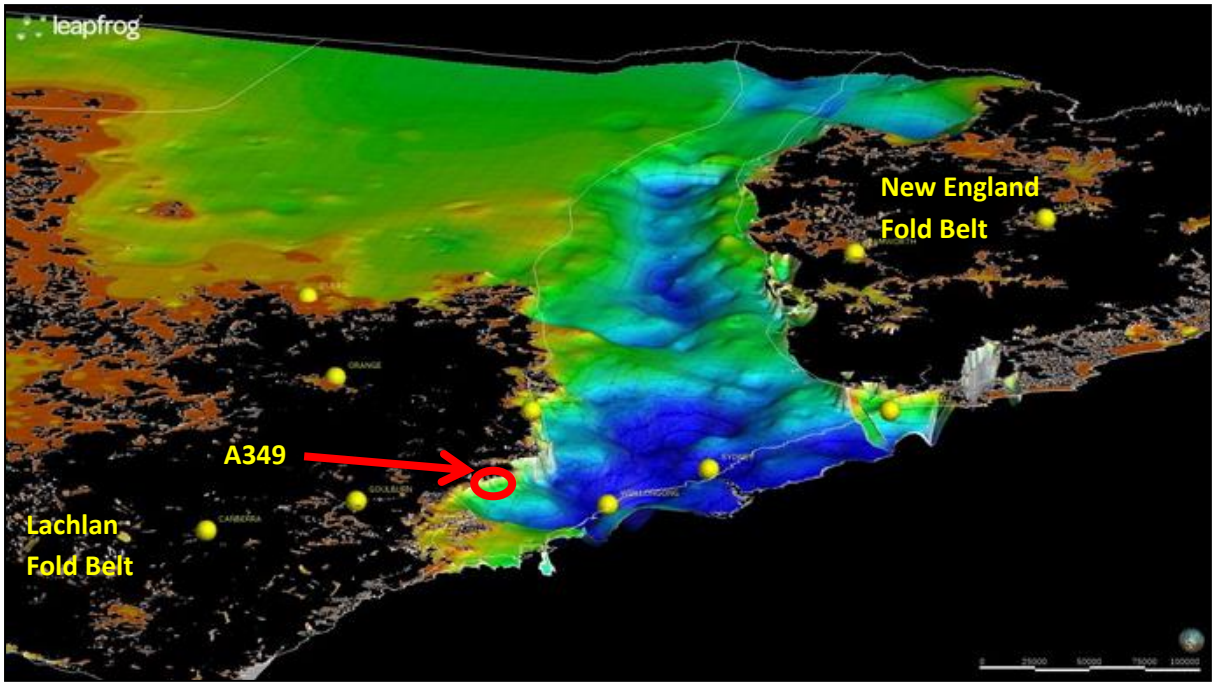



**Figure 2. The Sydney Basin in a 3D layout. (Prepared by the NSW Government)**

The erosional nature of the HBSS means that it has eroded through significant strata and down through the Narrabeen Group (if deposited) and into the Illawarra Coal Measures(ICM). Across A349 many exploration drill holes have been drilled into and below the Wongawilli Seam – the target coal seam. These exploration holes are comprised of two groups; the historical holes drilled pre-Hume Coal and are 168 in number, and the second group is the Hume Coal holes of which there are 139 exploration holes. In addition, there are an additional 41 (non-exploration) holes drilled for water investigations e.g. piezometers and not focussed on obtaining exploration data. Combined there are 307 exploration holes in an area of approximately 89 sq km. For an underground mining proposal this is an intense number of drill holes. One underground Coal mine near Appin commenced operations with 6 exploration holes drilled.

| STRATIGRAPHY AT HUME COAL PROJECT AREA | | | | |
|---|---|---|---|---|
| **AGE** | **GROUP** | **SUB-GROUP** | **FORMATION** | **MEMBER** |
| TRIASSIC | WIANAMATTA GROUP | | ASHFIELD SHALE | |
| | | | HAWKESBURY SANDSTONE | |
| PERMIAN | ILLAWARRA COAL MEASURES | SYDNEY SUB-GROUP | ECKERSLEY - UPPER | |
| | | | | BURRAGORANG CLAYSTONE |
| | | | ECKERSLEY - LOWER | UNM3 |
| | | | WONGAWILLI COAL | WWR PLY |
| | | | | FARMBOROUGH CLAYSTONE |
| | | | | WWA to WWJ |
| | | | KEMBLA SANDSTONE | |
| | | | ALLANS CREEK FORMATION | AMERICAN CREEK COAL |
| | | | DARKES FOREST SANDSTONE | |
| | | | BARGO CLAYSTONE | HUNTLEY CLAYSTONE |
| | | | | AUSTINMER SANDSTONE |
| | | | TONGARRA COAL | |
| | | | WILTON FORMATION | |
| | SHOALHAVEN GROUP | | | |

**Figure 3. Stratigraphy in the A349 area.**

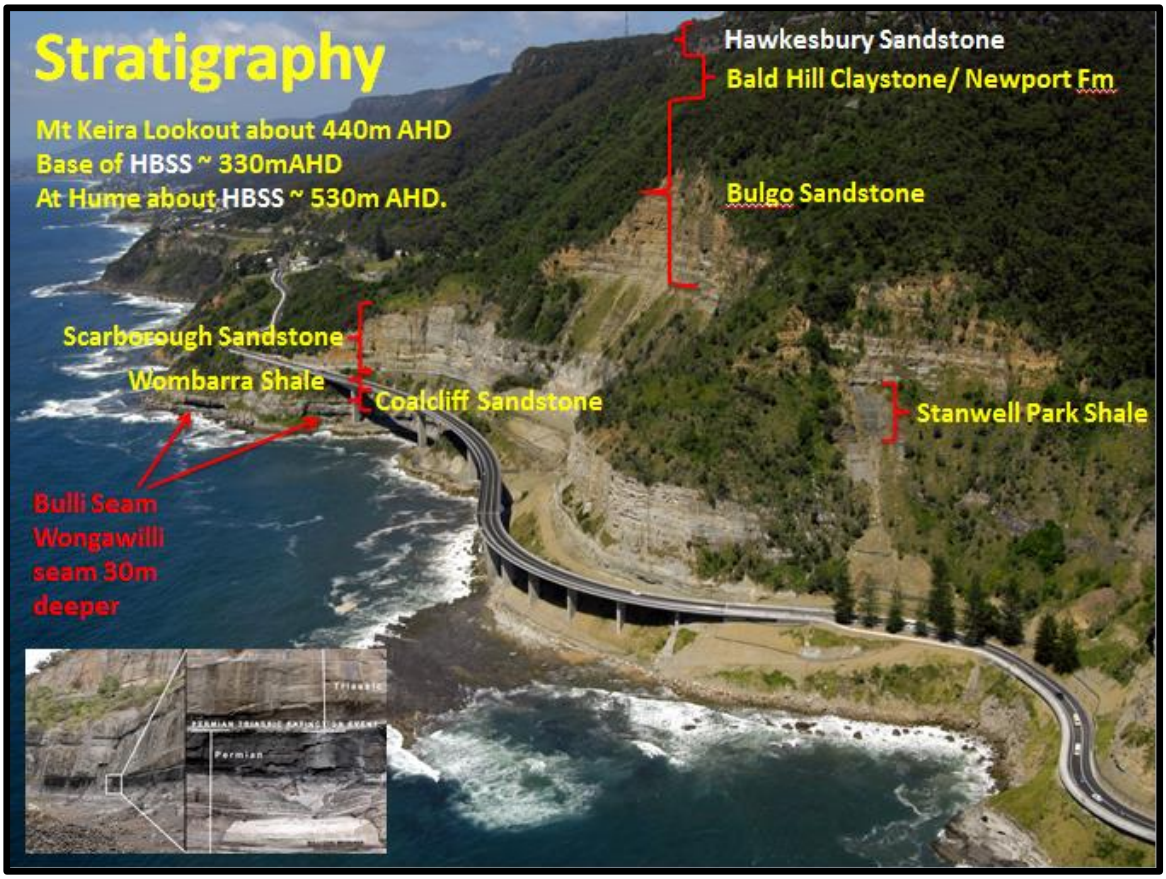



**Figure 4. The Stratigraphy in the area of the Seacliff Bridge – near Coalcliff.**

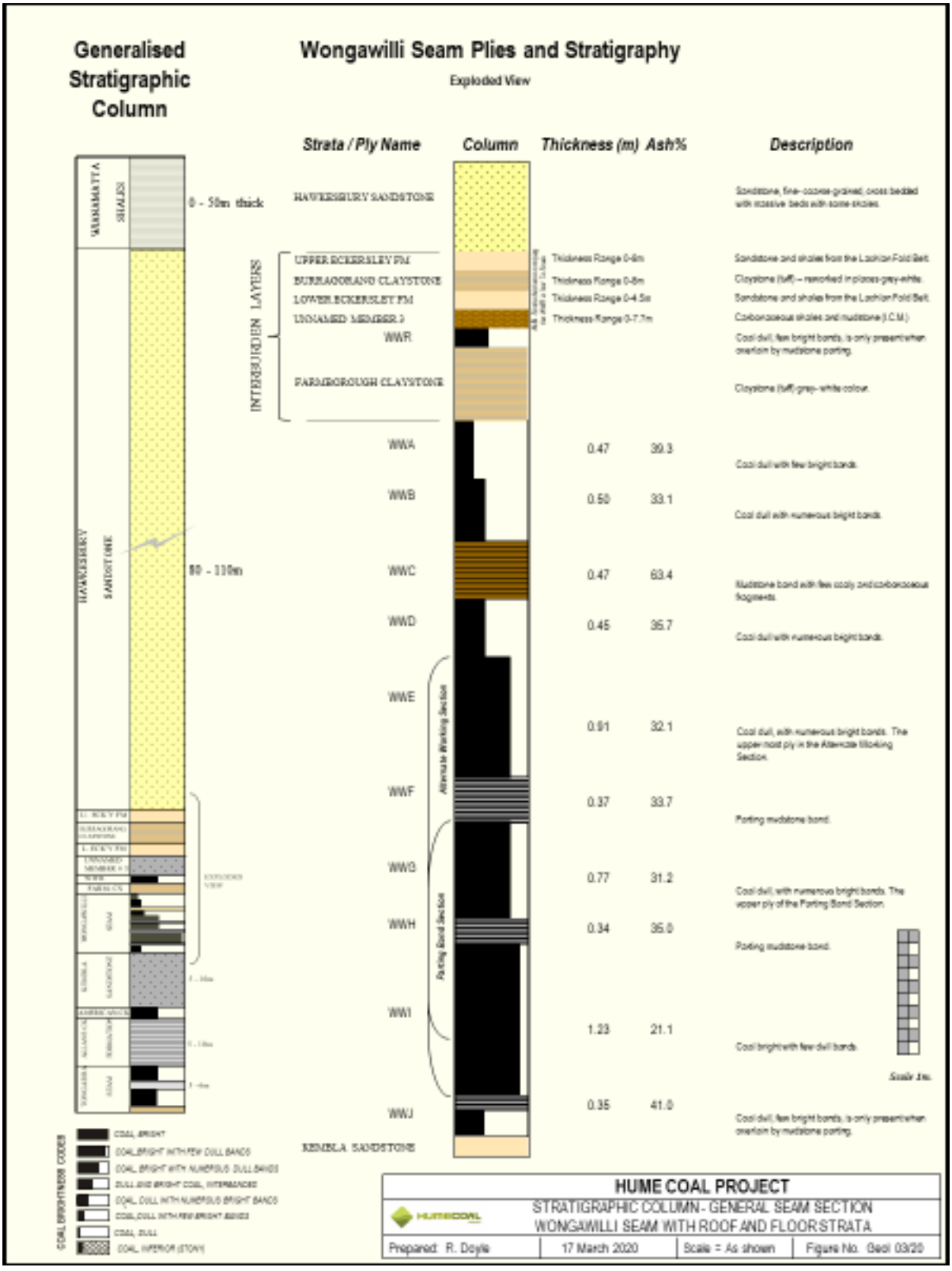



**Figure 5. A borehole profile of the A349 Stratigraphy.**

Figure 5 above shows the typical stratigraphy present in A349. In the eastern portion of A349 the Wianamatta Shales (WMSH) are present. The WMSH is underlain by the Hawkesbury Sandstone (HBSS) which outcrops in the west of A349. The HBSS is underlain by portions of the Eckersley Formation and the Burragorang Claystone (tuff) and by the remainder of the Illawarra Coal Measures

(ICM) which form part of what Hume Coal have termed the “interburden”. Then the upper parts of the Wongawilli Seam – e.g. the Farmborough Claystone Member (FCM). (For more detail on this section the reader is referred to the report by Sedpet services, included in this response.)

Then beneath the FCM are further plies of the Upper Wongawilli and then the mining section of the Wongawilli Seam (WWSM). Beneath the WWSM is the immediate floor of the WWSM the Kembla Sandstone (KBSS) a member of the ICM. Beneath the ICM is the Shoalhaven Group. Note. the erosional nature of the HBSS may have removed significant strata; the Narrabeen Group and some of the ICM, including; some, all or none of the Wongawilli Seam (WWSM) depending on the location or because of the location of the area in the south-west of the Basin, the Narrabeen Group may never have been deposited in any significant thickness here.

As noted above in places the original strata overlying the WWSM, remains in place in some of the area of A349, but is comparatively thin or absent. This strata has been termed the ‘Interburden’ by Hume Coal, i.e. the strata between the base of the HBSS and the base of the FCM. Part of the interburden strata is the Unnamed Member No 3 (UNM3) which is typical of the Illawarra Coal Measures and is different in appearance to the rocks above (i.e. the HBSS) or the coal below (the main body of the WWSM). The UNM3 contains fine grained sediments, generally grey or dark grey in appearance and includes; considerable carbonaceous whisps and sometimes coal and white tuffaceous volcanic ash fall deposits. In addition, the interburden includes the coal above the Farmborough Claystone Member (FCM) as well as the upper horizon of the WWSM – i.e. the WWR ply. The Interburden sediments are shown in Figure 6, the UNM3 is the grey unit with short black parallel lines. The white coloured sections represent the tuff deposits the FCM, which averages about 0.6m in thickness when present and the Burragorang Claystone which ranges from being absent to in excess of 4m. Note, due to erosion by the HBSS and or the Eckersley Formation (Upper and Lower) the interburden is not present across the entire lease area.

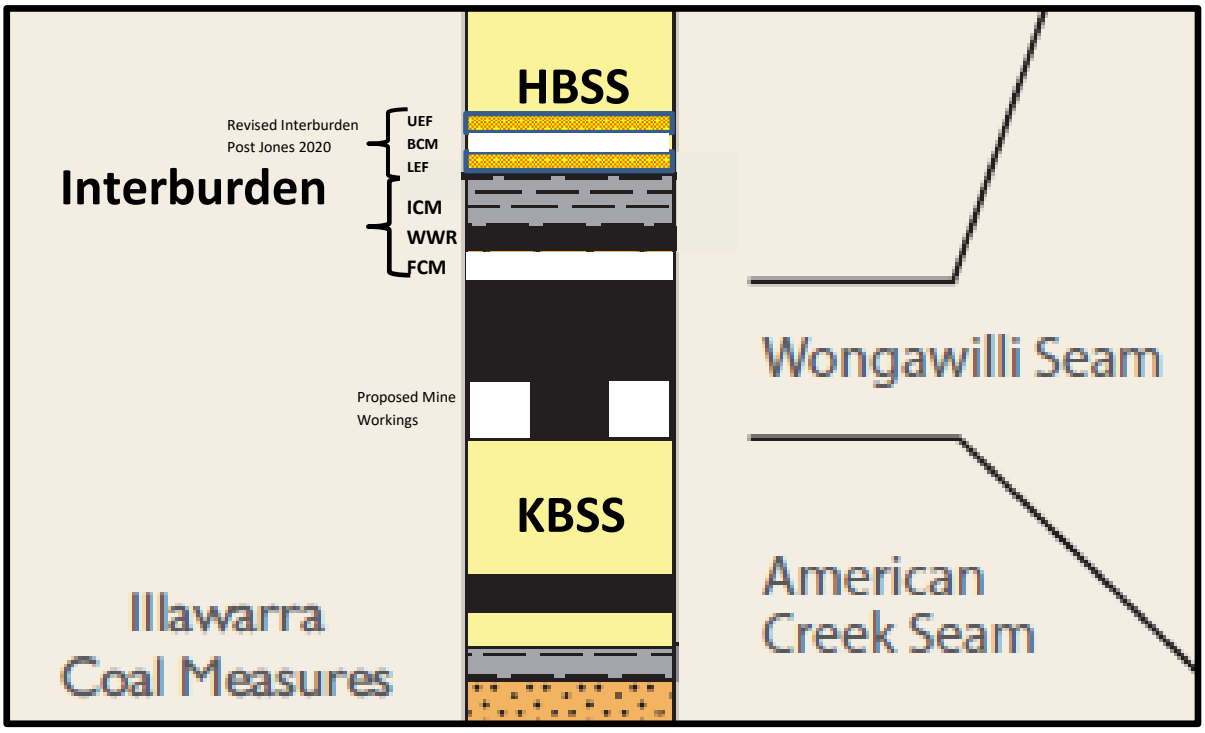



**Figure 6. Stratigraphy of most boreholes highlighting the Wongawilli Seam and Interburden.**

Below photographs are presented from six boreholes to show what the interburden actually looks like in core. The holes are respectively named HU0006CH, HU0036CH, HU0065PC, HU0130CH, HU0135CH & HU0144CH.

There is a significant database of geological information collected by Hume Coal which inputs into a geological model which in turn is input into the water models conducted over time. All this work has been undertaken by professional people who take great pride in their work.

**Coal Resources and Reserves**

The Coal Resources of A349 have been determined and reported in accordance with the JORC Code, the work has been a joint effort between Hume Coal and a consultant company called Palaris by recognised 'Competent Persons'. The Coal Reserves were also determined by Palaris. This work is reported in the EIS. The Government acknowledges that "there is a valuable coal resource … which would lead to economic benefits."

The Division of Resources and Geoscience undertook an audit of the geological information that Hume Coal provided to the Division. The NSW government has a copy of all geological information that Hume Coal has obtained through their exploration. After reviewing the data and attending a face to face session the Division concluded that, "there is a Coal Resource that has a clear benefit to the State." They would not have been able to give that assurance if Hume Coals geological information was inadequate. Further the Division notes that Export Trade is valuable not only to NSW, but also to Australia as a whole.

**The Wongawilli Seam – Depth of Cover**

The Wongawilli Seam is at comparatively shallow depth compared to its coastal Southern Coal mine equivalents (closed and operating), but of similar depths to mines that have operated in the Southern Highlands e.g. Berrima or Medway Mine. Its depth in the proposed mining area ranges from 80 to 180m. Data from the exploration boreholes is examined to determine the actual depth of the coal seam. That information (more than 300 data points) is presented in Figure 7 below shows the depth of cover over the Wongawilli seam.

Hume Coal have designed the mine to be conservative in terms of recovering resources and will leave significant coal resources underground to protect the overlying strata, its aquifer and the environment.

**Geological Structures**

A purpose for drilling the exploration boreholes is to assess the nature of geological structures in the area, including; faults, dykes, joints, sills or diatremes. Figure 8 below (Figure 6.5 from the EIS) which represents the interpretation that has been made as a result of combining data from exploration drilling, the use of geophysical logs, surface seismic, aerial and surface magnetic studies, surface mapping investigations and the geological model. All the borehole data is entered into a geological model and the outcome is a model which honours the data. The model can be interrogated and assists in developing an interpretation of geological structures.

For example, faults can be predicted, their orientation, their throw (which side is up or down) and by how much, as well as their nature, normal or reverse etc. The latter (sense of faulting) is an indication of whether the stress at the time of faulting was impacting on the ground in a compressive or extensional manner. This information is helpful for mine design. The faults are graded into various categories to describe the confidence levels associated with them. For example, Low Confidence, Moderate Confidence or High Confidence depending on how certain one is about the faults existence and its nature. While a fault may be located in a borehole, its orientation may not be determined, or the throw and the sense of fault (normal or reverse) may remain unknown.

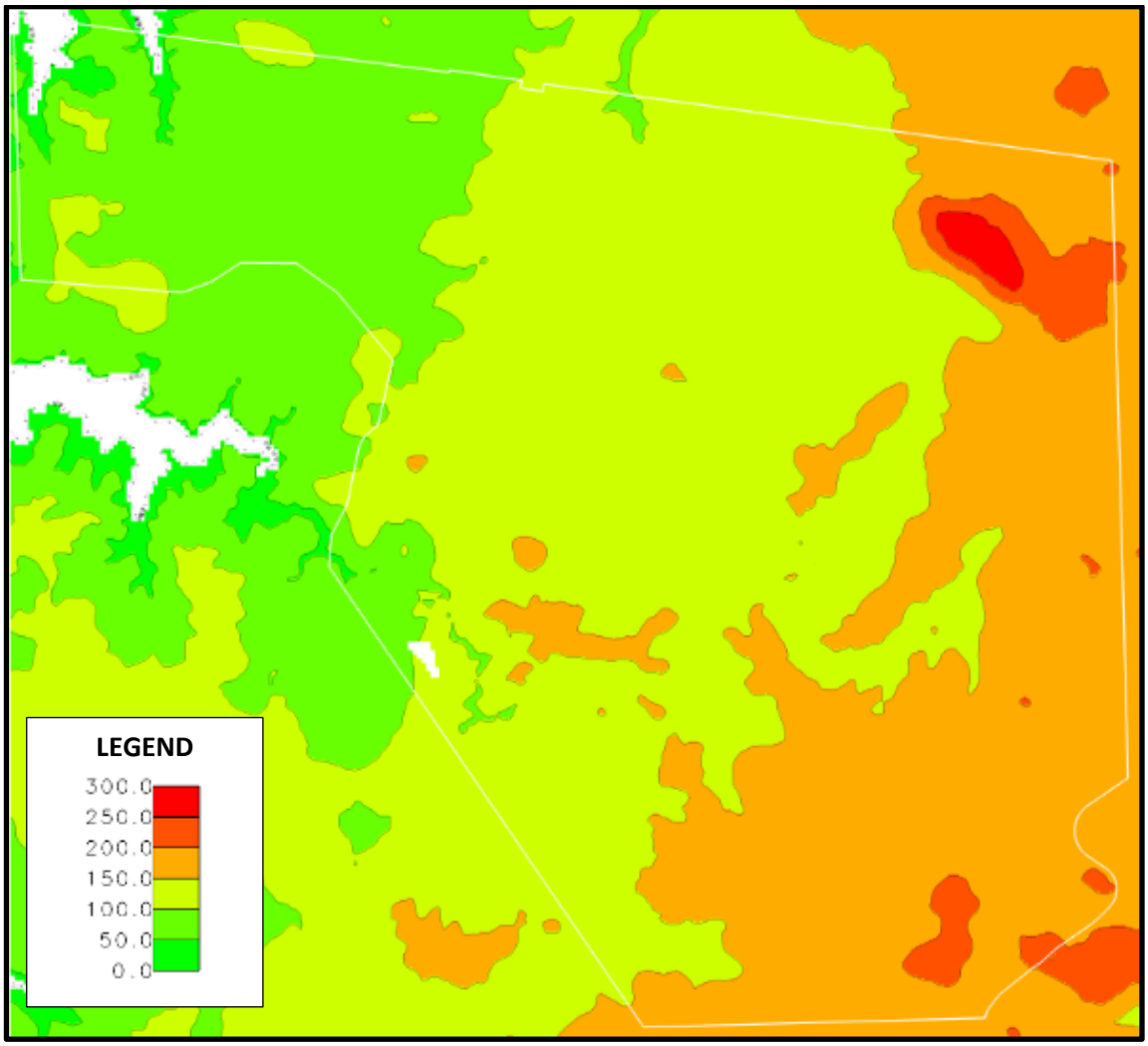



**Figure 7 Depth of Cover over the Wongawilli Seam.**

While the interpretation of the faults involve some uncertainty associated with them the diatremes which are like mini volcanoes are easily located by magnetic surveys that have been undertaken. An aerial magnetic survey clearly shows the location of these structures. To verify these observations field mapping was undertaken where access was permitted. In addition, some surface magnetic surveys were conducted. Figure 9 below shows the magnetic response of a diatreme.

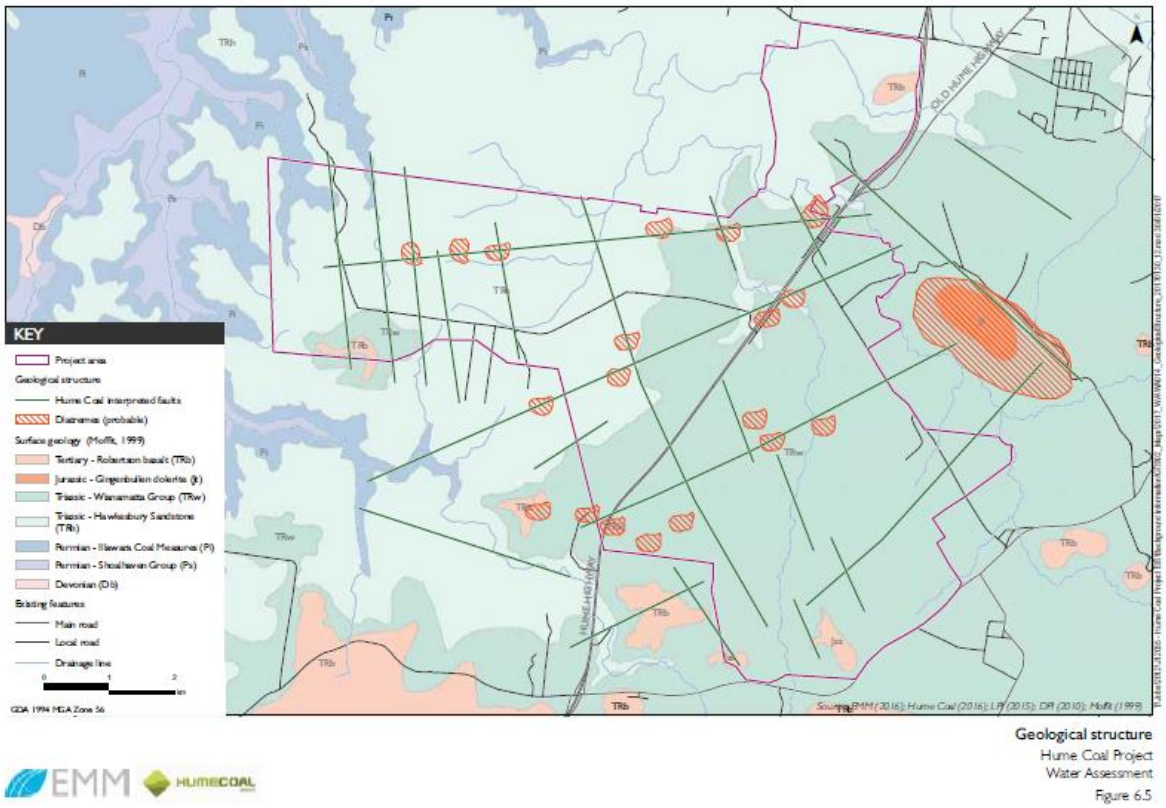



**Figure 8. Taken from the EIS – Fig 6.5 shows the location of geological structures.**

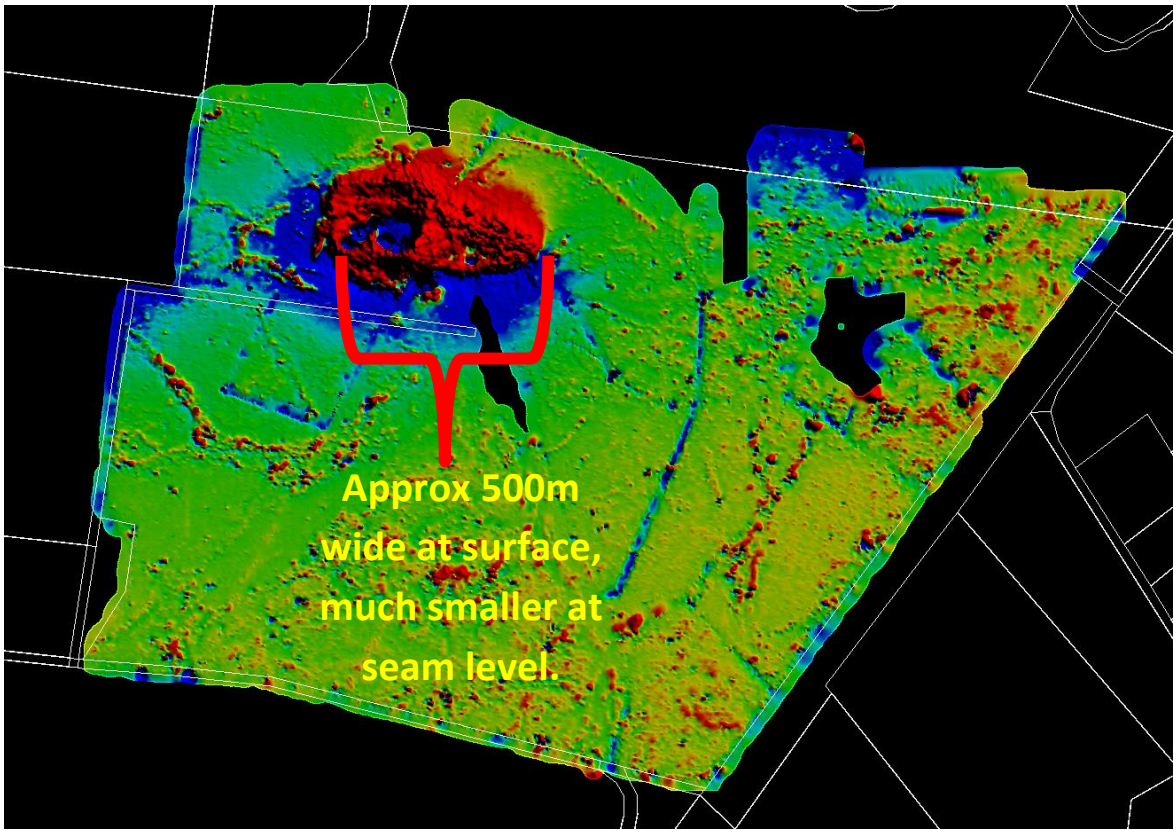



**Figure 9. Highlights the location of a diatreme in red – high magnetic resonance. In A349 basalt is often located on the surface above diatremes.**

This short summary of geological structure and the Government's own audit highlights that Hume Coal has collected substantive information regarding geological structures. And that geological structures have been thoroughly considered during the design of the mine plan and during risk assessments.

The NSW government has acknowledged that the Hume Coal Project coal is a Hard Coking Coal and the only new hard coking coal project in NSW. With the local and worldwide steel industry still showing strong demand for metallurgical coal, i.e. coal suitable to make coke for blast furnaces. The fact is that there is strong demand for coking coal and this is very evident in the current price. Coking coal is an essential ingredient for steel manufacturing, which in turn is critical to supply for the manufacture of wind turbines and other items to develop less reliance on fossil fuels.

Figure 10 below shows the location of the historic exploration bores (in red) and the Hume Coal boreholes in yellow.

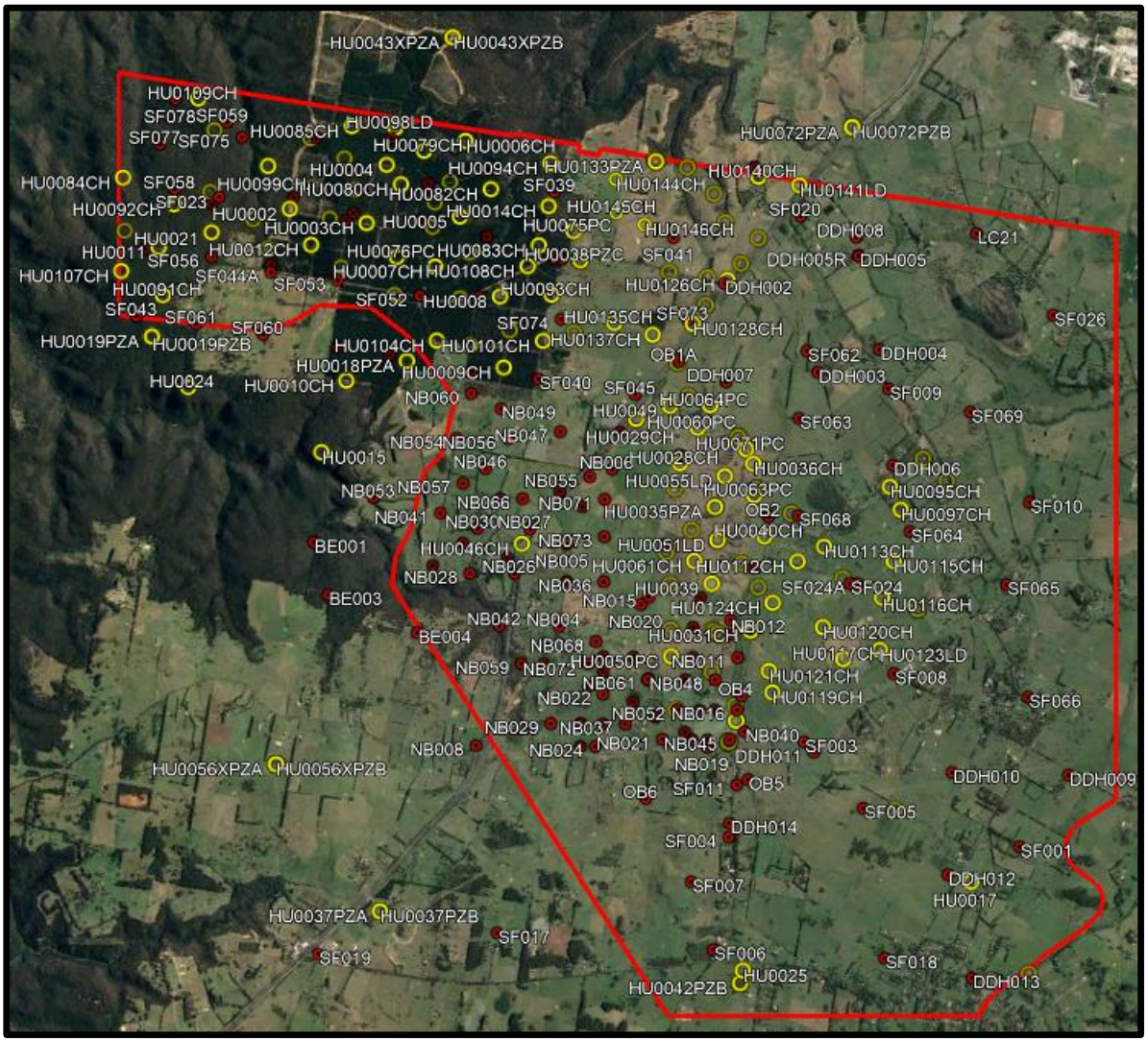
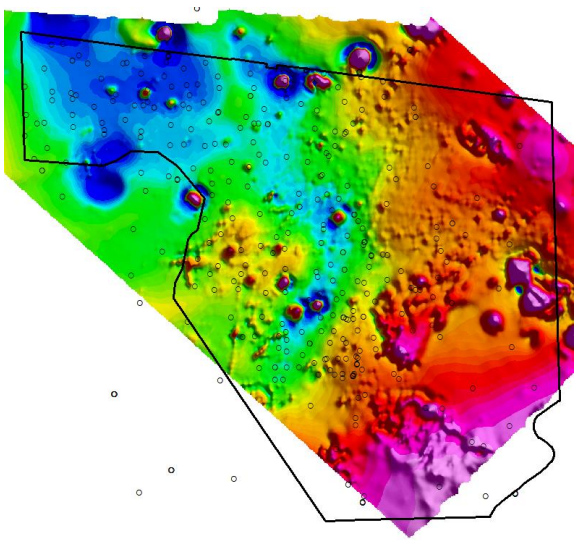



**Figure 10. Location of Exploration Drill Holes.**

To assist with determining the location and features of geological structures gravity data was collected by air and a repeat of the magnetics was also undertaken. The quality of the magnetics data appears good, but the main purpose would have been to obtain the gravity data.



