



PROJECT CHINA STONE

Groundwater Report





Australasian
Groundwater
and Environmental
Consultants Pty Ltd
(AGE)



Report on

Project China Stone Groundwater Report

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Project China Stone

Groundwater Report

1. Introduction

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) was commissioned by Hansen Bailey on behalf of MacMines Austasia Pty Ltd (the proponent) to complete a groundwater assessment as part of the Environmental Impact Statement (EIS) for Project China Stone (the project).

The project involves the construction and operation of a large-scale coal mine on a greenfield site in Central Queensland. The project site (the area that will ultimately form the mining leases for the project) is remote, being located approximately 270 km south of Townsville and 300 km west of Mackay at the northern end of the Galilee Basin (Figure 1). The closest townships are Charters Towers, approximately 285 km by road to the north, and Clermont, approximately 260 km by road to the south-east. The project site comprises approximately 20,000 ha of well vegetated land, with low-lying scrub in the south and east and a densely vegetated ridgeline, known as 'Darkies Range', running north to south through the western portion of the site.

The mine will produce up to approximately 55 million tonnes per annum (Mtpa) of Run of Mine (ROM) thermal coal. Coal will be mined using both open cut and underground mining methods (Figure 2). Open cut mining operations will involve multiple draglines and truck and shovel pre-stripping. Underground mining will involve up to three operating longwalls. Coal will be washed and processed on site and product coal will be transported from site by rail. It is anticipated that mine construction will commence in 2016 and the mine life will be in the order of 50 years.

The majority of the mine infrastructure will be located in the eastern portion of the project site (Figure 2). Infrastructure will include coal handling and preparation plants (CHPPs), stockpiles, conveyors, rail loop and train loading facilities, workshops, dams, tailings storage facility (TSF) and a power station. A workforce accommodation village and private airstrip will also be located in the eastern part of the project site.

The scope of this groundwater assessment is restricted to assessing activities that are proposed to be undertaken within the project site and no off-lease activities are considered in this assessment.

1.1 Scope of assessment

The project site is located on the eastern margin of the Galilee geological basin. There is a long history of exploration data relating to oil, gas, coal and water resources across the region. This data has been supplemented by recent groundwater studies for proposed coal mining projects. The local geology and hydrogeology are therefore well understood.

Darkies Range, an elevated ridge located at the western boundary of the project site, forms a regional catchment divide, and represents the easternmost extent of the Clematis Sandstone, a regional aquifer of the Great Artesian Basin (GAB). The Clematis Sandstone is underlain by the Rewan Formation, a recognised aquitard of tightly interbedded sediments. West of Darkies Range, the Clematis Sandstone and overlying sediments are known to provide sources of groundwater to watercourses, artesian springs and wetlands and Lake Buchanan. East of Darkies Range, the Clematis Sandstone is absent. In this area, coal measures and basement geology are overlain by a blanket of Tertiary sediments and more recent deposits associated with present day watercourses.

Mine development has the potential to result in depressurisation of the target coal seams and surrounding geology. Depressurisation of the local geology can potentially induce dewatering of groundwater bearing strata in the vicinity of the mine, and influence local and regional hydrogeology. The availability of groundwater resources, the reliability of water supplies, and groundwater expression in surface waters and springs can potentially be affected as a result.

This report presents an assessment of depressurisation effects arising from the development of proposed open cut and underground mining areas in the project site. A numerical model has been developed to quantify these depressurisation effects in terms of groundwater level change and groundwater inflow rates during the operations phase and post mine closure. The report provides an assessment of the potential impacts of these changes on groundwater users and the surrounding environment. The report also provides an assessment of the potential impacts of the project on groundwater quality.

1.2 Report structure

This report is structured as follows:

- Section 1: Introduction: provides an overview of the project and the assessment scope;
- Section 2: Regulatory Setting: describes the regulatory framework relating to groundwater;
- Section 3: Environmental Setting: describes the environmental setting of the project including the climate, topography, land uses and other environmental features relevant to the project;
- Section 4: Geological Setting: describes the geological setting of the project including the regional geology and local stratigraphy;
- Section 5: Investigation Methodology: describes the assessment method including the collection and analysis of hydrogeological data;
- Section 6: Hydrogeological Data: provides an interpretive summary of the hydrogeological data used in the groundwater assessment;
- Section 7: Existing Hydrogeology: describes the existing local groundwater regime for the project site and surrounding area;
- Section 8: Impact Assessment: provides a detailed description of the proposed mining activities and the potential effects on the local groundwater regime. This section also presents the predicted effects on groundwater and the assessment of resulting impacts on groundwater users and the receiving environment; and
- Section 9: Groundwater Monitoring and Management Plan: describes the proposed measures for monitoring and management of groundwater impact.

Appendix A provides a detailed description of the field investigations undertaken as part of this assessment. This appendix comprises a summary of the investigation methods and is supported by a detailed summary of bore data for on-site and private bores, and construction details and quality data for bores drilled during the field investigations.

Appendix B provides a detailed description of the numerical modelling undertaken for the project, including details of model construction, calibration and validation.

2. Regulatory framework

The following sections summarise Commonwealth and Queensland groundwater legislation and policy relevant to the project.

2.1 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Commonwealth Government's principal piece of environmental legislation, and is administered by the Department of the Environment (DotE). The EPBC Act is designed to protect national environmental assets, known as Matters of National Environmental Significance (MNES), which include water resources impacted by large scale coal mining developments.

The project was declared a controlled action by the DotE on 30 October 2014. The potential impact of the project on water resources is a Controlling Provision. Approval is therefore required from the Commonwealth Government for the impacts of the project on water resources, including groundwater.

2.2 Queensland regulatory framework

2.2.1 Groundwater resources

The Queensland *Water Act 2000* (Water Act), supported by the subordinate *Water Regulation 2002*, is the primary legislation regulating groundwater resources in Queensland. The purpose of the Water Act is to advance sustainable management and efficient use of water resources by establishing a system for planning, allocation and use of water.

The water resource planning process provides a framework for the development of catchment specific Water Resource Plans (WRPs). A WRP provides a management framework for water resources in a plan area, and includes outcomes, objectives and strategies for maintaining balanced and sustainable water use in that area. Resource Operations Plans (ROPs) implement the outcomes and strategies of WRPs.

Management Areas (MAs) and their component Management Units (MUs) are defined under WRPs. Authorisation is required to take water from a regulated MA or MU for specified purposes. The specified purposes are defined under a WRP, the *Water Regulation 2002* or a local water management policy.

2.2.2 Groundwater resources of the Great Artesian Basin

The *Water Resource (Great Artesian Basin) Plan 2006* (GAB WRP) defines the availability and manages the take of water within the plan area. The plan area is defined under Schedule 1 of the GAB WRP (Figure 3). Figure 3 shows that the project site is located within the aerial extents of the GAB WRP area.

The GAB WRP applies to water in or from management units in the plan area, including artesian water, subartesian water connected to artesian water, and water in springs connected to these waters.

The GAB WRP area comprises 25 MAs. The project is located within the aerial extents of the Barcaldine North MA as defined under Schedule 2 of the GAB WRP (Figure 3). The Barcaldine North MA is divided into three MUs, with each MU comprising specific aquifers, as follows:

- MU 1 comprising the Wallumbilla Formation;
- MU 2 comprising the following aquifers:
 - Cadna-owie Formation;
 - Wyandra Sandstone Member;
 - Hooray Sandstone;
 - Westbourne Formation;
 - Adori Sandstone;
 - Birkhead Formation;
 - Ronlow Beds; and
 - Hutton Sandstone.
- MU 3 comprising the Moolayember Formation and the Clematis Sandstone.

The Clematis Sandstone occurs within the project site, and therefore the project is within Barcaldine North Management Unit 3. The Moolayember Formation subcrops between 1 km and 7 km west of the project site, whilst the Ronlow Beds are more remote occurring at least 26 km west of the project site. The remaining aquifers are not present in the vicinity of the project site. The regional and local geology relevant to the project is detailed in Section 4. The potential project impacts on these designated aquifers has been assessed as part of this groundwater study and are discussed in Section 8.5.1.

The GAB WRP is implemented through the *Great Artesian Basin Resource Operations Plan 2007* (GAB ROP). The GAB ROP requires that the Queensland government maintain a register of the springs that support significant cultural and environmental values. The closest spring system on the register is the Doongmabulla Spring Complex, located some 22 km south of the proposed mining areas (Figure 3).

2.2.3 Groundwater licensing and reporting requirements

The taking of or interfering with groundwater is regulated under the water licensing provisions of the Water Act. The Water Act requires that a water licence is required to take or interfere with artesian groundwater anywhere in Queensland. A water licence is also required to take or interfere with sub-artesian groundwater within areas declared as management areas or declared areas under subordinate Queensland legislation. A water licence applies to direct and indirect take of groundwater.

As discussed in Section 8.5.1, the project will result in the take or interference with groundwater. The proponent will specifically require the following water licences prior to commencement of mining activities:

- A licence for take from the GAB under the GAB WRP; and
- A licence for take from the Greater Western Sub-Artesian Area under the Queensland *Water Regulation 2002*.

The administering authority for the Water Act is the Queensland Department of Natural Resources and Mines (DNRM). The proponent will be required to comply with the requirements and conditions of the water licence. The licence will specify the approved location and the source aquifer for groundwater take, along with an approved volumetric groundwater allocation. The licence will also include standard conditions that identify existing water supplies to be protected, require the proponent to make-good any pre-existing water supplies unduly affected by the project, and specify monitoring, assessment and reporting requirements. The licence will also impose requirements in relation to mine closure for the management of post mining groundwater take.

The DNRM licensing approach is designed to ensure that the total allocated groundwater take permissible in granted water licences remains within the sustainable yield of the groundwater resource. This approach ensures that individual and cumulative licensed groundwater take do not adversely impact the sustainability of the affected groundwater resource. Provided that the licensing regime does not overallocate the total take from the available groundwater resources, this regulatory approach will also ensure that the licensed take has no significant residual impact on water resources of the GAB or other aquifers.

The *Water Reform and Other Legislation Amendment Act 2014* (the Water Reform Act) was passed on 26 November 2014. The Water Reform Act includes a number of changes to the Water Act that would potentially affect the regulation of groundwater take associated with the project. Commencement of the Water Reform Act provisions has been deferred pending further review by the Queensland government.

The proponent will consult with the DNRM in relation to its obligations under the Water Act and will comply with the relevant requirements for groundwater take.

2.2.4 Groundwater values

The *Environmental Protection (Water) Policy 2009* (EPP Water) provides a framework to protect and/or enhance the suitability of Queensland waters for various beneficial uses. Groundwater resources within the project site are not scheduled under the EPP Water. Section 7 describes the groundwater setting and groundwater uses, with Section 8 describing the impacts on the aquifers and users. The environmental values relevant to the local groundwater setting and uses are outlined in Sections 6 and 7.