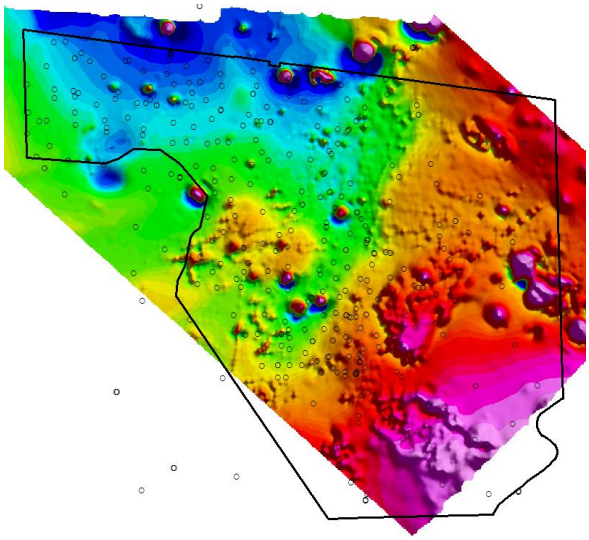
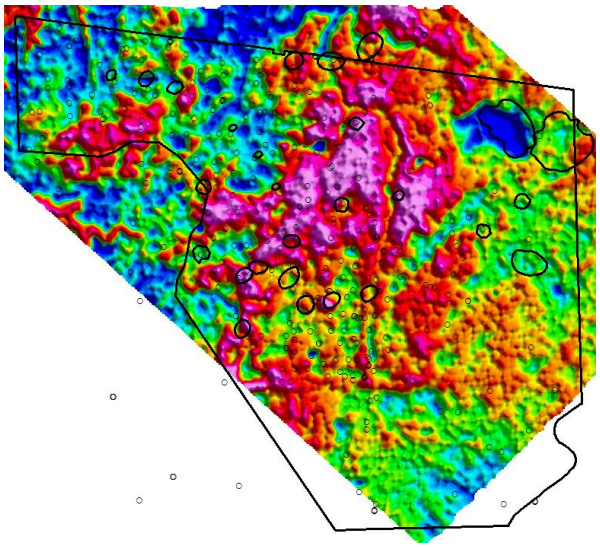


**Figure 11. 2001 Image Reduction to Pole** **Total Magnetic Intensity**

The Reduction To Pole (RTP) image is generated as a result of using an algorithm that removes the bias associated with the measurement within the earth's magnetic field, making the data uniform to the poles. The Total Magnetic Intensity is a measure of the magnetic signature at a particular location, measuring the site-specific features after the Earth's normal magnetic intensity is removed. These images can be compared to the identified features shown in the boreholes described above.



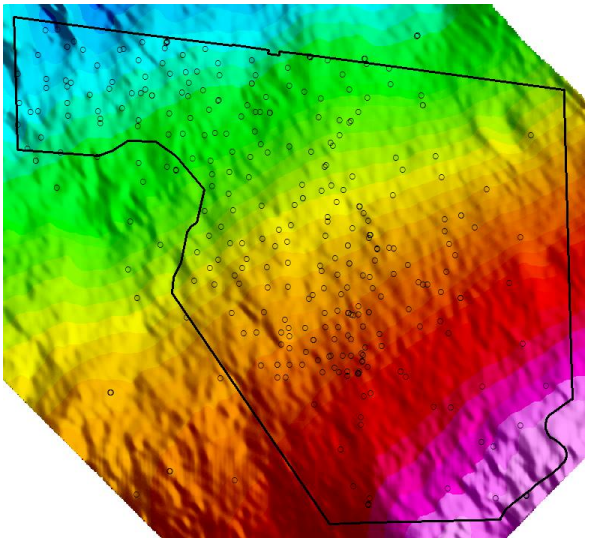


**Figure 12. 2001 Total Count Radiometrics.** **2011 Gravity (Density) Image**

Radiometrics focuses on measuring three specific elements, those elements are Potassium (K) Uranium (U) and Thorium (Th). The total count combines all three of these elements and presents it.

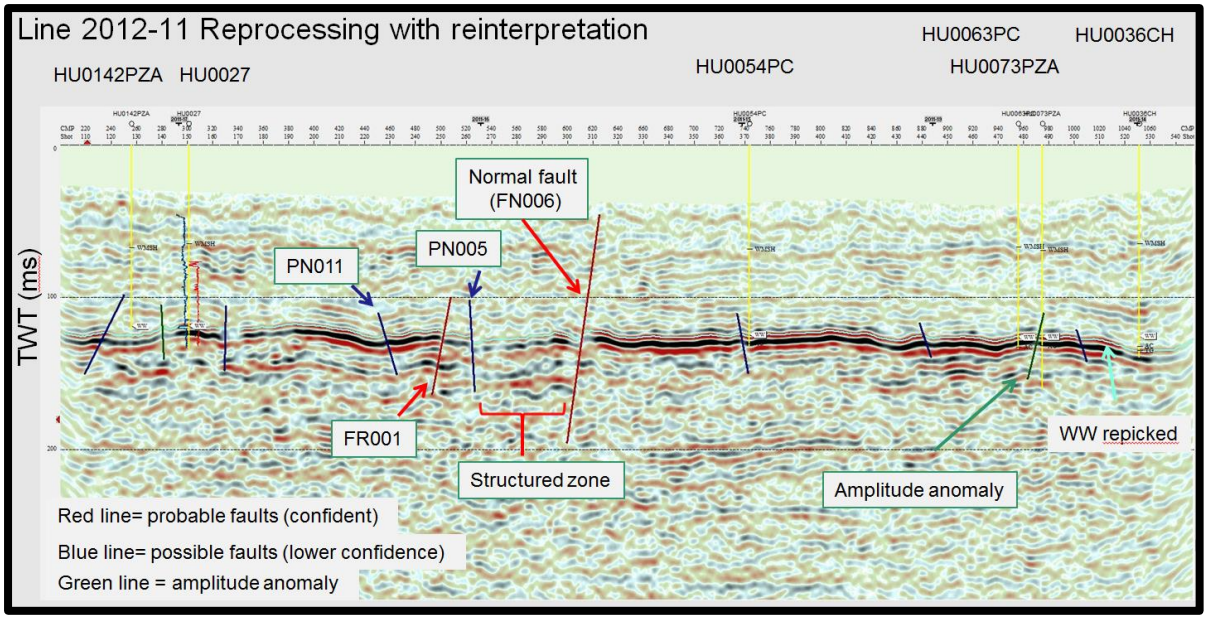



**Figure 13. An example of the Seismic survey undertaken.**

A interpretation of aerial photographs was undertaken in an effort to assist define geological structures from all sources available. In Figure 14 below the aerial photographic interpretation represents the results of this work. The blue green colour on the LHS of the figure represent the outcrop of the Hawkesbury Sandstone, while the lighter and darker greens represent the outcrop of the Wianamatta Shale units. The purple in the top LH corner represents the Illawarra Coal Measures where they outcrop. There are a number of features identified as potential geological structures, synclines and faulting etc. Mt Gingenbullen is an obvious feature in the top RHS of the image. Diatremes are also observed.

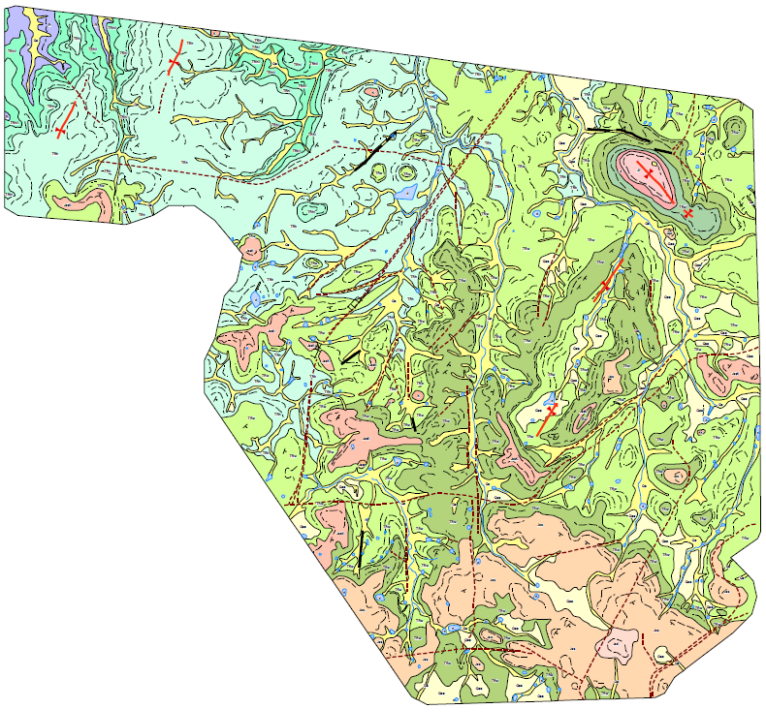


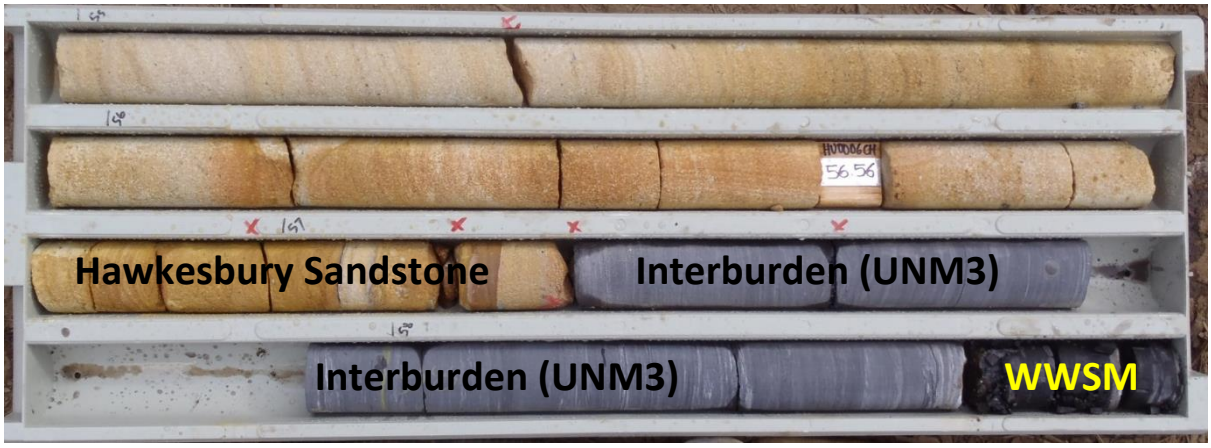
**Figure 14. Aerial Photography – Mapping.**

Minex geological modelling software was used to develop a geological model for the deposit. For determining if any faulting could be interpreted at the level of the Wongawilli Seam thirty-three (33) seam sections were 'cut' through the model and working sections were printed off so that a comparison of the work could be made. Thirteen (13) of these sections ran roughly east west or with dip. Another twenty (20) sections were made running roughly NW-SE with a degree of overlap across the first group of sections and again oriented roughly with known seam dip.

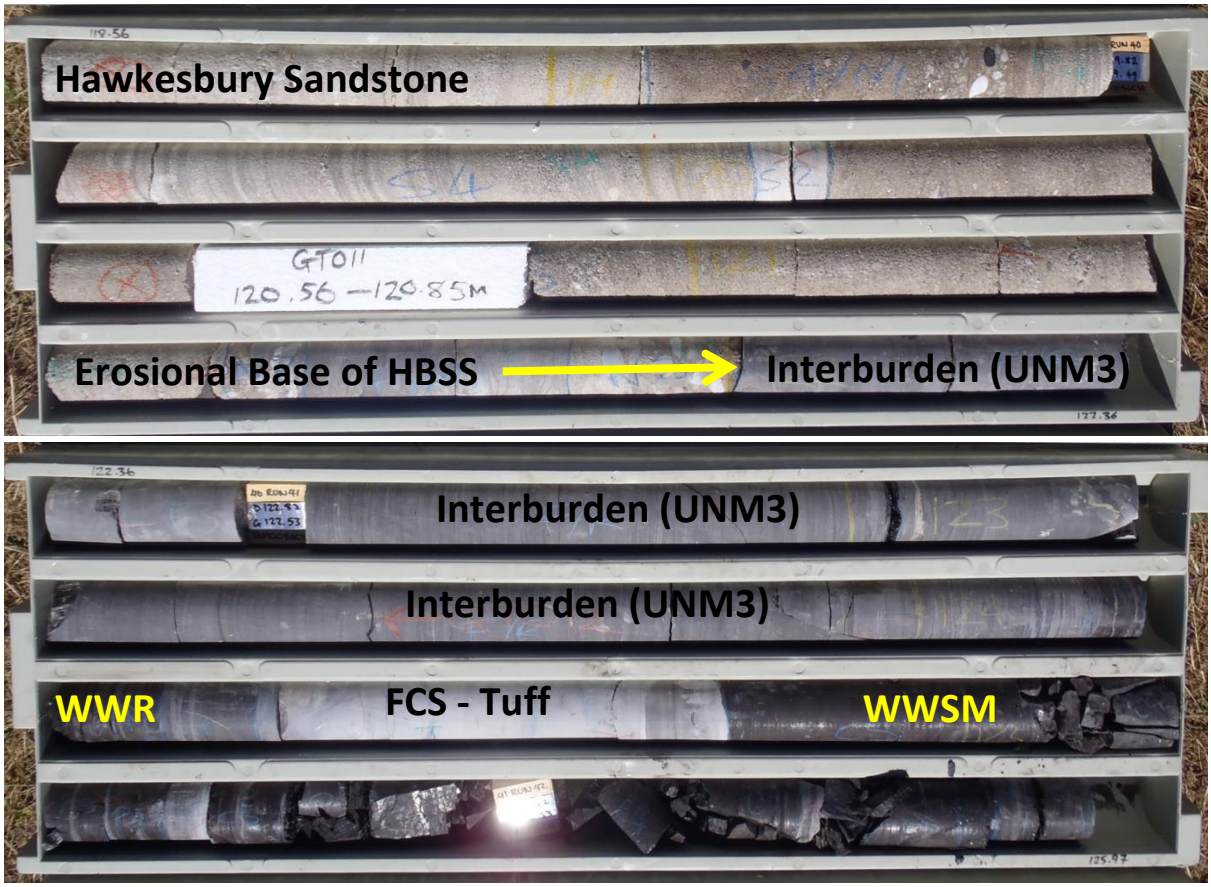
**Figure 15. Plan of Cross-Sections made through the Geological Model.**

A process of examining the sections closely and looking for points of inflexion or excessive change in grades was undertaken. Then a comparison of one section to the next was done, effectively building up a 3D interpretation of features. This overall process derived good results and the more agreement one section had with its neighbours the more confidence was built up. These interpreted features were then compared to the suite of borehole features identified to further enhance the levels of confidence across the deposit.

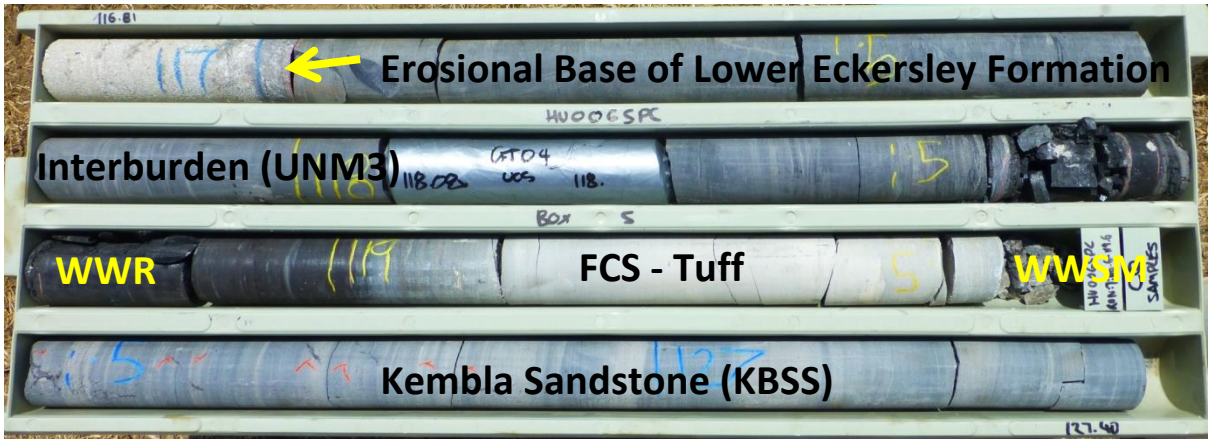
**Bore HU0006CH**




**Bore HU0036CH**



**Bore HU0065PC**



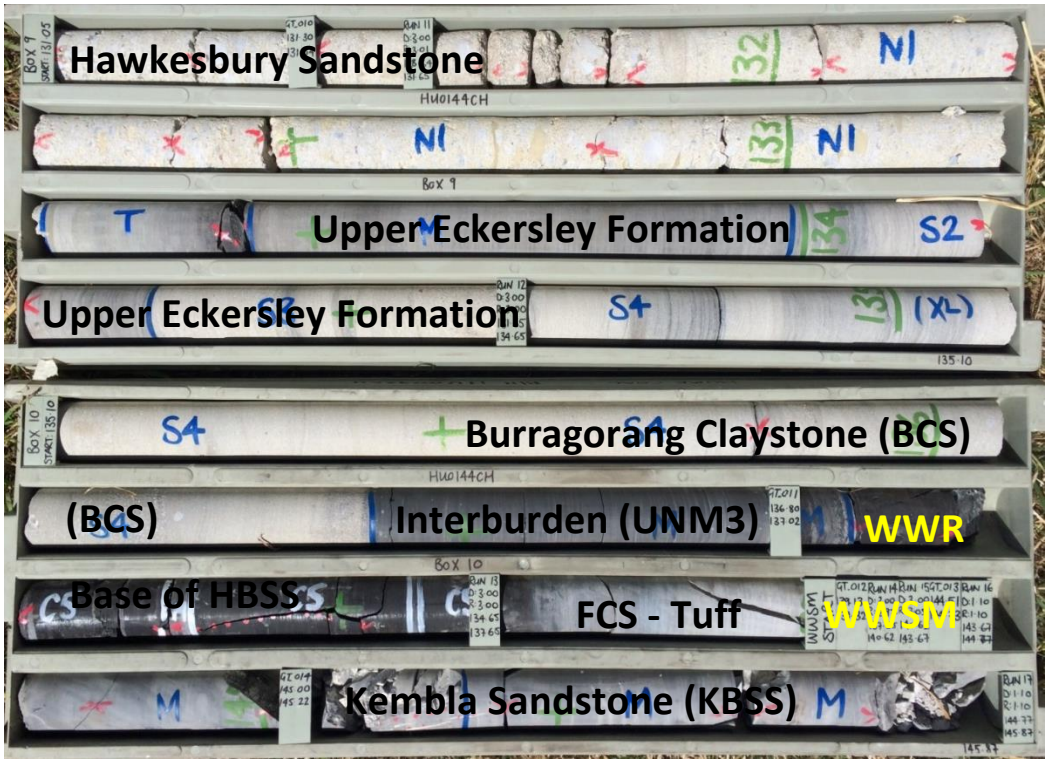

*Note in HU0065PC apart from the WWR ply the rest of the Wongawilli Seam has been removed for coal quality testing.*

**Bore HU0130CH**

**Bore HU0135CH**

*Note in HU0135CH portions of the Wongawilli Seam have been removed for testing purposes.*

**Bore HU0144CH**




*Note in HU0144CH the Wongawilli Seam has been removed for testing purposes.*

**Significance of the Resource - Resource/Reserve Audit**

**Process and Project Economic Data Request**

The State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) 2007 was amended in November 2013. This amendment was introduced to ensure that the significance of the resource must be considered in the decision-making process as an important factor.

NSW Trade & Investment is required to provide advice on the 'Significance of the Resource' under *Clause* 12AA as defined by the State Environmental Planning Policy (Mining, Petroleum Production and Extractive Industries) Amendment (Resource Significance) 2013. This is undertaken by the Division of Resources & Energy (DRE).

This audit process is designed to validate the resource/reserve estimates stated in a proponent's Environmental Impact Statement (Table 1). It will also confirm if the production schedule and product mix by market segment is feasible. Additional project data is also requested to allow DRE to conduct an independent analysis of the economic significance of the resource; which includes an estimate of the total revenue to be generated by the Project, royalties to the State generated over the life of the Project, direct and indirect employment provided by the Project, capital expenditure estimates, use of infrastructure such as port and rail facilities and other broad economic benefits of the Project.

**Approach**

Due to the complexity of deposits, the variety of software systems used in resource/reserve estimation and time/resource constraints the DRE considers that the following resource/reserve audit process will ensure a consistent approach to assessing a proponent's 'Significance of the Resource'.

Representatives of the Geological Survey NSW and from Industry Coordination will undertake the resource/reserve audit process onsite. DRE will validate the database and geological model that generated the coal resource/reserve estimates contained in the proponent's Environmental Impact Statement. DRE will then make an independent assessment of the total in-situ, run-of-mine (ROM) and product tonnes contained within the project area and if resource utilisation is maximised.

Prior to arriving on-site DRE will send the audit questions to allow adequate time to prepare responses. During the on-site audit all responses will be documented. After completing the audit a report will be prepared and a response addressing the Significance of the Resource requirements will be completed. The audit report will focus on any areas deemed to materially affect the reserve estimate tonnage or quality reported by the proponent in their Environmental Impact Statement. These areas will be discussed with the proponent and if material differences are noted the estimated effect on the proponent's reserve estimate will be reported.

**Table 1.** The audit process to independently verify coal resource/reserve estimates for use in DRE submissions on the "Significance of the Resource".

| Geology & Mining | |
|---|---|
| **Audit Subject** | **Audit Process / Required responses** |
| **1. Collars** | a. Report collars, number of holes & depths. |
| | b. Report holes excluded from modelling. Comment on why these holes were excluded and if any of the holes would significantly affect reserves? |
| | c. Report a collar to topographic surface comparison noting any significant differences. |
| | d. Plot holes in 3D. Comment on distribution, depths and any outliers. |
| | |
| **2. Stratigraphy** | a. List the modelled seams/horizons and seams excluded from modelling. |
| | b. Report number of seam intervals on a seam by seam basis. |
| | c. Document seam by seam contribution to reserves as a percent. |
| | d. Compare seam intervals to main seams contributing to reserve estimates. |
| | e. Document seam splitting methodology. |
| | f. Report the splits and split percentages or father/son parameters and comment on appropriateness. |
| | g. Review logical sections through the LOM pit design areas showing target seams and borehole intervals. |
| | h. Plot a number of borehole profiles showing geophysical logs, coal quality intervals, working section intervals and lithology. Report any major inconsistencies between lithology, geophysics and quality intervals. |
| | |
| **3. Borehole database** | a. Report seam interburden and thickness. Document and comment on any negative results. |
| | b. Report barren holes. Are these excluded from intersecting thickness grids? |
| | c. Plot seam thickness histograms for main seams (seams contributing most tonnes to reserves) noting any outliers. |
| | d. Plot coal quality crossplots for main seams noting any significant outliers. Crossplots may include ash vs rd, ash vs cv. |
| | |
| **4. Grids** | |
| Mesh sizes | a. Report mesh sizes and comment on their appropriateness. |
| Topography | b. Display topography surfaces. Report the date of any 'mined' surface topography. Note any issues. |
| Base of weathering | c. Subtract the BOW grid from topography. Report min, max, mean depths. |

| Geology & Mining | |
|---|---|
| **Audit Subject** | **Audit Process / Required responses** |
| Seam floor grids | d. Display seam floor grids. Is the model representative of the areas geology? |
| | e. Annotate the difference between main seam grid floors and borehole interval floors. Report any significant differences. |
| Seam thickness grids | f. Contour plot main target seam thicknesses. Note any 'bullseyes'. |
| | g. Annotate the difference between main seam grid thicknesses and borehole interval thickness. Report any significant differences. |
| Faulting | h. Have faults been included/excluded from modelling. Plot faults from geometry and export figure. |
| Pit Design | i. Plot LOM pit design and lease boundary. |
| | |
| **5. Geometry** | a. Plot dykes, sills, rivers, faults, washouts etc. within the proposed mining area. Are these excluded from reserve estimates? |
| | |
| **6. Resources/Reserves** | a. Report reserve tonnes between the appropriate surface and LOM pit design. Using relevant modifying factors (provided by the company) i.e. min thickness, recovery, sills, etc. report reserves on a seam by seam basis. Export results and comment on any significant differences with those reported in the proponent's EIS. |
| | b. Report all 'modifying factors' and comment on their appropriateness. |
| | c. Document proposed product coal qualities. Report major target seam grid qualities within the reserve area and discuss any significant differences. Is it likely the target product will be met? |
| | |

Some question not directly related to Geological Aspects have been deleted from the end of the Governments questionnaire.

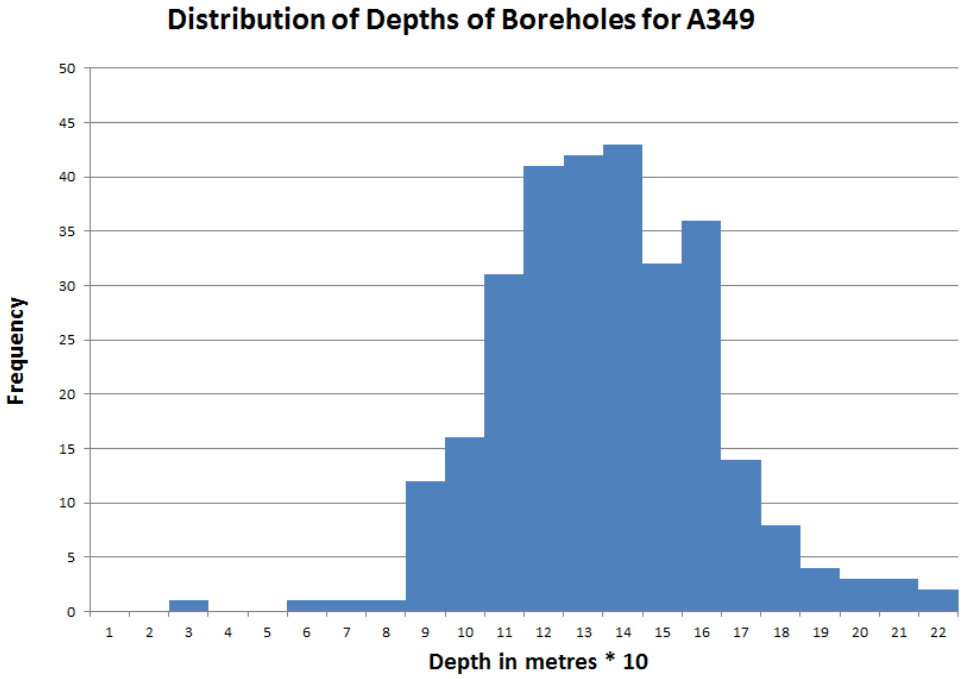
# Significance of Resource Commentary
# Hume Coal Response (c 2017)

***Item 1 Collars (d) Comment on distribution of holes and depths and outliers***

Bores in A349 are reasonably well distributed across the Exploration Licence area.

There are approximately 306 exploration boreholes drilled in an area of about 89km2. Which on average is about 3.4 bores per square kilometre. The depth of the exploration holes range from 29 to 213m, with an average depth of 130m. (Note that these statistics do not include the non-REF holes drilled as part of the Hume Coal groundwater investigations and are 39 in number. In addition there are 15 historic holes for which we do not have final depth details as no written logs have been located. Some of the groundwater bores are also drilled outside the licence area.)

Regarding outliers, SF24 was only drilled to 29m depth and was redrilled as bore SF24A. SF75 & SF78 were both drilled in the far North West in the shallowest part of the Belanglo State Forest area where the Wongawilli Seam is shallowest. The deeper holes are not considered outliers and 4 holes greater than 200m depth are in the South East of the lease (DDH12, DDH13, HU016 & HU017.)




Two areas have reduced coverage by boreholes. The first is an area around the Golden Vale Road which has a much broader spaced distribution of boreholes with a ratio of about 1 borehole per square kilometre (nom 4.5km$^2$). The REF3 attempted to infill this area, but access was not achieved. This area is covered by the current mine plan and therefore has a lower level of confidence. The second area is to the south of the Illawarra Highway, but is outside the MLA area and mine plan. This area also has a ratio of about 1 borehole per square kilometre (nom. 24km$^2$).

***<u>Item 2 Stratigraphy (a)</u> List the modelled seams/horizons and seams excluded from modelling.***

All zones in the Geobank database include:-

**AC** - American Creek Seam – modelled.
**BC** - Base of Casing – **not modelled i.e. EXCLUDED.**
**BH** - Base of HBSS – modelled.
**BS** - Base of Wianamatta Shale – modelled.
**BTB** - Base Tertiary Basalt - **not modelled i.e. EXCLUDED.**
**BW** - Base of Weathering - **not modelled i.e. EXCLUDED.**
**DFSS** - Darkes Forest Sandstone **- not modelled i.e. EXCLUDED.**
**FCM** - Farmborough Claystone Member – modelled.
**KBSS** - Kembla Sandstone (floor of Wongawilli Seam) – modelled.
**TG** - Tongarra Seam – modelled.
**UM3** - Unnamed Member No 3 – modelled.
**WLFM** - Wilton Formation **not modelled i.e. EXCLUDED.**
**WWR** - Wongawilli Ply – modelled. (Rider Seam)
**WWA** - Wongawilli Ply – modelled.
**WWB** - Wongawilli Ply – modelled.
**WWC** - Wongawilli Ply – modelled.
**WWD** - Wongawilli Ply – modelled.
**WWE** - Wongawilli Ply – modelled.
**WWF** - Wongawilli Ply – modelled.
**WWG** - Wongawilli Ply – modelled.
**WWH** - Wongawilli Ply – modelled.
**WWHI** - Wongawilli Ply – modelled.
**WWI** - Wongawilli Ply – modelled.
**WWJ** - Wongawilli Ply – modelled.

***<u>Item 2 Stratigraphy (b)</u> Report number of seam intervals on a seam by seam basis.***

***Wongawilli Seam***

**WWR** = Wongawilli Seam Rider
**FCM** = Farmborough Claystone Member
**WWA** = Wongawilli Seam Ply A
**WWB** = Wongawilli Seam Ply B
**WWC** = Wongawilli Seam Ply C
**WWD** = Wongawilli Seam Ply D
**WWE** = Wongawilli Seam Ply E
**WWF** = Wongawilli Seam Ply F
} Alternate Working Section where seam thickness dictates.

**WWG** = Wongawilli Seam Ply G
**WWH** = Wongawilli Seam Ply H
**WWI** = Wongawilli Seam Ply I
} Main Working Section (may include J ply when present).

**WWJ** = Wongawilli Seam Ply J } Where present is mined with Main Working Section.

**AC** + American Creek Seam
**TG** + Tongarra Seam

***<u>Item 2 Stratigraphy (c)</u> Document seam by seam contribution to reserves as a percentage.***

The Wongawilli Seam contributes 100% of Coal Reserves of the Reserve.

**<u>Item 2 Stratigraphy (d)</u> Compare seam intervals to main seams contributing to reserve estimates.**

The Wongawilli Seam, while being the No3 seam of the Illawarra Coal Measures is the Upper most seam at this location due to high erosional activity in this area. As such there is no interval to any overlying seams. The Wongawilli seam is the only economic seam at this location and as such is the only one to contribute to the Resource and Reserve Estimation. See Item 2B above to see Main and Alternate Working Sections.

***<u>Item 2 Stratigraphy (e)</u> Document seam splitting methodology.***

There is no seam splitting at Hume Coal. The Wongawilli Seam is deposited in well-defined overlying ply by ply formation.

The Wongawilli seam is eroded into at most locations by the Sandstones. Washouts do occur in places and this sometimes causes uncertainty with ply definition.

The Unnamed Member No 3 is sometimes present – mostly in the central north of the Authorisation. Where present the entire Wongawilli seam is present. The Farmborough Claystone Member is present – mainly to the north of the Authorisation. It is eroded from the sequence to the south of the EL where the seam is thinner.

***<u>Item 2 Stratigraphy (f)</u> Report the splits and split percentages or father son parameters and comments on appropriateness.***

There is no seam splitting at Hume Coal. The Wongawilli Seam is deposited in well-defined overlying ply by ply formation. There are no splits or split percentages or father son relationships used for modelling.

***<u>Item 2 Stratigraphy (g)</u> Review logical sections through the LOM pit design areas showing target seams and borehole intervals.***

Wongawilli seam is the only target seam. Logic for mining section is:-

A) Minimum mining height of 1.5m
B) Plies GHI (J)
C) Plies EFGHI(J)
D) Maximum mining height of 3.50m, including 0.15m dilution (roof and floor)
E) Overprinting mining height will be a coal quality interpretation (to be completed).

***Item 3 Borehole Database (a) Report seam interburden and thickness. Document and comment on any negative thickness.***

Three seams are located on the A349, the Wongawilli (uppermost and target seam) the American Creek and the Tongarra Seam. The Wongawilli Seam is considered the only economic coal in this area.

While the Wongawilli seam contains minor bands, it does not exhibit any interburden within the seam. The sequence is contiguous from the base upwards, however it has been eroded and in places to the south does not exist on the A349 due to erosion. A full sequence including the Farmborough Claystone Member only occurs in the northern half of the A349 area.

The American Creek seam exhibits seam splitting or interburden, but is a seam of inferior quality, thickness and is sometimes split, it is not economic.

The Tongarra seam has been identified in 25 of the holes drilled on the lease area. The seam ranges from 0.34m to 6.78m in thickness. The average thickness is 3.67m. Average ash levels of those sections tested is 56% ash. The seam is not considered economic.

Overall there are no negative thickness within the geological model.

***Item 3 Borehole Database (b) Report Barren holes. Are these excluded from intersecting thickness grids.***

For a list of Barren holes see xls file in S drive – named "Hume Coal Excluded Bores.xlsx". Several holes have been omitted from the model, but only six (6) holes are considered to be Barren. Those holes are NB027, NB041, SF050A & SF055 none of which intersected the full Wongawilli seam. SF026 & SF057 both hit cindered coal, thought to be the Wongawilli seam. None of these holes are included in the model or thickness grids.

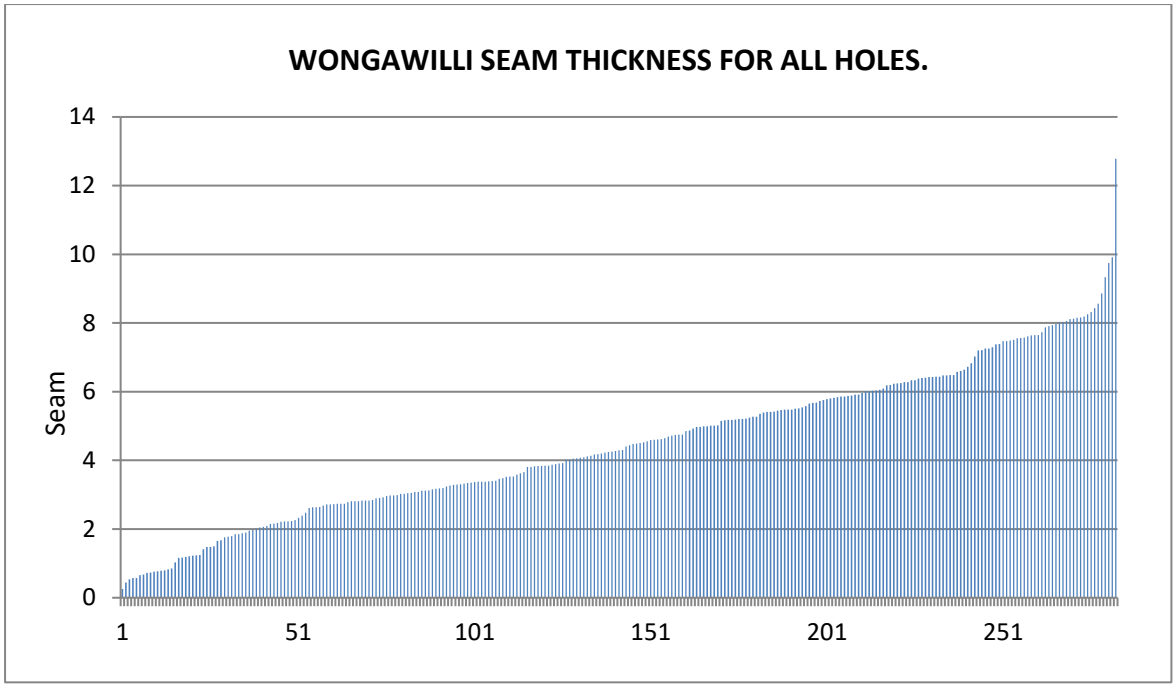
***Item 3 Borehole Database (c) Plot histograms for seam thickness.***

The Wongawilli Seam is the only one proposed to be mined and is the only one with Resources and Reserves estimated. Mining seam thickness of the WWSM has been determined as being a minimum of 1.5m thick with a maximum mining thickness of 3.35m with a combined dilution of 0.15m from both roof and floor. In most locations the dilution may be coal in the roof and may be either stone or coal from the J ply in the floor. All ROM is proposed to be washed.

Thickness histogram is presented below.

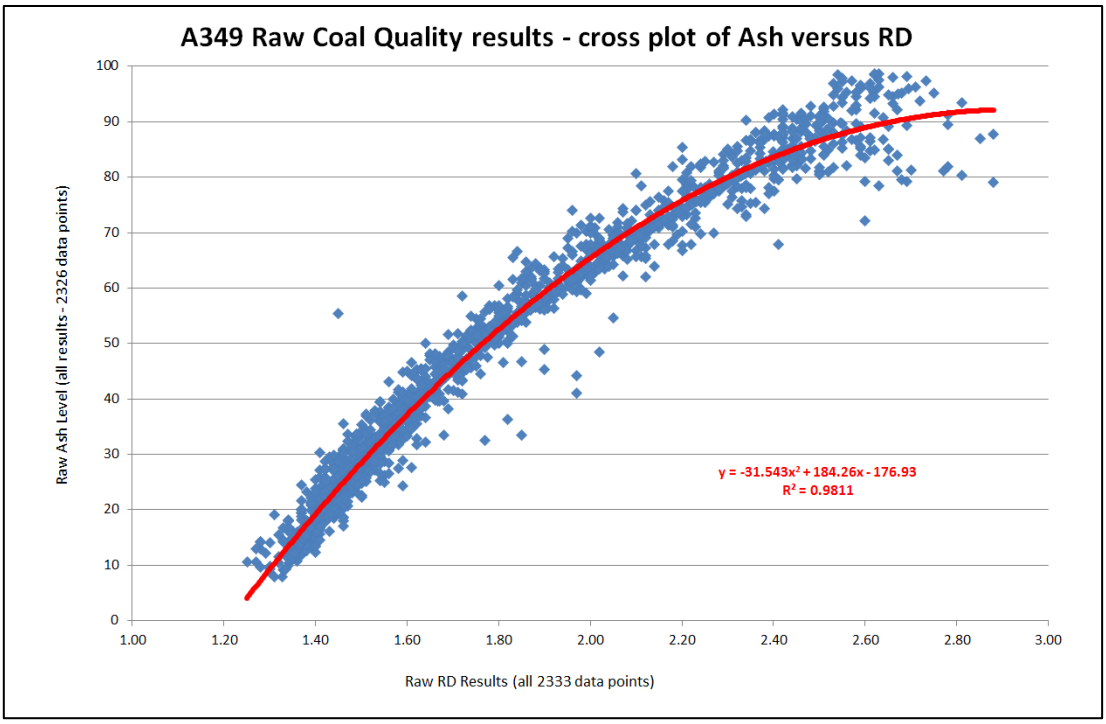
Outliers are mostly thin sections which demonstrate the nature of erosion that has taken place.

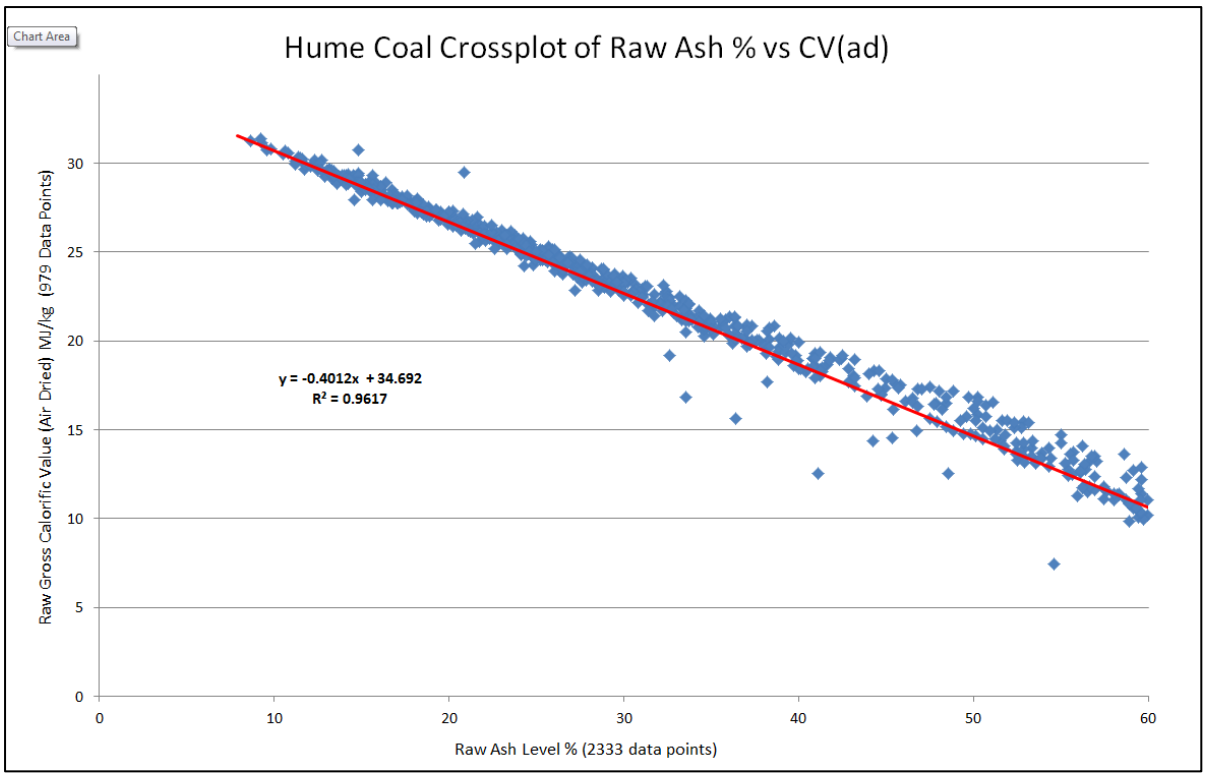
One thick hole (>10m) is present and is anomalous.



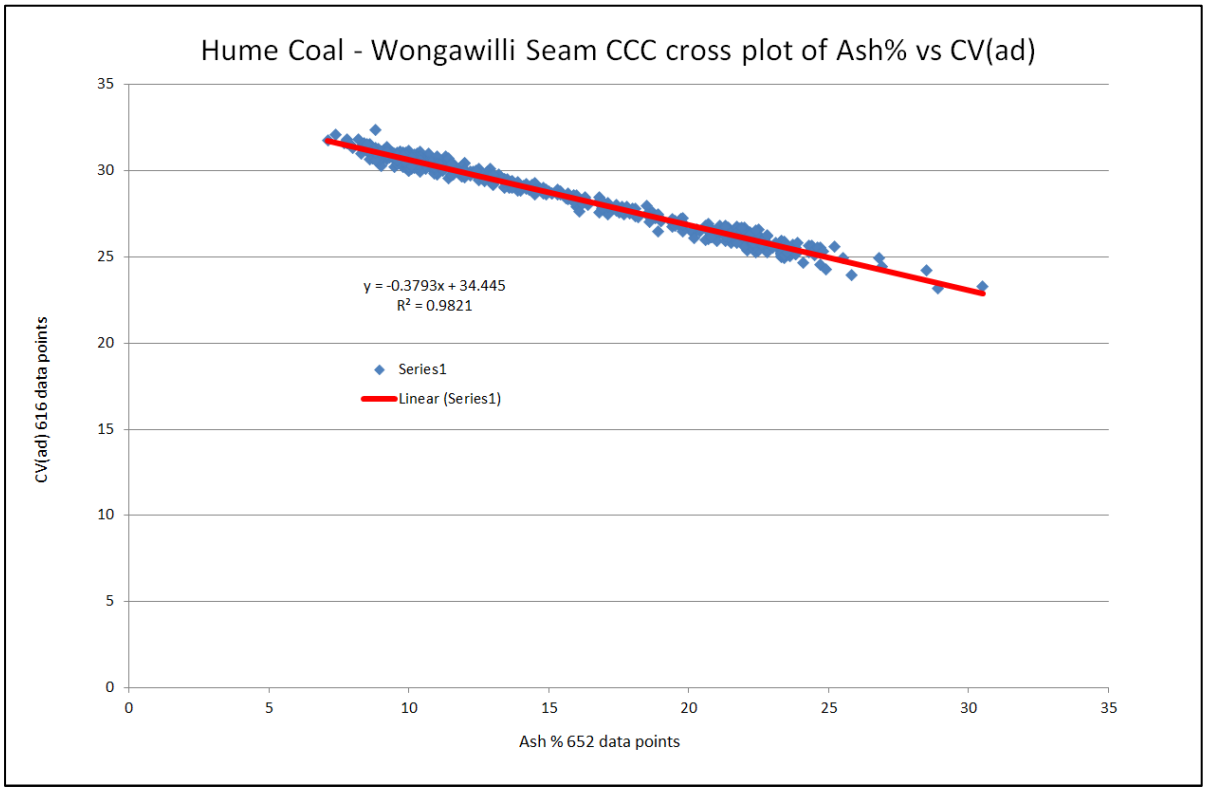

***Item 3 Crossplots (d) Plot coal quality crossplots for main seams noting any significant outliers. Crossplots may include Ash vs RD, Ash vs CV.***

The $R^2$ value for the trend-line is very high (0.98) which suggest that the data is consistent with being a very good data set. Nevertheless, there are some minor examples of outliers. Which may result from lab errors or peculiarities. For example, the one outstanding one has a value of RD 1.45 and an Ash of about 55%. It comes from a historic hole NB68 and the coal immediately below the sample has been cindered, which may explain the anomaly.






The cross-plot above shows Ash compared to CV(ad) there is a good correlation with nearly **1000** data points for the raw coal. Again, there are some outliers mostly with the ash levels greater than 30%. Below is shown a Clean Coal Composite comparison of Ash vs CV.



***<u>Item 4 Grids (a)</u> Mesh sizes***

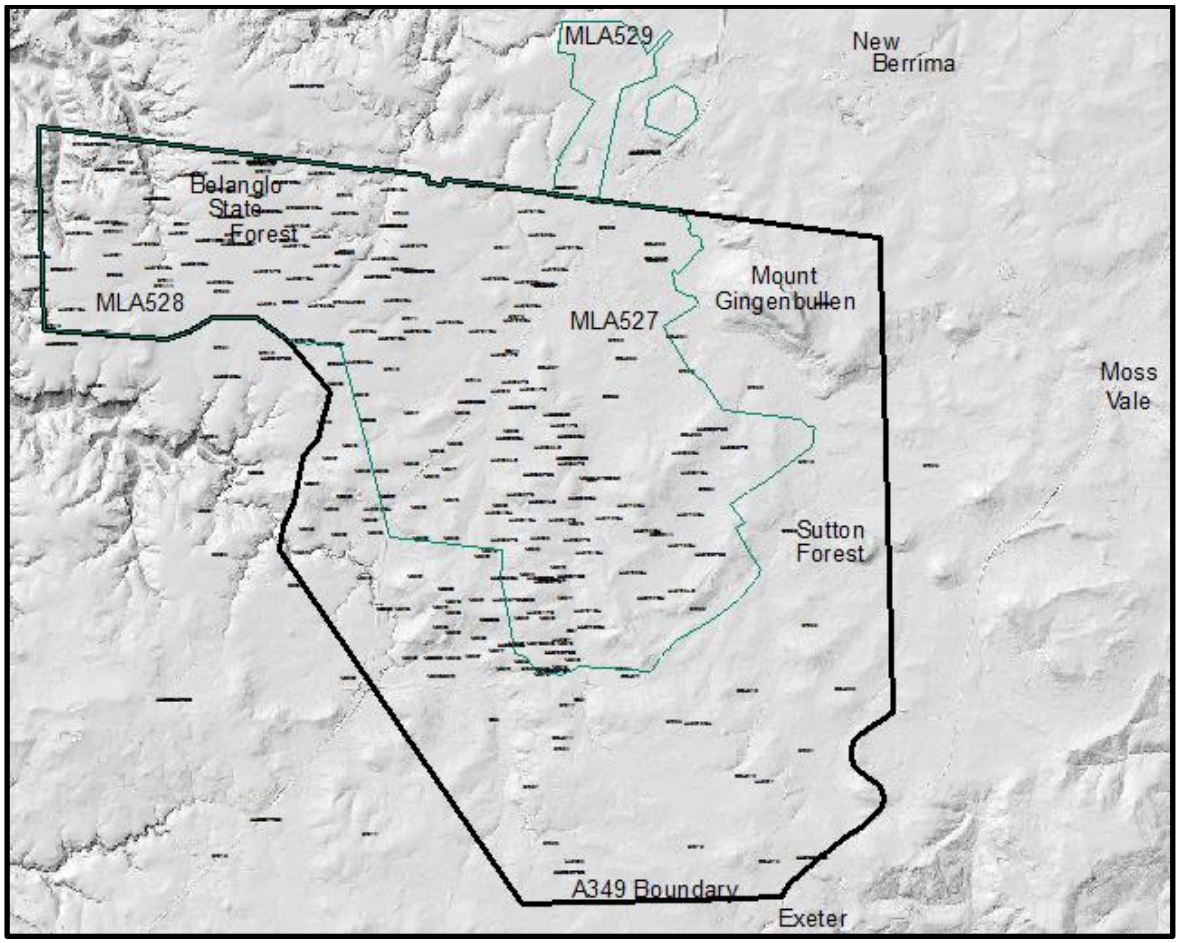
The mesh size used in the gridding of the Minex model were 50m * 50m. This has been deemed appropriate and there are no unusual aspects with the model as a result of using this mesh sizing.

***<u>Item 4 Grids (b)</u> Topography.***

The topographical surface used in modelling has been determined from a LIDAR survey undertaken late in 2013. This surface can be displayed in Minex.

With the exception of the surface quarry on Mt Gibralter there have been no mined surfaces within the Authorisation.

Because of the historic nature of some drill holes – drilled from the 1950's and their original survey co-ordinate data from two different Topographical Sheets. The location of some holes would appear to have a margin of error associated with them. The Topographical Maps being used were the 1" to the mile series dating back to 1933 e.g. Moss Vale Sheet at 1:63,360 and the 1971 Series 2" to the Mile e.g. Canyonleigh Sheet at 1:31,680. Locations and elevations from these plans would have needed to be converted to the Integrated Survey Grid (ISG) and then the more recently to the Globally Positioning System Grid (GMA).




**LIDAR - Surface Topography in grey scale.**

***<u>Item 4 Grids (c)</u> Base of weathering.***

Base of weathering is a difficult horizon to pick over much of the EL. In many holes the Hawkesbury Sandstone goes through weathering zones into fresh rock and then returns to weathered horizons at greater depth. This is not uncommon. However, where the Wianamatta Shale (east of the Hume Highway) is present the Hawkesbury Sandstone is generally always fresh.

While the Wongawilli Seam outcrops in gorges to the west it appears to be in fresh condition at the adit in the Belanglo State Forest, which has been located there and it is also fresh in **all** borehole intersections. As such the BOW is not given significant weighting as a defined horizon for the geological model. No resources or reserves have been lost due to weathering. Also because the resources are all proposed to be underground there are no resources that would be affected by any possible lox-line effects.

***<u>Item 4 Grids (d)</u> Display seam floor grids. Is the model representative of the areas geology?***

Grid plots for each and every coal ply were displayed on site at the Hume Coal offices in Minex software.

***<u>Item 4 Grids (e)</u> Annotate the difference between main seam grid floors and borehole interval floor. Report any significant differences.***

Originally, the main seam grid comprised of a nominal Working Section and is a combination of Wongawilli seam plies G+H+I. There was also an Alternate Working Section (AWS) developed to increase the mining thickness and combined the E+F+G+H+I plies. Currently, Hume is considering a maximum mining height of 3.5m (including dilution of 0.15m) up to the maximum of the E ply. Where the Wongawilli seam is eroded there is a minimum mining height of 1.50m and will take all available coal as the seam thins.

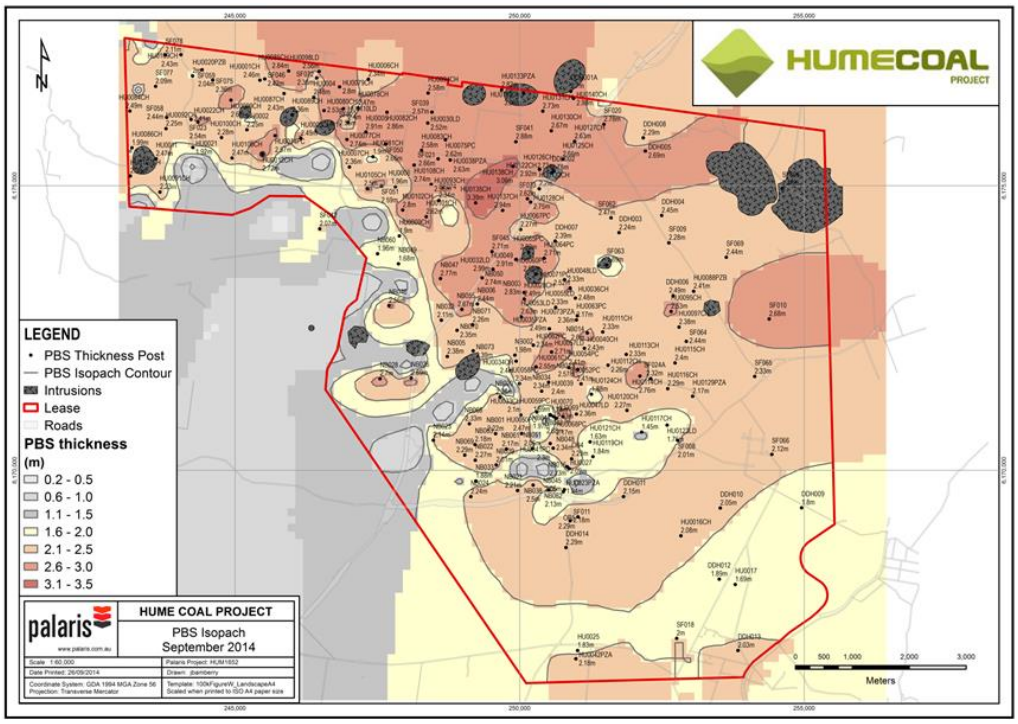
The basal ply of the Wongawilli Seam is the J ply. In places this coal has significantly higher ash than most plies and has lower yields. However, it is recognised as the basal ply and floor of the Wongawilli seam. If it is at all possible to leave this ply unmined then that may be advantageous to mine for increased yields. In some places the J ply has not been identified, in which case it wasn't developed or was distinguished from the overlying I ply. In which case, the I ply will form the floor of the working section.

Plies A, B, C, D & R are generally high in ash and not considered to be economic. They are also outside any practical mining section given the conditions present at the proposed mine site.

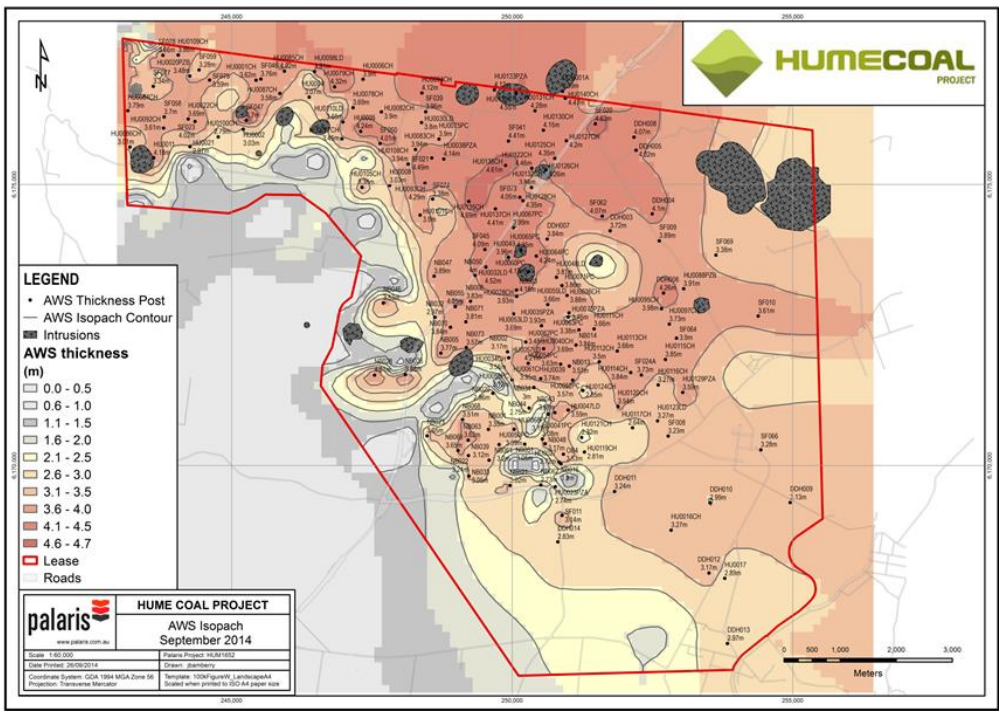
There are no other significant differences between the base of the main seam grid and the floor of the seam to report.

***<u>Item 4 Grids (f)</u> Contour plot main target seam thicknesses. Note any 'bullseyes'.***

As noted above the Wongawilli seam has been strongly eroded and in places, the normally 8m+ thick seam, is less than 1m thick or eroded out altogether. In the area of the Belanglo State Forest (BSF) there are several washouts identified. In addition to the BSF, there are areas towards the Illawarra Highway that are also washed out and appear as bull-eyes in the thickness plots. See PBS and AWS plots below.




**Above - Contour plot of PBS (GHI) thickness. Below – Contour plot of AWS (EFGHI) thickness.**



The proposed mining area excludes these known bull-eyes from its design. However, there is one bulls-eye which has been intruded and the coal has possibly been ingested. It is located in the middle of what is otherwise determined to be a consistent coal thickness, the hole is SF063.

The irregular nature of the washouts may mean that some minor coal resources are over or under estimated. However, the current mining process of effective first workings will mean that the operation will have a great deal of flexibility and be able to mine coal to minimum thickness without high losses.

***<u>Item 4 Grids (g)</u> Annotate the difference between main seam grid thicknesses and borehole interval thickness. Report any significant differences.***

Originally the main seam grid comprised of a nominal Working Section that is the combination G+H+I plies. There was also an Alternate Working Section (AWS) developed to increase the mining thickness and combined the E+F+G+H+I plies. Currently, Hume is considering a maximum mining height of 3.5m up to the maximum of the E ply (including dilution). Where the Wongawilli seam is eroded there is a minimum mining height of 1.50m and will take all available coal as the seam thins.

The base of the Wongawilli Seam is the J ply. In places this coal has higher ash than most plies and has lower yields. However, it is recognised as the basal ply and floor of the Wongawilli seam. If it is at all possible to leave this ply unmined then that may be advantageous for yields. In some places the J ply has not been identified and as such the I ply will form the floor of the working section.

Plies A, B, C, D & R are generally high in ash and not considered to be economic.

There are no other significant differences between the main seam grid thickness and the thickness from borehole intervals to report.

***<u>Item 4 Grids (h)</u> Have faults been included/excluded from modelling. Plot the faults from geometry and export file.***

Faults were not used during the modelling process. This is mainly because of the mixed level of confidence in geological structures from low to high. A diagram below shows the predicted faulting and intrusions and can be found on S drive (12/7/External Reporting). A review of our ground magnetometer and aeromag data is was completed in August 2016.

This should allow more confidence in the geological structures to include it at some time in the future, at the next modelling process. The mine plan now reflects some of the more confident features, such as diatremes and major faults and dykes. Some panels have been omitted from the mine plan to accommodate the potential of significant impacts by faulting. However, because of the mining technique the geological structures should only have a minor impact on overall reserve calculations. Orientation of the workings for the most part has also been designed to parallel the proposed geological faulting system.

| Ply | Thick | Avg Ash | Section |
|---|---|---|---|
| UNM3 | ? | - | |
| R | 0.35 | - | |
| FCM | 0.6 | - | |
| A | 0.47 | 39.3 | |
| B | 0.50 | 33.1 | |
| C | 0.47 | 63.4 | |
| D | 0.45 | 35.7 | |
| E | 0.91 | 32.1 | |
| F | 0.37 | 33.7 | |
| G | 0.77 | 31.2 | |
| H | 0.34 | 35.0 | |
| I | 1.23 | 21.1 | |
| J | 0.35 | 41.0 | Where Present |

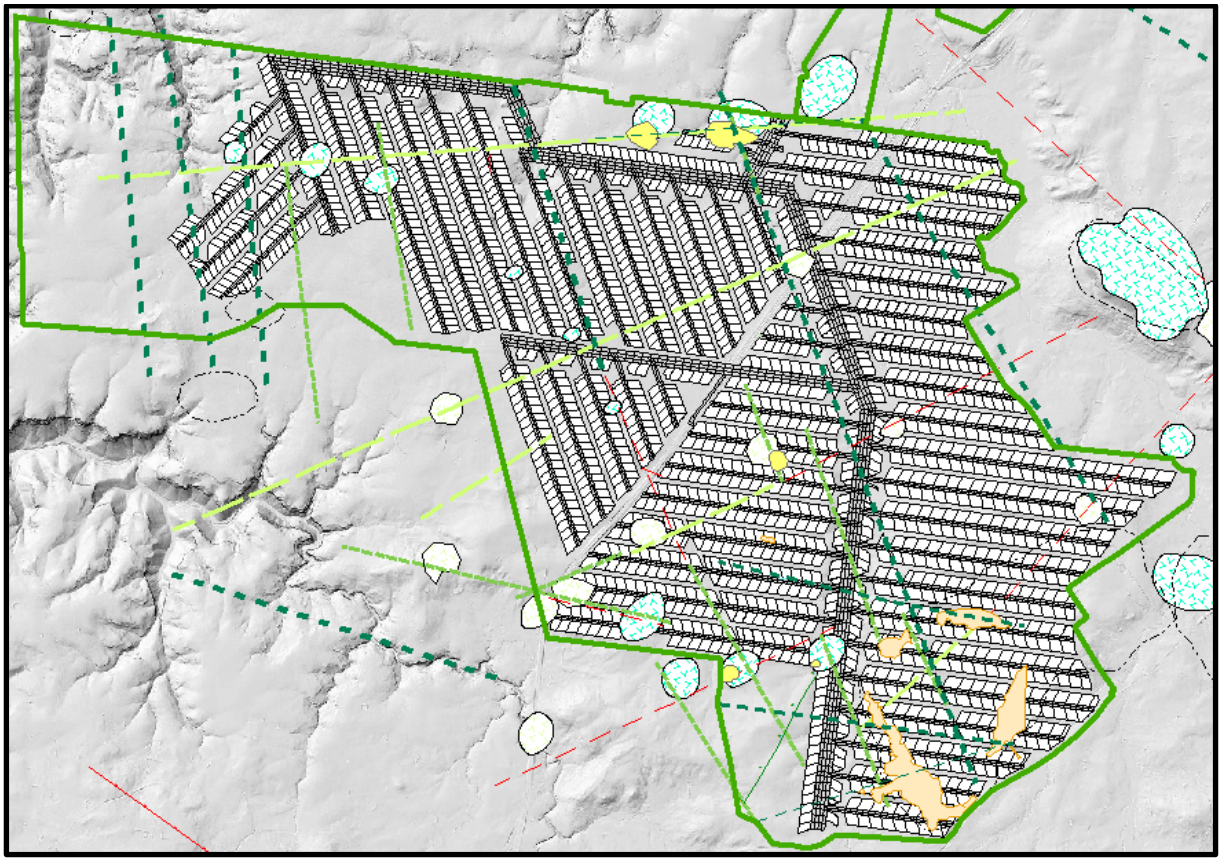
**Plot of plies from the Wongawilli Seam, with average thicknesses and ash levels.**

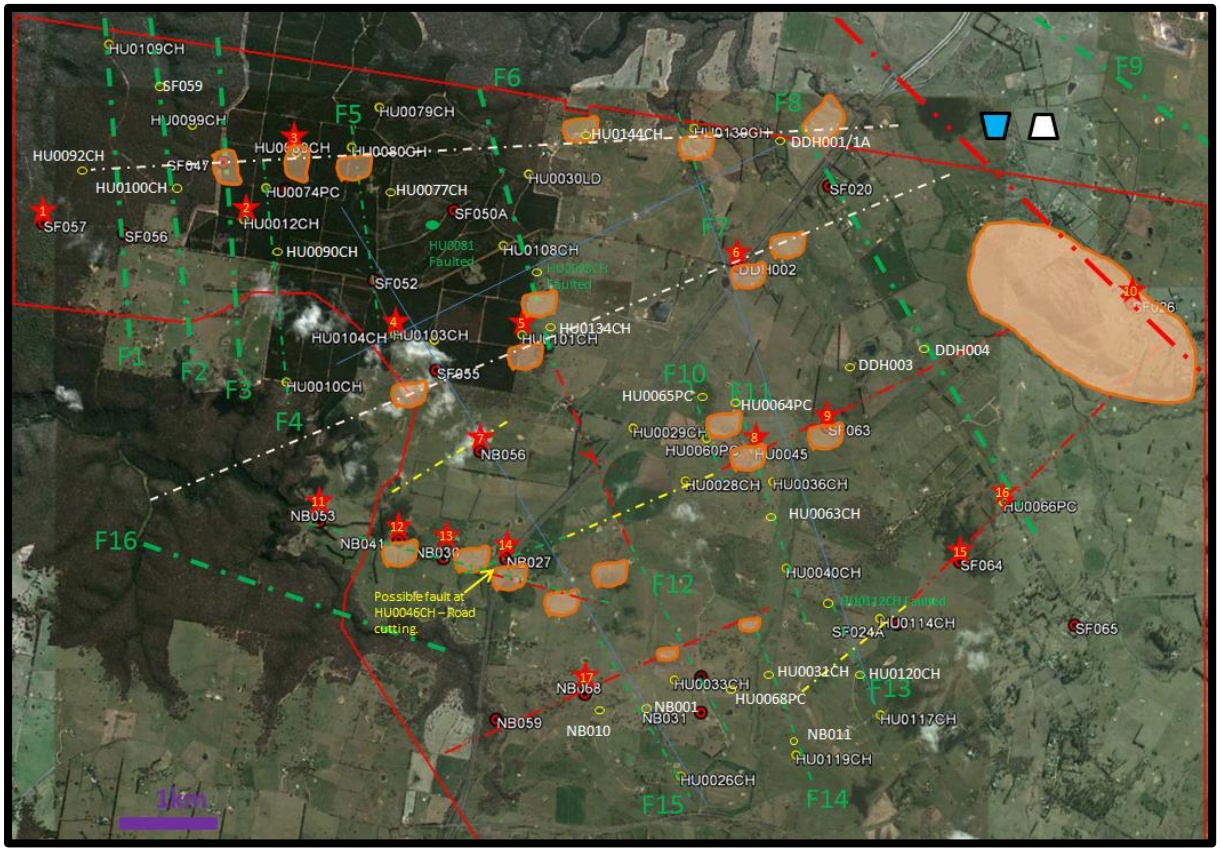
***<u>Item 4 Grids (i)</u> Plot LOM pit design and lease boundary.***

The proposed mine plan and lease boundaries are shown in the above image.

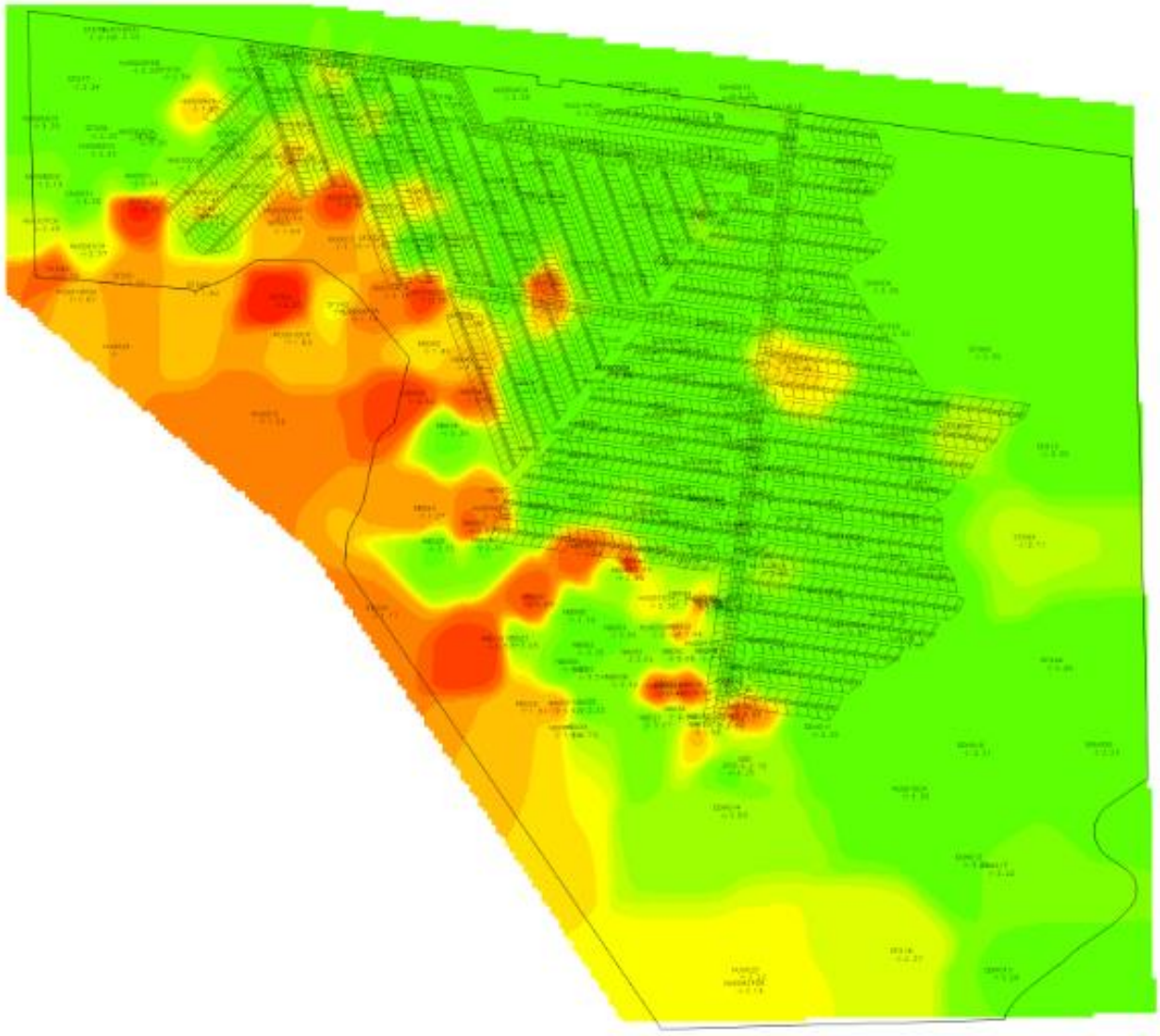
***<u>Item 5 Geometry (a)</u> Plot dykes, sills, rivers, washouts, etc within the proposed mining area. Are there excluded from reserve estimates?***

An aerial magnetic survey has been undertaken over the Authorisation. It provides a higher level of confidence in igneous related features compared to that of faulting. Many of the interpreted intrusions were taken into account when determining the reserve tonnages. Structured areas have only been left out of the mine plan where these features have a high level of confidence.