3. Environmental setting

This section describes the regional and local setting of the project. The location, land use, climate and topography are discussed in this section. The geological setting of the project site is discussed in Section 4.

3.1 Location

The project site is remote, being located approximately 270 km south of Townsville and 300 km west of Mackay at the northern end of the Galilee Basin (Figure 1). The closest townships are Charters Towers, approximately 285 km by road to the north, and Clermont, approximately 260 km by road to the south-east.

3.2 Land use

The project site comprises approximately 20,000 ha of well vegetated land, with low-lying scrub in the south and east and a densely vegetated ridgeline, known as 'Darkies Range', running north to south through the western portion of the site.

Cattle grazing on native pasture is the main land use on the project site. A number of unsealed farm access tracks and exploration tracks traverse the project site. Other minor farm infrastructure present includes livestock fences, farm dams and bores.

The predominant surrounding land use is cattle grazing. Clearing and pasture development with buffalo grass has been undertaken regionally. Limited sheep grazing for wool production is also undertaken in the region.

The only mine or mining project in the vicinity of the project site is the Carmichael Coal Mine Project. The northern boundary of the Carmichael Coal Mine Project site adjoins the southern boundary of the project site.

Other mines and mining projects are located at considerable distance from the project site. Table 1 summarises the details for each mine.

Table 1 Galilee Basin coal mines and mining projects

Mining Project	Distance from Project Site
Kevin's Corner Coal Project	125 km
Alpha Coal Project	138 km
China First Coal Project	160 km
South Galilee Coal Project	196 km

No coal seam gas projects are currently proposed in the vicinity of the project site. The potential for cumulative groundwater impacts associated with existing and proposed mining and coal seam gas activities is discussed in Section 8.6.

3.3 Topography and drainage

At a regional scale, the landform is characterised by the remnants of a deeply weathered plateau, made up of gradually sloping plains with occasional steeper areas fronting low ranges and escarpments.

The topography of the project site is shown on Figure 4. The surface topography within the project site ranges from approximately 275 m above Australian height datum (mAHD) to 500 mAHD. Darkies Range forms a thin ridgeline in the south-western area of the site, widening to a tabletop plateau in the north-western areas. The ridgeline falls from 490 mAHD in the north, down to 395 mAHD in the southern part of the project site. The land slopes to the east of Darkies Range at a gradient of approximately 1:50, before forming the low-lying, flat to gently undulating plains that characterise the south and east of the site. The land slopes more gently to the lower lying areas west of Darkies Range.

The project site generally drains towards the east from Darkies Range, which forms a catchment divide along the western boundary of the site (Figure 4). An upper tributary of Tomahawk Creek traverses the north-eastern corner of the project site (Figure 4). The project site is located in the headwaters of the Belyando River catchment and site drainage lines are highly ephemeral, only flowing after rainfall. This contrasts with the adjacent Carmichael Coal Mine Project that is in the lower lying catchment of the Carmichael River, a major perennial river traversing the mining area. The lower elevation and shallower water table promotes the presence of springs in the vicinity of the Carmichael Coal Mine Project site.

The catchment of Lake Buchanan extends from Darkies Range to the west of the site. The project site does not lie within the Lake Buchanan catchment. Lake Buchanan lies approximately 20 km west of the project site. A minor area in the south west of the project site also drains to the Carmichael River catchment via minor drainage lines (Figure 4).

3.4 Climate

The climate is semi-arid with variable summer-dominant rainfalls. Climate data has been collected since 2003 from the Bureau of Meteorology (BoM) Carmichael weather station (036122). The Carmichael weather station (036122) is located 11 km south-west of the project site and is the closest weather station (Figure 4). The Ronlow Park (036096) and Bulliwallah (036010) weather stations are located 30 km west and 50 km east of the project site, respectively, and provide more extensive long-term datasets for comparison.

The mean daily summer temperature ranges from 23° C to 35.8° C. The mean winter temperatures range from 7.7° C to 22.5° C.

Table 2 summarises the available data for average monthly rainfall, showing an annual average rainfall rate of between 525 mm and 599 mm. The region is too far north to receive reliable winter rain and too far south to receive monsoonal wet periods typical of northern Australia. December, January and February are the wettest months indicating summer dominant rainfall.

Table 2 Mean monthly rainfall

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Bulliwallah (036010)*	110.3	118.6	75.0	38.5	24.8	25.1	21.9	13.9	12.5	28.6	51.3	83.2	599.1
Ronlow Park (036096)#	113.1	114.7	67.1	33.3	23.4	15.5	17.2	14.2	13.3	27.5	56.6	76.5	572.5
Carmichael (036122)^	127.1	122.0	55.2	32.5	14.6	23.8	15.5	11.9	21.3	17.9	61.7	65.0	525.4

Note: values are in mm, * Data record from 1912-2014; # Data record from 1961 – 2014; ^ Data record from 2003 - 2014

Recent rainfall years have been put into historical context using the Cumulative Rainfall Departure (CRD) method. This method is a summation of the monthly departure of rainfall from the long-term average monthly rainfall. A rising trend in the CRD plot indicates periods of above average rainfall, whilst a falling slope indicates periods when rainfall is below average. Figure 5 shows the CRD graph for Bulliwallah (036010), for the period 1972 to present.

The CRD graph indicates that the area has experienced distinct cycles of above average and below average rainfall since 1972. More recently, since 2012 the region has experienced lower than average rainfall. The Queensland Department of Agriculture, Fisheries and Forestry declared the area drought affected in September 2013.

BoM¹ mapping of average annual evaporation shows that the evaporation rate for the region is approximately 2,000 mm/yr. Annual evaporation is therefore approximately three to four times greater than the average annual rainfall.

¹ <http://www.bom.gov.au/watl/evaporation/>

4. Geological setting

The geological setting has been informed by the following data sources:

- Geology logs from petroleum exploration test wells drilled from the 1960s onwards;
- Seismic survey reports for petroleum exploration;
- Geology logs from stratigraphic bores drilled by the Commonwealth Department of Mineral Resources during the 1960s;
- Geological data from private water bore drilling on properties in the region;
- Coal mining exploration drilling logs from the mid-2000s onward; and
- Coal seam gas exploration drilling logs.

The proponent engaged McElroy Bryant Geological Services (MBGS), a specialist geological modelling consultant, to develop a regional 3D geological model of the major stratigraphic units from this data.

The MBGS geological model provided the structural framework for developing a 3D numerical groundwater model by AGE. Appendix B includes a standalone report that describes the approach to the groundwater modelling in detail.

4.1 Regional geology

The regional geology comprises a sequence of three sedimentary geological basins overlying a stable tectonic basement. These basins comprise from oldest to youngest, the Drummond Basin, the Galilee Basin and the Eromanga Basin. The eastern margins of these basins outcrop in a north-south orientated arc across central Queensland and regionally dip to the west.

The project site is underlain by Galilee Basin and Drummond Basin units. The Eromanga Basin subcrops west of the project site and does not underlie the project site.

The Galilee Basin covers an area of approximately 250,000 km² in central Queensland. It is a sedimentary basin comprising Carboniferous to Triassic age geology. The underlying Drummond Basin comprises Devonian to Permian sediments and outcrops approximately 40 km east of the project site. The stratigraphy of each sedimentary basin is shown in Table 3.

Table 3 Summary of Regional Geology

Basin	Age		Stratigraphic Unit	Description		
Eromanga Basin	Great Artesian Basin	Cretaceous/Jurassic		Ronlow Beds ¹ Quartz sandstone Regional aquifer		
Galilee Basin		Triassic	Middle	Moolayember Formation ¹	Shales, mudstones, siltstones, sandstones Regional aquifer	
				Clematis Sandstone ¹	Quartz sandstone Regional aquifer	
			Early	Dunda Beds	Sandstone, siltstone, claystone Local aquitard - not present in project site	
				Rewan Formation	Siltstone, claystone and minor fine grained sandstone Regional aquitard	
			Permian	Late Early	Betts Creek Beds	Coal measures
			Carboniferous	Late	Joe Joe Group	Coal measures
Drummond Basin		Carboniferous	Early	Drummond beds	Fluviatile sediments and volcanics	
	Devonian	Late				

1. GAB WRP – Barcaldine North Management Unit

Regionally, a thin veneer of more recent Tertiary sediments typically overlies these basins. Figure 6 shows the subcrop of the main stratigraphic units underlying the Tertiary cover. Quaternary sediments are localised to present day drainage features. Figure 7 shows the surface geology within the project site and surrounding area.

4.2 Project Site geology

The following main stratigraphic units occur within the project site (from oldest to youngest):

- Joe Joe Group;
- Betts Creek Beds;
- Rewan Formation;
- Clematis Sandstone; and
- Tertiary sediments.

Figure 8 shows a typical stratigraphic column. Figure 9 presents cross sections through the northern, central and southern areas of the project site.

Whilst developing the geological model MBGS reviewed available literature describing the stratigraphy of the Galilee Basin. This review highlighted three main discrepancies in the published literature. Firstly, the occurrence of the Warang Sandstone and Clematis Sandstone was inconsistent in the literature and geological maps. Secondly, the Permian coal measures were inconsistently referred to as either the Betts Creek Beds, or the Colinlea Sandstone/Bandanna Formation. And lastly the location of the occurrence of the Dunda Beds was also inconsistent. MBGS sought clarification from the Department of Mines and Energy (DME) and Geological Survey of Queensland (GSQ) (Dr John McKellar at the DME and Sally Edwards at GSQ).

In the vicinity of the project site the literature states that Triassic units comprise the Moolayember Formation, Clematis Sandstone and Rewan Formation. However, the published geological maps displayed Warang Sandstone instead of Clematis Sandstone, with the literature describing Warang Sandstone as the lateral equivalent of Clematis Sandstone and Rewan Formation. Dr J McKellar indicated this was due to an error on the geological map and Warang Sandstone is actually Clematis Sandstone at the project site. The Warang Sandstone occurs further north in the Pentland area and north western Galilee Basin well beyond the project site.

Another discrepancy noted in the literature was the occurrence of varying Late Permian formations in different parts of Galilee Basin. The literature states that in southern Galilee Basin the Late Permian geology includes Bandanna Formation and Colinlea Sandstone while in the north of Galilee Basin, Betts Creek Beds occur. The Betts Creek Beds are a northern correlative of the combined Bandanna Formation and Colinlea Sandstone to the south. It is not clear in the literature where the transition is between each Formation. MBGS discussions with Dr J McKellar and S. Edwards indicated that the exact boundary between each formation is unknown due to sparse drilling data in the region. MBGS set the boundary in the geological model at approximately 24°S, which is level with the northern extent of Springsure shelf. The southern extent of the project site is well north of this boundary and the Betts Creek Beds is the coal bearing formation proposed for mining.