**Google Earth Image showing geographical features and proposed faults dykes and diatremes.**



**Seam thickness plot – highlighting washouts (in red).**

Washouts have generally been well defined in the area of the Belanglo State Forest, but to a lesser extent in the southern portion of the EL area. Seam thickness has a direct impact on the resource and reserve. Anything less than 1.50m has been excluded from the reserve.

***<u>Item 6 Resources/Reserves. (a)</u> Reserves Report (tonnes).***

A reserve report is available from Palaris, it is located of S drive.

***<u>Item 6 Resources/Reserves. (b)</u> Report all modifying factors and comment on their appropriateness.***

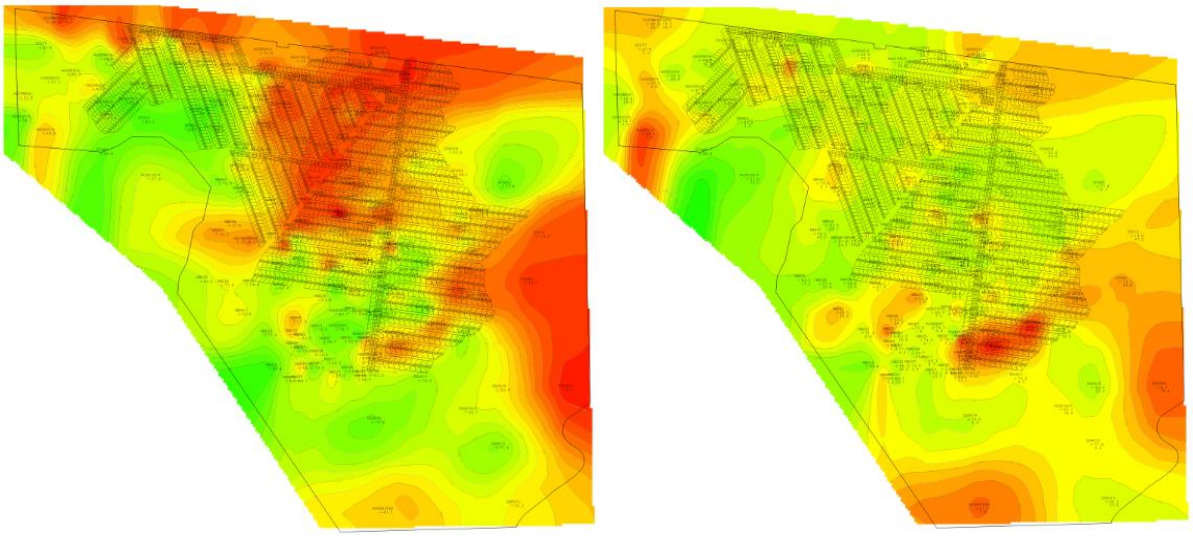
Review Palaris Reserve statement located on S drive.

***Item 6 Resources/Reserves. (c) Document proposed product coal quality***

Two target products are currently being investigated:-

- Nominally a 10% ash coking coal product for export sale. Approximately 55% of all coal washed will meet this target ash.
- A thermal coal product will also be targeted at 22% ash. Markets will be targeted within Australia. Approximately 45% of all coal washed will meet this target ash.
- A waste of approximately 20% of ROM will be returned to the underground openings for storage underground.

Expectations are that there is a high confidence that the target products will be met.



***Images show LHS – Primary Yield & Total Yield Plots.***

***Conclusion***

While this brief summary does not show anywhere near all the geological information collected for the Project, the information provided clearly demonstrates that Hume Coal has extensive geological information. Further it has provided all of its confidential information to the NSW Government on different occasions. This information has informed the EIS, the RTS and also this response to the IPC report. For any one to claim that the Project does not have enough geological information to justify the Projects is incorrect.

Annexure C

# Independent expert model review (GW-SW Pty Ltd)

# Review of Groundwater Modelling Undertaken for the Hume Coal Project

prepared for:

EMM Consultants

by:

Dr Lloyd Townley

GW-SW Pty Ltd

16 March 2020

GW-SW Pty Ltd
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# Executive Summary

This is a review of groundwater modelling undertaken for the Hume Coal Project. It has been prepared in response to a request from EMM Consultants (EMM), on behalf of Hume Coal Pty Ltd (Hume Coal), the owner of and applicant for the Hume Coal Project.

At the start of this review, EMM asked that the review should focus on the revised modelling presented during the Response to Submissions (RTS), rather than on earlier modelling prepared as part of the Environmental Impact Statement (EIS). The revised modelling is not a replacement for earlier modelling but complements and adds to earlier modelling results. It has therefore been necessary in this review to refer to the original modelling for the EIS as well.

The focus of this review is on:

> *"groundwater modelling" and the appropriateness of the modelling that has been undertaken to assess the potential impacts of the proposed Hume Coal Project*.

In its report to the Minister dated 21 May 2019, the Independent Planning Commission (IPC) of NSW made specific reference to groundwater modelling (their Recommendation R5) and asked four questions. In the opinion of the author of this review:

- The revised model should be considered to be Class 2 according to the criteria of the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). This conclusion is supported by Hydrogeologic (2018) who reviewed the model on behalf of DoI Water.
- Additional work could be undertaken to predict slightly less drawdown in the later years of the project, but such additional work is unnecessary. Current predictions are conservative.
- Uncertainty analysis has been undertaken with a large number of spatial distributions of hydraulic conductivities. The range of parameters is sufficient and should not be larger.
- Additional geological information would have little effect on the predictions that have been made.

EMM asked a number of additional questions and these have been answered systematically in this review.

The review provides useful summaries of the history of groundwater modelling for the project, and the sequence of reviews. The modelling undertaken for the Hume Coal Project has been extensively reviewed by many of the leading experts in modelling in Australia.

The review also provides comments on the Australian Groundwater Modelling Guidelines, and the way different parts of the Guidelines should be interpreted and applied.

The author of this review believes that modelling undertaken for the project is fit for purpose, for the purpose of predicting groundwater inflows to the proposed mine and drawdown of the water table within and near the project area.

Hume Coal Pty Ltd has modified the design of its mine during the process of environmental impact assessment, in order to ensure that potential environmental impacts are significantly lower than they would be with mining methods used in many other projects.

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# 1. Introduction

This report has been prepared in response to a request from EMM Consultants (EMM), on behalf of Hume Coal Pty Ltd (Hume Coal), the owner of and applicant for the Hume Coal Project.

Hume Coal has been planning and designing the Hume Coal Project since 2008. In 2017, Hume Coal submitted an Environmental Impact Statement (**EIS**) for the project. In 2018, following receipt of submissions on the EIS, Hume Coal prepared and submitted a Response to Submissions (**RTS**). In December 2018, the NSW Department of Planning and Environment (DPE) released a report entitled "Hume Coal Project and Berrima Rail Project, State Significant Development Assessment (SSD 7172 and SSD 7171)", currently identified on the NSW Planning Portal https://www.planningportal.nsw.gov.au/major-projects/project/10881 as a "Preliminary Assessment Report".

On 4 December 2018, the Minister for Planning asked the Independent Planning Commission (IPC) in NSW to assess the proposed Hume Coal Project. During the IPC's assessment, the Department of Industry - Water responded to questions asked by the IPC in a document dated 17 April 2019. On 17 May 2019, EMM wrote to the IPC providing comments on and questioning aspects of the Department of Industry - Water's response. In its report to the Minister dated 21 May 2019, the IPC recommended (see Recommendation R5 and paragraph 10 in the Executive Summary) that:

> *"Because the Applicant and Department of Industry - Water remain a considerable distance apart regarding their positions on the groundwater modelling, the Commission suggests that the Department or the Applicant, or both of them jointly (and in any case in consultation with Department of Industry - Water), engage a new independent expert (or alternatively a small technical group with a Chair) with experience in groundwater modelling with a view to resolving ongoing differences of opinion."*

A meeting took place on 30 July 2019, attended by representatives of the new DPIE Water[1], DPIE Planning & Assessment, Hume Coal, EMM and HydroSimulations. The Meeting Minutes do not refer explicitly to IPC's Recommendation R5, but EMM has advised the author of this review that DPIE Water did not agree to engage a new independent expert jointly with EMM/Hume Coal. As a result, this review has been commissioned by EMM, and has been prepared without any communications between the author and DPIE Water.

This review report has been prepared by Dr Lloyd Townley, whose qualifications and experience are summarised in Attachment 1. The author has had no previous involvement in the project and has no conflicts of interest.

The review has involved:

(i) an initial briefing (teleconference);
(ii) initial review of documents;
(iii) meetings in Sydney and a site visit to the area of the proposed mine;
(iv) review of documents, discussions with Hume Coal and their consultants, and preparation of this report;
(v) subsequent meetings (teleconferences) to present and discuss the results of the review; and
(vi) finalisation of this review report.

[1] On 1 July 2019, the Department of Planning, Industry and Environment (DPIE) was created as a merger of the previous Department of Planning and Environment (DPE) and Department of Industry (DoI). The Department of Industry - Water became DPIE Water.

In a letter dated 11 October 2019, EMM asked for the review to address a number of specific questions. The questions included general questions about the impact of mining, questions about the "Class" of the model, questions about prediction uncertainty, and questions about adequacy of data to support modelling. This review endeavours to answer those questions, each time in a bounding box, starting with "***Question***". Section 8.4 addresses the four dot points in IPC's Recommendation R5, also in a bounding box.

At the start of this review, EMM asked that the review should focus on the revised modelling presented during the RTS, rather than on earlier modelling. The revised modelling is not a replacement for earlier modelling but complements and adds to earlier modelling results. It has been necessary to refer to the original modelling for the EIS as well.

The focus of this review is on "groundwater modelling" and the appropriateness of the modelling that has been undertaken to assess the potential impacts of the proposed Hume Coal Project. The purpose is not to comment on NSW policies and interpretation of those policies.

Groundwater affects and is affected by mining and mining methods. Groundwater is connected with surface water and must be considered as part of "integrated water management" during planning for any new mining project and during operations. For these reasons, this review includes comments on other aspects of the proposed project, specifically related to mining and integrated water management.

# 2. Source Materials

Most of the documents reviewed were downloaded from a shared drive created by EMM. Some were provided as attachments to emails. Some were downloaded from the NSW Planning Portal https://www.planningportal.nsw.gov.au/major-projects/project/10881.

Attachment 2 provides formal references to primary source documents, so that the sequence of studies and documents can be clearly understood. Short names (acronyms) used in this review are also defined at the start of Attachment 2.

Broadly speaking, the documents reviewed include the EIS and the RTS, and responses to these documents, but as mentioned above, EMM asked that the review of modelling should focus on revised modelling presented in the RTS.

The author has taken into account several documents that are not available on the NSW Planning Portal. These include interactions between DI/DPIE Water, EMM (on behalf of Hume Coal) and the IPC before and after the release of the IPC Report dated 27 May 2019.

Some additional documents have been sourced, including scientific literature. Additional references not available on the NSW Planning Portal or not provided by EMM are listed in Section 10.

# 3. Structure of This Review

Section 4 of this review provides comments on the Australian Groundwater Modelling Guidelines (2012), explaining those parts of the guidelines that are especially relevant to the proposed project and expressing the author's views on how the concept of "confidence level classification" should and should not be used.

Section 5 introduces the proposed Hume Coal Project, lists potential groundwater management issues and summarises the history of groundwater-related investigations and reports. The purpose of this section is to demonstrate that a significant level of understanding has been gained during the process of this review. Its purpose is also to introduce terminology and concepts referred to in Sections 6 to 9.

Section 6 focuses on the numerical groundwater modelling undertaken for the Hume Coal Project, being the methodology used to assess potential groundwater impacts of the proposed project. Groundwater modelling is inherently difficult, and predictions are uncertain, but groundwater modelling is the only methodology that can be used to predict potential impacts of proposed projects.

Section 7 provides comments on the potential impacts of the proposed project.

Section 8 considers the reviews and recommendations that have been made internally, by third parties, by DPE and by the IPC, during the assessment process.

Section 9 provides a summary of the review.

Section 10 lists additional references not listed in Attachment 2.

# 4. Australian Groundwater Modelling Guidelines (2012)

The purpose of this section is to provide comments on the Australian Groundwater Modelling Guidelines (the Guidelines), based on the reviewer's experience as an author of the Guidelines.

The Guidelines were developed with support from the National Water Commission. The process of developing the Guidelines included consultation with representatives of governments and industries from around Australia. The Guidelines are not focused on the mining industry, but have been used by many government agencies during assessment of proposed mining projects.

The Guidelines were intended to help stakeholders of many kinds to understand what is meant by "groundwater modelling", and some of the challenges faced by those involved in the process of developing and using groundwater models. It is important for modellers to understand the Guidelines, but modellers learn to become professional modellers through years of training at university and through many years of experience in real modelling projects.

Following publication of the Guidelines, seminars were held around Australia to attempt to provide guidance on how the Guidelines should be used. The authors of the Guidelines know that the Guidelines are interpreted and used differently in different States.

Some parts of the Guidelines seem to have been more difficult to interpret than others.

- While model calibration and uncertainty analysis are skills that must be learned and applied in groundwater modelling, the authors did not intend to imply that uncertainty in values of model parameters and uncertainty in predictions are so great that models are not useful. On the contrary, the authors hoped to explain that professional groundwater modellers gain skills through training

and experience to develop models that can be used to make useful predictions. Modellers endeavour to develop the best possible model, given available resources (modelling effort and budget), taking into account all available information. They set out to develop models that have low uncertainty, so that stakeholders can have more confidence in the predictions.

- The authors did not intend the concept of "confidence level classification" to be prescriptive. The Guidelines do not state that a model must have any specific "Class" for any specific purpose. This notion seems to have been adopted by some stakeholders, but this practice was not anticipated by the authors. Table 2-1 of the Guidelines lists "key indicators" characteristic of models with different confidence level classifications. The length of time for which predictions are made, relative to the period for which calibration has been possible, is one key indicator. The maximum stress experienced during the prediction period, relative to the maximum during the calibration period, is another. Most "greenfields" mining projects have few data over a short calibration period with stresses much lower than during future proposed mining, so this almost automatically implies that confidence in predictions is less, and such a model would have a confidence level classification of Class 1. The Guidelines never suggest that this is not acceptable. They simply explain the obvious: that confidence will be less.

The Guidelines recommend an iterative process, and reviews of different kinds. The authors of the Guidelines discussed at length the fact that when reviewers make suggestions during model development, and when the reviewers' suggestions are taken into account and implemented, the reviewers almost become part of the modelling team. This occurs regardless of whether the reviewers are commissioned and paid by the proponent of a project (internal reviewers) or by the government (independent "third party" reviewers), i.e. even independent reviews can ultimately influence the end results. Reviews of all kinds generally lead to better modelling outcomes, with better utilisation of all types of data, and consensus between stakeholders.

These comments on the Guidelines are relevant to the discussion that follows relating to whether or not the model developed for the Hume Coal Project is fit for purpose.

# 5. Proposed Project, Potential Groundwater Issues and History of Groundwater Investigations

## 5.1 The Proposed Project

The proposed project is described in detail in the EIS, specifically in Chapter 2 of EMM (2017a).

### 5.1.1 The project area

The project area is shown in Figure 1. The area includes forested hills, undulating and flat pastures, drainage lines and valleys.

The area has a long history of mining. Figure 1 shows the boundary of the Berrima Colliery[2] mining lease, as well as the locations of eight other historical coal mines, including the Loch Catherine Mine which has been referred to in previous documents. The Longacre Adits occur inside the Hume Coal Project Area. Most of these mines were relatively small, but the mine workings of Berrima Colliery cover a relatively large area.

[2] The Berrima Colliery is also known as the Berrima Mine.

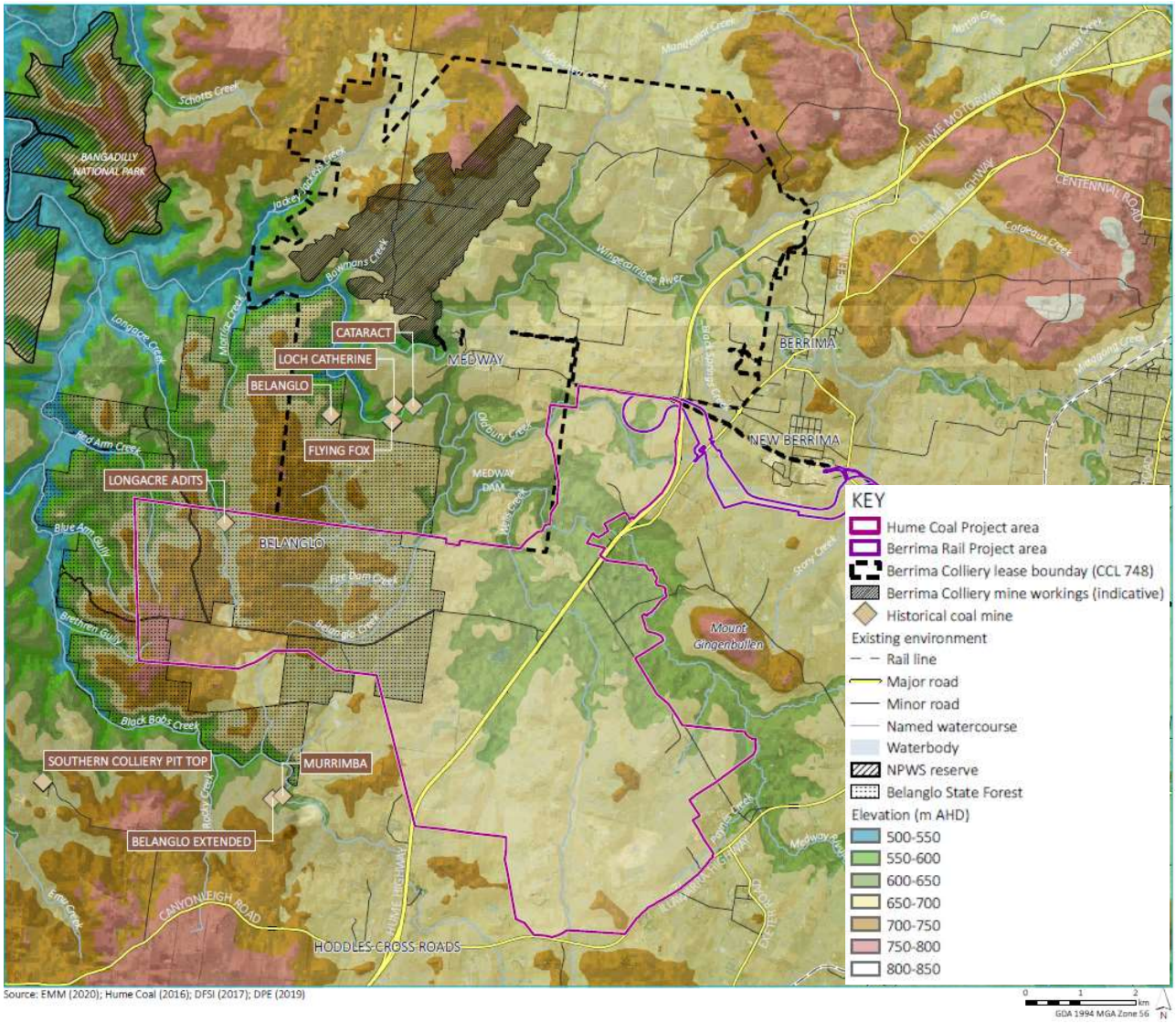



**Figure 1: Topography and locations of Hume Coal Project Area relative to Berrima Colliery and other mines**

### 5.1.2 Mine plan and schedule

The mine plan and schedule are the fundamental causes of impacts on groundwater, so an understanding of the mine plan and schedule are essential for assessment of groundwater issues.

Figure 2 shows the mine plan, based on a "pine feather" mining method within "panels". The panels are very different from longwall mining panels. They have similar width, but the roof does not collapse in the same way, so the impact on overlying strata and groundwater flow above the mine is much less. Figure 3 shows a mine schedule (progression), which is "indicative" in the sense that mine schedules always change and need to adapt to circumstances after mining commences. A key feature of the schedule is that only a fraction of the mine plan (area) will be active at any time.

A key feature of the proposed project is the mining method, and the plan to install hundreds of bulkheads progressively after mining, and to actively fill mined voids with slurry and water. The proposed mining method will greatly reduce deformation in the strata above mined seams, and this in turn is likely to reduce groundwater inflows into mine workings while they are being dewatered. The proposal to backfill and/or flood voids will further reduce cumulative inflows into mine workings. These two aspects of the mine plan are a direct result of the environmental impact assessment process and show that Hume Coal has actively sought to reduce potential environmental impacts.

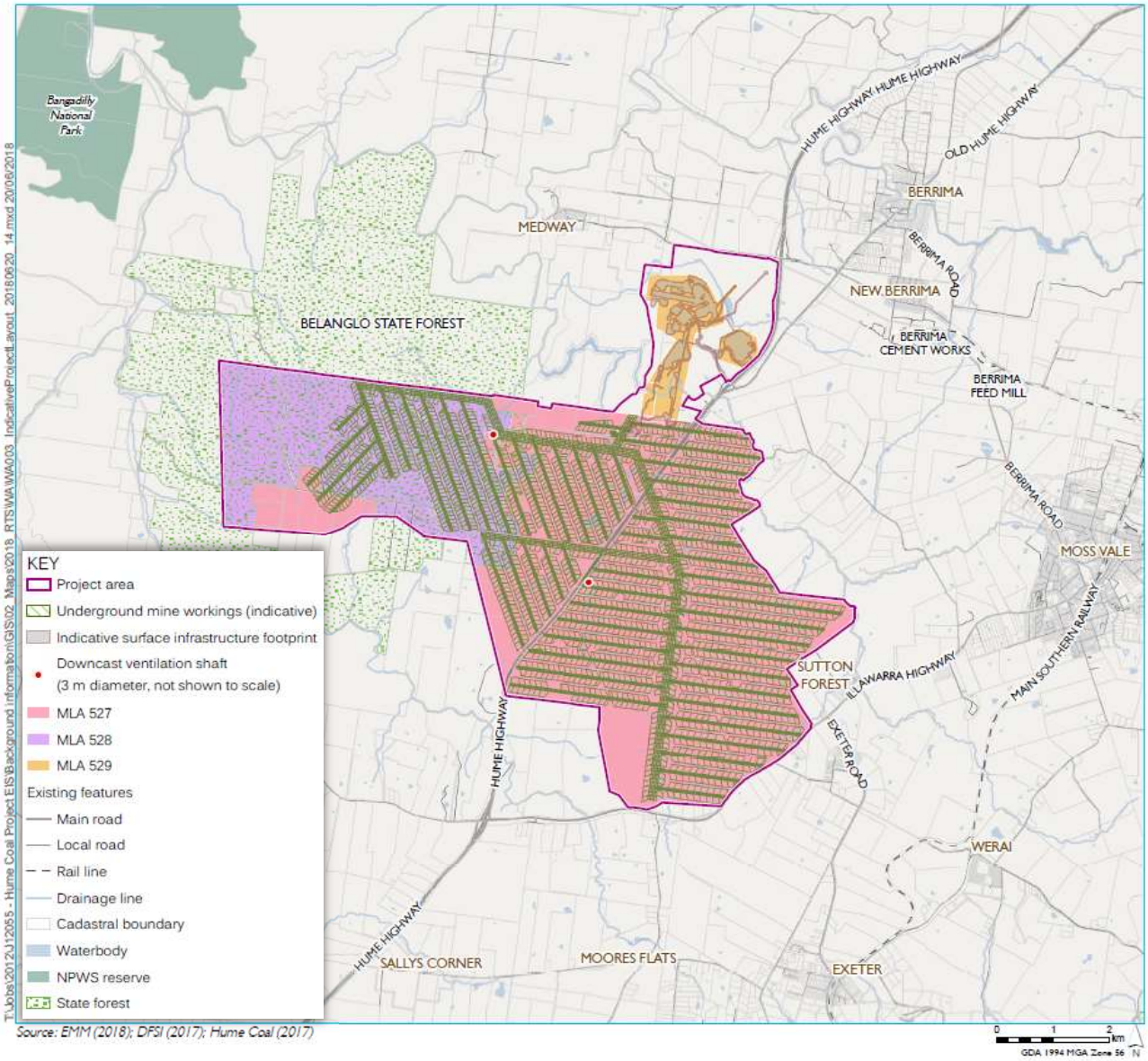



**Figure 2: Mine plan and surface infrastructure layout, Figure 1.5 in EMM (2018b)**

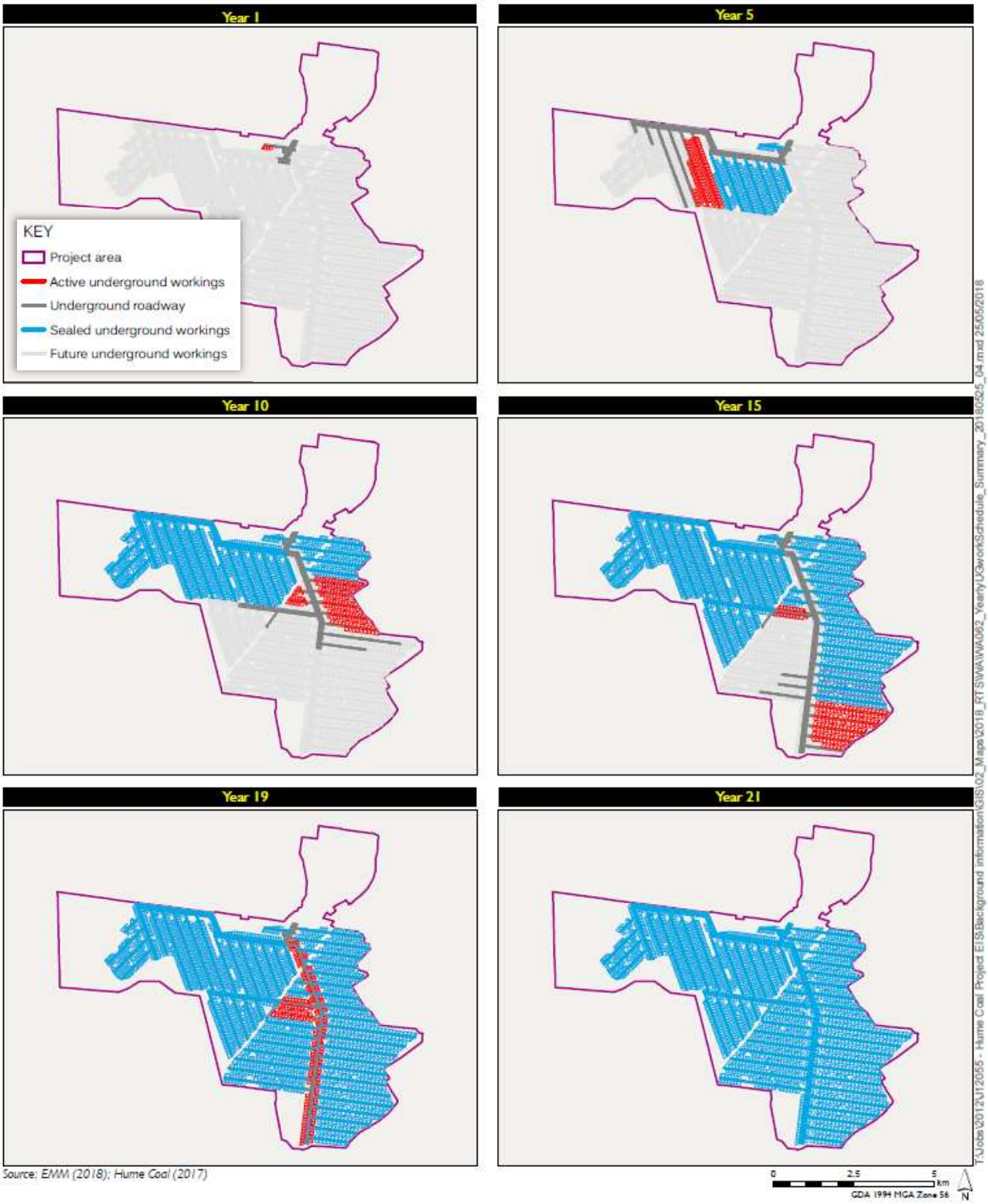



**Figure 3: Indicative mine progression, Figure 2.5 in EMM (2018b)**

## 5.2 Potential Groundwater Management Issues

There are many ways to consider integrated water management in mining, but it is useful to distinguish between three periods of importance: pre-mining, during mining operations, and post-closure, and to discuss the importance of each of these periods separately. Understanding processes in each period is an essential part of the "conceptual model" required for assessment of groundwater issues in mining.

### 5.2.1 Pre-mining

It is important to understand the hydrogeological system and its interactions with surface water, prior to mining. In many places, the elevation of the water table is said to be a "subdued reflection of the topography"; this means that the shape of the water table follows the land surface but is more smooth, it lies just below the land surface in valleys and alluvial flood plains, and somewhat further below the tops of hills.

Figure 4 shows the water table (in red) in a north-south cross-section passing through the historical Berrima Colliery mining lease and the Hume Coal Project area. There are four distinct regions in this cross-section. In regions 1 and 3, the water table is near the land surface. In region2, near the Berrima Colliery and Loch Catherine Mine, the water table has been lowered to the elevation of mining, but above much of the mine, there is also a perched aquifer with a second water table much closer to the land surface. In region 4, there is a regional water table near the land surface, but there is also an unsaturated zone beneath the Wianamatta Group, and a second water table, so the upper aquifer is also perched. This cross-section is based on measurements that are relatively far apart. Importantly, the mining method in the Berrima Colliery caused significant damage and desaturation above the mine (see Section 6.6 below); the mining method in the proposed Hume Coal Project is very different and will not have the same impacts on the water table.

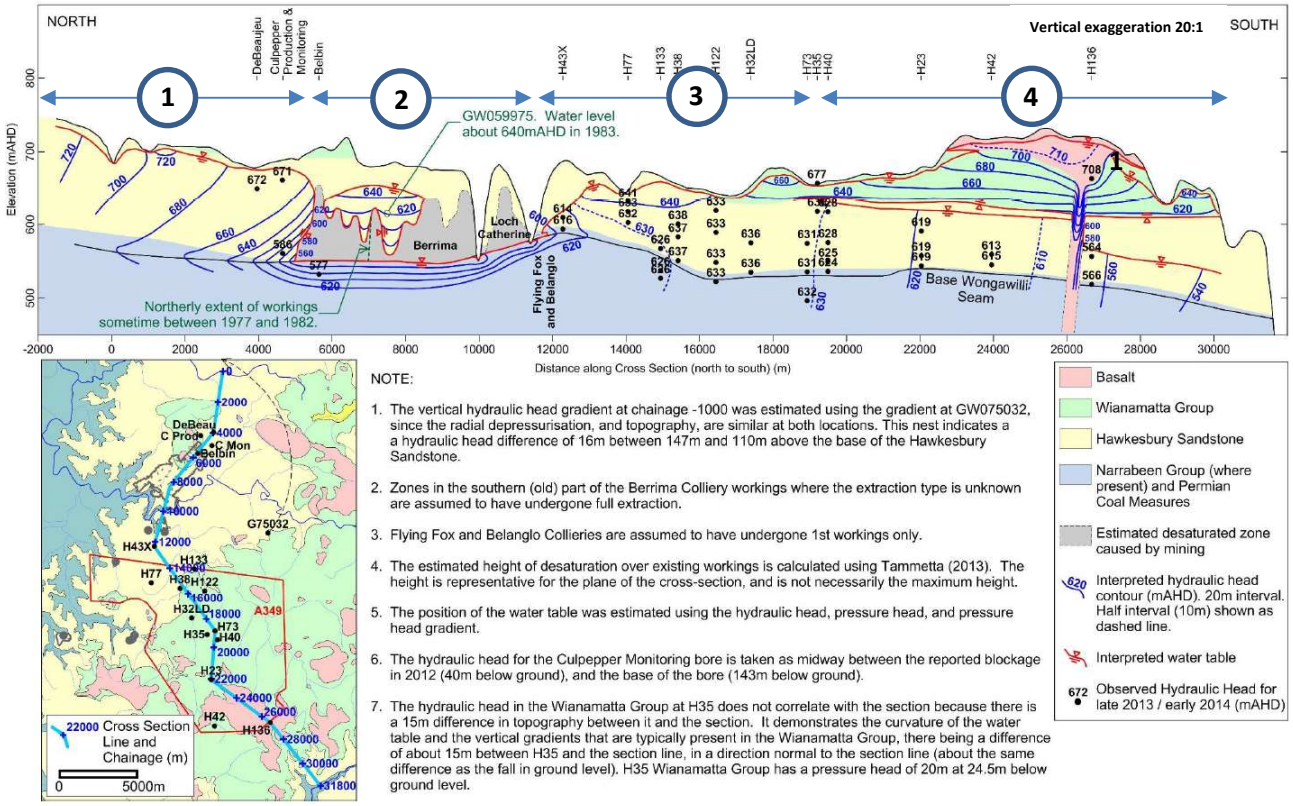



**Figure 4: Interpreted piezometric head distribution in late 2013 / early 2014 in a cross-section through the Berrima and Hume mine leases, Figure 6.1 in Coffey (2016a)**

Groundwater tends to flow from locations with high piezometric head (a measure of gravitational potential energy) to areas with lower piezometric head. While water table elevation is important as a driving force, it is also important to understand the concept of piezometric head, and how it varies in the natural pre-mining situation. This is explained in the box below.

In regions 1, 3 and 4, the distributions of piezometric heads show that groundwater flow in the Hawkesbury Sandstone is relatively horizontal. In the Wianamatta Group, there is a tendency for downwards flow. In the Narrabeen Group below the Berrima Colliery there is a tendency for upwards flow.

***Piezometric head*** (also known as potentiometric head)

Piezometric head h(x,y,z,t) at any location (x,y,z) and time t is defined as the sum of "elevation" z at that point and "pressure head", which is equal to pressure P divided by the density of water $\rho$ and acceleration due to gravity g. This is illustrated in the schematic diagram below.