The Carmichael Coal Mine Project EIS identified the presence of Dunda Beds at the Carmichael Coal Mine Project site (GHD, 2013). The available literature describes the Dunda Beds as occurring in the east of the Galilee Basin, but not being laterally consistent across the basin (Van Heeswijck 2006). The DME geological maps confirm occurrence of the Dunda Beds approximately 20 km south east of the project site. Extensive investigation work within the project site confirmed that the Dunda Beds does not occur between the Clematis Sandstone and Rewan Formation. There is a transition from Rewan Formation outcrops to Dunda Beds outcrops between Buchanan and Galilee mapping sheets south of the project site.

The following sections describe the stratigraphic units that occur within the project site.

4.2.1 Joe Joe Group

The Carboniferous Joe Joe Group comprises conglomerate, lithic sandstone, siltstone, minor mudstone and coal. The Joe Joe Group is the base unit of the Galilee Basin and underlies the Betts Creek Beds, which contain the target coal seams for the project. The Joe Joe Group subcrops to the east of the project site under the Tertiary sediments, and therefore is not exposed at the surface in the project site.

4.2.2 *Betts Creek Beds*

The Late Permian Betts Creek Beds comprises interbedded sandstone, siltstone, mudstone, shale and coal. The Betts Creek Beds are up to 180 m thick and are typically consistent regionally throughout the northern Galilee Basin. This unit is an equivalent of the Colinlea Sandstone and Bandana Formation units.

The Betts Creek Beds contains seven coal seams, named sequentially from A to G with increasing depth. Typically, the A Seam is approximately 30 m below the upper boundary of this unit. Cumulative thickness of coal within the Betts Creek Beds is approximately 35 m, with the thickest coal horizon being the A and B Seams.

4.2.3 *Rewan Formation*

The Rewan Formation is a thinly interbedded sequence of siltstone, claystone and fine grained sandstone. This forms a hydraulically tight unit that is a recognised regional aquitard. This unit is an equivalent of the Dunda Beds unit. The Rewan Formation outcrops along the eastern margins of Darkies Range and in the project site unconformably overlies the Betts Creek Beds.

4.2.4 *Clematis Sandstone*

The Clematis Sandstone is predominantly a massive sandstone unit, with minor interbeds of siltstone and claystone. This unit is a recognised regional aquifer of the GAB. The formation outcrops as the western slopes of Darkies Range and is up to 200 m thick, thinning to the east due to erosion. This unit is deeply weathered along Darkies Range and in this area weathering has promoted vertical flow of groundwater to depths of over 100m. The unit weathers to pink and red and is naturally white when fresh. Prominent red laterite horizons occur on Darkies Range.

The Clematis Sandstone unconformably overlies the Rewan Formation. Along the eastern slopes of Darkies Range, localised erosion of the Clematis Sandstone has exposed the underlying Rewan Formation and Betts Creek Beds.

4.2.5 *Tertiary and Quaternary Sediments*

The Tertiary sediments comprise fine to coarse grained, weakly indurated sandstone and siltstone with lesser claystone. This unit is a highly weathered detrital deposit sometimes with a lateritic red colouring and covers much of the low-lying areas either side of Darkies Range. The Tertiary sediments either side of the Darkies Range vary in thickness from 10 m to 77 m, but are typically between 30 m and 60 m. Figure 7 shows the extent of the Tertiary sediments. Whilst geological maps show some localised deposits of Tertiary sediments on the plateaus of Darkies Range, drilling has confirmed they are typically absent from these elevated areas.

Regional geological mapping indicates the presence of fluvial sediments associated with present day drainage features (Figure 7). The distribution of these sediments in the vicinity of the project site was further investigated through targeted groundwater drilling and stream geomorphology assessments. These assessments are discussed in Section 5.3.1 of this report and the EIS Surface Water section, respectively.

These studies confirmed that the minor drainage features and overland flowpaths present within the project site and downstream catchment are characterised by rock channels or exposed Tertiary materials. Extensive, deep alluvial deposits and associated shallow groundwater are therefore absent from the project site and surrounding area. Fluvial sediments present in the vicinity of the project site are limited to thin (less than 1 m) patches of mud and gravel that dry quickly following flow events.

This contrasts with the extensive alluvial deposits associated with the regionally significant Belyando and Carmichael River systems. These alluvial deposits are recharged by direct rainfall to large catchments and seepage from major rivers during periods of surface flow. These alluvial deposits are known to support a perennial water table and exhibit high yields and permeability. The Belyando River alluvium is located 50 km downstream of the project site and Carmichael River alluvium is located in a separate catchment from the project site.

4.3 Geological structure

Historical exploration for petroleum has not detected any large or extensive faults within the region of the Galilee Basin surrounding the project site. At the project site exploration drilling detected one normal fault of limited extent running through the northern portion of the project site (Figure 6). The fault is aligned north-northwest to south-southeast within the Triassic and Permian sediments. Figure 6 and Figure 7 show the fault alignment and extents. Geological data indicates the fault opens and closes at the southern and northern extremities with 100 m maximum displacement in the centre. The fault breaks the continuity of the Clematis Sandstone and on the downthrown eastern side of the fault, places this unit in direct contact with the Rewan Formation that lies on the western side of the fault. Section 7.3 discusses the hydrogeological behaviour of the fault in detail.

5. Investigation methodology

This section outlines the methodology adopted for the collection of hydrogeological data to inform the groundwater assessment. A detailed description of the field investigation methods and findings is provided in Appendix A. Groundwater data including field investigations results from the project site and the surrounding area are presented in Section 6.

5.1 Overview of methodology

A detailed background study was undertaken to develop an understanding of the hydrogeological setting of the project. This included:

- Review of regional and local groundwater studies and other relevant technical reports, including publicly available reports prepared in relation to the Carmichael Coal Mine Project;
- Review and interpretation of regional and local geological data, including an extensive exploration and geological database collected by the proponent;
- Review of hydrogeological data held on the DNRM Groundwater Database (GWDB) for existing private water bores; and
- An extensive field investigation drilling and testing program to refine the understanding of the groundwater regime at the project site. This included:
 - Targeted drilling and installation of groundwater monitoring bores and vibrating wire piezometers (VWP);
 - Completion of field tests to determine local hydrogeological characteristics;
 - Completion of a census of unregistered private bores to confirm groundwater use and quality in the vicinity of the project; and
 - Collection of water samples from monitoring and private bores to characterise groundwater quality.

All relevant hydrogeological data was compiled and analysed to conceptualise the groundwater regime in detail. A numerical groundwater model was developed to predict the scale and extent of any changes to the groundwater regime throughout the mine operations phase and post closure. These predictions were used to assess the potential project and cumulative impacts on groundwater resources and levels, water quality, and groundwater users. Appropriate groundwater monitoring and management strategies were developed to address any potential for significant adverse impacts and validate the findings of the assessment.

5.2 Carmichael Coal Mine Project field investigations

The Carmichael Coal Mine Project site adjoins the southern boundary of the project site. The geological setting of the Carmichael Coal Mine Project and the project are therefore comparable, and where key stratigraphic units are present on each site these can be considered equivalent.

Extensive field investigations were completed between 2011 and 2013 at the Carmichael Coal Mine Project site to support the EIS and supplementary reports (GHD 2013). These investigations included the installation of a monitoring bore network, collection of permeability data in all major stratigraphic units, water quality sampling and analysis, and a bore census of surrounding private bores.

The groundwater monitoring network comprised 64 standpipe piezometers located at 35 sites and a further 24 nested VWPs at eight sites. Figure 10 shows the locations of the monitoring sites at the Carmichael Coal Mine Project.

A total of 123 water quality samples were collected over three sampling rounds between October 2011 and May 2013. Samples were analysed for major cations and anions, trace metals, and nutrients.

Hydraulic permeability was measured in each of the major stratigraphic units within the Carmichael Coal Mine Project site as shown in Table 4. Methods used to collect the data included falling head and rising head tests on monitoring bores, packer tests on open holes, and 48 hour constant rate pumping tests on selected bores installed in the coal seams.

Table 4 Permeability testing - Carmichael Coal Mine Project

Stratigraphic Unit	Falling / Rising Head Tests	Packer Tests	Pumping Tests
Quaternary Sediments	6	-	-
Tertiary Sediments	6	-	-
Clematis Sandstone	2	-	-
Dunda Beds	6	-	-
Rewan Formation	12	6	-
Permian Overburden (Betts Creek Beds above A Seam)	9	6	-
A / B Seam	2	9	1
Permian Interburden (Betts Creek Beds between coal seams)	7	17	-
D Seam	1	6	2
Total	51	44	3

A number of permeability tests were undertaken on the Quaternary and Tertiary Sediments occurring at the Carmichael Coal Mine Project site. As discussed previously, the superficial geology of the project site differs significantly from that of the Carmichael Coal Mine Project. The project is located within the headwaters of a minor sub-catchment where significant Quaternary Sediments are not present and the Tertiary sediments are largely dry.

A census of private bores completed for the Carmichael Coal Mine Project identified 26 registered bores within 10 km of the Carmichael Coal Mine Project site boundary. Of the 26 identified in the DNR database, only seven could be located. Section 6.4 discusses the results from the Carmichael Coal Mine Project bore census in conjunction with the results from the project site bore census. Figure 11 shows the landholder stations and private bores.

5.3 Project site field investigations

An integrated geological exploration and groundwater field investigation program was developed for the project site. This program was intended to maximise the use of each exploration drilling location for collection of hydrogeological data relevant to the groundwater assessment.

Based upon the project setting, regulatory context and understanding of the local geology, the key objectives of the integrated field investigation program were to:

- Collect detailed site-specific geological data to refine the understanding of the project site geology, including confirmation of the extents of key hydrogeological units across the project site;
- Collect detailed drilling logs and core samples from all stratigraphic units to accurately characterise the units that are likely to govern the local groundwater regime;
- Target drilling depth and distribution to stratigraphic units that are known GAB sediments or confining units;
- Target stratigraphic units overlying proposed longwall mining areas;
- Extend geological drilling depths to target stratigraphic units below the target coal seams to provide information on the composition, distribution and hydraulic properties of the underlying materials;
- Extend geological drilling depths as far as practical to maximise the groundwater intersected across the project site;
- Target drilling layouts to proposed mining waste storage facilities; and
- Target drilling to the fault in the north of the project site to refine the understanding of fault alignment and displacement.

To maximise the rigour of the groundwater assessment, the extensive field investigations undertaken at the project site have been used in association with previous investigations including drilling associated with the adjoining Carmichael Coal Mine Project. Section 5.2 describes relevant field investigations undertaken within the vicinity of the project site.

Field investigations into the hydrogeology of the project site were undertaken between December 2012 and October 2013 and included:

- drilling and constructing a groundwater monitoring network;
- post-drilling measurements of groundwater quality and hydraulic properties including falling head and packer testing; and
- a census of private bores to confirm the extent of existing groundwater use and surface expression of groundwater.