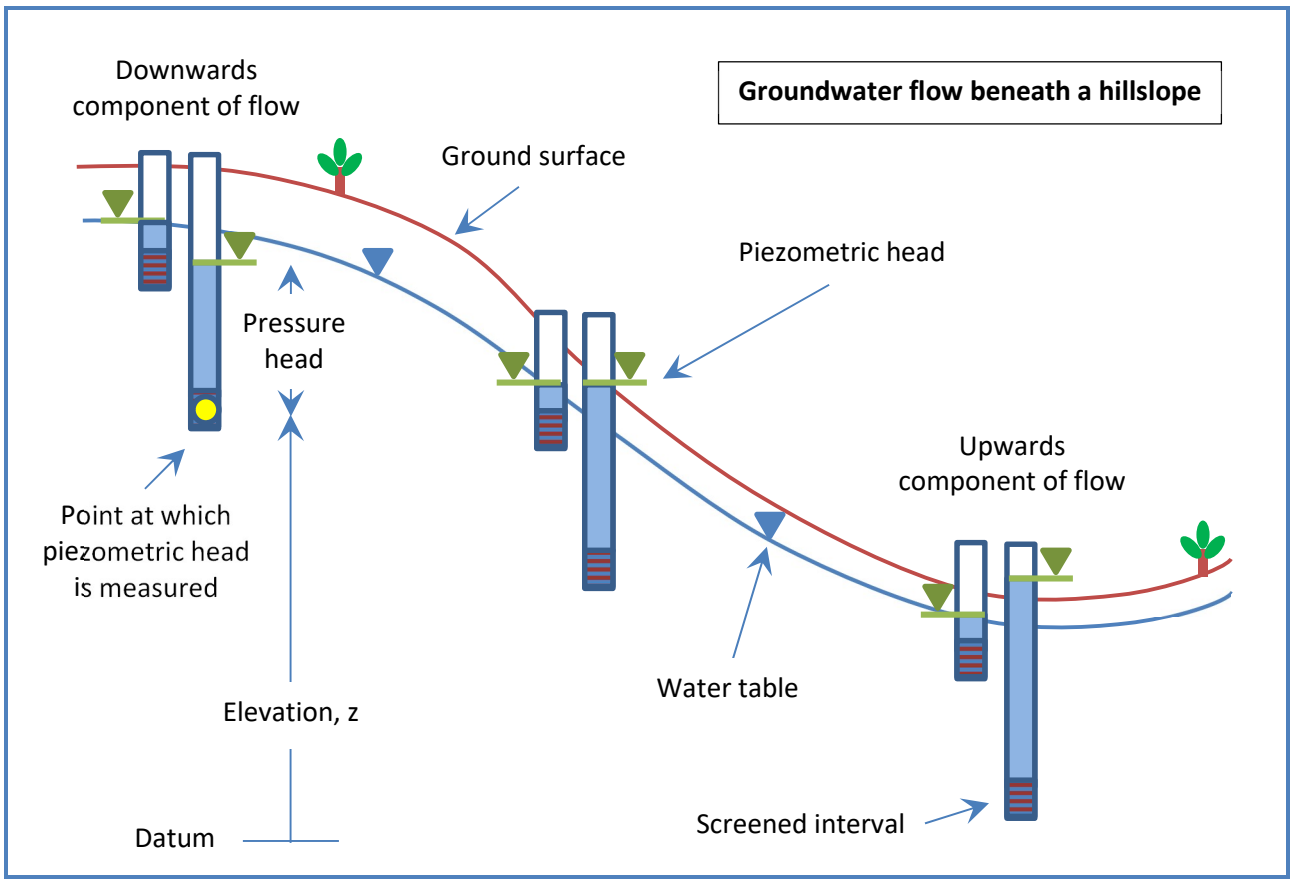
At any point on the water table, P = 0 atm, so h = z. That is, piezometric head at water table is equal to water table elevation, but at other locations below or above the water table, this is not always the case.

An observation bore functions as a piezometer. Generally, an observation bore consists of a plastic PVC tube, inserted down the middle of a drilled borehole. The tube is sealed at the bottom with an end cap. A screen is installed over some range of elevations, often 2 m to 6 m long, towards the bottom of the borehole. The screen is often made of PVC, with thin vertical or horizontal slots that allow water to move through the slots, but sufficiently narrow that particles of sand or host rock cannot pass through. The annulus around the screen is typically filled with sand or gravel, but from the top of the screen to the ground surface, the annulus is typically filled with bentonite clay or cement to prevent movement of water in the annulus.

After an observation bore has been constructed and cleaned, groundwater moves through the slots in the screen and rises inside the tube. We say that the water inside the tube equilibrates with groundwater outside the screen. The elevation to which water rises in the tube is a measure of piezometric head at the elevation of the screen. This elevation is shown in green in the schematic diagram below. Since the screen has some finite length, we generally assign the measurement to the mid-elevation of the screen. The measurement combines the elevation of the screen and the pressure of groundwater outside the screen.

Piezometric head in an observation bore can be above or below the water table elevation at the same horizontal (x,y) location. A good way to understand this is to think about the distribution of piezometric heads beneath a typical hillslope. Piezometers screened at depth near the top of a hill show that piezometric head is lower than water table elevation above, and this explains why groundwater flow has some component of downwards flow near the tops of hills. Piezometers screened at depth beneath the valley floor show that piezometric head is higher than the water table elevation above, and this explains why groundwater flow has some upwards component towards streams in valley floors. Piezometers half-way down the hill may have heads almost equal to water table elevation, because groundwater at that location is flowing parallel to the slope of the water table.

All human activities that affect groundwater lead to changes in piezometric heads and changes in flow directions and rates. Pumping and mining both affect the distribution of piezometric heads in space and time. Experienced hydrogeologists understand the meaning of piezometric head, and the distinction between piezometric head and water table elevation.




### 5.2.2 During mining operations

Mining operations cause changes in hydrogeological and hydrological systems.

- Underground mining causes groundwater to flow into the voids created by the mining process. This happens because the mining voids are filled with air at roughly atmospheric pressure, so piezometric head on the roof, walls and floor of mining voids is approximately equal to the elevation of each point on these surfaces. Lowering the piezometric head in the mine causes groundwater to flow downwards from above, upwards from below and laterally from the area surrounding the mine. Because hydraulic conductivity is often significantly greater in the horizontal direction, or within hydrostratigraphic units, more water often flows into mines laterally than from above or below. In any case, where the water comes from is one of the questions that should be considered and understood.
- If water comes from above, this can cause lowering of the water table. This can affect the operation of bores within the cone of depression caused by mining.
- Groundwater pumped from a mine needs to be managed. While some water can be used in a coal handling and preparation plant, excess water needs to be managed. The Hume Coal Project proposes to reinject some of the excess water in the mined voids, stored within slurry and sometimes separate from solid waste behind bulkheads. Any mined void that is sealed with a bulkhead and filled with slurry and/or water would quickly experience a rise in pressure and piezometric head, thus greatly reducing and quickly stopping further flow of groundwater towards that mined zone. Storing water in this way would reduce the extent and depth of the cone of depression caused by mining and accelerate groundwater recovery after the end of mining. Figure 5 shows groundwater inflows at different stages during and after mining.

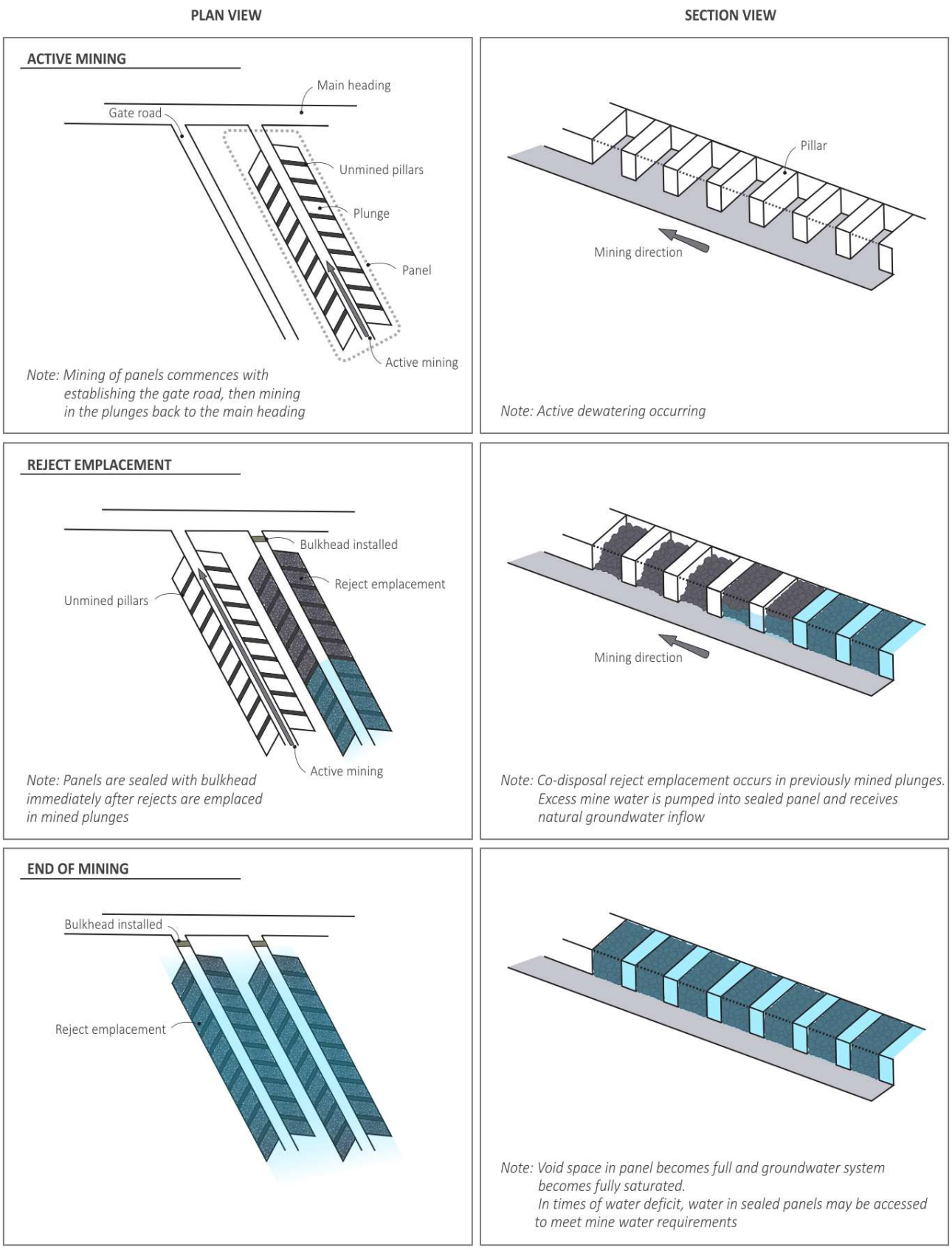



**Figure 5: Schematic diagram showing mine progression, reject emplacement and water injection, provided by EMM**

### 5.2.3 Post-closure

- At the end of mining, when mine dewatering ceases, groundwater continues to flow into mined voids and water levels in formerly drained voids slowly rise. This water must come from somewhere. While the water table elevation and piezometric heads near a mine rises, the water table elevation and piezometric heads far away may continue to decline. The time at which maximum drawdown (of the water table) or maximum depressurisation (reduction in piezometric head) occurs can be long after closure.
- As mentioned above, storing waste and/or water in mined voids during mining would enhance the rate of recovery after mining.

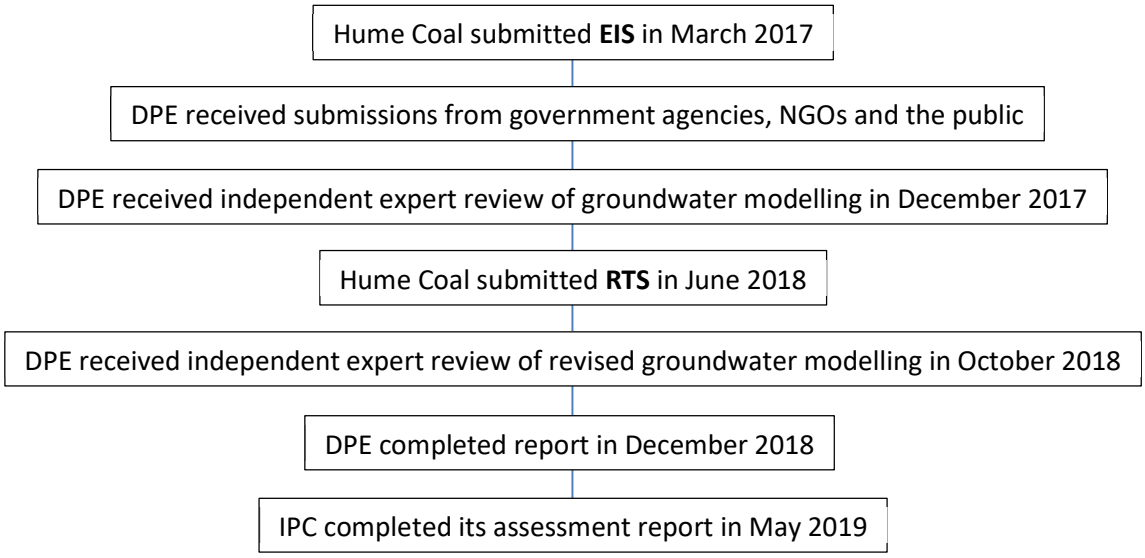
## 5.3 History of Groundwater-Related Investigations and Reports

### 5.3.1 History of investigations and reports

Hume Coal has been planning the proposed Hume Coal Project since 2008. In 2011, Hume Coal established a number of groups for community consultation, including a Water Advisory Group (EMM, 2017d).

While many reports were prepared in earlier years, the most important reports on investigations related to groundwater and groundwater modelling were published during the environmental impact assessment process, which started with submission of the EIS in 2017.

The last few years have seen the following sequence of reports and responses:




The author of this review understands that Hume Coal is currently preparing a response to the IPC assessment report (IPC, 2019), and that this response will be submitted in March 2020. This response has not been sighted during preparation of this review.

Nearly all the important public documents related to groundwater are contained in the EIS and the RTS. These include documents prepared by consultants on behalf of organisations submitting responses to the EIS. Not every document prepared by Hume Coal is publicly available, partly because the volume of material would be too great. A lot of data and information related to groundwater and groundwater modelling exists in the form of databases, data files and model output files.

Attachment 2 to this report lists key documents related to groundwater and mining, with a total length of about 2900 pages. It takes time for experts to understand and assimilate the available information. The

frequency of requests for reviews and submissions of more information suggests that those making those requests may not always have taken into account all the available material.

As part of the process of preparing this review, the author prepared the following summary of documents prepared on behalf of Hume Coal, as part of the EIS and RTS. Attachment 2 provides formal references for those parts of the EIS and RTS that are referred to in this report.

*Environmental Impact Statement, March 2017*

Volume 1, Hume Coal Project, Environmental Impact Statement, Main Report, prepared by EMM, dated 8 March 2017, starts with a description of the proposed project in Chapter 2, describes the existing environment in Chapter 5, summarises the potential impact on water resources in Chapter 7, and refers to groundwater in all of these Chapters and many more. The EIS Main Report has 21 Appendices A to U. The detailed assessment of water-related issues is contained in Appendix E, as outlined below.

- Appendix E contains a "**Water Impact Assessment Report**". It was prepared by EMM, dated 3 March 2017, and was published/printed in two physical volumes, Volumes 4A and 4B. On the NSW Planning Portal https://www.planningportal.nsw.gov.au/major-projects/project/10881, "Appendix E - Water" is provided in 24 parts.
  - The Water Impact Assessment Report starts with a Main report, includes Chapter 6 on "Groundwater", then Chapter 7 on "Site conceptual model", Chapter 11 on "Groundwater assessment", and 15 Appendices A to O related to groundwater. Other Chapters also refer to groundwater.
    - **Appendix H** entitled "**Groundwater Assessment, Volume 1: Data Analysis**", was prepared by Coffey, dated 17 November 2016. It has its own six Appendices A to F. Appendix H includes sections on climate, surface hydrology, geology, subsurface hydraulic properties, groundwater levels, groundwater inflows to the Berrima Mine, groundwater quality, groundwater use and a hydrogeological conceptual model.
    - **Appendix I** entitled "**Groundwater Assessment, Volume 2: Numerical Modelling and Impact Assessment**", was prepared by Coffey, dated 17 November 2016. It has its own eight Appendices A to H.
    - **Appendix J** entitled "**Groundwater Assessment Peer Review Reports**", containing two reviews by HydroAlgorithmics Pty Ltd dated 14 September 2016 and Kalf and Associates Pty Ltd dated 12 September 2016.
    - **Appendix K**, entitled "**Hydrogeochemical Assessment**", was prepared by Geosyntec Consultants. It includes many Tables in its own Appendix A.
    - **Appendix L**, entitled "**Bore Logs**", contains bore logs prepared by Parsons Brinckerhoff on behalf of Hume Coal. These logs were prepared specifically for groundwater investigations and do not include logs of exploration drillholes.
    - Appendix M, entitled "Project impact and total impact water table drawdown over time", was prepared by EMM, using outputs from groundwater modelling.
    - Appendix N, entitled "Project impact and total impact landholder bore drawdown over time", was prepared by EMM, using output from groundwater modelling.
    - Appendix O, entitled "Drawdown impacts in landholder bores – proposed 'make good' provisions", was prepared by EMM, dated 14 February 2017, using output from groundwater modelling. It has its own three Appendices A to C.

*Response to Submissions, June 2018*

Volume 1, Hume Coal Project and Berrima Rail Project, Response to Submissions, Main Report, prepared by EMM, dated 29 June 2018, includes Part A "Submissions received and response approach", Part B Chapter 5 "Revised Water Assessment" and Part C "Response to Submissions", including Chapter 8 on "Surface water", Chapter 9 on "Groundwater", and Chapter 11 on "Water licensing". The RTS Main Report has seven Appendices 1 to 7. The detailed assessment of water-related issues is contained in Appendix 2, as outlined below.

- Appendix 2 contains a "**Revised Water Impact Assessment Report**". It was prepared by EMM, dated 27 June 2018 and was published/printed in five physical volumes, Volumes 2A to 2E. On the NSW Planning Portal, Volumes 2A to 2E are provided in 16 parts, referred to as "Appendices" 2A to 2E.
  - The Revised Water Impact Assessment Report starts with a "Main Report" in Appendix 2A, Chapter 4 on "Baseline monitoring" including Section 4.2 on "Groundwater monitoring", Chapter 5 on "Surface water", Chapter 6 on "Groundwater", Chapter 7 on "Site conceptual model", Chapter 8 on "Assessment methods" including **Section 8.6** on "**Groundwater numerical flow model"**, Chapter 9 on "Assessment criteria including Section 9.3.2 on Groundwater", Chapter 11 on "Groundwater assessment", Chapter 12 on "Water licences", Chapter 13 on "Monitoring, mitigation and management" including Section 13.1.2 on "Make good provisions" and **Section 13.5** on "**Groundwater model validation**", and 13 Appendices A to M.
    - **Appendices A to C** contain three checklists related to the Secretary's Environmental Assessment Requirements (**SEARs**), the **IESC Guidelines** and the NSW Aquifer Interference Policy (**AIP**), in physical Volume 2A.
    - **Appendix E**, entitled "**Concept on-site wastewater management assessment**", was prepared by Harris Environmental Consulting, in physical Volume 2D. It includes its own 20 Appendices i to xx.
    - **Appendix F**, entitled "**Revised Groundwater Modelling**", was prepared by HydroSimulations[3], in physical Volume 2D. It includes its own six Appendices A to F. Of these, Appendices E and F are copies of Appendices H and I to EIS Appendix E "Water Impact Assessment Report", i.e. Coffey's Volumes 1 and 2 from 17 November 2016.
    - Appendix G, entitled "EIS Groundwater Assessment peer review reports", in physical Volume 2E. This is identical to Appendix J in EIS Appendix E "Water Impact Assessment Report".
    - **Appendix H**, entitled "**Critique of Pells Consulting Modelling Studies**", was prepared by EMM on 20 June 2018, in physical Volume 2E.
    - Appendix I, entitled "Hydrogeochemical Assessment", in physical Volume 2E. This is identical to Appendix K in EIS Appendix E "Water Impact Assessment Report".
    - **Appendix J**, entitled "**Hydrogeochemical modelling assessments**", was prepared by RGS Environmental Pty Ltd, dated February 2018, in physical Volume 2E. It includes two Attachments A and B.
    - Appendix K, entitled "Bore logs", in physical Volume 2E. This is identical to Appendix L in EIS Appendix E "Water Impact Assessment Report".

[3] HydroSimulations (the trading name of NPM Technical Pty Ltd) was founded by Dr Noel Merrick, also the founder and director of HydroAlgorithmics Pty Ltd. HydroSimulations was sold to SLR Consulting in March 2019. Comments on Appendix F have been sought from Dr Noel Merrick and are referred to in this review as being his personal comments.

- **Appendix L**, entitled "**Landholder bore drawdown over time**", in physical Volume 2E. This is an *updated* version of Appendix N in EIS Appendix E "Water Impact Assessment Report".
- **Appendix M**, entitled "**Make good strategy**", was prepared by EMM, dated 12 June 2018, using output from revised groundwater modelling, in physical Volume 2E. It has its own four Appendices A to D. This is an *updated* version of Appendix O in EIS Appendix E "Water Impact Assessment Report".

- Appendix 7 provides "Mine design additional information – 3D numerical modelling". It was prepared by EMM, dated 27 June 2018 and is part of physical Volume 3. On the NSW Planning Portal, Volume 3 is referred to as "Appendix 3".
  - Appendix 7.1 is a report by K.A. Heasley entitled "Pillar design analysis using LaModel – Hume Coal Project".
  - Appendix 7.2 is a report by Mine Advice Pty Ltd entitled "Hume Coal Project - Interpretation of the numerical modelling study of the proposed Hume Project EIS mine layout".

Note that the Revised Water Impact Assessment Report includes some components of the original Water Impact Assessment Report. The use of **bold text** above is intended to emphasise the documents that are the most relevant to the present review.

This review is focused on Appendix F of RTS Appendix 2 "Revised Water Impact Assessment Report". Other documents are referred to as necessary.

### 5.3.2 Relevance of investigations

The purpose of this Section, which concludes the introduction to this review, is to explore whether or not the groundwater investigations are likely, in a general sense, to be sufficient to address the potential groundwater management issues.

Table 1 contains a list of potential issues associated with groundwater. This list is much shorter than the list of questions asked of Hume Coal. Groundwater modelling, which is the focus of this review, cannot answer all these questions; rather, the conceptualisation of some processes, e.g. of surface water – groundwater interaction, influences model structure and the model may help to quantify those processes. The modelling undertaken for the Hume Coal Project is focused on groundwater flow and cannot predict changes in groundwater quality or changes in the quality of surface water flows.

**Table 1. List of potential groundwater issues**

| Timing | Groundwater issue |
|---|---|
| Pre-mining | Understand the hydrogeological flow system, including recharge and discharge mechanisms and flow in aquifers, under pre-mining conditions |
| | Understand surface-water groundwater interaction under pre-mining conditions |
| | Understand the extent of pumping by landholders and other licensed bores, and the water balance of aquifers under pre-mining conditions |
| During mining | Predict potential groundwater inflows to underground mines, both laterally and from above; predict lowering of the water table and impact on bores; predict depressurisation in confined aquifers, and the impact of depressurisation, with possible impacts on surface water – groundwater interaction |
| | Predict the possible impact of placement of solids and water in mined voids after mining individual panels |
| After mining | Predict the rate of recovery of pressures and piezometric heads in confined aquifers and the rate of recovery of the water table, including the continued expansion of cones of depression of the water table and cones of depressurisation in deeper aquifers, as water continues to flow towards the former mine |
| | Predict potential impacts on groundwater quality and ultimately on surface water flows and quality, long after mining |

# 6. Numerical Groundwater Modelling Undertaken for the Hume Coal Project

Numerical groundwater modelling is the only methodology that can be used to predict the future behaviour of groundwater systems. This review includes discussion about the adequacy of data, the process of groundwater modelling, parameter uncertainty and prediction uncertainty, to explain the role of modelling in assessment of potential groundwater management issues.

Ultimately, it is important that stakeholders have confidence in predictions. Even for professionals with many years of experience, there are always challenges that lead to uncertainty in predictions. In this Section, comments are provided on the modelling undertaken for the Hume Coal Project, especially the revised modelling reported in the RTS, in the context of questions asked by EMM, the IPC and various other reviewers.

## 6.1 Objectives of Modelling

### 6.1.1 General discussion about objectives and requirements of modelling

The Guidelines distinguish between the objectives of a project (e.g. Hume Coal's objectives wanting to develop the Hume Coal Project) and the objectives of a model. A numerical groundwater model cannot answer all questions at all scales in space in time. A model needs to be designed to answer specific questions.

It has become increasingly apparent in recent years that once a model is developed to answer a specific set of questions, as well as possible given the available data, reviewers and stakeholders seem to expect that the same model can answer other questions. The challenges are of many kinds. A regional scale model cannot be expected to make accurate predictions at specific locations within a very large region; a regional scale model is by its very nature capable of providing larger scale answers that are in some sense "averaged" in space and time. A local scale model cannot be expected to make large-scale predictions for a

region much larger than originally anticipated. These challenges lead to a need for clear and agreed objectives.

The Guidelines describe a modelling process (see Section 1.6), which starts with planning. During the planning stage, modellers should focus on "*gaining clarity on the intended use of the model, the questions at hand, the modelling objectives and the type of model needed to meet the project objectives*". Section 2 of the Guidelines explain the planning stage in more detail. The intended use of a model should be considered and documented. Figure 2-1 in the Guidelines suggests that the result of the planning process should be "*explicit agreement amongst stakeholders on what is required from the model*" and a "*common view of the modelling process*". Guiding Principles 2-1 and 2-2 are even more explicit, explaining that modelling objectives should be prepared early and used regularly throughout the modelling process. Table 9-2 in the Guidelines provides a detailed checklist for reviewers. The first four questions in the checklist ask about project objectives and model objectives. It is very important to be clear about objectives.

Groundwater modelling is usually undertaken for two overarching reasons:

- Modelling is undertaken **at the request of the proponent of a mining project**, during project Feasibility Studies, **to facilitate mine design**. It is essential for a mining company to estimate groundwater inflows, and to design water management infrastructure to manage and contain mine inflows, for operational reasons. Mining cannot proceed without safe access to active mining surfaces, so it is in the mining company's interests to obtain estimates that are as accurate as possible. It is not in a mining company's interests to underestimate groundwater inflows to mines, or to underestimate the cost of operational water management. An objective of groundwater modelling is therefore to estimate groundwater inflows to a mine throughout the life of a project.
- Modelling is also undertaken **at the request of governments**, **to assess potential environmental impacts.** Governments have obligations to protect the environment and the rights of other groundwater users, on behalf of the community. Objectives of groundwater modelling are therefore also to estimate potential impacts on the water table, potential impacts on existing bores, potential impacts on nearby groundwater-dependent ecosystems (GDEs) and potential impacts on baseflows to nearby rivers and streams.

Most groundwater modelling undertaken for proposed mining projects is focused on the quantity (or flow) of groundwater rather than on groundwater quality. Predicting changes in groundwater quality at regional scale is extremely difficult, so it is rarely attempted.

In the case of the Hume Coal Project, modelling to meet government requirements was driven by three sets of requirements summarised by EMM (2018c,d,e). They include the DPE Secretary's Environmental Assessment Requirements (SEARs), an IESC guidelines checklist and an AIP checklist. The SEARs include (i) Section 78A(8A) of the Environmental Planning and Assessment Act 1979, (ii) numerous documents prepared by NSW government agencies in July and August 2015, and (iii) Supplementary Environmental Assessment Requirements sent by DPE to Hume Coal on 18 January 2016, listing assessment requirements relevant to the Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act). The list of requirements is long.

- Fundamentally, Section 78A(8A) requires "*an assessment of the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources, having regard to the EPA's, DPI's and Water NSW's requirements and recommendations*", and "*an assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users*". It requires adherence to "*environmental planning instruments, guidelines, policies, and plans*

*that may be relevant*", including the NSW State Groundwater Policy Framework Document, the NSW State Groundwater Quality Protection Policy, the NSW State Groundwater Quantity Management Policy, the NSW Aquifer Interference Policy, the Guidelines and more. It does not explicitly require that groundwater modelling be undertaken.

- The agency requirements include a request by DPI Water that an EIS should include "*Assessment of impacts on surface and ground water sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, wetlands, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts*", "*full technical details and data of all surface and* ***groundwater modelling****, and an* ***independent peer review of the groundwater model***", "*assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts*" and "*the* ***results of any models*** *or predictive tools used*".
- The Supplementary Environmental Assessment Requirements ask for information to be provided on "*any substantial and measurable changes to the hydrological regime of the water resource, for example a substantial change to the volume, timing, duration or frequency of ground and surface water flows*". They also require an EIS to provide sufficient information to allow review by the IESC.

Section 1.5 of the Revised Water Impact Assessment Report (EMM, 2018b) describes assessment requirements in detail. Section 1.6 describes the purpose of the water assessment. The SEARs are summarised in Appendix A to EMM (2018b), described here as EMM (2018c); the requirements mentioned above are listed by EMM (2018c) as AR15, AR29 and AR58. In summary, the SEARs do not prescribe in detail how groundwater modelling should be undertaken.

The IESC guidelines (EMM, 2018d) are more explicit about the need for groundwater modelling. They require conceptualisation, as a precursor to numerical modelling. The modelling should be undertaken in accordance with the Guidelines and should include peer review. But again, the IESC guidelines do not require specific levels of accuracy in predictions and leave most important decisions to the modellers.

EMM (2013e) addresses the AIP and explains how groundwater modelling was used to meet the requirements of the AIP. Responses are structured to facilitate assessment of the project.

### 6.1.2 Objectives of groundwater modelling undertaken for the Hume Coal Project

The introduction (Section 1) in Coffey (2016a) explains that "*the purpose of the assessment was to assess impacts on the groundwater system and dependent user from proposed mining*". The assessment included "*development of a groundwater flow numerical model to simulate drawdown of the groundwater system due to mining and any consequent drawdown interference in private bores in the region, and any effects on surface water hydrology*". Similar statements are made in Section 1 of Coffey (2016b) which describes the development of the model. Section 4.3.5 of Coffey (2016b) discusses the question of whether the model is fit for purpose; Coffey state that the model is "considered fit for estimating impacts from proposed mining in the Hume lease area".

Documentation for the revised groundwater modelling undertaken for the RTS (HydroSimulations, 2018) refers to comments by reviewers (see reference to Hydrogeologic (2017) in Section 3) and repeats the claim that the model is "fit-for-purpose" (see Section 5.4 and Section 9). The objectives for modelling are not stated clearly and explicitly.

Following development of the model by Coffey (2016b), two peer reviews were prepared.

- HydroAlgorithmics Pty Ltd (2016) followed an approach described in earlier groundwater modelling guidelines (Middlemis et al., 2001) as a "model appraisal" (see Table E1 in these "MDBC Guidelines"). The MDBC Guidelines did not emphasise the importance of "modelling objectives", which is one reason why the Guidelines chose to do so. As a result, there is only one question in the model appraisal checklist related to "project objectives". HydroAlgorithmics found that both reports by Coffey (2016a,b) met this objective well.
- Kalf and Associates Pty Ltd (2016) also used the model appraisal checklist provided in the MDBC Guidelines and scored the description of "project objectives" highly.

Following submission of the EIS, Hydrogeologic (2017) provided a review of the modelling for DPE. Section 3.2 of Hydrogeologic (2017) used the groundwater model "compliance checklist" provided as Table 9-1 in the Guidelines. In answer to the question "are the model objectives … clearly stated", the answer was "yes", in the context of mining impact assessment. The same answer was provided to DPE following review of revised modelling by HydroSimulations (2018), see Section 3.2 of Hydrogeologic (2018).

Sections 1 and 2 of Coffey (2016b) provide very good descriptions of the proposed Hume Coal Project, however the author of this review believes that more emphasis on the distinction between project objectives and model objectives and more narrative about what modelling is intended to achieve would have helped to avoid the current situation. The Guidelines explain the importance of consensus among stakeholders. Differences of opinion, such as those described by the IPC in Section 1 above, can be avoided by open discussion about what is needed and what can be achieved. Defining and constraining objectives at the start of a modelling process can help avoid what is sometimes called "scope creep", where each time results are provided, more and different questions are asked.

## 6.2 Baseline Data

Baseline data are provided by Coffey (2016a). Their report "presents the results of compilation and analysis of the groundwater database". Section 2 and 3 describe climate and surface drainage, respectively. Section 4 describes the geology, including stratigraphy, faults and intrusions. Section 5 describes subsurface hydraulic properties, including hydraulic conductivity, specific yield and specific storativity. Measurements of "groundwater levels" are presented in Section 6; the author of this review prefers very explicit reference to measurements of water table elevation and measurements of piezometric head (the levels in

piezometers screened at some depth below the water table), however the less precise terminology is widely used. Section 7 describes data obtained at the abandoned Berrima Colliery, just to the north of the proposed Hume Coal Project (see Figure 6.1 in Coffey (2016a)); having any data from a nearby mine within the domain of a model is rare and extremely valuable. Water quality data are summarised in Section 8 and the distribution of private bores is presented in Section 9.

Bore logs are presented in an Appendix to EMM (2017b), described here as Parsons Brinckerhoff (2014) because the dates on bore logs are all in 2014. Geosyntec (2016) provide much more detailed information on hydrogeochemistry. Six Appendices to Coffey (2016a) provide additional data.

Baseline data are summarised in Section 4.2 and Chapter 6 of the Revised Water Impact Assessment Report (EMM, 2018b), and further summarised in Chapter 9 of the RTS Main Report (EMM, 2018a).

The author of this review accepts that the baseline data are adequate and well presented.

***Question:*** *Is additional geological information required to undertake the modelling as undertaken – i.e. with reference to the expectation of geological information available for a Class 2 model, given the level of impact predicted and in accordance with industry standards?*

The Guidelines provide no specific advice on the amount of geological or hydrogeological information required to undertake modelling for a project like the Hume Coal Project. Nor are there industry standards. Table 2-1 in the Guidelines refer to the spatial distribution of bore logs and the need to infer stratigraphy and hydrostratigraphy (the location of "aquifers" and other units), but the guidance is not prescriptive.

There is no requirement for the proponent of a mining company to make public all geological data. Section 9.2 of the RTS Main Report (EMM, 2018a) explains that "*the conceptualisation of geological layers is developed from geological mapping, historical geological logs and exploratory and monitoring bore drilling*". This is consistent with all mining projects, where the amount of exploratory drilling to define the target mineral resource far exceeds the amount of drilling as part of groundwater impact assessment studies. Section 79 of IPC (2019) quotes a review by Dr Bruce Hebblewhite explaining that "*Hume Coal has extensive geological data over Authorisation 349, including historic holes drilled by previous title holders as well as exploration holes drilled by the company, totalling 345 holes in A349 (an area of 89 km$^2$). There are 179 holes in the proposed mining area itself (an area of 35 km$^2$).*"

Section 9.3.4(xiv) of the RTS Main Report (EMM, 2018a) explains that "the raw data files and all information used to develop the conceptual and numerical models has been made available to the NSW Government independent peer reviewer" (cf. the review by Hydrogeologic (2017)), and "it is not a requirement that this same information be made publicly available, and/or provided to known objectors of projects in NSW".

***Question***: *Is the hydraulic testing undertaken (and hydraulic test data available) considered adequate for an EIS given other available external data including Berrima Colliery information and information from other nearby mines? (i.e. number of pumping tests, packer tests, monitoring bore numbers and available data?)*

The Guidelines provide no specific advice on hydraulic testing, on how much hydraulic testing should take place and how estimates of hydrogeological parameters should be used. Section 5.2.4 of the Guidelines explain that "modelling and model calibration should utilise and take into account all available information" including "prior estimates of hydrogeological properties obtained following aquifer tests, slug tests and even permeameter tests". Interpretation of even a single "aquifer test" (also known as a "pumping test") is difficult, since it is on its own a type of model calibration, that relies on a local conceptual model of the hydrostratigraphy near the pumped bore. A test of this kind leads to an estimate of hydrogeological properties that is quite local in scale, perhaps an average with a radius of

tens or one hundred metres. Slug test provide averages at a scale of a metre, and permeameter test provide averages at a scale of tens of centimetres. Experienced modellers know that all prior estimates of hydrogeological properties are useful, but much less useful than calibration of a regional scale model against measurements of water table elevation and piezometric head at locations spread across the model domain.

Experienced modellers also know that any measurements of fluxes are very useful and help to constrain estimates of model parameters in regional scale models. Measurements in any part of a model domain that has been significantly stressed are also extremely valuable. While the existence of an historic (previously operating) mine like the Berrima Colliery inside the model domain is not unique, it is relatively unusual. The fact that Coffey (2016a,b) attempted to use data from and near the Berrima Colliery should provide confidence in their efforts.

Table 9.2 of the Main Report of the RTS (EMM, 2018a) provides a summary of hydraulic testing undertaken for 19 proposed mining projects approved in NSW since 2013, in comparison with testing undertaken for the Hume Coal Project. The comparison suggests that hydraulic testing undertaken for the Hume Coal Project is adequate for an EIS. HydroAlgorithmics Pty Ltd (2016) and Kalf and Associates Pty Ltd (2016) both characterised the analysis of hydrogeology data as "very good". Hydrogeologic (2017, 2018) found no reason to criticise the amount of aquifer testing, based on a good understanding of the model calibration process.

## 6.3 Hydrogeological Conceptual Model

Section 10 of Coffey (2016a) uses all information presented earlier in this report to develop and explain a hydrogeological conceptual model. The conceptual model is represented pictorially in Figure 10.3 of that report, reproduced here as Figure 6. Note that the conceptual model is based on Figure 4 above.

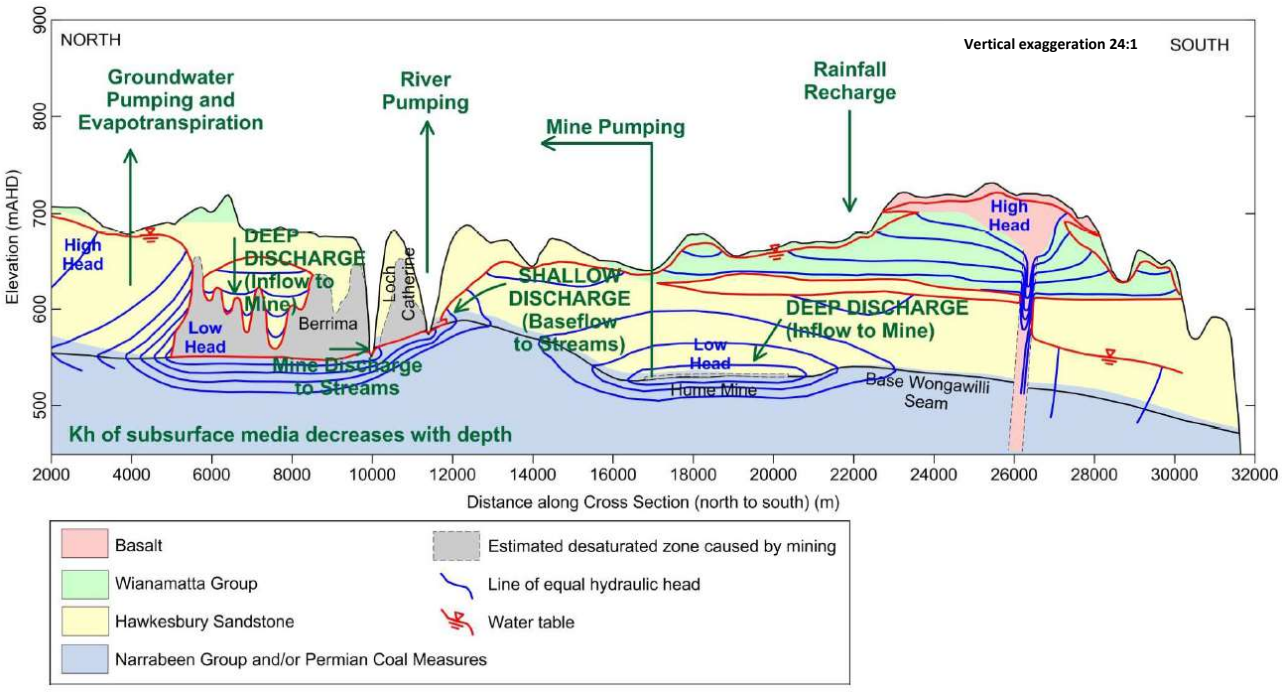



**Figure 6: Hydrogeological conceptual model, Figure 10.3 in Coffey (2016a)**

Sections 6.1 to 6.3 of EMM (2018b) provide additional background information on the regional and local geology and hydrogeology, essentially supporting the earlier conceptual model provided by Coffey (2016a). Sections 6.6 and 6.7 explore groundwater flow in lateral and vertical directions, respectively. Section 7 describes an expanded conceptual model, integrating surface water and groundwater (cf. Figure 7.1).

A key feature of the proposed Hume Coal Project (Coffey, 2016b, Section 2; EMM, 2018a, Section 5.3) is the "first workings" mining method, known as "pine feather", and the plan to backfill mined voids by co-disposal[4] of rejects, coal fines and excess mine water. After completion of each panel, a bulkhead (a tapered concrete plug designed to withstand four times the maximum possible pressure) would be built to contain the slurry, and any remaining volume would be filled with more mine water. This plan is specifically aimed at filling voids to prevent additional drainage into the mine and additional lowering of the water table above.

The hydrogeological conceptual model is adequate, and in some respects better than in many similar modelling studies. What makes the model better is the good description of proposed mining methods and the recognition that in order to design a numerical groundwater flow model, one needs to conceptualise both the natural pre-mining hydrogeological system and the processes that will occur once mining starts. The fact that mining and backfilling have been considered and described in detail demonstrates the experience of the modelling team.

## 6.4 Choice of Groundwater Modelling Software

Coffey (2016b) used MODFLOW-SURFACT V3 to develop a regional scale groundwater flow model. HydroSimulations (2018) explain that they first updated the earlier model data sets to allow them to run in MODFLOW-SURFACT V4, and then converted them to run in MODFLOW-USG. This kind of progression is reasonable and standard. Experienced modellers with access to different software packages understand the relative merits of different computational "engines" in different graphical user interfaces (GUIs). Each software package is slightly different but can be used appropriately by experienced modellers.

Both MODFLOW-SURFACT V4 and MODFLOW-USG support so-called "time-varying material properties", which are very useful for representing complex mine schedules.

## 6.5 Model Structure and Parameterisation

The model structure is described in Section 3 of Coffey (2016b). This model structure is preserved in subsequent modelling by HydroSimulations (2018).

The model domain covers an area of 752 km$^2$, as shown in Drawing 1 in Coffey (2016b), reproduced here as Figure 7. Note the location of Berrima Mine and Loch Catherine Mine to the north of Medway Rivulet, just to the north of the proposed Hume Coal Project. The original model grid had 15 layers; HydroSimulations (2018, Section 1.1.3) removed two layers at the base of the model because these had been set inactive. Cells are 50 m square within the Hume lease, expanding to 200 m square at the extremities of the model domain. Layer thicknesses vary in space.

The Guidelines (Section 4.7) introduce the importance of parameterisation. Parameterisation (see also Section 5.2.3 in the Guidelines) is the process by which model parameters are defined. Model parameters are quantities for which values must be assigned, either based on prior knowledge or through the process of model calibration, to describe spatial variation in hydrogeological properties and spatial and temporal variations in boundary conditions (including recharge and pumping).

As shown in Figure 8 below, HydroSimulations (2018) developed several models during the process of revising the groundwater modelling described by Coffey (2016b) for the EIS. There are no Sections or Tables in which HydroSimulations explicitly summarise the parameterisation in the so-called Modified EIS Model

[4] Note that Coffey (2016b) use the term "tailings" to refer to rock and coal fragments left over from washing and processing coal. EMM (2018a, Executive Summary ES85) use the term "rejects".

or the Mean K Baseline model. The model developed by Coffey (2016b) had single values of horizontal hydraulic conductivity Kh, vertical hydraulic conductivity Kv, specific storativity Ss and specific yield Sy in each model layer, i.e. these properties were assumed to be uniform or homogeneous over the whole model domain in each layer. This parameterisation was maintained in the Modified EIS Model.

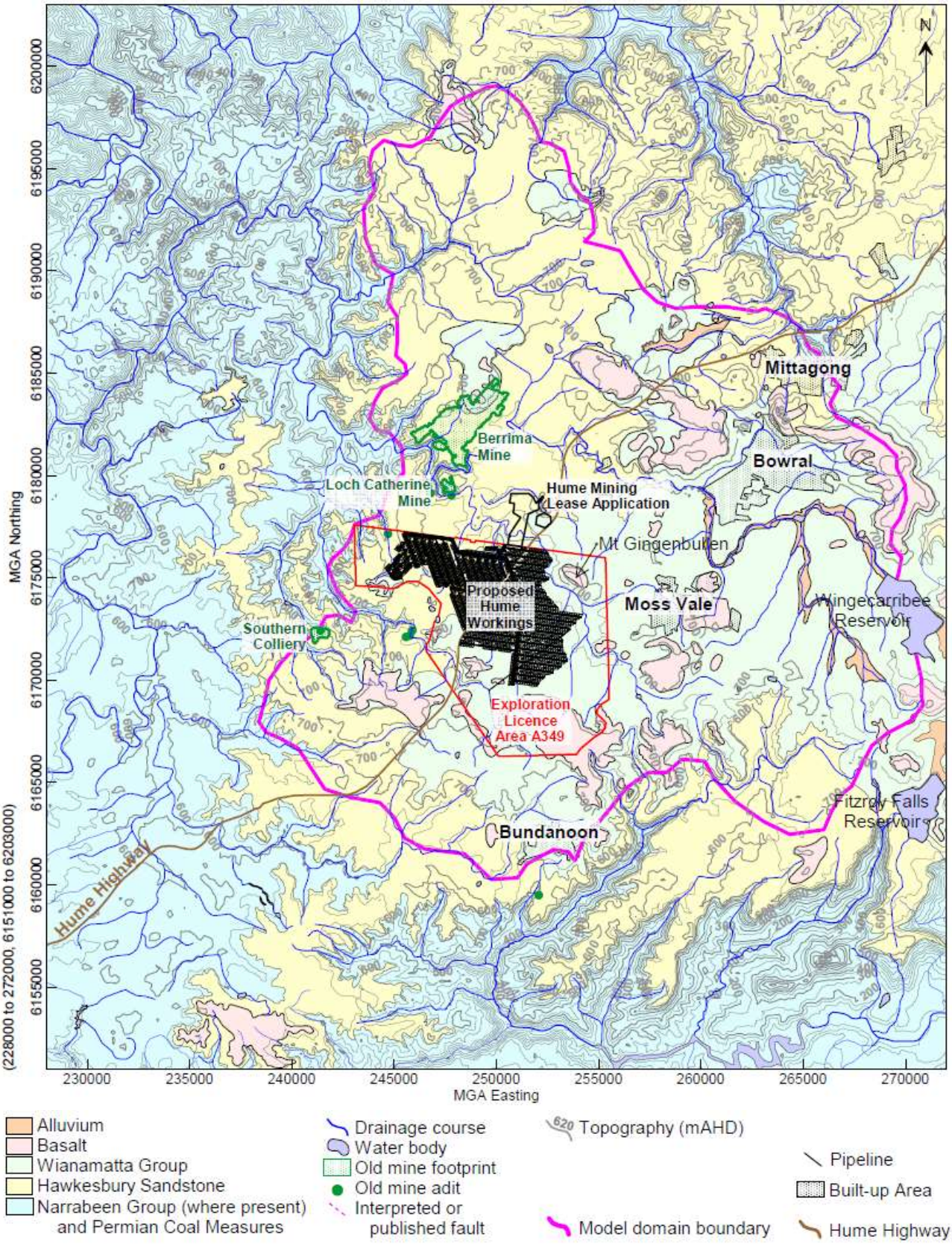



**Figure 7: Regional locality plan, Drawing 1 in Coffey (2016b)**

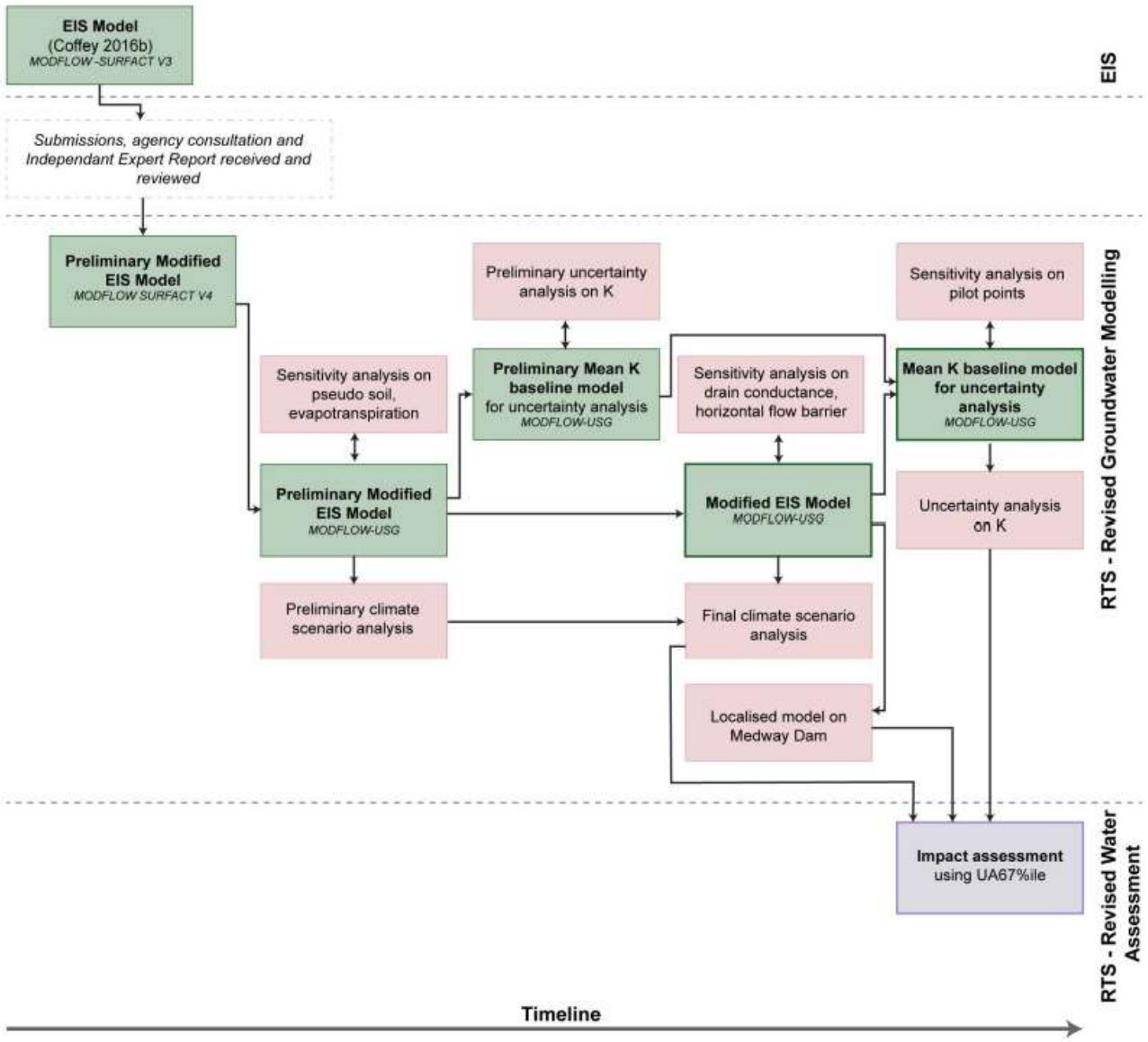



**Figure 8: Versions of groundwater models, Figure 1 in HydroSimulations (2018)**

HydroSimulations (2018) introduced spatially-varying and depth-dependent hydraulic conductivities, Kh and Kv, but only in the Mean K Baseline Model that was used for uncertainty analysis (HydroSimulations, 2018, Section 5). HydroSimulations (2018) do not describe in detail the kriging algorithm used to interpolate between values generated at pilot points in the Mean K Baseline Model. Noel Merrick (pers.comm.) has indicated that ordinary kriging was performed using the "calc_kriging_factors_auto_2d" algorithm included as part of the PLPROC processor (Doherty, 2016). This algorithm uses default parameters to ensure smooth interpolation between values assigned at pilot points.

## 6.6 Representation of Mining and Groundwater Flow above Underground Mining

Groundwater modelling software has never been designed or developed to represent mining. Representation of open cut and underground mines using available software remains one of the greatest challenges for experienced groundwater modellers. To represent an underground mine and mine schedule, data sets must be created to set piezometric heads equal to or near the elevation of each part of the mine,

during the period of mining at that location. Since the size of model cells does not match the dimensions of each part of the mine, the geometry of the mine is approximated. Heads are often set equal to the floor or invert level of the mine, either using prescribed head boundaries or mixed boundary conditions known as "drain" boundaries in MODFLOW.

It is not uncommon in modelling studies for proposed mines for this aspect of model development to be poorly understood. In this case, the modeller responsible for Coffey (2016b) has written extensively about the deformation that occurs above underground coal mines (Tammetta, 2013, 2015, 2016). This explains the level of detail provided in Sections 10.5 and 10.6 of Coffey (2016a) and Section 3.2.5 of Coffey (2016b), explaining the likely extent of desaturation above proposed "pine feather" mining in the Hume Coal Project and the vertical extent of desaturation above the Berrima and Loch Catherine Mines. Coffey (2016b) suggest that damage (goaf formation) above some parts of Berrima Mine could extend to a height of 53 m above the mine, whereas the average "relaxation height" above the Hume Coal Project is estimated to be 2 m. That is, there will be no goaf formation above the Hume Coal mine.

Coffey (2016b, Section 5.3) describe how pine feather mining is represented in the model. The Drain (DRN) package in MODFLOW-SURFACT was used to set a drain elevation 0.1 m above the mined floor level, dynamically according to the mine schedule (see Figure 9 below). Section 3.2.5 of Coffey (2016b) explains that the height of desaturation was estimated *a priori* and "*drains are used to simulate drainage in each layer intersected by the deformed zone*". Hydrogeological properties were not changed in time above the proposed Hume Coal mine, because the height of desaturation is so small (Coffey, 2016b, Section 5.3). The process of setting up model data sets to represent the mine schedule is complex and requires attention to detail. Appendix A in Coffey (2016b) provides details of the mine schedule used in modelling for the EIS.

HydroSimulations (2018, Section 1.1.3) explain that in the original model, drain cells were activated according the mine schedule and "drain cells remained active after the completion and sealing of a mine panel". Following conversion to MODFLOW-USG, the revised model turned off drain cells following the end of activities in each panel. Furthermore, the Time Varying Materials package in MODFLOW-USG was used to modify properties in mined panels during and after mining.

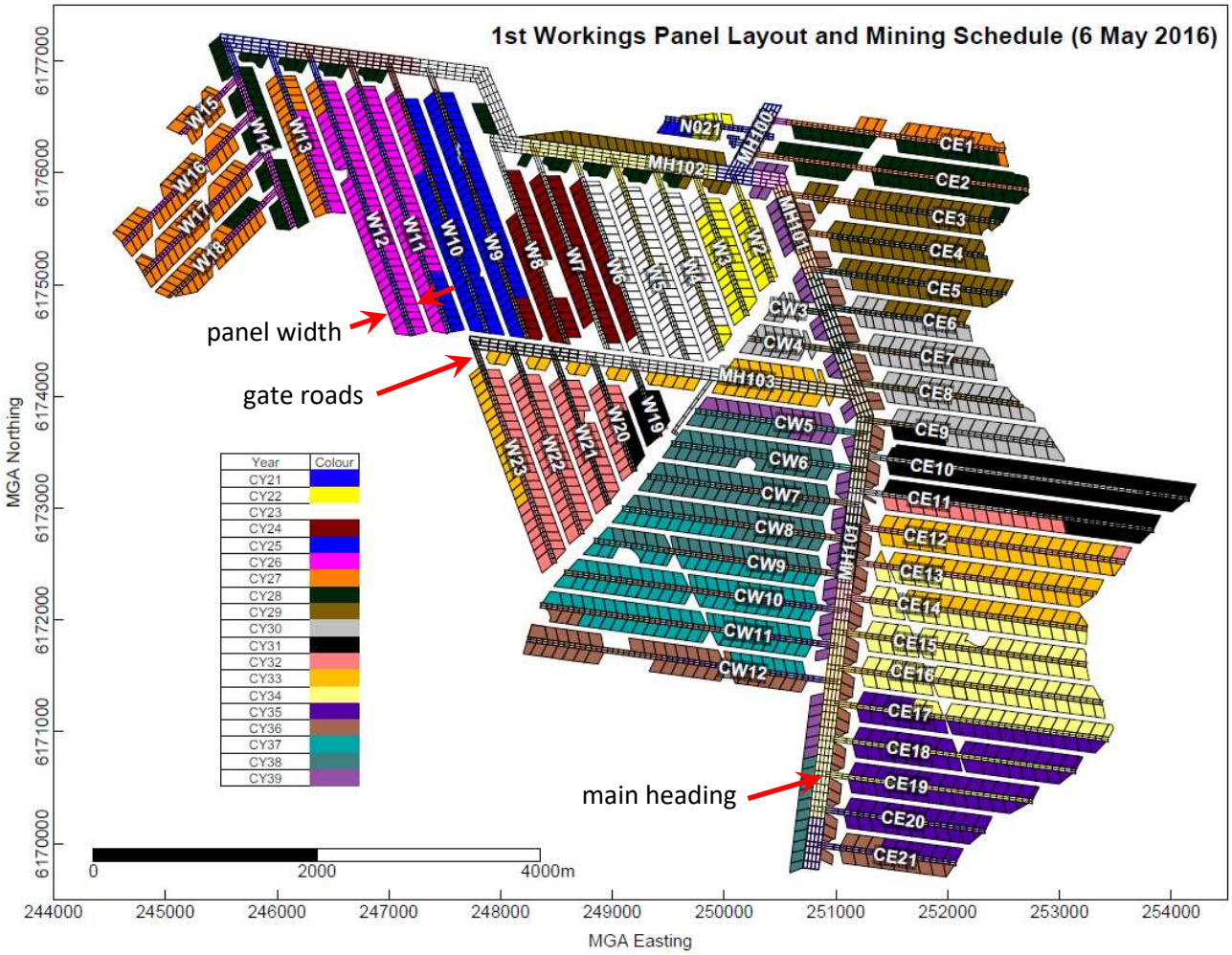



**Figure 9: Pine feather panel layout and mine schedule (6 May 2016), Appendix A in Coffey (2016b)**

## 6.7 Representation of Refilling of Mined Voids behind Bulkheads

The use of bulkheads is described by Coffey (2016b, Section 5.3.1). After completion of mining in each panel, bulkheads would be built in the three gate roads connecting the panel to a main heading (see Figure 9 above). These would allow Hume Coal to fill each mined panel void in a timely manner, so that (i) recovery of the regional hydrogeological system is accelerated, and (ii) the volumes of solids and excess water that would need to be managed and/or stored in perpetuity at the surface are reduced. The Table in Appendix A of Coffey (2016b) lists 59 panels in the mine plan dated 6 May 2016 (see Figure 9 above). Three bulkheads are required to seal each panel. Additional bulkheads would be constructed in main headings when access to these headings is no longer required. The total number of bulkheads would therefore be of the order of 200. The large number of bulkheads would not only reduce the risk associated with failure of a bulkhead (because the volume of free water stored in any one panel would be relatively small), but would also create many horizontal barriers that would reduce the effective bulk hydraulic conductivity of the mined void after closure.

The resolution of the model grid is not fine enough to represent every bulkhead; one cell is used to represent each set of three bulkheads for each panel. The model does not represent bulkheads in main headings. Nevertheless, the author of this review is not aware of any previous attempts to simulate refilling of mine voids behind so many bulkheads using a regional scale groundwater flow model. Modellers are constrained to using the capabilities of modelling software. Neither MODFLOW-SURFACT nor MODFLOW-

USG includes any special mechanism for representing bulkheads, or the processes that will occur behind bulkheads as mine voids are filled, so a modeller needs to find a way to represent those processes reasonably well.

Coffey (2016b, Section 5.3.1 and Figure 5.4) explain how recovery behind bulkheads has been simulated. The volume of the void behind each bulkhead is filled partly manually and partly by groundwater inflows, with drain cells active. When the volume is essentially full, the drain cells are de-activated. The time at which de-activation occurs is determined iteratively, by running the model many times.

HydroSimulations (2018, Section 1.1.3) explain that the time-varying materials (TVM) package in MODFLOW-USG was used in revised modelling, and that this facilitated turning off drain nodes at the end of mining in each panel. Section 5 of HydroSimulations (2018) refers to Table 8 and Table 9, which describe changes in modelling approach and "new model features", respectively, in the so-called "Modified EIS Model". Quite a few changes were made:

- Drain cells are turned off at the end of mining, rather than at the end of refilling of each backfilled void (see Table 8);
- Drain cells are not used in any panels that are mined in the up-dip direction, because cells in those panels would drain towards main headings once material properties are adjusted (see Table 8);
- Hydraulic conductivities in active mine panels are increased significantly relative to their original values when mining commences (see Table 9);
- Specific yield is varied in time and space to account for backfilling in panels after mining, which assumes that specific yield is being used by MODFLOW-USG in those cells, as panels refill;
- Hydraulic conductivities in cells that represent bulkheads revert to their original in situ values when bulkheads are installed (see Table 9), while hydraulic conductivities remain enhanced in other cells within mined panels (Noel Merrick, pers.comm.); and
- Changes in hydraulic conductivities are lagged one stress period to reduce the chance of numerical instabilities (see Table 9).

All these changes relative to the earlier model are quite technical and seem to be reasonable. The fact that hydraulic conductivities remain high in mined panels is reasonable because backfilling of mined panels is unlikely to lead to remove all conduits within mined panels.

The description provided by HydroSimulations (2018) does not completely describe how placement of slurry and additional mine water behind bulkheads is taken into account, but it is clear that deactivating drain cells and changing specific yield in the mined voids at least starts the process of recovery of piezometric heads adjacent to these mined and backfilled panels. The effective specific yield in mined panels after mining varies between 0.15 and 0.27 (Noel Merrick, pers.comm.), which means that the during the period of recovery after mining, and after cessation of mine dewatering (via drain cells), groundwater continues to flow into the mined panels until the volume of voids implied by the spatially-varying specific yield is full. The model does not explicitly represent the process of injecting water behind bulkheads, so the model over-estimates the impact on the water table during the recovery stage.

## 6.8 Model Calibration

Chapter 5 of the Guidelines makes a number of key recommendations about model calibration, including:

- Guiding Principle 5.2: The calibration process should be used to find model parameters that prepare a model for use during predictions of future behaviour, rather than finding model parameters that explain past behaviour.
- Guiding Principle 5.4: Performance measures should be agreed prior to calibration and should include a combination of quantitative and non-quantitative measures. The scaled root mean squared error (SRMS) is a useful descriptor of goodness of fit when the only objective is to fit historical measurements of heads but is less useful when automated calibration methods are used. A target SRMS of 5% or 10% is only meaningful when those setting the target know that it is achievable for a particular kind of problem and a particular environment with a known density of informative data.

Guiding Principle 5.2 is important. Model development should focus on the potential impacts of mining on landholder bores and perhaps on potential impacts on streamflow, although experienced modellers would always understand that the latter is far less likely to be significant. The model parameters that will have the greatest effect on drawdown of the water table (the cone of depression) will be (i) vertical hydraulic conductivity in hydrostratigraphic units above the mine, (ii) specific yield at all elevations from the pre-mining water table to the deepest extent of the cone of depression (because specific yield is only relevant at the elevation of the water table, at every location and time) and (iii) horizontal hydraulic conductivity beyond the extent of the cone of depression (because this will affect the rate of lateral flow towards the cone of depression). It is never certain that historical measurements of water table elevation and piezometric heads, utilised during the process of manual or automated model calibration, will "inform" (provide information about) the parameters that will have the most effect on future behaviour (i.e. that will affect model predictions). This should be explained in any discussion about model calibration.

Guiding Principle 5.4 is also important. SRMS is useful "when the only objective is to fit historical measurements of heads", but best practice requires modellers to attempt to fit measurements or prior estimates of hydrogeological properties as well as measurements of baseflow (if available). The Guidelines do not state or imply that there is any need to achieve any specific target value of SRMS. If stakeholders suggest that a specific target is mandatory, this is not consistent with the Guidelines. Experienced modellers know that they can only achieve what they can achieve. Ultimately, groundwater modellers understand a groundwater system better than any others associated with a project, because by working with data and model parameters, they come to feel how a system responds. This feeling cannot be quantified by a number such as SRMS.

Section 5.4.5 of the Guidelines states that "*experience has shown that it is not always desirable to specify a target value of some performance measure in advance*". Furthermore, "*model acceptance should be based on a number of measures that are not specifically related to model calibration*". Table 5-1 of the Guidelines discuss the importance of model convergence, water balance and qualitative measures that are sometimes described as a "sanity test", i.e. does the model make sense.

Calibration of the original EIS model (Coffey, 2016b, Section 4) was undertaken manually. As explained in Sections 4.1 and 4.3.5, calibration took advantage of four large and independent data sets:

- Hydraulic heads;
- Hydraulic conductivities;
- Shallow groundwater discharge (baseflow to streams); and
- Deep groundwater discharge (inflows to the Berrima Mine).

Coffey (2016a, Executive Summary) described the model calibration as being based on "the optimal set of data for calibration of a numerical groundwater flow model". Hydrogeologic (2017, Section 4) describes Coffey's (2016b) approach to model calibration as "best practice history match calibration methods". In the opinion of the author of this review, it is rare to have data sets of these four kinds, so the comments made by Coffey (2016a) and Hydrogeologic (2017) are justified.

In developing the Modified EIS Model, HydroSimulations (2018) refer to model calibration many times, but do not explain in detail how model calibration was undertaken. In fact, HydroSimulations (2018) relied entirely on the manual calibration undertaken by Coffey (2016b) (Noel Merrick, pers.comm.). Hydrogeologic (2018, Section 3.1 and Table 3) states that the approach to calibration reported by HydroSimulations is "based not only on SRMS but also on 4 other key criteria, consistent with the Guidelines", i.e. (i) matches of heads during a period "that includes substantial hydrological variability (climatic and mine dewatering stresses)", (ii) consistency between estimates of aquifer properties to field measurements, (iii) matches to baseflow and (iv) matches to mine dewatering fluxes.

In the opinion of the author of this review, a focus by stakeholders on SRMS is completely unfounded. It is counter to the Guidelines, and counter to the theoretical basis for multi-objective optimisation methods that are embedded in modern model calibration methods. Perhaps because stakeholders continue to ask about SRMS, modellers continue to report its value. Following conversion of the original EIS model to MODFLOW-USG, the SRMS was reduced from 11.9% to 10.76% (HydroSimulations, 2018, Section 3.1.2, Section 4.1.3).

Section 6.10 below describes uncertainty analysis, which is focused on uncertainty in predictions of the impact of the Hume Coal Project. Nevertheless, every simulation (realisation) in uncertainty analysis was also run during the so-called calibration period. The same statistics that were calculated during model calibration were calculated for every realisation in the uncertainty analysis. This allowed calculation of the statistics. HydroSimulations (2018) report that about 30% of realisations achieved less than 10% SRMS. On its own, the SRMS statistic, which only measures how well heads are matched, ignoring the other three types of data, is not particularly informative. An SRMS of 10% is not uncommon, nor is it evidence that a model is inadequate or not fit for purpose.

Many of the calibration graphs provided by HydroSimulations (2018) show differences between observed and simulated heads that are larger than stakeholders would like to see. These large differences lead to large values of SRMS. Figures 5, 7, 8 and 10 in HydroSimulations (2018) show situations where much greater head differences exist in the real world, between different elevations, than in the model. This suggests that values of vertical hydraulic conductivities may be much lower than in the model, i.e. that anisotropy is greater. Small vertical hydraulic conductivities would lead to much smaller impacts of mining on the water table above. Of course, one cannot use an argument like this on its own to justify a model or to argue that a mine's potential impact will be small, because such an argument could be described as "cherry picking". At the same time, systematic commentary on how and why the model may not fit observed data could at least help stakeholders to understand more about the system and more about the challenges of calibrating a model. Focusing on numerical values of SRMS takes all stakeholders away from the physical situation which is more important.

## 6.9 Model Predictions

While model calibration is an important part of modelling, the crux is in the predictions. After all, the objectives of modelling are to predict future behaviour of the groundwater system. In the Hume Coal Project, there is special focus of attention on drawdown at the location of landholder bores and potential impacts on streamflow.

In the process of developing the Modified EIS Model, no single set of model predictions was made to address the questions that would be asked of the Modified EIS Model. Predictions were made as part of uncertainty analysis, as discussed in Section 6.10 below.

## 6.10 Sensitivity and Uncertainty Analysis

In recent years, there has been increasing focus on uncertainty analysis. This trend was one of the reasons for developing the Guidelines in 2012, but the Guidelines may not have led to models having any greater accuracy, or to stakeholders having any more confidence in predictions, than before these Guidelines were written.

In the past, modellers were expected to provide some kind of "best estimate" predictions, with a number of reasonable alternatives as part of "sensitivity analysis". Uncertainty analysis requires that a much larger number of scenarios be run, so that predictions can be viewed statistically. This requires more expertise on the part of the modeller, and more expertise and experience on the part of stakeholders, as they try to understand both the methodology of uncertainty analysis and the meaning of probabilities associated with every prediction.

Prior to the recommendation that modelling include uncertainty analysis, the focus in assessing reasonableness of modelling was on uncertainty in model parameters and the likely impacts on predictions. Now there tends to be focus on uncertainty in the uncertainty analysis. This is one step further removed from the physical world. It is more abstract, and even harder to resolve.

There is a tendency now for stakeholders to demand some types of analysis without a complete understanding of what is being requested. It is really important to focus on the real issues that need to be addressed, and to undertake analysis based on thinking rather than the options available in sophisticated technical software.

HydroSimulations (2018, Section 1.1.5) acknowledge the recent release of draft guidelines by the IESC (see also EMM (2018a, Section 3.6.5) which explain that the draft guidelines were released in March 2018). The final guidelines were subsequently published by Middlemis and Peeters (2018), with a companion 4-page summary published by IESC (2018). EMM (2018a, Section 3.6.5) explain that HydroSimulations (2018) were able to take the draft guidelines into account during planning for uncertainty analysis. The 4-page summary (IESC, 2018) suggests that "most large coal mines … would be classified as high environmental risk" and that "*a more detailed quantitative uncertainty analysis may be needed… The IESC suggest that the proponent and the regulator engage early and regularly*". IPC's Recommendation R5 (IPC, 2019) is consistent with this recommendation, and Hume Coal has since attempted to interact with the relevant regulator, DPIE Water (EMM, pers.comm.).

HydroSimulations (2018, Section 1.1.5) explain that outputs from uncertainty analysis included mine inflows, drawdown at locations of landholder bores and reductions in baseflow in four streams. These are logical choices for predictions on which there should be focus. Further sensitivity studies were undertaken (HydroSimulations, 2018, Section 1.1.6) to assess sensitivity to specific aspects of the Modified EIS Model.

Uncertainty analysis (HydroSimulations, 2018, Section 7) focused on assessing the impact of hydraulic conductivities on key predictions. As mentioned above, vertical and horizontal conductivities would be expected to influence drawdown and the lateral extent of the cone of depression (at the water table). Specific yield at elevation of the water table is also important, but as long as Sy is reasonable, an uncertainty analysis focused on hydraulic conductivities would be expected to span a large range of relevant combinations of parameter values. While lowering of the water table is important, changes in piezometric heads at depth are also important; the analogous change is a "cone of depressurisation" that can extend to considerable distances laterally, because specific storativity is small. Even if this has not been described in the reporting, its effect on baseflow will be included in the modelling.

The details for how Kh and Kv were generated are described by HydroSimulations (2018, Section 7.2.1), using the terminology Kx and Kz. Additional details were sought during this review and were provided by Noel Merrick (pers.comm.). Values of Kh were generated based on assuming that Kh at each pilot point is log-normally distributed, with mean and standard deviation dependent on depth below land surface; no spatial correlation was assumed. According to Section 7.1.5, the Kh versus depth function is derived from field data. Values of Kz were generated by assuming that Kh/Kv is uniformly distributed, with a range from 3 to 100. As explained in Section 6.5, values of Kh and Kv at cells between pilot points were obtained by ordinary kriging, to ensure a smooth interpolation between the values generated at pilot points.