Appendix A provides more detail on the methodology employed for these field investigations.

5.3.1 Groundwater monitoring network

A total of 31 groundwater monitoring bores and 12 VWP in four holes were installed on 23 sites across the project site between December 2012 and August 2013. Appendix A summarises the field investigations and contains the composite bore construction and stratigraphy logs for each site.

5.3.2 *In-situ permeability testing*

As a part of the investigation, 18 falling head tests were completed on 16 bores. The testing was designed to evaluate the hydraulic conductivity of material surrounding the bore screen.

A total of 68 packer tests were completed in eight HQ² core holes during the investigation targeting the all the major coal seams along with the Rewan Formation and the Permian interburden and overburden. The Clematis Sandstone was commonly dry and relatively weak, and therefore required casing to stabilise the borehole during drilling. It was therefore not practical to test this unit with the packer apparatus. Falling head tests were instead undertaken in monitoring bores where saturated Clematis Sandstone was present.

Packer tests consisted of isolating a section of a bore hole with inflatable packers so tests could be conducted on a discrete zone or feature (e.g. a coal seam). Figure 12 shows the sites where packer testing was undertaken. The packer testing intervals were selected to ensure representative data was collected for each of the major Permian and Triassic units.

Appendix A summarises the falling head and packer test details. Section 6.2 presents the results from the in-situ permeability testing in the project site.

5.3.3 *Water quality sampling*

A total of 38 groundwater samples were collected over two rounds of sampling from 21 groundwater monitoring bores between March 2013 and April 2014. The water samples were submitted to ALS Environmental Laboratories (ALS) for analysis. ALS is National Association of Testing Authorities (NATA) accredited. The field pH and electrical conductivity (EC) was measured during each sampling event.

Appendix A summarises the water quality sampling method and presents the suite of parameters analysed. Section 6.3 presents the water quality results.

5.3.4 *Bore census*

A census of private bores was carried out by AGE between December 2012 and June 2013 at the project site and surrounding properties. The bore census was completed to identify the condition and use of all registered and unregistered private bores surrounding the project site that could potentially be impacted by the project. In addition, data from a bore census conducted by GHD as part of the groundwater investigation for Carmichael Coal Mine Project was also utilised.

Section 6.4 presents a summary of the bore census results. Appendix A presents the bore census results in detail.

² HQ is a standard core barrel size of 96mm outside diameter, producing a rock core of 63.5mm diameter

6. Hydrogeological data

This section presents an overview of the hydrogeological data collected as part of the field investigation programs at the project site and surrounding area, including data collected from the Carmichael Coal Mine Project site, where relevant to the current assessment.

6.1 Groundwater distribution and flow

Water level readings provide useful information on the vertical and lateral hydraulic gradients, and can also be used to interpret hydraulic conditions such as relative permeability. Key trends demonstrated by water level data are as follows:

- a downward vertical gradient on Darkies Range that indicates a groundwater recharge area;
- stable groundwater levels during the monitoring period indicated limited recharge and discharge;
- the Tertiary Sediments are largely dry and unsaturated in the project site due to the topography and elevation of the project site relative to the surrounding area. A water table forms in these sediments as the elevation drops to the south-east. The water table encroaches on the extreme south-eastern portion of the project site (Figure 13);
- the Clematis Sandstone is largely dry and unsaturated in the project site due to its location at the outer margins of the formation and the significant elevation of the formation within the project site relative to the surrounding topography;
- on Darkies Range the potentiometric surface is generally within the Rewan Formation beneath the Clematis Sandstone; and
- the potentiometric surface measured within the Rewan Formation is some 10 m higher than the potentiometric levels measured in the underlying Betts Creek Beds, indicating the Rewan Formation has a low permeability retarding downward movement of groundwater to the underlying Permian stratigraphy. This confirms that the Rewan Formation behaves as an aquitard.

Figure 14 presents hydrographs for VWP1, VWP2, VWP3 and VWP4. These VWPs are located in the west of the project site on Darkies Range. The hydrographs show the downward hydraulic gradient present in the Darkies Range area from the shallower to the deeper formations, confirming that Darkies Range is a groundwater recharge area, and also that the Rewan Formation retards the flow of groundwater. It is important to emphasise that whilst water samples and water levels have been measured within the Rewan Formation and the Permian Sediments, it does not mean these units form aquifers. When boreholes were drilled into these formations, below the regional potentiometric surface, they were very slow to fill with water confirming low permeability, inconsistent with aquifer characteristics.

Figure 15 presents groundwater level hydrographs recorded in groundwater monitoring bores. Only bores with sufficient data to allow meaningful interpretation of water levels over time were included. The groundwater level data, logged at six hourly intervals, indicate that groundwater levels were relatively static over the monitoring period.

The hydrographs show that piezometric levels within the Triassic Rewan Formation are generally between 310 mAHD to 330 mAHD across the project site, while piezometric levels within the Permian stratigraphy ranges between 280 mAHD and 310 mAHD. Although the water levels are largely controlled by topography, the higher levels in the Rewan compared to the Permian is further evidence of the downward gradient observed in the vibrating wire piezometers.

The bores logs presented in Appendix A show the Tertiary Sediments and Clematis Sandstone are generally dry and unsaturated across the project site.

Figure 16 shows the regional groundwater levels spatially and the interpolated equipotential contours. Spatially, the groundwater levels appear to be influenced by the local geomorphology. In the vicinity of the project site, groundwater levels are dominated by the presence of Darkies Range. Groundwater levels generally flow in an east to south-easterly direction on the eastern side of Darkies Range. To the west of Darkies Range groundwater generally flows in a west to south-westerly direction.

As discussed previously much of the project site is elevated in the catchment headwaters and therefore the Tertiary Sediments are largely dry, and only saturated in lower lying areas of the project site. Figure 13 shows where the Tertiary Sediments are saturated, the saturated thickness in the base of the unit and the depth to the potentiometric surface. It confirms that the Tertiary sediments are largely dry where mining is proposed, only becoming saturated in the eastern lower lying portion of the project site.

6.2 Hydraulic conductivity testing

Figure 17 graphically presents the results of 114 packer tests and 40 rising / falling head test results from both the project site and the Carmichael Coal Mine Project. Key trends demonstrated by these data include:

- the Clematis Sandstone shows a greater hydraulic conductivity than the other formations in the vicinity of the project and is relatively permeable;
- the Quaternary alluvium also reported relatively permeable results but is not present in the Project site; and
- the Rewan Formation and the Betts Creek Beds recorded the lowest hydraulic conductivity indicating generally low permeability.

6.3 Groundwater quality

Groundwater quality data provides useful information on the beneficial use of the groundwater associated with the major stratigraphic units. Appendix A presents the water quality data collected during the project site investigation.

Key trends demonstrated by the water quality data include:

- groundwater from all the major stratigraphic units is of suitable quality for stock watering. This is currently the main groundwater use in the region;
- some groundwater samples were suitable quality for irrigation, although limited bore yields preclude this groundwater use in the project site. This groundwater use is not known to occur within the region; and
- groundwater from all the major stratigraphic units is typically unsuitable for use as drinking water supply. This groundwater use is not known to occur within the region.

Salinity is a key constraint to water management and groundwater use, and can be described by total dissolved solid (TDS) concentrations. TDS concentrations are commonly classified on a scale ranging from fresh to extremely saline. Figure 18 shows a histogram of the available TDS data using this classification convention. The distribution of TDS values shows that groundwater quality across all geological units varies from fresh to moderately saline.

Salinity and dissolved metal and metalloid concentrations were all below the Australian and New Zealand Environment and Conservation Council (ANZECC, 2000) guideline levels for livestock drinking water.

To assess the suitability of groundwater for irrigation use, a number of factors must be considered. These include bore yields, water salinity, soil properties, plant salt tolerance and climate. Whilst some groundwater bores yielded recorded relatively fresh water, the general lack of irrigation in the region suggests other factors prevent the use of water for irrigation.

6.4 Bore locations and groundwater use

As discussed within Section 5.3.4, the bore census collated data from all private bores within the vicinity of the project site and beyond. Private bores comprise DNRM registered bores, unregistered landholder bores and bores identified in the Carmichael Coal Mine Project EIS. Data collected from these private bores through the bore census was incorporated into the wider field investigation dataset and informed the understanding of the hydrogeological setting and groundwater modelling (described in Section 7 and Appendix A of this report, respectively). The full list of private bores within the area of the groundwater model is included in Appendix A.

Private bores were also used to assess the current groundwater use within the vicinity of the project site. A total of 52 private bores were identified within 20 km of the project site.

Figure 11 shows the location of the private bores relative to the project site and geological unit each bore is expected to draw water from. Table 5 provides a summary of the number of bores in each geological unit.

Table 5 Summary of Private Bores by Stratigraphic Unit within 20 km of Project Site

Screened unit	Number of private bores ¹
Alluvium	2
Tertiary Sediments	17
Moolayember Formation	8
Clematis Sandstone	8
Rewan Formation	3
Betts Creek Beds/Joe Joe Group	14
Total	52

1. Includes private bores where response zones interpolated from detailed geological model

The bore census identified the primary use for private bores is for stock water supply. Generally, bores which are located to the west of the project site are screened within the Moolayember Formation and Clematis Sandstone. Private bores to the east of the project site are generally screened within the Tertiary Sediments, where a water table is present on properties east of the project site. For some of the private bores construction details are limited. Where the bore response zone is unclear, the geological model was used to determine the most appropriate surfaces / units based on bore depth.

7. Existing hydrogeology

This section details the existing hydrogeology of the project site and surrounding area, by describing the hydrogeological properties of each geological unit based on the data collected as discussed in Section 5.

The following stratigraphic units are identified as influencing the existing groundwater regime within the project site and immediate surrounds:

- Betts Creek Beds;
- Rewan Formation;
- Clematis Sandstone; and
- Tertiary sediments.

In addition, the Moolayember Formation, whilst not located within the project site and immediate surrounds, is a GAB unit and influences the wider regional groundwater regime. This unit is discussed for completeness. Other regional stratigraphic units have negligible bearing on this assessment.

The following sections discuss the groundwater distribution and quality, hydraulic characteristics, and groundwater use associated with each of these hydrogeological units.

7.1 Betts Creek Beds

7.1.1 Distribution

The Permian Betts Creek Beds sub-crop under the Tertiary sediment cover immediately east of Darkies Range and dip gently towards the west. The sub-cropping Betts Creek Beds are deeply weathered and the coal seams are typically absent within this weathered profile. As the seams dip under the Darkies Range the depth increases to between approximately 200 m and 450 m at the western extent of the project site. Figure 19 shows structure contours for the base of the Betts Creek Beds and the depth from the ground surface to the base.

7.1.2 Hydrogeological parameters

Testing from the project site indicates the Permian Betts Creek Beds form a sequence typical of coal measures, where the coal seams act as a low to moderately permeable aquifer system, confined between low permeability interburden that acts as discrete aquitards between the coal seams.

Hydraulic testing shows that the interburden, which comprises siltstones and sandstones, has a low permeability of between 1.1×10^{-4} m/day and 1.9×10^{-2} m/day. The coal seams are more permeable due to cleat networks that more readily transmit water, with hydraulic conductivity of the seams ranging between 1.5×10^{-3} m/day and 2.3×10^{-1} m/day.

7.1.3 Recharge, flow and discharge

Rainfall recharge to the Betts Creek Beds is very low. VWP installed through Darkies Range indicate a downward hydraulic gradient, and therefore some recharge through the elevated topography into the underlying Betts Creek Beds. However, the amount of recharge is limited by the layered low permeability interburden and the nature of the overlying Rewan Formation that retards flow vertically. Higher recharge is likely to occur where the coal seams subcrop, however again the recharge rate will be low due to the weathered clayey nature of the Permian Sediments underlying the Tertiary cover. Runoff from Darkies Range that collects in the drainage lines at the break of slope is also considered an area where recharge to the Permian Betts Creek Beds occurs, although the volumes will be limited by the small area of this zone. The relatively deep water levels also support a low rainfall recharge rate to the Betts Creek Beds.

Measurements of groundwater levels within the monitoring network indicates groundwater flow is a subdued reflection of the topography and surface water catchments, i.e. from topographically elevated areas to lower lying parts of the landscape. Darkies Range acts as a groundwater divide, with groundwater flowing west towards Lake Buchanan and east following the surface water catchments. The southern part of the project site has a south-easterly groundwater flow direction, again following topography (Figure 4).

Groundwater recharge is considered low, and therefore it follows discharge volumes are also very low. Slow discharge into overlying formations is the expected main discharge mechanism.

7.1.4 Water quality

Groundwater samples collected from the monitoring bore network installed at the project site indicate groundwater quality varies depending on depth and sample location. Water samples collected from the coal seams recorded slightly brackish to brackish groundwater, whilst fresh to slightly brackish samples were obtained from bores screening the interburden. Fresher groundwater potentially occurs at the break of slope zone where recharge is enhanced.

7.1.5 Yields and use

The groundwater database and the bore census findings show that 14 private bores intersect the Betts Creek Beds / Joe Joe Group within 20 km of the project site (Figure 11). All of the private bores are located east of Darkies Range on the Hyde Park, Dooyne, Moray Downs and Laboona properties. The bores are between 4 m and 120 m in depth and generally record fresh to slightly brackish water quality, with low yields of between 1.5 L/s and 4 L/s. Whilst this suggests the Permian units form a water bearing system, these bores represent the boreholes that successfully intersected a water supply. Bores that failed to encounter sufficient water are rarely notified and listed on the GWDB. Therefore, the groundwater database represents private bores that were successfully drilled in more fractured areas, and likely represent an upper bound in terms of water supply rates from the Betts Creek Beds. The true average yield is expected to be much lower than suggested by the GWDB.

7.2 Rewan Formation

7.2.1 Distribution

The Rewan Formation is a thinly interbedded sequence of siltstone, claystone and minor fine grained sandstone. The Rewan Formation outcrops along the eastern margin of Darkies Range and unconformably overlies the Permian Betts Creek Beds. Figure 20 shows structure contours for the base of the Triassic Rewan Formation and the depth from the ground surface to the base.

The potentiometric surface is relatively deep under Darkies Range where groundwater levels within the Rewan Formation can be more than 100 m below the surface.

7.2.2 Hydrogeological parameters

The Rewan Formation is considered a regional aquitard and acts as a confining unit beneath the GAB aquifers.

This unit is characterised by low primary porosity and as a result, groundwater flow is controlled by local fracture sets. Where fractures are intersected testing shows slightly higher permeability, and conversely, where no fractures are intersected testing shows lower permeability associated with the primary porosity. At a local scale, this is reflected in the measured hydraulic conductivity range of between 5.3×10^{-4} m/day and 1.6×10^{-1} m/day.

Bulk permeability of this unit is constrained by connection between any localised fractures (i.e. groundwater must flow through low permeability areas reducing the flow rates). This means that at the regional scale the representative average hydraulic conductivity is expected to be towards the lower end of the values measured by field testing. This is reflected in the regional interpretation of this unit as an aquitard.

7.2.3 *Recharge, flow and discharge*

The recharge / discharge mechanisms and flow directions in the Rewan Formation are equivalent to those of the Betts Creek Beds. Recharge is very low occurring via diffuse rainfall infiltrating through Darkies Range, at the edge of the range where runoff concentrates and via seepage through the Tertiary sediments. The potentiometric surface and flow directions reflect the surface topography and catchments with limited discharge into overlying formations. The deep unsaturated zone running along Darkies Range again confirms the relatively low recharge rates.

7.2.4 *Water quality*

Groundwater samples collected from monitoring bores installed within Darkies Range within the Rewan Formation indicate a variable water quality from fresh to moderately saline.

7.2.5 *Yields and use*

There are potentially three private bores that may intersect the Rewan Formation within 20 km of the project site (Figure 11). All of the bores are located on Moray Downs, a property purchased by the proponent of the Carmichael Coal Mine Project. The bores are drilled to between 55 m and 105 m in depth, and whilst no data is available on yields they are expected to be low given the low permeability of the sediments that form the Rewan Formation.

7.3 **Triassic Clematis Sandstone**

7.3.1 *Distribution*

The Clematis Sandstone outcrops or sub-crops along the north-south aligned Darkies Range. In these areas the water table is deep, in places exceeding 100 m below surface and the Clematis Sandstone is therefore typically dry and unsaturated. The exception is on the eastern side of the fault that bisects the Northern Underground of the project site. Figure 21 shows structure contours for the base of the Clematis Sandstone and the depth from the ground surface to the base of this unit. To the east of the fault, a thin wedge of Clematis Sandstone sediments are below the water table. In this area the saturated thickness of the Clematis Sandstone reaches 50 m, gradually reducing to the east as the base of the unit rises above the water table. Figure 22 shows the saturated thickness of the unit, highlighting the wedge of sandstone saturated along the fault zone. This represents the potentiometric surface subtracted from the base of the Clematis Sandstone. Down-dip the unit becomes confined by the overlying Moolayember Formation and beyond this point the contours represent the pressure head above the base of the aquifer.

7.3.2 *Hydrogeological parameters*

As Figure 22 shows, the largely unsaturated nature of the Clematis Sandstone within the project site has limited the amount of testing of saturated hydraulic conductivity that could be undertaken within this unit. Two measurements of hydraulic conductivity within the Clematis Sandstone at the project site recorded hydraulic conductivity measurements of 5×10^{-3} m/day and 9×10^{-2} m/day, indicating moderate to low permeability. These hydraulic conductivities reflect the significant depth of weathering occurring along the Darkies Range that results in the Clematis Sandstone being clay bound in this area.

7.3.3 Recharge, flow and discharge

The recharge / discharge mechanisms and flow directions in the Clematis Sandstone are similar to those describe above for the underlying Rewan Formation and Betts Creek Beds. The generally dry nature of the Clematis Sandstone and relatively deep water table within the vicinity of Darkies Range indicates low recharge rates. Groundwater flows reflect surface topography and catchments, with limited discharge into overlying formations. Lake Buchanan is also an inferred indirect discharge zone for the Clematis Sandstone groundwater via the overlying Moolayember Formation. The salt pans that surround Lake Buchanan and the saline water quality indicates volumes of groundwater discharging to the lake are low and readily removed by evaporation³.

7.3.4 Water quality

Groundwater samples collected from the Clematis Sandstone indicate a fresh to slightly brackish water quality.

7.3.5 Yield and use

There are eight private bores that intersect the Clematis Sandstone within 20 km of the project site (Figure 11). Five of the bores are south of the project site with two of these on the Moray Downs property, two on the Carmichael property and one on Doongmabulla property. One bore is north-west of the project site on the Yarrowmere property, and two relatively new bores drilled in 2013 are present to the west on the Moonoomoo property. The bores are generally used for stock water supply, with the Wild Bore on the Carmichael property used for domestic supply (camp).

The yields from the Clematis Sandstone bores are moderate and range from 0.5 L/sec to 6 L/sec, indicating this unit forms the most productive aquifer within the vicinity of the project site.

The bore on the Doongmabulla property (RN16895,) has been documented as intersecting the Moolayember Formation in the GWDB. However, review of the lithological logs and depth of the bores indicates it likely intersects the Clematis Sandstone. The modelling described in latter sections of this report assumes this bores is in the Clematis Sandstone aquifer, to ensure a conservative approach to potential groundwater impacts.

7.4 Moolayember Formation

7.4.1 Distribution

The Moolayember Formation is the uppermost unit within the package of Triassic sediments. The Moolayember Formation subcrops to the west of the project site along the western edge of Darkies Range with a blanket of Tertiary sediments obscuring any outcrop. The formation comprises mudstones, siltstones and lithic sandstones reaching up to 600 m in thickness. As it occurs well to the west of the project site no monitoring bores targeted this formation.

Figure 23 shows structure contours for the base of the Triassic Moolayember Formation and the depth from the ground surface to the base.

³ http://www.environment.gov.au/cgi-bin/wetlands/report.pl?smode=DOIW&doiw_refcodelist=QLD082

7.4.2 Hydrogeological parameters

The Moolayember Formation is widely considered a low permeability unit that confines the underlying Clematis Sandstone due to the marginal marine or tidal-flat depositional environment. However, there are instances of bores being screened in coarser water bearing zones of the unit, that presumably were deposited during periods of marine transgression, when higher energy sediments were deposited.

7.4.3 Recharge, flow and discharge

Diffuse rainfall recharge to the Moolayember Formation is considered to occur through the blanket of overlying Tertiary sediments, and also along leaky drainage lines and at the break of slope along the western edge of Darkies Range. Groundwater flows are expected to be controlled by surface topography and catchments with limited discharge into overlying formations. In the vicinity of the project site, groundwater movement is expected to follow local topography towards Lake Buchanan in the west and the Carmichael River in the south. Lake Buchanan is an inferred discharge zone for this unit and the underlying Clematis Sandstone.

7.4.4 Water quality

Whilst data is limited, private bore RN153581 recorded 'salty' water when drilled in 2013 (Figure 11). It is expected that water quality within this unit will be more variable than the Clematis Sandstone due to the lower permeability and longer groundwater residence times (i.e. slightly brackish to brackish).