It is difficult to assess whether or how the realisations of Kh and Kv fields throughout the model domain are reasonable or similar to the actual distributions of Kh and Kv in the Hume Coal Project area. While kriging ensures smoothness between the pilot points, the lack of spatial correlation may lead to distributions that are quite spiky. The independence between fields of Kh and Kh/Kv allows the possibility of extremely large Kv (when Kh is randomly large and Kh/Kv is small) and extremely small Kv (when Kh is randomly small and Kh/Kv is large). It is relatively common in stochastic analysis to take into account correlations in space and between Kh and Kv. The lack of correlation may lead to realisations that are less likely to occur.

The average spacing between pilot points is 1.7 km (HydroSimulations, 2018, Section 7.1.1). This means that anomalous regions with large or small values of Kh or Kv would be of the order of 1 $km^2$ in size. Both large and small values would have been generated in the many realisations of the spatial fields. Some would have been filtered out by failing to fit observed heads during the calibration period sufficiently well. However, in the opinion of the author of this review, it seems likely that the distributions of hydraulic conductivities generated by HydroSimulations (2018) are conservative, in the sense of over-estimating mine inflows and over-estimating the likelihood of drawdown caused by mining. This is because predictions will be more sensitive to the occurrence of large values of hydraulic conductivity than to the occurrence of small values of hydraulic conductivity. The author of this review cannot demonstrate that this claim is true, based on information provided, but the claim is based on the reviewer's lifetime of experience which is explained in Attachment 1.

***Question:*** *Is the range of input parameters for sensitivity analysis considered suitable (i.e. should a larger range have been considered)?*

Sensitivity analysis does not become better or more useful simply because the range of input parameters is large. The key issue is that the range of input parameters should be realistic. Variability within generated spatial fields of hydraulic conductivities and storage coefficients should be consistent with variability observed in the real world. It is well known (it has been known for more than 40 years) that large-scale regional groundwater flow systems are sensitive to and depend on average values of hydrogeological properties, with properties averaged over relatively large distances, from tens to hundreds of metres, or more. It is true that transport of contaminants and travel times are sensitive to small-scale variability, but flow systems are sensitive to large-scale averages.

A spatial average has smaller variance and longer correlation in space, so there are good arguments for the range of parameters that represent spatial averages not being too large. This phenomenon has not been discussed by either HydroSimulations (2018) or Middlemis and Peeters (2018).

The range of the distributions of horizontal hydraulic conductivity Kh generated by HydroSimulations (2018) is probably large enough and may be too large. The lack of spatial correlation between values of Kh and Kh/Kv generated at pilot points has probably led to distributions that are more spiky than in the real world. Some realisations with very large Kv may not be filtered out based on statistics during the calibration period, but may have significant influence on predictions of mine inflows and drawdown of the water table.

The range of Kh/Kv may be too small, as it is not uncommon for Kh/Kv to be 1000 or 10,000 in some materials in the Sydney Basin. If Kh/Kv were larger, Kv would be much smaller, so that rates of movement of groundwater towards mined panels and impacts on the water table would tend to be smaller.

***Question:*** *Is the uncertainty analysis undertaken in accordance with industry best practice?*

There are few examples of "industry best practice". While the study by Turnadge et al. (2018) may be considered to be an example of best practice, (i) it is unique, (ii) it was undertaken by highly qualified researchers at CSIRO supported by researchers in other institutions, and (iii) the circumstances under which their research project was undertaken were quite different from a typical mining project.

The uncertainty analysis undertaken by HydroSimulations (2018) is an example of an attempt to use relatively modern techniques, at a time when uncertainty analysis is considered a way forwards but remains "immature". HydroSimulations have developed their own cloud-based platform. HydroSimulations (2018) do not explain many details of their analysis, and the reporting is different in style than Turnadge et al. (2018). But the level of detail provided in research reports is nearly always much greater. The approach taken by HydroSimulations (2018) is at the level of best practice in the consulting industry.

*a. Were the parameter ranges suitable (should they have been broader) to provide more* ***certainty*** *to model results?*

An interesting finding by Turnadge et al. (2018, Section 8) was that "*the use of improved aquitard conceptualisations and parameterisation does not necessarily result in overall reduction in predictive uncertainty. However, incorporation of a more data-driven and spatially heterogeneous hydraulic conductivity parameterisation always results in a more technically defensible model and provides more credible model predictions.*" In other words, the authors suggest that uncertainty analysis is not on its own a way to provide more certainty.

The fact that many simulations were carried out with different spatial distributions of hydraulic conductivities and that the realisations were filtered to select those that maintained a reasonable fit with observed data are good signs. The fact that predictions made with many realisations were summarised statistically should give some confidence to stakeholders. A wider range of parameter values may not have led to more confidence.

*b. was the decision to undertake uncertainty analysis on hydraulic conductivity reasonable given:*

*i. most sensitive parameter*

*ii. required computing power for additional uncertainty parameters to be considered simultaneously*

*iii. actual benefits of more complicated uncertainty analysis to inform an EIS model for a greenfields site*

Given the arguments presented to support estimates of specific yield, the focus on hydraulic conductivities is justifiable. It was found that mine inflows were sensitive to vertical hydraulic conductivity.

Increasing the number of parameters in an uncertainty analysis may mean that additional computing time may be needed. The real challenge with uncertainty analysis is in choosing the relationships between the many parameters. Spatial distributions of hydrogeological properties must be realistic,

taking into account spatial correlation within and between each of the properties being generated. Generating these distributions is time-consuming.

The proposed mine site is in some ways a greenfields site, and in other ways a brownfields site, because the model has benefitted from data from the Berrima Coal Mine which lies within the model domain. A more "complicated" uncertainty analysis may not have made it any easier to communicate the effects of uncertainty to stakeholders. As explained by IESC (2018), "*decision-making should be guided by an understanding of risk within a robust risk assessment framework*"; the focus should be on helping stakeholders to understand, in physical terms, rather than making uncertainty analysis more complicated.

## 6.11 Water Balance

Groundwater modelling is water balance modelling. A model simulates flows of groundwater inside the model domain, into and out of the domain through boundaries (recharge, pumping, discharge to baseflow, mining) and changes of storage inside the model domain. Water balance is essential, and this is why Table 5-1 in the Guidelines (see Section 6.8 above) emphasises water balance as an important criterion for model acceptance.

The water balance in the original EIS modelling was discussed by Hydrogeologic (2017) and this discussion is summarised by HydroSimulations (2018, Section 3.1.1). In Section 4.1.4 of HydroSimulations (2018), it is shown that mass balance errors in the Modified EIS model using MODFLOW-USG are negligibly small.

## 6.12 Confidence Level Classification

As discussed in Section 4 of this review report, the authors of the Guidelines did not intend the concept of "confidence level classification" to be prescriptive. The Guidelines do not state that a model must have any specific "Class" for any specific purpose.

Guiding Principle 2.3 in Section 2 of the Guidelines states that "*A target model confidence level classification should be agreed and documented at an early stage of the project to help clarify expectations*". The authors of the Guidelines believed that there should be agreement with regulators about model objectives and the likely confidence in predictions, not that regulators would prescribe a specific Class, i.e. 1, 2 or 3. In practice, situations have risen where proponents of projects have been unable to have discussions of this kind with regulators, prior to the completion of groundwater modelling studies.

Table 2-1 in the Guidelines (Attachment 3 to this report) "*provides a set of quantifiable indicators from which to assess whether the desired confidence-level classification has been achieved*". The Guidelines explain that "*it is not expected that any individual model will have all the defining characteristics of Class 1, 2 or 3 models. The characteristics described in Table 2-1 are typical features that may have a bearing on the confidence with which a model can be used. A model can fall into different classes for the various characteristics and criteria included in Table 2-1. It is up to the modelling team and key stakeholders to agree on which of these criteria are most relevant for the model and project at hand, and to agree on an overall confidence level classification that reflects the particular requirements and features of that model. In general, it should be acknowledged that if a model has any of the characteristics or indicators of a Class 1 model it should not be ranked as a Class 3 model, irrespective of all other considerations. It may also be appropriate to provide classifications for each of the three broad sectors included in Table 2-1 (i.e. data, calibration and prediction) based on all characteristics and criteria for that sector. An overall model classification can be chosen that reflects the importance of the individual criteria and characteristics with*

*regard to the model and project objectives. If a model falls into a Class 1 classification for either the data, calibration or prediction sectors, it should be given a Class 1 model, irrespective of all other ratings.*"

The authors of the Guidelines would probably almost unanimously agree today that the guidance provided was not sufficient and may have caused confusion. The Guidelines provided no examples of how Table 2-1 could be used. To fill this gap, Middlemis and Peeters (2018, Section 7.2 and Table 5) provide guidance based on experience at applying the Guidelines over many years.

HydroSimulations (2018) discuss confidence level in Section 3.2. They explain that Hydrogeologic (2017) found that the EIS model could be considered to be a Class 2 model. HydroSimulations (see Table 2 below) then assessed the confidence level classification for the so-called Preliminary Modified EIS Model developed using MODFLOWSURFACT V4, prior to conversion to MODFLOW-USG. HydroSimulations concluded that after some modifications, the model was now Class 2/3.

**Table 2: Confidence level classification for the Preliminary Modified EIS Model (HydroSimulations, 2018, Table 1)**

| CLASS | DATA | CALIBRATION [5 yrs] | PREDICTION [19 yrs] | INDICATORS |
|---|---|---|---|---|
| 1 [COUNT 4] | Not much.<br>Sparse.<br>No metered usage.<br>Remote climate data. | Not possible.<br>Large error statistic. (with VWP)<br>Inadequate data spread.<br>Targets incompatible with model purpose. | Timeframe >> calibration.<br>Long stress periods.<br>Transient prediction but steady-state calibration.<br>Bad verification. | Timeframe > 10x (recovery)<br>Stresses > 5x<br>Mass balance > 1% (or single 5%) (original model)<br>Properties <> field.<br>Bad discretisation.<br>No review. |
| 2 [COUNT 9] | Some.<br>Poor coverage.<br>Some usage info.<br>Baseflow estimates. | Partial performance.<br>Long-term trends wrong.<br>Short time record.<br>Weak seasonal replication.<br>No use of targets compatible with model purpose. | Timeframe > calibration.<br>Long stress periods.<br>New stresses not in calibration.<br>Poor verification. | Timeframe = 3-10x (end mining)<br>Stresses = 2-5x<br>Mass balance < 1%<br>Some properties <> field measurements.<br>Some key coarse discretisation.<br>Review by hydrogeo. |
| 3 [COUNT 12] | Lots.<br>Good aquifer geometry.<br>Good usage info.<br>Local climate info.<br>K measurements.<br>Hi-res DEM. | Good performance stats.<br>Long-term trends replicated.<br>Seasonal fluctuations OK.<br>Present day data targets.<br>Head and flux targets. | Timeframe ~ calibration.<br>Similar stress periods.<br>Similar stresses to those in calibration.<br>Steady-state prediction consistent with steady-state calibration.<br>Good verification. | Timeframe < 3x<br>Stresses < 2x (revised model)<br>Mass balance < 0.5%<br>Properties ~ field measurements.<br>Some key coarse discretisation.<br>Review by modeller. |

HydroSimulations could have prepared another version of this Table after conversion to MODFLOW-USG. The conclusions would have been similar.

The reader may notice that Table 5 in Middlemis and Peeters (2018) includes an acknowledgement to N. Merrick (pers.comm.), the lead author of HydroSimulations (2018). Both Middlemis and Merrick were authors of the earlier MDBC Guidelines (Middlemis et al., 2001) and have been leaders in the development and application of modelling methods in Australia since long before 2001. The author of this review is an author of the Guidelines and provided feedback during preparation of the MDBC Guidelines. If consensus is ultimately achieved by three experienced modellers, it is because of their long cumulative experience, well over 100 years, not only in reviewing models but also working as consultants, developing models for clients, and faced with the day-to-day challenges of wanting data, resources and time to do more.

When reviewing models used for assessing the potential impacts of mining projects, the author of this review often chooses to focus on two key indicators in Table 2-1 of the Guidelines. The same indicators are acknowledged with green stars in Table 2 above, now also enclosed in blue rectangles.

- It is not uncommon for groundwater models to be developed for greenfields mining projects with data collected over a period of a few years, yet mining may be planned over a period of 20-30 years, and recovery of the water table may take 100 years or more. Almost by definition, the "predictive time frame", whether focused on mining for 20 years or recovery over 100 years, is many times the length of the period for which data are available. It is impossible for mining companies to achieve a ratio of 3 suggested for a Class 3 model, and almost impossible to achieve a ratio of 10 which would be a characteristic of a Class 2 model. This on its own should not mean that all models for greenfields mining projects are Class 1 models. Stakeholders should be aware that predictions a long time in the future are less certain than short-term predictions.
- The issue of "stress" is sometimes poorly understood. Section 4.3.5 in Coffey (2016b) refers to pumping as a stress but not to the role of mining excavation. In most greenfields mining situations, there has been no significant (i.e. deep) excavation within the model domain, and pumping tests may only have been carried out for periods of days, at pumping rates far less than predicted rates of inflow into mines. Construction of a mine puts stress on a groundwater system by causing groundwater to flow into the mine, because the mined surfaces are new low points in the system. Before mining, the stresses are much lower than after mining. Proponents of mining projects can rarely argue that future stresses will be no more than 2 or 5 times higher than historical stresses. In the case of the Hume Coal Project, the existence of the Berrima Coal Mine and the availability of some data that have been used in calibration is a significant advantage. These data mean that modelling for the Hume Coal Project should not be considered to be Class 1. Modellers have attempted to learn from experience at the nearby Berrima Coal Mine.

Table 3 summarises this discussion. Based on these extremely important key indicators, the groundwater modelling undertaken for the Hume Coal Project should be considered to be Class 2.

**Table 3: Consideration of confidence level classification based on key indicators in Table 2-1 of the Guidelines (Barnett et al., 2012)**

| Confidence Level Classification | Model predictive time frame | Comments | Stresses in predictions | Comments |
|---|---|---|---|---|
| 1 | More than 10 times longer than transient calibration period | The time frame to the end of recovery is more than 10 times the calibration period | More than 5 times higher than those in calibration | Stresses are more than 5 times the stresses above the footprint of the mine plan |
| 2 | Between 3 and 10 times the duration of transient calibration | The time frame during mining is in this range | Between 2 and 5 times greater than those included in calibration | Stresses are in this range if we take into account observations near the Berrima Coal Mine |
| 3 | Less than 3 times the duration of transient calibration | | Not more than 2 times greater than those included in calibration | |

The Guidelines (Section 2.5) emphasise agreement between stakeholders. "*Agreement and documentation of a target confidence level classification allow the model owner, modellers, reviewers and other key stakeholders to have realistic and agreed expectations for the model. It is particularly important for a model reviewer to be aware of the agreed target model confidence level classification so that it is possible to assess whether or not the model has met this target.*" In the case of the Hume Coal Project, agreement was never reached.

***Question:*** *Is the model considered to be Class 2 as per the current industry interpretation of the Australian Groundwater Modelling Guidelines? If not, what is required to make it a Class 2?*

In the opinion of the author of this review, the model is a Class 2 model, and even has some elements of a Class 3 model. Earlier reviews by Hydrogeologic (2017) and HydroSimulations (2018) considered all aspects of the model and argued that the model is Class 2. The author of this review accepts those arguments, but also chooses to place special emphasis on two key indicators related to (i) the length of time for which predictions are made relative to the time period of calibration, and (ii) the magnitude of future stresses relative to historical stresses during the calibration period. Because transient data are available during historical mining at the Berrima Coal Mine, the modelling undertaken for the Hume Coal Project should be judged to be Class 2. These two key indicators often lead to models of greenfields mining projects being considered to be Class 1, but this conclusion is not reasonable for the Hume Coal Project.

### 6.13 Model Reviews

The Guidelines recommend that a model be reviewed at different stages during model development. Modelling undertaken for this project has been extensively reviewed: (i) internally during model development, (ii) by third parties following submission of the EIS, (iii) by an independent expert on behalf of DPE, (iv) by Government agencies during review of the EIS and RTS, and (v) now in this review.

The significant number of reviews has been acknowledged by DPE (2018, Section 6.2.2). Section 8 below provides comments additional information about the number and nature of reviews.

## 7. Potential Impacts of the Proposed Hume Coal Project

As foreshadowed in Section 5.3.2 and Table 1 above, a number of specific potential impacts of a mining project lead to questions that can potentially be addressed by groundwater flow modelling. Three types of impacts are addressed below.

### 7.1 Potential Impact on the Water Table and Landholder Bores

Underground mining causes groundwater to flow into the mine. The groundwater comes from above (ultimately from the water table), from surrounding areas via lateral flow, and from above, below and around the mined voids (through expansion of water when pressure and piezometric head are reduced).

- Mining companies need estimates of groundwater inflows to underground mines in order to design pipes and pumps to move such water away from active mining areas. It is not in any company's best interest to underestimate these inflows.
- Mining companies need to estimate the impact on the water table above, especially if landholders have licences to extract groundwater, regardless of whether or not the landholders use their entire allocation. Mining companies are required to estimate these potential impacts as part of environmental impact analysis.

Predictions of mine inflows and impacts on the water table and landholder bores are intimately linked. Both mine inflows and impacts on the water table can only be predicted using regional scale models. Regional scale models produce large-scale answers.

Figure 10 shows predicted total mine inflow, based on uncertainty analysis. Total mine inflow is a combination of the rate at which water must be pumped from areas being actively dewatered for mining (water reporting to active drain cells in the model) and the rate at water flows into other parts of the mine that are no longer actively pumped (e.g. into panels that have bulkheads and are still refilling, or into main headings and other parts of the mine that are represented in the model with high effective hydraulic conductivities rather than drain cells). The RTS groundwater model predicts there is a 33% chance that maximum mine inflows will exceed 5.8 ML/d in year 18 (see Figure 10 below). Some of this water would be returned underground as part of the process of refilling mined panels. The total mine inflow should be compared with third party licensed entitlements totalling 14.5 ML/d (within the model domain in 2016), an adjusted value of 14.1 ML/d (97% of the actual entitlements) used by Coffey (2016b) in the calibrated EIS Model, and an additional 0.008 ML/d for stock and domestic use (see Coffey, 2016b, Section 3.2.6). Licensed extraction of 14.1 ML/d and an additional 0.008 ML/d for stock and domestic use are maintained throughout the period of mining, and may be an overestimate of actual pumping because some of this extraction may cease during mining.

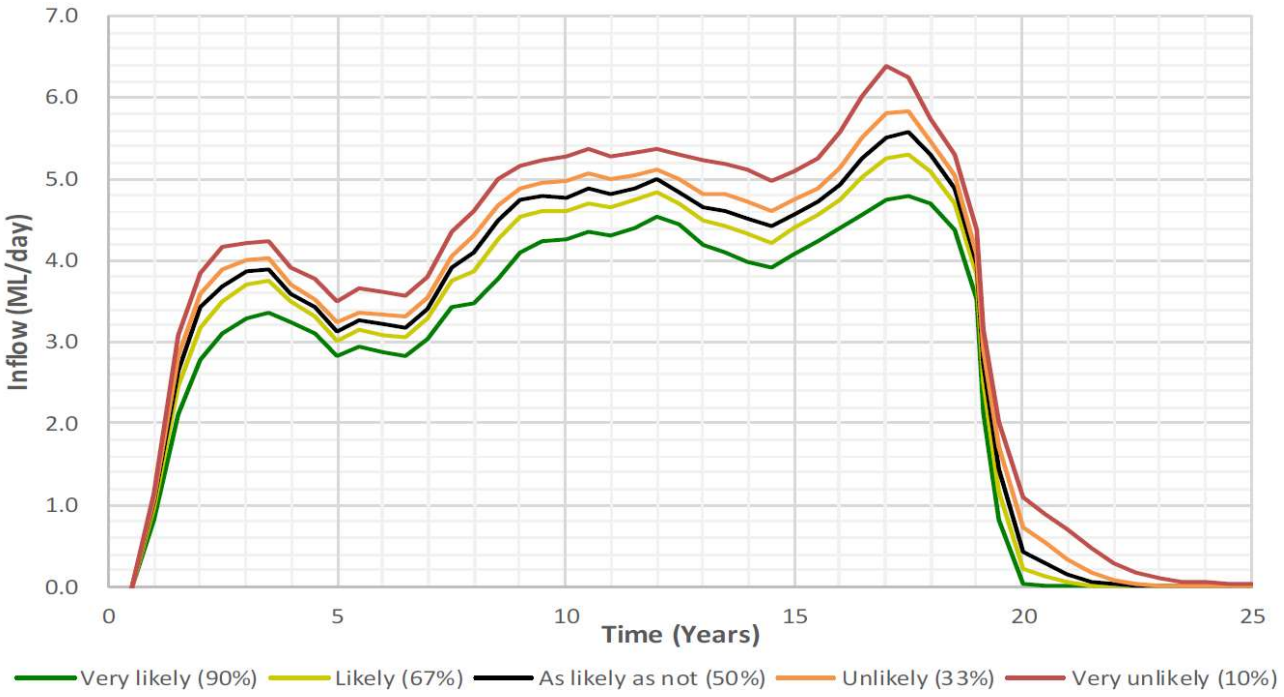



**Figure 10: Predicted probability of exceedance of total mine inflow, Figure 44 in HydroSimulations (2018)**

Regional scale models are designed to predict regional scale impacts, they are not signed to predict drawdown at individual pumping or observation bores. There are many reasons why models do not represent individual bores. First, model grids are generally not fine enough to have many cells between neighbouring bores, as would be necessary to represent the curvature of the spatial distribution of piezometric heads near pumping bores. Second, even if they do, there is never enough or the right kind of data to infer the spatial distribution of hydrogeological properties in the neighbourhood of every bore. Landholder bores are turned on and off at irregular intervals, they are pumped at different rates at different times, and records, even if they were kept, are generally not available. There are generally always insufficient observation bores, and observations cannot be related to actual pumping rates nearby.

When a regional scale model is calibrated to sparse data, the final model using best estimates of model parameters to represent hydrogeological properties and boundary conditions during the calibration period will predict how the water table behaves in an average sense, and predictions of water table elevation at any particular bore will not match observations (even if they exist). When the same model is used to predict future behaviour, the model can predict changes in water table elevation, but not the absolute level in mAHD.

Figure 9.13 in EMM (2018a) shows the predicted maximum drawdown and the number of landholder bores affected. The Figure is reproduced here as Figure 11. The extent of 2m drawdown is sufficiently far from the western boundary of the model domain that the precise nature of lateral boundary conditions is likely to be insignificant. It is important to note that the maximum drawdown does not occur at the same time at all locations. The maximum drawdown over panels W9 and W10 (see Figure 9, to be mined in calendar year 2025 according the 2016 mine plan), for example, would occur much earlier than the maximum drawdown over panels CW6 and CW7 (to be mined in 2038). By the time CW6 and CW7 are mined, significant recovery would be expected above W9 and W10.

Figure 11 is actually based on Figure 42 in HydroSimulations (2018). The predicted maximum drawdown is more correctly described as a maximum drawdown at the 67-percentile level in the ensemble of realisations. This means that the results do not come from a single simulation with a single set of model parameters. Rather, the Modified EIS Model was run more than 2,200 times (HydroSimulations, 2018, Section 7.2) during the uncertainty analysis, and of these, 481 simulations (realisations) were accepted for further analysis. The maximum drawdown at each location was computed in each run, a frequency distribution of maximum drawdown was then computed at each location, and the value of drawdown exceeded 33% of the time was chosen as the value at the 67-percentile level.

In explaining the results in this way, the author of this review is not arguing that these predictions are correct or that drawdown is acceptable, rather that the predictions seem to be reasonable compared to predictions made at many other mines. There are many ways to show model results. Figure 11 is one way. A time series of plots may have helped stakeholders to understand, but with the recent encouragement of uncertainty analysis comes additional challenges in communication of results.

During the course of this review, additional information was provided by Noel Merrick (pers.comm.). Figure 12 shows the locations of bores at which predictions have been extracted from the Modified EIS Model. Figure 13 shows predicted heads in different model layers, ordered (left to right, top to bottom) by the time of maximum impact of mining. The predictions show (i) that heads in model layer 11 (the Wongawilli Seam) are lowered to the within the seam, during mining, and (ii) that heads in model layer 3 (in the Hawkesbury Sandstone) remain relatively high, even though heads in lower model layers are lowered during the few years when mining impacts are the greatest. The water table elevation would be higher than heads in model layer 3.

Section 10 of Middlemis and Peeters (2018) focuses on engagement and communication. The authors recommend that stakeholders engage with each other to discuss and agree on how uncertainty analysis will be carried out and communicated. This is the kind of engagement recommended by IPC Recommendation R5 (IPC, 2019). The author of this review has not seen minutes of meetings to prove that uncertainty analysis was the topic of specific meetings with stakeholders; indeed, it is not always possible to arrange such meetings, e.g. if some stakeholders are not willing to meet. It is important to note that Hydrogeologic (2018, Section 4.7) reported to DoI Water that “uncertainty analysis and sensitivity analysis has been conducted consistent with best practice (Barnett et al, 2012; Middlemis and Peeters, 2018)”.

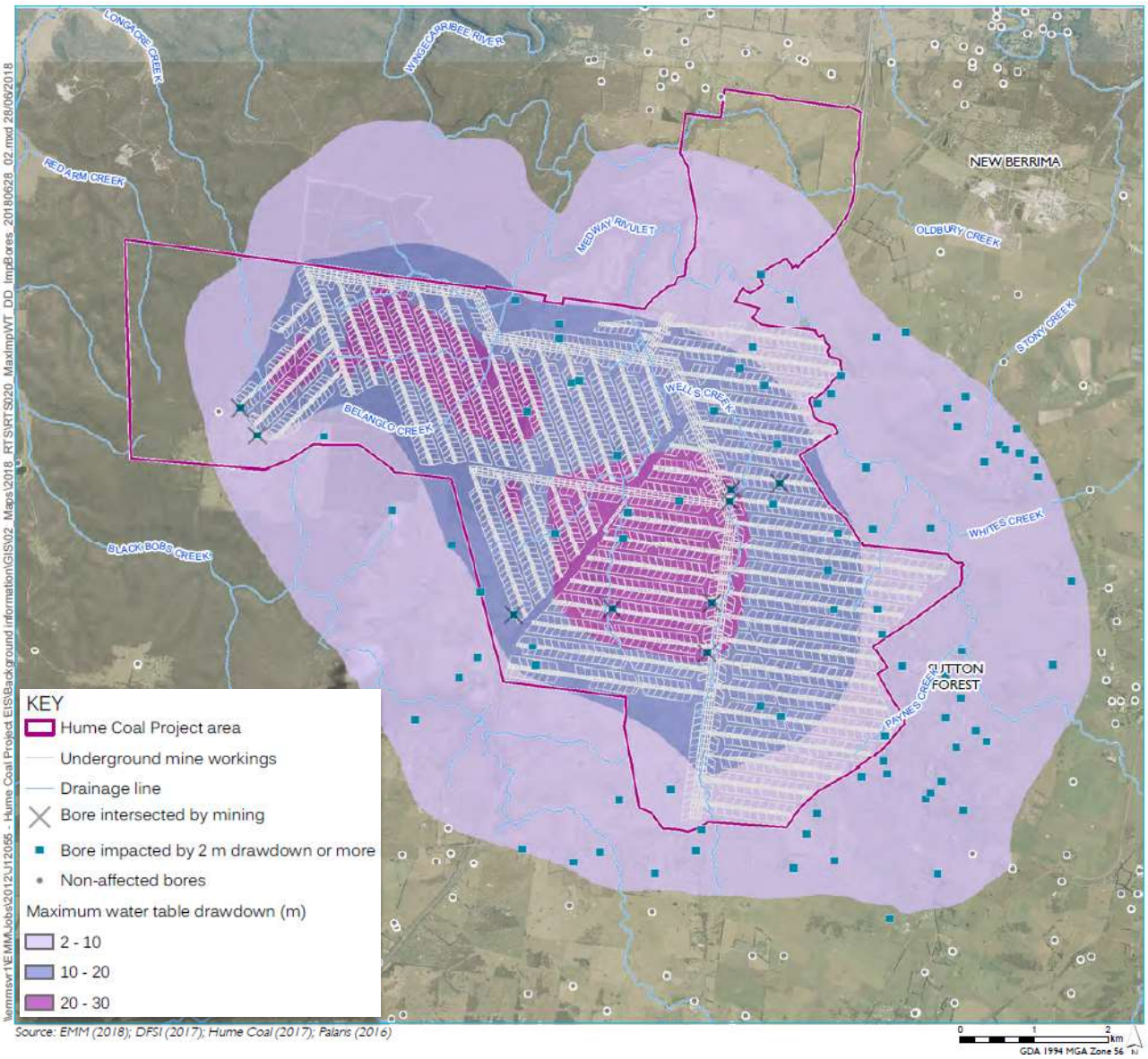



**Figure 11: Predicted maximum drawdown of the water table, Figure 9.13 in EMM (2018a)**

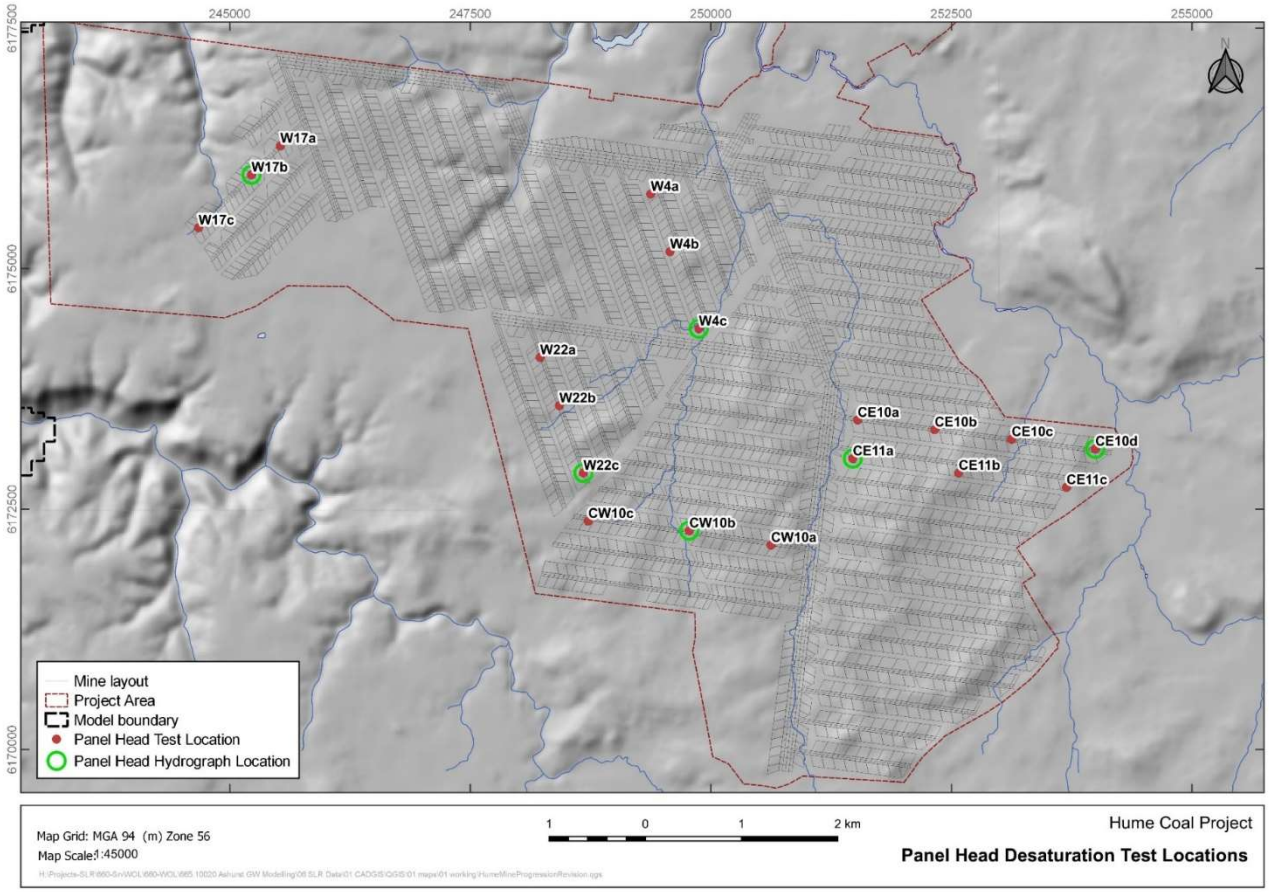



**Figure 12: Locations of hydrographs provided by Noel Merrick (pers.comm.)**

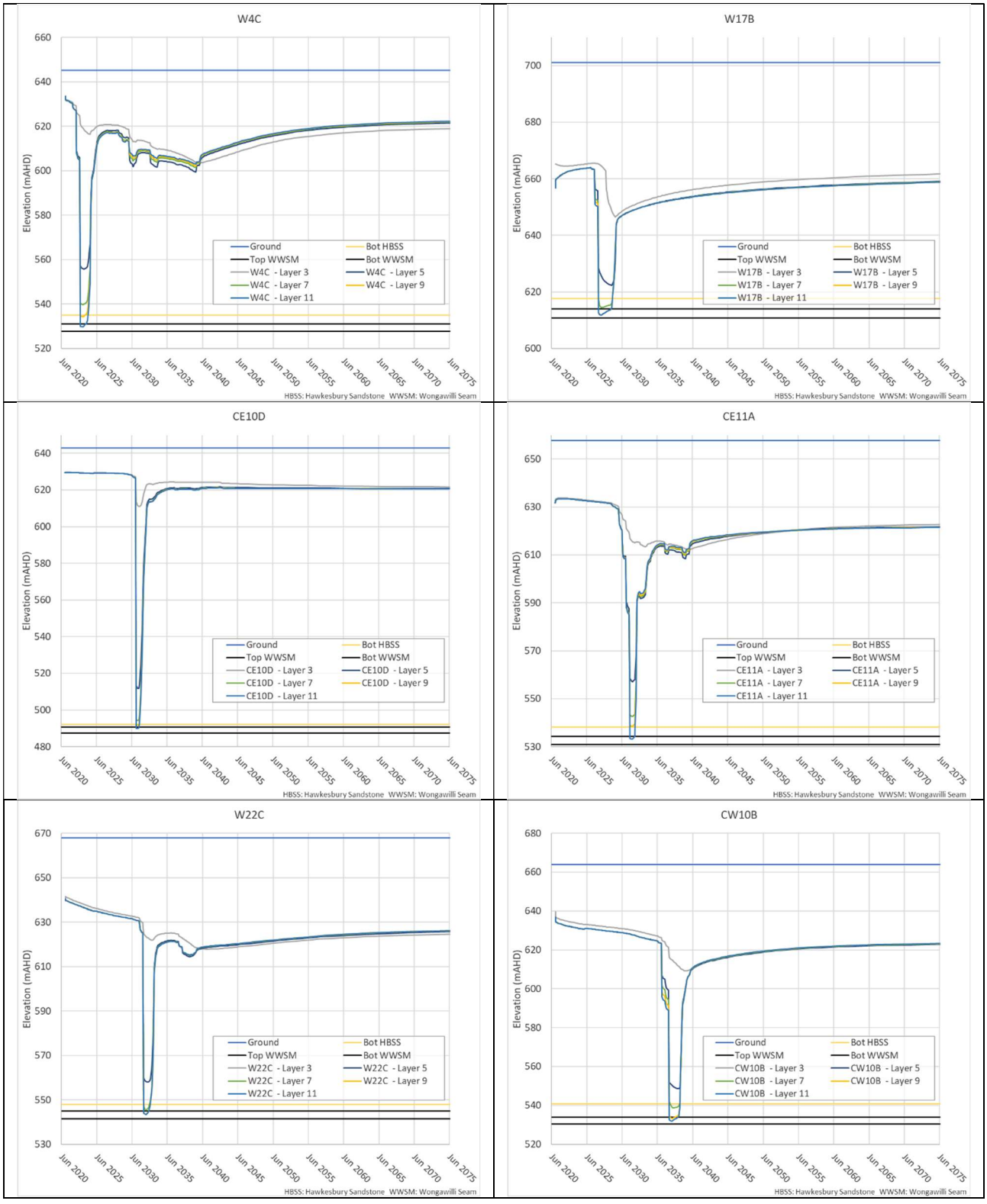



**Figure 13: Hydrographs provided by Noel Merrick (pers.comm.)**

***Question:*** *Is the assessment of impact to bores (i.e. drawdown in landholder bores) from the modelling considered reasonable given:*

*a. Regional models are traditionally then used to determine 'impacts' which needs to consider landholder bores.*

Regional scale models are traditionally used to predict regional scale impacts on the water table, and these predictions are used to explain possible impacts on landholder bores inside the cone of depression. It is often the case that there is little information about the depth of landholder bores, the hydrostratigraphic units in which they are screened, or the rate at which they are ever pumped. Regional models give general or generalised indications of possible impacts on water table elevation. Their purpose is not to predict impacts at specific bores, because model grids can never be sufficiently refined near every pumping bore, and it would be impossible to estimate hydrogeological properties at an appropriate spatial resolution for such highly refined models. The approach adopted for the Hume Coal Project is reasonable and consistent with industry best practices.

*b. Impacts to landholder bores are 'predictions' based on the model and available information at EIS stage – with additional information (landholder survey, additional data over time and then once mining commences and real stresses on the groundwater systems can be measured and used to recalibrate the model), more refined and accurate predictions can be made and the make good adapted and adjusted as needed.*

It is correct to say that additional information usually becomes available later, once a project is approved and started. It is often the case that modelling continues after the commencement of mining, and that better predictions are possible once mine inflow rates are measured and first impacts are seen at the water table. Such modelling would not change the final outcome but would allow for better management of impacts during a project.

*c. There is limited information on landholder bores in the NSW database (i.e. screen depths are not generally known, the SWL in bores is generally one point measured at time of drilling).*

It is correct that the NSW database does not always have accurate information. The author of this review does not have any knowledge about the accuracy of data inside the project area.

In summary, the approach taken by Hume Coal and its consultants is reasonable and typical.

***Question:*** *Are the assessment of 'impacts' of the mine, (specifically, volume of inflow to the mine and drawdown estimates in landholder bores) adequate, in accordance with expectations from SEARS, AIP and industry standards?*

In the opinion of the author of this review, the methodology used to estimate mine inflows and potential drawdown in landholder bores is reasonable and typical. The SEARs and AIP do not prescribe how these impacts should be assessed. HydroSimulations (2018) describe an approach based on uncertainty analysis, broadly consistent with the most recent guidelines prepared by Middlemis and Peeters (2018). The latter guidelines were released after completion of modelling for this project.

The author of this review believes that the modelling undertaken for the Hume Coal Project is of high quality relative to similar recent projects. The Hume Coal Project has some unique aspects, such as the mining method and the methodology for backfilling panels after mining, so a direct comparison is not possible. Modelling undertaken by HydroSimulations (2018) uses software for uncertainty analysis that would not have been available to other modellers.

***Question:*** *Are the assessment of 'impacts' of the mine, (specifically, volume of inflow to the mine and drawdown estimates in landholder bores) – reasonable and 'accurate'?*

In the opinion of the author of this review, the predicted impacts, calculated by an uncertainty analysis, seem reasonable. The methodology appears to be robust, and consistent with good practice, if not best practice. The issue of accuracy relates more to the reporting; it is assumed that the reporting by HydroSimulations (2018) and others accurately reflects the work that has been done.

***Question:*** *The Department comments that the project "significantly exceeds the 'minimal impact' threshold" (i.e. 2 m) and therefore questions whether this is an "acceptable impact on this highly productive aquifer". The reviewer is invited to comment specifically on:*

*a. The fact a 2 m drawdown is being cited as potentially 'unacceptable', where references to irrigation bores in many places experience drawdown of tens of metres, and other mines (i.e. open cut mines and longwall mines) experience significantly more than 2 m drawdown*.

This reference is to Section 6.2.3 of DPE (2018), being DPE's SSD assessment in December 2018.

In the experience of the author of this review, drawdown in both irrigation areas and mining areas often exceeds 2 m and can sometimes be tens of metres or more. Pumping in a single bore as part of an irrigation scheme can cause drawdown of tens of metres locally near the pumping bore. An open cut mine that extends to a depth of 100 m below the pre-mining water table causes drawdown of the water table at and near the walls of the pit. How the water table falls and how long it takes depend on circumstances. In a homogeneous porous medium, the water table would fall almost to the toe of each pit wall, leaving some metres of seepage face above the toe, so in this kind of situation, drawdown near the wall of the pit would be almost 100 m. Some underground mines cause significant drawdown. Examples include block cave mines where the caved zone can extend as high as the land surface, and shallow longwall coal mines where the goaf above each panel can extend to the surface or at least until it intersects the base of a shallow aquifer, causing levels in that aquifer to decline. What happens will always depend on a unique combination of factors. In the Hume Coal Project, the pine feather mining method will ensure that a significant goaf will not be formed above each panel. However, the groundwater modelling that has been undertaken, with many spatial distributions of hydraulic conductivities during uncertainty analysis, predicts maximum drawdown that exceeds 2 m.

In the opinion of the author of this review, it would be difficult to find an example of a mining project, supported by a groundwater flow model, where the maximum predicted drawdown is less than 2 m. The corollary to this is that many mines have been approved when the predicted drawdown significantly exceeds 2 m somewhere within the model domain.

## 7.2 Rehabilitation and Groundwater Recovery

Following the end of mining, the water table in the project area will recover to pre-mining levels, or at least to a dynamic equilibrium in balance with the climate (annual recharge) at that time. Piezometric heads at depth will also recover. Estimating the time scale for recovery is an important part the environmental impact assessment.

***Question:*** *Is additional work required to establish the extent to which the emplacement of water in mined out void will reduce the level of drawdown in later years of the project? Can sensitivity of this be demonstrated from additional information made available by the groundwater modellers? Is the current approach to simulating mining conservative (by not simulating reinjection of slurry (solids and water) behind sealed bulkheads)?*

The Modified EIS Model already includes some representation of the construction of bulkheads and of refilling of the mined voids behind these bulkheads. By deactivating drain cells and changing hydraulic conductivities and storage parameters after the end of mining in each pine feather panel, some account is taken of the dynamics of refilling. This means that each model simulation during uncertainty analysis already partially includes the effect of backfilling and emplacement of water.

Of course more could be done. It is always possible to find ways to improve predictions or to add more detail. In the opinion of the author of this review, the approach taken is conservative, in the sense that if backfilling were simulated in more detail, including injection of water into voids behind bulkheads, the model would predict faster recovery after the end or mining and smaller values of maximum drawdown. This would be apparent in every individual simulation undertaken during uncertainty analysis, and therefore in the statistics of the ensemble.

Because it is difficult to get a physical feeling for the effect of backfilling and refilling from an ensemble of realisations in uncertainty analysis, it might have been useful for the modellers to take a single realisation, and to explain in detail the sequence of events: how the water table responds as a function of time to the mine schedule, how movement of the water table changes as the location of active mining moves to another part of the mine plan (footprint), whether there is any recovery of water levels before the end of mining or whether there is simply a slowing in the rate of decline etc. (cf. the discussion about Figures 12 and 13 in Section 7.1 above). It would also be useful to summarise for every panel the rate of inflow of groundwater into the panel and how the inflow slows after completion of backfilling and refilling. This could be reported in the context of sitewide water management, in order to demonstrate, even for a single climatic scenario, how excess mine water and rainfall runoff is managed at the surface in mine water ponds. GoldSim modelling (EMM (2018b, Section 8.2.1), WSP (2018)) has been undertaken as part of planning for site water management, but analysis and discussion of a single realisation may have been useful, to help stakeholders to understand the results.

# 8. Comments on Reviews and Recommendations

The main purpose of this section is to list the many review of the Hume Coal Project groundwater modelling to date, and then to respond to two specific questions asked by EMM and to Recommendation R5 of the IPC.

According to DPE (2018, Section 6.2.2), by December 2018 there were “at least 10 groundwater experts that have provided input or comments on the groundwater impact assessment process and/or groundwater model”. In fact, the number is considerably more than 10. They include:

- on behalf of Hume Coal: Dr Noel Merrick, Dr Frans Kalf, Neil Manewell and Liz Webb;
- on behalf of regulators: Hugh Middlemis, representatives of IESC, DI – Water hydrogeologists and WaterNSW hydrogeologists; and
- on behalf of the community: Dr Steven Pells, Doug Anderson, Chris Jewell and John Lea.

Figure 14 is a schematic diagram showing reports on groundwater modelling and the many reviews. The two boxes shaded in blue are the reports prepared and submitted in the EIS and RTS. All other boxes are reviews. The blue lines with arrows show the primary targets of each review.

Section 9.3.7 in EMM (2018a) provides further discussion on the history of peer reviews.

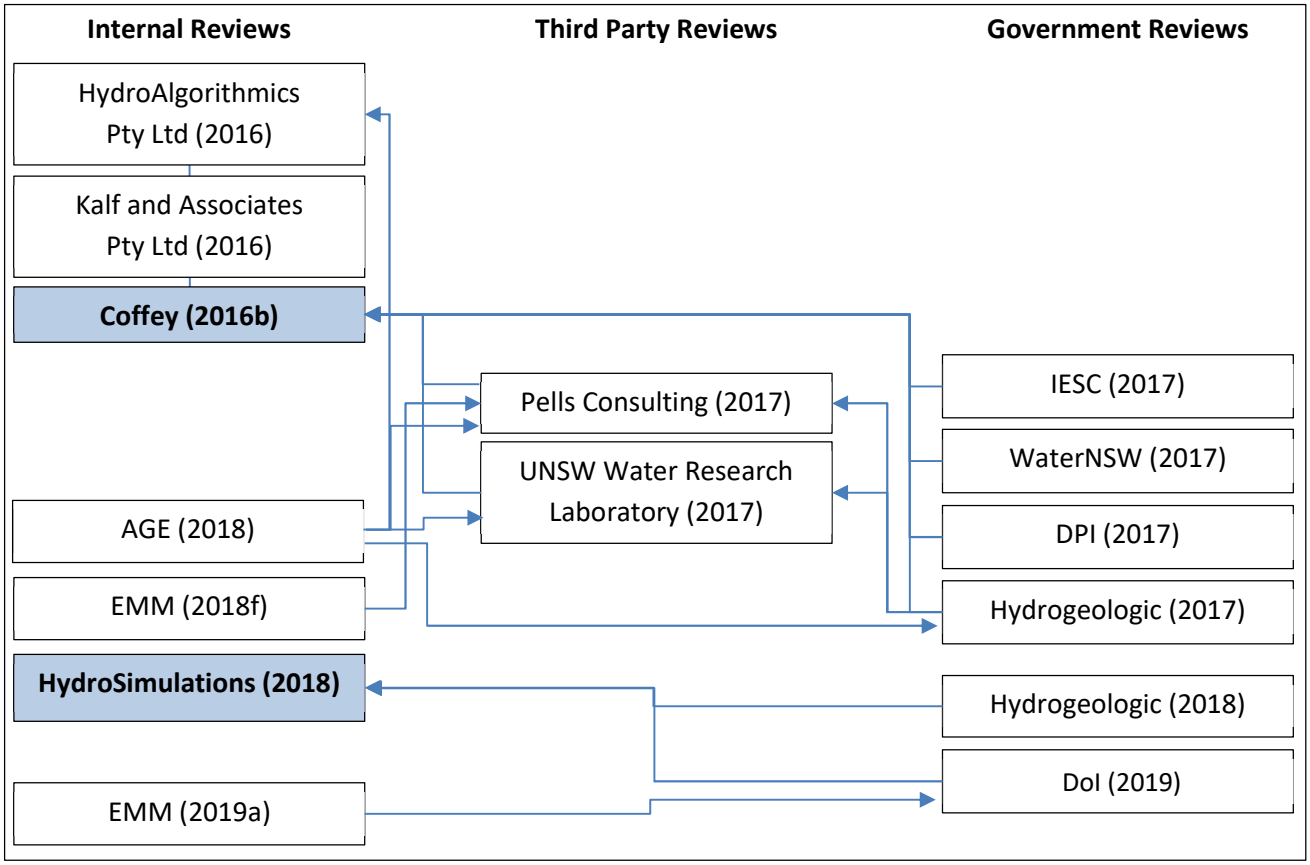



**Figure 14: Schematic showing the history of reviews of groundwater modelling to date**

## 8.1 Internal Reviews Undertaken During Model Development

Internal review is an important part of model development.

During development of the original EIS Model by Coffey (2016b), "internal" reviews were undertaken by HydroAlgorithmics Pty Ltd (2016) and Kalf and Associates Pty Ltd (2016). These reviews were included in Appendix J to the EIS (EMM, 2017b) and Appendix G to the RTS (EMM, 2018b).

AGE (2018) undertook a Groundwater Model Audit, also referring to four reviews undertaken by others.

## 8.2 Reviews Submitted by Third Parties

Following publication of the EIS, Coal Free Southern Highland Inc. (CFSH) commissioned reviews by Pells Consulting (2017) and UNSW Water Research Laboratory (2017). Another review by C.M. Jewell & Associates Pty Ltd (2017) is mentioned here for completeness, because it relates to groundwater quality, but technically this was not a review of the regional groundwater modelling which is the focus here.

The author of this review was not asked directly to comment on the reviews commissioned by CFSH, however a few comments can be made:

- EMM (2018f) provide a detailed review of Pells Consulting (2017), as part of the RTS.
- Some of the claims made by Pells Consulting (2017) and UNSW Water Research Laboratory (2017) are refuted by Hydrogeologic (2017), whose review was commissioned by DPE (see Section 8.3 below).
- HydroSimulations (2018, Section 3) address the reviews by Pells Consulting (2017), UNSW Water Research Laboratory (2017) and Hydrogeologic (2017). HydroSimulations explain the extent to which the Modified EIS Model addresses the concerns of the various reviewers. [As noted above, HydroSimulations was previously known as HydroAlgorithmics Pty Ltd, in other words the developers of the Modified EIS Model were reviewers of the original EIS model.]

## 8.3 Reviews and Comments by DPE and Other Agencies

IESC (2017) provided a brief review following submission of the EIS.

WaterNSW (2017) and DPI (2017) provided comments on the original EIS model.

Hydrogeologic (2017) reviewed the original EIS model on behalf of NSW DPE. Hydrogeologic (2018) provided a further review of the Modified EIS Model after submission of the RTS. Both reviews found that the models were fit for purpose.

Following release of the report by DPE (2018) and immediately before the release of the report by IPC (2019), DoI (2019) provided a letter from Department of Industry – Water containing "additional technical advice to the Independent Planning Commission (IPC) about the Hume Coal Project". This advice was in response to a series of questions sent by the IPC.

A copy of DoI (2019) was provided to Hume Coal, and EMM (2019a) subsequently sent a response to IPC.

***Question:*** *Does the reviewer agree with Hydrogeologic (2018) and the NSW Government that 'make good' (either by redrilling or provision of alternate water supply options) is '**technically feasible'** for bores affected by mining?*

The author of this review has had no direct experience in practical implementation of make good requirements. Furthermore, the feasibility of make good requirements does not depend on groundwater modelling, which is the focus of this review. However, the reviewer understands the issues associated with make good requirements and can provide some comments.

Section 9.4.2 in EMM (2018a) explains the make good commitments. Further support is provided in EMM (2018h).

Fundamental to the concept of make good commitments is that they are hierarchical. If the water table elevation at the location of a pumping bore declines, it may be possible to lower a pump inside the casing, or it may be possible to drill a new deeper bore at the same location. Ultimately, if water is required and it cannot be pumped, then it can be pumped or trucked from another location until the water table elevation recovers.

While the number of bores potentially affected by the project is significant (i.e. of the order of 100 bores, as distinct from 10 or 1000), not all of the bores would be affected at once. The situation would evolve slowly such that Hume Coal would have ample time to understand needs and implement solutions.

With reference to proposed make good arrangements, Hydrogeologic (2018, Section 4.4) states that "all these arrangements are reasonable, in principle, and are consistent with make good arrangement guidelines in Queensland". DPE (2018, Section 6.2.5) states that "While the Department agrees that the options of deepening or replacing bores may present challenges, the Department generally accepts that the Applicant's proposed make good options are technically feasible." The author of this review agrees that the proposed make good commitments are technically feasible.

***Question:*** *With reference to the advice of Department of Industry - Water to IPC (dated 24 April 2019) and the Applicant's response (17 May 2019), please consider the following questions:*

*a. Is the modelling approach appropriate and consistent with industry standard? Is the model calibrated to an acceptable level?*

The modelling approach is appropriate and consistent with the Guidelines. The calibration methodology is not only consistent with the Guidelines, but in the experience of the author of this review, this is one of the first times that four separate types of data have been used in a model of a proposed mining project, in an attempt to balance the different sources of information. The methodology is supported by the Guidelines, which explain in Recommendation 5.4 that over-emphasis on fitting a model to observations of piezometric heads using an arbitrary value of SRMS is not appropriate.

*b. Is it appropriate or reasonable for stakeholders to expect model calibration and predictions to have accuracy at a sub-metre scale?*

In their response to IPC's Question 1 about the Class of the model, DoI Water assert that specific objectives for modelling include: "predicting water level and volume impacts to the water supply aquifer due to mine dewatering (to a sub-metre scale resolution for drawdowns)".

Regional scale groundwater models can never predict water table elevation or piezometric heads with an accuracy of less than 1 m. No reference to this requirement was provided, and it is unreasonable to suggest that this level of accuracy is ever possible.

*c. Is the model grid and overall model design considered by the reviewer to be appropriate?*

The design of the model and the grid are reasonable and consistent with model design for mining projects proposed in Australia in recent years. EMM (2018b, Section 8.6) explain that "EIS model boundaries were developed in consultation with the NSW Government, and in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al., 2012). The NSW Government independent expert peer concludes that: 'The model software, design, extent, grid, boundaries and parameters form a good example of best practice in design and execution' (Hydrogeologic, 2017)."

*d. Is the approach to simulating mining appropriate? i.e. the use of drain boundary conditions.*

In their response to IPC's Question 6 about the approach taken to decide on drain conductance values used in the modelling, DoI Water claimed to have "recommended that wells are alternatively used also instead of drains to effect dewatering".

In the opinion of the author of this review, the manner in which mining has been represented is appropriate and completely consistent with the way mining has been represented in models for many years. The sequence of mining can be represented using prescribed head (Dirichlet or 1st Type) boundary conditions or mixed (Cauchy or 3rd Type boundary conditions). In each of these, the elevation of mining is specified as part of the boundary condition, as a function of time, and the flow of water towards the boundary nodes is computed at the end of every time step. Since the flow to each node is unknown a priori, it is impossible and completely inappropriate to suggest that mining can be represented using flux (2nd Type) boundary conditions, i.e. wells.

*e. Does the reviewer consider the model to be fit for purpose? Is the conceptual model appropriately presented?*

The author of this review accepts the conceptual model developed and presented for the proposed mine, and has noted in Section 6.3 that in some respects the conceptual model is better than in many similar modelling studies. This is because of the efforts taken to describe methods for mining and backfilling, and the effects of these on groundwater flow.

The author of this review believes that the model is fit for purpose.

## 8.4 Recommendations in IPC Report

The IPC discusses groundwater in Section 8.2.1 of its report (IPC, 2019). A number of recommendations are made, and these are repeated in the Executive Summary. Recommendation R5 is of particular relevance to this review.

***IPC Recommendation R5:*** *Because the Applicant and Department of Industry - Water remain a considerable distance apart regarding their positions on the groundwater modelling, the Commission suggests that the Department or the Applicant, or both of them jointly (and in any case in consultation with Department of Industry - Water), engage a new independent expert (or alternatively a small technical group with a Chair) with experience in groundwater modelling with a view to resolving ongoing differences of opinion. The independent expert/Chair should consider:*

- *What practical steps, if any, can be taken to make the model a Class 2 model or seek agreement on the Class of the model?*

In the opinion of the author of this review, the model developed and described by HydroSimulations (2018) is already Class 2. This is explained in Section 6.12 above.

Arguments that the model is currently no more than Class 1 would normally be based on the length of the predictive time frame relative to the length of the period for which calibration data are available, and on the magnitude of stress during mining relative to the magnitude of stress during the calibration period. Strong arguments can be made that on both counts, there are sufficient data during a period with sufficient stress for the model to be considered to be Class 2.

This conclusion is supported by Hydrogeologic (2018) who reviewed the model on behalf of DoI Water.

- *What additional work is required to establish the extent to which the emplacement of water in mined-out voids will reduce the level of drawdown in the later years of the project?*

This question is explored in Section 7.2 above. In the opinion of the author this review, additional work could be undertaken to predict slightly less drawdown in the later years of the project, but such additional work is unnecessary. Current predictions are adequate and are supported by uncertainty analysis. There is no question that the water table will be drawn down in some locations and that piezometric heads at depth will also be lowered. The magnitude of drawdown and depressurisation is consistent with expectations.

- *Is the range used for input parameters in the modelling sensitivity/uncertainty analysis sufficient or is a wider range required so that there is no unreasonable truncation of results?*

This question is explored in Section 6.10 above. Uncertainty analysis has been undertaken with a large number of spatial distributions of hydraulic conductivities. Large-scale groundwater systems respond to aquifer properties averaged over length scales of tens or hundreds of metres, and it is not clear that the statistics chosen for horizontal and vertical conductivities take into account such averaging, or spatial correlation between values at neighbouring pilot points. It seems possible that variances may already be too large, rather than too small. In the opinion of the author of this review, the range used is sufficient, and should not be larger.

- *Is additional geological information required?*

In the opinion of the author of this review, additional geological information would have little effect on the predictions that have been made. All available geological and hydrogeological information has been used during the process of constructing a regional scale groundwater flow model. The model has been calibrated using available data. The only data that could significantly improve the model calibration would be measurements taken during periods of high stress on the system, similar in nature to the proposed mining.

# 9. Summary of Review of Groundwater Modelling Undertaken for the Hume Coal Project

The primary objectives of modelling were to be able to predict groundwater inflows into the proposed mine, and to predict drawdown of the water table within and near the project area. It is always important to state modelling objectives clearly, in order to manage expectations.

The history of modelling is presented in this review, but a very good summary is that provided in Section 9.3 of EMM (2018a).

A key feature of the Hume Coal Project is the fact that the project has been significantly modified in order to reduce potential environmental impacts. If Hume Coal had proposed longwall mining, the potential impacts would have been much larger than with the pine feather mining method. The decision to build bulkheads and to backfill and flood mining voids behind these bulkheads was motivated entirely by reduction of potential environmental impacts. Hume Coal has followed the philosophy of environmental impact assessment, by assessing potential impacts and re-designing to reduce potential impacts.

The groundwater modelling has been extensively reviewed. Reviews by HydroAlgorithmics Pty Ltd (2016), Kalf and Associates Pty Ltd (2016) and Hydrogeologic (2017, 2018) on behalf of DPE concluded that the original EIS model and subsequently the Modified EIS Model were fit for purpose.

The author of this review has reached the same conclusion. The Modified EIS Model prepared by HydroSimulations (2017) is fit for purpose. It is fit for the purpose of predicting groundwater inflows into the proposed mine and predicting drawdown of the water table within and near the project area.

Uncertainty analysis undertaken using the Mean K Baseline Model has allowed predictions to be presented in a probabilistic framework. The range of parameters explored in the uncertainty analysis gives confidence in the predictions made.

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# Attachment 1. Qualifications and Experience of the Reviewer

This review has been prepared by Dr Lloyd Townley of GW-SW Pty Ltd, whose qualifications and experience are summarised below:

*Qualifications*

- BE (Civil, Hons 1), The University of Sydney, 1976
- MS (Environmental Engineering Science), California Institute of Technology (Caltech), 1978
- PhD (Hydrology and Hydrodynamics), Massachusetts Institute of Technology (MIT), 1983, with thesis entitled "*Numerical models of groundwater flow: prediction and parameter estimation in the presence of uncertainty*"

*Experience in groundwater and other modelling*

- Developer of numerous groundwater modelling software packages, including AQUIFEM-1 (1979-80), CERT (1983), AQUIFEM-N (1985), AQUIFEM-P (1986), FlowThru (1992)
- User since the early 1990s and Australian reseller for many years of all versions of MODFLOW, MODFLOW-SURFACT and FEFLOW
- Teacher and research scientist at UWA (1983-87) and CSIRO (1988-97), focused on model calibration, surface water – groundwater interaction, and the response of aquifer to periodic (sinusoidal) forcing; author of numerous journal papers on these topics, including some that are highly cited
- Consultant (1997-2017), specialising in advice related to mining, agriculture and the water industry; expert user of GoldSim for integrated water and solute balance modelling for mining projects and operations
- Author of the *Australian Groundwater Modelling Guidelines* (2012); lead author of chapters on calibration and sensitivity analysis, and surface water – groundwater interaction, and contributor to other chapters

*Experience in the mining sector*

- Founding member of CSIRO's Minesite Rehabilitation Research Program (MRRP) and the Australian Centre for Minesite Rehabilitation Research (ACMRR) (1992-95)
- Chairperson of the Advisory Group in Environmental Geomechanics to the Australian Centre for Geomechanics (ACG), University of Western Australia (1994-97)
- Consultant in the mining industry (1997-2005, 2009-17), on behalf of mining companies, government agencies and community groups; managing complete Environmental Impact Assessments, planning and auditing rehabilitation and closure, and undertaking specialised studies related to groundwater, tailings management and integrated water management
- Principal Adviser – Water Management in Rio Tinto Technology and Innovation (2005-08); contributed to the development and rollout of Rio Tinto Technology and Innovation's *Excellence in Water Management* program; prepared new guidance notes for Corporate HSE to support Rio Tinto's *Environment Standard on Water Use and Quality Control*, specifically in relation to preparation of Water Management Plans with an operational focus; developed internal guidelines to improve the level and consistency of sitewide water, solute and mass/tailings balance models throughout Rio Tinto
- Expert reviewer and consultant on high-level inquiries, including: Commonwealth Commission of Inquiry, Shoalwater Bay, Capricornia Coast, Queensland (1993); Environment, Resources and Development Committee of the Parliament of South Australia water leakage inquiry at Roxby Downs (seepage from a tailings dam at a uranium mine) (1995); International Geomechanical Commission (IGC) and International Atomic Energy Agency (IAEA) Working Group 4 entitled *Radionuclide transport in the geosphere* (1996-97), investigating the hydrological and radiological effects, respectively, of French underground nuclear testing at Mururoa and Fangataufa Atolls in the Pacific Ocean; three reviews on behalf of the Planning and Assessment Commission (PAC) and the Independent Planning Commission (IPC) in NSW (2010 and 2018-19)
- Leader and developer of NCGRT's 3-day short course on *Groundwater in Mining*, taught four times in 2012-14

# Attachment 2. Source Materials

The following abbreviations are used in the main body of this report and in this Attachment:

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| AGE: | Australasian Groundwater and Environmental Consultants Pty Ltd |
| AIP: | NSW Aquifer Interference Policy 2012 |
| CFSH: | Coal Free Southern Highland Inc. |
| DoI: | NSW Department of Industry (part of DPIE since 1 July 2019) |
| DPE: | NSW Department of Planning and Environment (part of DPIE since 1 July 2019) |
| DPI: | NSW Department of Primary Industries |
| DPIE: | NSW Department of Planning, Industry and Environment |
| EIS: | Environmental Impact Statement |
| EMM: | EMM Consultants |
| IESC: | Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development |
| IPC: | Independent Planning Commission |
| RTS: | Response to Submissions |
| SEARs: | (DPE) Secretary's Environmental Assessment Requirements |

| Category | Reference | Sections of Interest |
|---|---|---|
| **EIS** prepared by consultants on behalf of Hume Coal (2017) | *EMM (2017a)*, Volume 1, Hume Coal Project, **Environmental Impact Statement**, Main Report, 8 March, 52 pp. | Chapters 2, 5 and 7 |
| | *EMM (2017b)*, **Water Impact Assessment Report**, Main Report, 3 March, 282 pp. Appendix E of EMM (2017a). | Chapters 6, 7 and 11 |
| | *Coffey (2016a)*, Groundwater Assessment, Volume 1, Data Analysis, 17 November, 132 pp. Appendix H of EMM (2017b). | All, including its own Appendices A to F |
| | *Coffey (2016b)*, Groundwater Assessment, Volume 2, Numerical Modelling and Impact Assessment, 17 November, 146 pp. Appendix I of EMM (2017b). | All, including its own Appendices A to H |
| | *HydroAlgorithmics Pty Ltd (2016)*, Hume Coal Project – Groundwater Impact Assessment Peer Review, 14 September, 14 pp. In Appendix J of EMM (2017b), entitled Groundwater Assessment Peer Review Reports. | All |
| | *Kalf and Associates Pty Ltd (2016)*, KA Peer Review of Coffey Groundwater Modelling Assessment of Hume Coal Project, 12 September, 10 pp. In Appendix J of EMM (2017b), entitled Groundwater Assessment Peer Review Reports. | All |
| | *Geosyntec Consultants (2016)*, Hydrogeochemical Assessment, 20 December 2016, 127 pp. In Appendix K of EMM (2017b), entitled Hydrogeochemical Assessment. | All, including its own Appendix A |
| | *Parsons Brinckerhoff (2014)*, Bore Logs for Project No. 2172599A, 58 pp. Appendix L of EMM (2017b). | All |
| | *EMM (2017c)*, Project Impact and Total Impact Water Table Drawdown over Time, 3 March, 9 pp. Appendix M of EMM (2017b). | All |
| | *EMM (2017d)*, Social Impact Assessment Report, 27 February, 132 pp. Appendix R of EMM (2017a). | All |
| Documents prepared by DPE, other agencies and their consultants (2017) | *IESC (2017)*, Advice to decision maker on coal mining project, IESC 2017-083: Hume Coal Project (EPBC 2015/7526) – New Development, 8 May, 9 pp. | All |
| | *WaterNSW (2017)*, Hume Coal Project (SSD 7172) and Berrima Rail Project (SSD 7171), 30 June, 19 pp. | All, including Attachments 1 to 5. |
| | *DPI (2017)*, Hume Coal Project (SSD 7172) and related Berrima Rail Project (SSD 7171), Comment on the Environmental Impact Statement (EIS), 16 July, 55 pp. | All, including Attachments A to H |
| | *Hydrogeologic (2017)*, Hume Coal Project EIS, Independent Expert Review, Groundwater Modelling, 6 December, 19 pp. (Note that Appendices A and B have not been viewed during this review.) | All |

| Category | Reference | Sections of Interest |
|---|---|---|
| Documents prepared by consultants on behalf of CFSH (2017) | *Pells Consulting (2017)*, Groundwater Modelling of the Hume Coal Project, prepared for CFSH, 22 June, 81 pp. | All |
| | *UNSW Water Research Laboratory (2017)*, Hume Coal Project SSD 15_7172: Peer review of Conceptual and Numerical Modelling that Predicted Likely Groundwater Impacts, prepared for CFSH, 23 June, 47 pp. | All |
| | *C.M. Jewell & Associates Pty Ltd (2017)*, Hume Coal Project Environmental Impact Statement - Potential Groundwater Contamination Issues Associated with Placement of Washery Fines Material into Mine Voids - Review of Appendix K: Hydrogeochemical Assessment, prepared for CFSH, 27 June, 8 pp. | All |
| **RTS** prepared by consultants on behalf of the Hume Coal (2018) | *EMM (2018a)*, Volume 1, Hume Coal Project and Berrima Rail Project, **Response to Submissions**, Main Report, 29 June, 572 pp. | Chapters 8, 9 and 11 |
| | *EMM (2018b)*, **Revised Water Impact Assessment Report**, Main Report, 27 June, 340 pp. Appendix 2 of EMM (2018a). | Chapters 4, 5, 6, 7, 8, 9, 11, 12 and 13 |
| | *EMM (2018c)*, SEARs and agency recommendations, 27 June, 11 pp. Appendix A of EMM (2018b). | All |
| | *EMM (2018d)*, IESC guidelines checklist, 27 June, 11 pp. Appendix B of EMM (2018b). | All |
| | *EMM (2018e)*, AIP checklist, 27 June, 29 pp. Appendix C of EMM (2018b). | All |
| | *WSP (2018),* Hume Coal Project, Response to Submissions, Revised Surface Water Assessment, 21 June, 314 pp. Appendix A is a Water Balance Assessment prepared by Parsons Brinckerhoff Australia Pty Ltd in December 2016. | Chapters 2, 3 and 4, and Appendix A |
| | *Harris Environmental Consulting (2018)*, Concept on-site wastewater management assessment, 15 May, 58 pp. Appendix E of EMM (2018a). | All, including its own Appendices i to xx |
| | *HydroSimulations (2018)*, **Revised Groundwater Modelling for Response to Submissions**, 8 June, 149 pp to end of Appendix D. Appendix F of EMM (2018b). Appendices E and F are copies of Coffey (2016a) and Coffey (2016b). | All, including four new Appendices A to D |
| | *EMM (2018f)*, Critique of Pells Consulting Modelling Studies, 20 June, 40 pp. Appendix H of EMM (2018b). | All |
| | *RGS Environmental (2018)*, Hume Coal hydrogeochemical modelling assessments, February, 84 pp. Appendix J of EMM (2018b). | All, including Attachments A and B |
| | *EMM (2018g)*, Landholder bore drawdown over time, 27 June, 2 pp. Appendix L of EMM (2018b). | All |
| | *EMM (2018h)*, Make good strategy, 12 June, 143 pp. Appendix L of EMM (2018b). | All |
| | *Heasley (2018)*, Pillar design analysis using LaModel for Hume Coal and Mine Advice, 29 May, 37 pp. | All |
| | *Mine Advice (2018)*, Interpretation of numerical modelling study of the proposed Hume Project EIS mine layout, 16 June, 100 pp. | All |
| By the DPE, IPC, and other agencies and their consultants (2019) | *Hydrogeologic (2018)*, Hume Coal Project EIS, Independent Expert Review, Groundwater Modelling, 16 October, 29 pp. | All |
| | *DPE (2018)*, Hume Coal Project and Berrima Rail Project, State Significant Development Assessment (SSD 7172 and SSD 7171), 6 December, 55 pp. | All |
| | *DoI (2019)*, Hume Coal Project, Letter containing Department of Industry (Water) additional technical advice dated 17 April 2019 to the Independent Planning Commission (IPC) about the Hume Coal Project, 24 April, 10 pp. | All |
| | *IPC (2019)*, Hume Coal Project SSD 7172 & Berrima Rail Project SSD 7171, Independent Planning Commission Report in relation to the Minister Planning's request dated 4 December 2018 under Section 2.9(1)(d) of the Environmental Planning and Assessment Act 1979, 27 May 2019, 122 pp. | All |

| Category | Reference | Sections of Interest |
|---|---|---|
| Other documents prepared by Hume Coal and its consultants | *AGE (2018)*, Hume Coal Project – Groundwater Model Audit, 16 February, 33 pp. | All |
| | *EMM (2019a)*, Groundwater consultant reply to DoI Water response to IPC questions, 17 May, 27 pp. | All |
| | *Hume Coal (2019)*, Hume Coal & Berrima Rail Projects, DPE Groundwater Modelling, Meeting of experts, 30 July, 50 PowerPoint slides. | All |
| | *EMM (2019b)*, Hume Coal Groundwater Meeting, Meeting Minutes, 30 July, 3 pp. | All |