7.4.5 Yields and use

There are eight private bores that intersect the Moolayember Formation within 20 km of the project site (Figure 11). Three of the bores are located on the Yarrowmere property, three on the Moonoomoo property, one on the Ulcanbah property and one on the Carmichael property. Bores typically intersect the Moolayember Formation at depths of between 60 m and 100 m depth. Lithological logs for the bores on the GWDB indicate the presence of sandy clay lenses within Moolayember Formation that yield between 0.15 L/s and 1.3 L/s of slightly brackish to saline water.

7.5 Tertiary Sediments

7.5.1 Distribution

The Tertiary Sediments blanket the low lying land either side of Darkies Range. The Tertiary Sediments are thin at the edge of the range and thicken as the topography falls to the east. The Tertiary Sediments comprise claystone and weakly indurated sandstone, and can look similar to weathered Clematis Sandstone in some instances. Figure 24 shows structure contours for the base of the Tertiary Sediments and the depth from the ground surface to the base.

7.5.2 Hydrogeological parameters

The Tertiary Sediments are dry and unsaturated along Darkies Range and the majority of the project site. A water table forms where the land surface falls and the sediments thicken in the eastern area of the project site. Figure 13 shows the extent of saturated Tertiary Sediments. Where drilling intersected saturated Tertiary sediments, testing has reported a low to moderate hydraulic conductivity of between 2.5×10^{-3} m/day and 6×10^{-1} m/day.

7.5.3 *Recharge, flow and discharge*

Recharge to the Tertiary Sediments is expected to be via diffuse rainfall and be enhanced along drainage lines with permeable beds or rock outcropping in the flowpath. The water table within the Tertiary Sediments is well below the level of the creek beds in the project site and remains below for at least 25 km to 40 km downstream. There is therefore no discharge from the Tertiary Sediments in the project site or within 25 km to 40 km downstream.

7.5.4 *Water quality*

The water samples collected from bores screened within saturated Tertiary sediments yielded fresh to slightly brackish water samples.

7.5.5 *Yields and use*

There are 17 private bores that intersect the Tertiary sediments within 20 km of the Project site (Figure 11). This makes it the most commonly accessed aquifer within the region, which is expected to be due to the lower cost of drilling into this formation. The bores are located on the Hyde Park, Dooyne and Moray Downs properties east of Darkies Range. The bores are typically drilled to 20 m to 30 m depth and are used for stock watering.

7.6 **Quaternary Sediments**

7.6.1 *Distribution*

The distribution of Quaternary sediments is described in Section 4.2.5. As discussed, investigations have confirmed that the minor drainage features and overland flowpaths present within the project site and downstream catchment are characterised by rock channels or exposed Tertiary materials. Extensive, deep alluvial deposits and associated shallow groundwater are therefore absent from the project site and surrounding area. Fluvial sediments present in the vicinity of the project site are limited to thin (less than 1 m) patches of mud and gravel that dry quickly following flow events.

Anecdotal information gathered during the bore census confirmed the history of landholder difficulties in sourcing cattle watering points in the vicinity from shallow groundwater. There are no confirmed alluvial bores in the vicinity of the project site.

This contrasts with the extensive alluvial deposits associated with the regionally significant Belyando and Carmichael River systems. These alluvial deposits are recharged by direct rainfall to large catchments and seepage from major rivers during periods of surface flow. These alluvial deposits are known to support a perennial water table and exhibit high yields and permeability. The Belyando River alluvium is located 50 km downstream of the project site and the Carmichael River alluvium is located in a separate catchment from the project site.

7.6.2 *Hydrogeological parameters and recharge*

As discussed, Quaternary sediments are largely absent from the project site. Consequently, hydraulic conductivity data for the project site is not available. These materials are present in the wider region. Data from the adjacent Carmichael River catchment shows that hydraulic conductivity is between 2.5×10^{-2} m/day and 1.1 m/day indicating a moderate to high permeability.

Localised recharge would be expected during flow events in drainage lines containing these sediments.

7.6.3 Yield and use

There are possibly two private bores that intersect the Quaternary sediments within 20 km of the project site. The bores are located east of Darkies Range on the Hyde Park property, along Bully Creek (RN103878) and near a minor tributary of Tomahawk Creek (RN89073) (Figure 11). Lithological logs for the two bores indicate they intersect water bearing gravels and coarse sandy clays, with yields of less than 2 L/S.

7.7 Summary of existing conceptual groundwater regime

This section describes the processes that control or influence the movement and storage of groundwater in a hydrogeological system. Figure 25 presents an east-west cross section through the project site, identifying the movement of groundwater within the region.

The geology of the region comprises geological units that dip in a westerly direction. However, the direction of groundwater flow is not down-dip, but from areas of high pressure to low pressure. Darkies Range forms an area of high pressure where groundwater is recharged through the outcropping Clematis Sandstone sediments, and at the break of slope where runoff concentrates after rainfall events. Whilst there is a recharge zone at Darkies Range, the depth to the water table is deep, and recharge is only expected to be a very small proportion of annual rainfall. The high evaporation rate in the region means sustained rainfall is required to saturate the soil profile and promote flow of water through the unsaturated profile, resulting in a low rate of recharge, compared to less arid areas.

Groundwater flows from the recharge area towards the west and the east. As the recharge rates are low, the discharge rates are also similarly low. Lake Buchanan, a large shallow in-land lake located within an internally draining basin, forms a discharge zone west of Darkies Range. The lake acts as a groundwater 'sink', with groundwater discharging to the lake bed and evaporating at the lake surface forming a salt crust. The fact Lake Buchanan is most commonly dry indicates evaporation rates from the lake exceed the inflow from underlying groundwater systems, confirming the low recharge/discharge volumes. Groundwater from Darkies Range also flows towards the east with the potentiometric surface reflecting the surface topography. The potentiometric surface remains at least 15 m below the ground surface over 20 km east of the project site and the only discharge mechanism from the groundwater systems is via pumping from private bores.

The fault that is located in the northern area of the project site also controls local groundwater flows. The fault trends in an approximately north-south direction with up to 100 m displacement within the Triassic and Permian sediments. The fault displacement truncates stratigraphic units and retards flow. This is particularly evident within the permeable Clematis Sandstone sediments on the eastern side of the fault. These permeable sediments have been displaced so that they now abut the low permeability Rewan Formation aquitard. Groundwater effectively pools against the low permeability unit and the fault forms a localised flow boundary.

The Tertiary Sediments thin out as topography increases towards Darkies Range and are largely unsaturated in the project site. There is no interaction between groundwater and surface water in the project site or surrounding area as the water table is between 25 m and 55 m below the base of the creeks and drainage lines.

8. Impact assessment

8.1 Introduction

Project activities have the potential to impact on the groundwater regime of the region through:

- Dewatering by extracting coal by longwall mining and open cut mining and in so doing lowering surrounding groundwater levels;
- Subsurface cracking of strata overlying the proposed longwall mine, changing the permeability of the overlying units and influencing groundwater levels;
- Construction of a TSF and power station waste storage facility (PSWSF), which have the potential to generate leachate and give rise to groundwater contamination;
- Use of hydrocarbons and chemicals which have the potential to give rise to groundwater contamination; and
- Formation of a residual void in the final mine landform, that has the potential to influence surrounding groundwater levels and quality.

This section provides a detailed assessment of these potential impacts and is structured as follows:

- Section 8.2 provides an overview of the proposed open cut and underground mining activities, and includes a general explanation of the way in which groundwater may be impacted by subsurface cracking associated with underground longwall mining;
- Section 8.3 provides an overview of the groundwater model that has been developed to assess the impact of mining. Appendix B provides a detailed technical description of the model development, construction and calibration;
- Sections 8.4 summarises the predictions of the groundwater modelling, including changes in groundwater levels during mining operations, groundwater inflow to the open cut pits and underground mine workings and post mine closure recovery of groundwater levels;
- Section 8.5 describes potential impacts to groundwater users and the environment;
- Section 8.6 outlines potential cumulative impacts with the adjacent Carmichael Coal Mine Project; and
- Section 8.7 describes potential for groundwater contamination from the TSF, PSWSF, overburden emplacements, and fuel and chemical storages.

8.2 Overview of mining

8.2.1 Open cut mining

The coal seams dip to the west and mining will generally progress down-dip in a westerly direction. The open cut pits will extend over a 12 km strike length and to a depth of approximately 300 m at the deepest point along the final highwall. Open cut mining will target the A and B Seams over the full extent of the mining area and the C seam in the southern section of open cut pit. Overburden removal will involve the use of multiple draglines and truck and shovel pre-stripping. In order to achieve the most efficient extraction of coal, several mining areas may be active at any point in time. Initial overburden will be stored in out-of-pit overburden emplacement areas to the east of the open cut mining area. As the open cut pits develop and progress, overburden will be placed in-pit.

The overburden emplacement areas will be rehabilitated progressively as the mine develops. Coal from the open cut pits will be mined with excavators, surface miners and rope shovels. Coal will be transported from the pits by haul trucks.

8.2.2 Underground mining

The project will involve establishing up to three longwall operations in the Northern and Southern Underground Mining Areas (Figure 2). The Southern Underground will involve a single longwall mining in the C Seam. The Northern Underground will involve dual longwalls mining in the A and D Seams.

The layout of the Northern Underground is constrained by the project site boundary as well as the geological fault that has been identified through the northern part of the Northern Underground area. The mine schedule indicates that the underlying D Seam will be extracted in advance of the overlying A Seam.

Seventeen longwall panels are also planned in the Southern Underground. The panels are planned to be extracted before the overlying seams are mined by the open cut operation.

The longwall panels in the A, C and D Seams are designed at 300 m wide with two heading gateroads. Chain pillar widths are 35 m.

Longwall mining will result in subsidence of the overlying strata. Subsidence results in the progressive formation of shallow trough-like depressions on the surface relative to natural topography. Subsidence will fracture strata overlying the longwall panel and has the potential to depressurise or fully drain these effected strata.

Appendix B describes how the groundwater model represented the proposed mining sequence.

8.2.2.1 Overview of subsidence effects on hydrogeology

Subsidence predictions are provided in the EIS Subsidence Report. The EIS Subsidence Report explains that longwall mining results in collapse of the overlying rock strata into the void left by coal extraction. The collapsed or disturbed overburden material is referred to as the goaf. The collapse propagates upwards from the extracted seam until bulking of the goaf limits vertical movement and the tensile strength of the rock strata is sufficient to hold up the overburden without failure. There are a number of zones above the goafed area that have different degrees of cracking and the height of cracking is important in assessing the impact of mining on the groundwater regime and groundwater inflow to the mine.

The EIS Subsidence Report describes the following subsidence zones in terms of the known geology of the project site (in order of increasing height above the extracted coal seam):

- Fractured (or continuous cracking) zone – changes in vertical and horizontal permeability are possible;
- Dilated (or discontinuous cracking) zone – no changes in vertical permeability, possible changes in horizontal permeability and storativity; and
- Constrained zone – unaffected by subsurface subsidence cracking.

Figure 26 shows the conceptual model of subsurface subsidence cracking.

8.2.2.2 Zone of continuous cracking

In the continuous cracking zone immediately above the extracted seam, broken rock and rubble is highly fractured and permeable. Above this broken rock and rubble, de-stressing of overlying strata results in fractures extending through individual beds, opening of bedding planes and shearing and dislocation of beds (“continuous cracking”). This cracking exhibits increased vertical and horizontal transmissivity and storativity which decreases with increasing elevation above the extracted coal seam.

Water can potentially drain from an aquifer or surface water body if:

- the zone of continuous subsurface cracking intersects the water body; or
- there is a connection between the continuous subsurface cracking zone and any surface subsidence cracking.

The extent of continuous cracking above the proposed underground mining areas is predicted in the EIS Subsidence Report. This report concludes that there is likely to be:

- an upper bound height of 120 m for continuous cracking associated with single seam extraction; and
- a conservative continuous cracking height of 180 m above the upper seam extracted in dual seam mining areas.

The majority of the Northern Underground involves dual seam mining (A and D Seams). This area is overlain by the Clematis Sandstone. The interburden thickness between the A Seam and the base of the Clematis Sandstone is variable with a minimum thickness of 115 m to 120 m on the western side of the fault, and 140 m to 160 m on the downthrown eastern side.

The EIS Subsidence Report predicts that the height of connective cracking will be up to 120 m above the seam in single seam mining areas and 180 m above the A seam in the dual seam mining areas of the Northern Underground. The height of connective cracking would therefore intersect the overlying Clematis Sandstone. Section 8.3 and Appendix B describe how the continuous cracking was represented by the groundwater model.

8.2.2.3 Zone of discontinuous cracking

Above the continuous cracking zone, a zone of “discontinuous cracking” may form. In this zone the strata sag allowing bed separation. This discontinuous cracking increases horizontal permeability, but does not lead to continuous or connected vertical cracking.

8.2.2.4 Constrained zone

A constrained zone occurs above the discontinuous cracking zone and is characterised by a stress level at which rock masses are not disrupted sufficiently to increase their permeability. Hence there is no significant change in transmissivity or storativity, and therefore groundwater systems which occur in this zone are hydraulically unaffected by subsidence.

8.2.2.5 Zone of depressurisation

The process of open cut and underground mining reduces water pressures in surrounding rock units beyond the zone directly mined or cracked by subsidence. The extent and magnitude of the pressure reduction beyond this area depends on the properties of the coal seams and other hydrogeological units, and the fracture network generated by subsidence above the longwall mining area. This zone is referred to as the zone of depressurisation, and is greatest at the working face, gradually reducing with distance from the mining areas.

8.3 Overview of groundwater modelling

A 3D numerical groundwater flow model was developed for the project using MODFLOW-SURFACT. A detailed description of the modelling logic is provided in Appendix B.

The model represented the key geological units as 18 layers and extended 75 km north-south and 85 km east-west.

Development of the model was based on the high resolution geological model developed by the proponent. The geological model was further enhanced by inclusion of all published lithological logs within the model extents, including drilling logs from the adjoining Carmichael Coal Mine Project and the DNRW GWDB.

The numerical groundwater model reflects the groundwater regime described in Section 7. The model was calibrated to existing groundwater levels using reliable measurements from all representative bores located over an area of 6,375 km². A detailed description of the calibration method is provided in Appendix B. The objective of the calibration was to replicate the groundwater levels measured in the monitoring network installed at the project site and the adjacent Carmichael Coal Mine Project site, in accordance with modelling guidelines developed by Barnett et al (2012). The calibration achieved a 5.7% to 7.7% Scaled RMS error which is well within acceptable limits (i.e. 10%) as recommended by the modelling guidelines. The model calibration is therefore considered robust.

Once calibrated, the model was used to predict changes in groundwater levels and inflows to the proposed mining areas in response to the project, including simulated mining of the open cut pit and longwall panels in accordance with the proposed mine plan. The modelling approach included simulation of subsidence induced cracking above the longwall panels.

As discussed in the previous section, continuous subsurface subsidence cracking may extend through the Betts Creek Beds and Rewan Formation, into the Clematis Sandstone. Continuous cracking will increase the vertical hydraulic conductivity throughout the affected zone, with the magnitude of the increase likely to decrease with increasing height above the extracted seam. However, as with the prediction of cracking height, the prediction of permeability changes due to continuous cracking is inherently uncertain. Given the combined uncertainty in cracking height and permeability change, this assessment has conservatively adopted the following key modelling assumptions as the basis for the prediction of subsidence impacts on groundwater:

- the continuously cracked zone will be highly permeable; and
- where the zone of continuous cracking is predicted to intersect only part of a geological unit, the entire thickness of that geological unit is assumed to be continuously cracked.

Based upon these assumptions, the vertical conductivity assigned to the cracked Clematis Sandstone is so high as to be considered uniformly free-draining (Gale, 2007). These assumptions more than adequately account for any uncertainty associated with subsidence cracking prediction, and therefore provide a conservative basis for assessing potential worst case groundwater impacts. Modelling of subsidence cracking effects is discussed further in Section B2.2.

The sensitivity of the model predictions to the input parameters was tested and analysed. The analysis included varying model parameters and design features that could most influence the model predictions. The model parameters were adjusted to encompass the range of likely uncertainty in key parameters. Sensitivity analysis included testing the effects of changes in:

- horizontal hydraulic conductivity, vertical hydraulic conductivity, specific yield and specific storage of all geological units and overburden; and
- the rainfall recharge rate across the model domain and overburden.

In addition, specific sensitivity analyses were undertaken to test the influence of the geological fault on the predicted results. These sensitivity analyses comprised modelling the fault as:

- a low permeability fault plane running through the underground mining area, represented with the Horizontal Flow Barrier Package (HFB) set with a conductance term of $1 \times 10^{-7} \text{ m}^2/\text{day}$; and
- a highly permeable fault plane represented by a zone of cells 75m x 75m cells set to the same hydraulic conductivity and specific storage as the Clematis Sandstone.

These changes capture extremes in the potential behaviour of the fault (i.e. groundwater conduit or groundwater flow barrier).

The analysis found that predicted groundwater inflows were most sensitive to changes in the storage parameters. Groundwater depressurisation is most sensitive to changes in storage and hydraulic conductivity during and post mining, while depressurisation was relatively insensitive to changes in the fault conditions.

It was also observed that changing the recharge and hydraulic conductivity parameters increased the overall model error. This shows that the magnitude of these changes reduced the ability of the model to match measured water levels, and indicates that the changes made during the sensitivity analysis are likely to represent conservative extremes for these parameters. Faulting sensitivity was concluded to result in no significant changes to calibration and predictions.

Overall, the sensitivity analysis confirmed that the measured sensitivity of the model calibration and predictions to changes in model parameters is in all instances acceptable.

Appendix B provides a detailed discussion of the sensitivity analyses undertaken. The following sections describe the predictions of the groundwater model.

8.4 Groundwater modelling predictions

8.4.1 Drawdown and depressurisation during mining operations

The influence of mining on the groundwater regime can be divided into two distinct areas. Firstly, the Northern Underground where dual seam underground mining is proposed, and subsidence fracturing will potentially interconnect the underground mining area with the overlying Clematis Sandstone, and secondly, the lower lying southern mining area where open cut mining and single seam underground mining is proposed, and the Clematis Sandstone is typically absent (except for a small proportion within the south of the project site where it is dry and unsaturated).

Figure 27 to Figure 33 show the predicted maximum depressurisation within the key stratigraphic units.

In the Northern Underground Mining Area, groundwater levels are predicted to be influenced by longwall mining in the A and D Seams. Longwall mining will depressurise the coal seam and overlying and underlying strata. Depressurisation will propagate through the Betts Creek Beds, Rewan Formation and Clematis Sandstone (where saturated), enhanced by the increased hydraulic conductivity of subsurface subsidence fracturing. The Clematis Sandstone is depressurised most significantly where it is saturated on the down thrown side of the fault and directly overlies the mining access roads (Figure 29). The saturated thickness of the Clematis Sandstone prior to mining in this area is some 50 m, with the modelling indicating lowering of the potentiometric surface by up to 33 m in response to subsidence and connective cracking. Beyond the mining area, the depressurisation of the Clematis Sandstone reduces with distance. Tertiary sediments do not occur on Darkies Range in the Northern Underground Mining Area where dual seam mining is proposed, and therefore will not be affected. The depressurisation in the coal seams and broader Betts Creek Beds in the north of the project site is localised to within approximately 2 km of the proposed underground mine workings (Figure 30 to Figure 33). In general the lateral extent of depressurisation is constrained in the Northern Underground Mining Area by the largely unsaturated and outcropping nature of the deposits that characterise the groundwater regime in this area (Figure 30 to Figure 33).

The depressurisation in the remainder of the project site differs from the Northern Underground Mining Area, because the Clematis Sandstone is either not present or, if present, is not saturated. The saturated extents of the Clematis Sandstone will not be intersected by either the open cut mine, or by fracturing above the Southern Underground. The Clematis Sandstone therefore is only impacted indirectly by mining reducing pressures in the Rewan Formation as it is exposed in the open cut mine, or fractured above the Southern Underground, resulting in pressure reduction propagating into the Clematis Sandstone. This results in the limited depressurisation shown in Figure 29. Groundwater levels may be lowered by up to 2 m in a zone around the Southern Underground Mining Area.

The zone of depressurisation in the target coal seams is comparable across the project site and is constrained to within a zone of about 2 km around the project site boundary.

The Southern Underground and Open Cut Mine will affect groundwater levels within the Tertiary sediments. Figure 27 shows the model predicts that depressurisation of the Tertiary sediments extends up to 2.2 km east and approximately 5.5 km north of the project site in the vicinity of the open cut pit.

In summary, the modelling indicates that during mining:

- Tertiary Sediments – groundwater levels impacted in a zone east and north of the Southern Underground and open cut area (Figure 27);
- Clematis Sandstone – water levels predicted to reduce by up to 33 m in a limited zone constrained along the fault that directly overlies the Northern Underground (Figure 29);
- Rewan Formation – drawdown remains within 3 to 4 km from mining areas (Figure 30); and
- Betts Creek Beds – drawdown remains within some 2 km of mining areas (Figure 30 to Figure 33).

Water levels in the Moolayember Formation are not predicted to be affected by the project.

8.4.2 Groundwater inflow to mining areas

Groundwater inflow to the mining operations will predominantly occur from the coal seams where these are exposed in the open cut and underground mining areas, and through the mine roof where longwall mining fractures and depressurises overlying strata. Figure 34 shows the predicted rate of seepage of groundwater into proposed mining areas.

The predicted seepage rates vary throughout the mining period. The variability is due to a range of factors including mining depth, permeability of strata, fractures generated above longwall mining areas, interactions between the mining areas and hydraulic gradients induced by the depressurisation. Seepage to the open cut mining area dominates the water budget in the early years of mining. This is due to the footprint of the open cut mine that extends along a 12 km strike length, to between about 200 m and 300 m below the ground surface. Inflow to the open cut pits peak at between 10 ML/day and 12 ML/day and then reduces to between 2 ML/day and 4 ML/day when underground mining of the C Seam occurs beneath the southern portion of the open cut mining area.

Seepage rates to the A and D Seams underground mines vary between 1 ML/day and 2 ML/day for the first 30 years of the project life. When mining of the D Seam is completed seepage rates into the overlying A Seam underground mine increase to between 2 ML/day and 4 ML/day due to the increased height of connective cracking and drainage of water from the overlying Clematis Sandstone where it is saturated above the mine. Groundwater inflow rates to the underground mining areas are less than the open cut areas, as longwall panels are allowed to flood after mining is completed.

The seepage rates presented in Figure 34 represent the total predicted removal of water from the groundwater systems. The actual volume of water pumped from the mining area will be less than that predicted by the model as a component of this water will be lost to evaporation, wetting of surfaces and infiltration, within mine workings.

8.4.3 *Post closure groundwater recovery*

The numerical model also simulated the rebound in the groundwater levels post mining. Appendix B outlines the set-up of the post mining groundwater model.

Predictive modelling was undertaken to simulate 200 years of groundwater recovery post mining. The simulation removed all drain cells representing mine dewatering from the coal seams, thus allowing the groundwater levels in the coal seams and the overlying water-bearing strata to recover.

The modelling indicates the final voids (and associated in-pit overburden emplacements) and the underground mines will gradually fill with water over time. This filling process will reduce the hydraulic gradient and magnitude of drawdown immediately surrounding the mined areas, but also allow the zone of depressurisation to continue to expand as water from the surrounding groundwater systems flow into the mines. Figure 35 to Figure 41 show the predicted extent and magnitude of drawdown at 200 years post mining. The post mining predictions are sensitive to recharge and hydraulic connectivity.

It is important to note that the model allows perfect hydraulic interconnection between the aquifers and aquitards represented in the model. The real world heterogeneity of the geology is not represented in the model. In reality, there are numerous structures in the groundwater systems, such as zones of poor interconnection between fracture networks, fine layering within sedimentary sequences and faults that would reduce the hydraulic interconnection between these units and further reduce the predicted post mining zone of influence. As the post mining zone of depressurisation expands, the potential to encounter more of these structures and boundaries to flow increases and the tendency of the model to over predict the impacts increases.

8.5 Project impacts

This section describes the operational and post-closure impacts of the project on:

- groundwater resources, including the GAB (Section 8.5.1);
- groundwater recharge (Section 8.5.2);
- groundwater users (Section 8.5.3);
- surface water features, including surface waterways, wetlands and Lake Buchanan (Section 8.5.4); and
- groundwater quality associated with contamination from mine waste storage facilities, hydrocarbon and chemical use, and the final void lake (Section 8.7).

The prediction and assessment of cumulative impacts of the project and other groundwater users is discussed in Section 8.6.

8.5.1 *Impact on groundwater resources*

The GAB underlies approximately one fifth of Australia extending beneath Queensland, New South Wales, South Australia and the Northern Territory. It stores an estimated 65,000 million ML of groundwater. The GAB WRP area comprises the area of the GAB that is regulated under Queensland legislation (as discussed in Section 2). The WRP plan area comprises at total of some 1.2 million km².

As discussed in Section 2.2.2, the Clematis Sandstone which occurs on the project site is an aquifer regulated under the GAB WRP. Both the Clematis Sandstone, and the Moolayember Formation which is located west of the project site, are within MU 3 of the Barcaldine North MA. The Ronlow Beds, which subcrop in excess of 26 km west of the project site, are within MU 2.

Modelling predictions for the Clematis Sandstone are described in detail in Section 8.4. Modelling predictions indicate that the project locally depressurises the Clematis Sandstone where it is saturated within and adjacent the project site (Figure 29). This causes groundwater levels to fall in the Clematis Sandstone by a maximum of 33 m where this unit overlies the Northern Underground area. In this area the existing saturated thickness is approximately 50 m.

This depressurisation will result in some water from the GAB MU 3 flowing into the mine. It will also reduce the volume of water flowing from the connected Rewan Formation and Betts Creek Beds into the Clematis Sandstone.

Figure 42 shows the conservatively estimated water take from the GAB aquifers due to the depressurisation induced by mining. It also shows the deeper non-GAB water take, which is equivalent to the mine inflow. The figure indicates the GAB water take gradually rises over the project life to approximately 4 ML/day as mining moves from areas where the Clematis Sandstone is dry to the saturated areas above the Northern Underground. The spike in water take of 9 ML/day occurs when fracturing from the A Seam longwall mine first interconnects the Northern Underground with the saturated Clematis Sandstone on the downthrown side of the fault. The water take from GAB aquifers is all from MU 3, which comprises the Clematis Sandstone and Moolayember Formation. There is no net take from the distant Ronlow Beds that are included in MU 2.

Post-mining, the conservatively estimated rate of water take from the GAB MU reduces due to the reduced hydraulic gradients present around the open cut and underground mining areas. The long term take from MU 3 peaks at almost 0.5 ML/day. There is also a very small take from the Ronlow Beds (MU 2) of 0.015 ML/day. This take occurs indirectly as a very slight reduction in flow from the Moolayember Formation to the Ronlow Beds. The volume is considered negligible. Based upon modelled groundwater inflows to the final void, the water take from non-GAB units (i.e. the Greater Western Sub-Artesian Area) is predicted to decrease post mining and reach an equilibrium of approximately 0.5 ML/day.

Obviously the predicted peak water take of up to 9 ML/day is inconsequential when compared to the estimated 65,000 million ML estimated to be stored within the GAB. On a local scale the acceptability of the predicted water take depends on the impact upon existing water users that hold entitlements, and the ability of the project to obtain a water entitlement. Section 8.5.2 outlines the impacts on water users with private bores.

Outside of the GAB aquifers there is a water take from the other formations in the Galilee Basin, i.e. the Betts Creek Beds and the Joe Joe Group. These formations are located within the Burdekin Water Resource Plan that does not regulate groundwater outside the coastal delta areas.

8.5.2 Impacts on groundwater recharge

It is considered improbable that there will be either a short term, or long term loss of recharge to the GAB as a result of the project. Section 7 explains that recharge occurs from diffuse rainfall, and is also likely concentrated at the break of slope and along drainage lines. Diffuse rainfall recharge will continue to occur during and post mining. A series of highwall drains will also allow water to flow around the open cut mine and mine infrastructure areas and continue to wet up drainage lines.

It is more likely that recharge will increase above the longwall mining areas and within the backfilled overburden emplacement areas post mining. This is likely in the underground mining areas due to the increased permeability of subsided strata, and the ability for these areas to store water. The overburden emplacement areas within the open cut mining area are relatively fractured compared to pre-mining conditions and it is also likely this will enhance recharge to the groundwater system.

For the purposes of ensuring that a conservative worst-case scenario is assessed, this additional recharge has not been considered when considering the post mining impacts.

8.5.3 Impact on groundwater users

Table 6 summaries the maximum predicted drawdown in private bores where the model predicts water levels will be reduced during mining. The location of the bores is shown on Figure 27 to Figure 33 along with the zone of influence.

Table 6 Predicted maximum drawdown in private bores

Registered No./Name	Assumed screen zone	Bore depth (m)	Water column (m)	Maximum drawdown - during mining (m)	Maximum drawdown - 200 years post mining (m)	Bore location
RN103875 (Roo Bore)	Betts Creek Beds	78.3	20.4	39.2	44.3	On 'Hyde Park' Within project site
RN103876 (Camp Bore)	Betts Creek Beds	74.1	24.6	16.1	25.1	On 'Dooyne' Within project site
RN90255	Clematis Sandstone	95.0	21.7	0.5	7.2	On 'Moray Downs' Outside project site
RN90259	Rewan Formation	104.9	64.4	0.4	5.3	On 'Moray Downs' Bore within Carmichael Coal Mine Project site
Lin Bore	Tertiary Sediments	-	-	0.1	4.8	On 'Dooyne' Outside project site
Lin Yards	Tertiary Sediments	-	-	0.1	4.5	On 'Dooyne' which Outside project site
Warratah Camp Bore	Clematis Sandstone	78.0	27.2	0.4	4.5	On 'Carmichael' Outside project site
Brumby Hole	Tertiary Sediments /Joe Joe Group	82.6	30.5	0.1	4.3	On 'Hyde Park' Outside project site
RN17981	Rewan Formation	61.0	19.8	0.2	3.7	On 'Moray Downs' Bore within Carmichael Coal Mine Project site
Pidgenhole	Tertiary Sediments	-	-	0.1	3.7	On 'Dooyne' Outside project site
Edgers Bore	Tertiary Sediments	-	-	0.02	3.5	On 'Dooyne' Outside project site
Wild Bore	Clematis Sandstone	-	-	0.1	3.1	On 'Carmichael' Outside project site
RN153583	Clematis Sandstone	97	20	0.54	2.5	On 'Moonoomoo' Outside project site
Gum Hole	Tertiary Sediments	43.9	3.1	0.02	2.5	On 'Hyde Park' Outside project site

Registered No./Name	Assumed screen zone	Bore depth (m)	Water column (m)	Maximum drawdown - during mining (m)	Maximum drawdown - 200 years post mining (m)	Bore location
RN132941	Tertiary Sediments	66.0	18.3	0.01	2.3	On 'Moray Downs' Bore within Carmichael Coal Mine Project site
Allens Bore	Tertiary Sediments	-	-	0.00	2.0	On 'Dooyne' Outside project site
RN153582	Clematis Sandstone	121	61.5	0.03	1.8	On 'Moonoomoo' Outside project site
RN17451 (Moonoomoo Bore)	Moolayember Formation	65.8	31.8	0.04	1.7	On 'Moonoomoo' Outside project site
RN132938	Betts Creek Beds	147.0	108.0	0.01	1.5	On 'Moray Downs' Bore within Carmichael Coal Mine Project site
8 Mile Bore	Moolayember Formation	-	-	0.1	1.4	On 'Yarrowmere' Outside project site
RN89072	Tertiary Sediments	42.7	20.4	0.00	1.3	On 'Hyde Park' Outside project site

A total of 52 private bores were identified during the bore census. The bore census indicated that groundwater use is sporadic and dispersed over a wide area due to the generally significant depth to groundwater and typically low yields. Water quality is variable, but is generally suitable for stock watering.

During mining operations the project is not predicted to impact bores located beyond the project site. Private bores within the project site will be managed through land access arrangements with landowners.

As discussed in Section 8.4.3, post mining groundwater effects have been predicted using highly conservative modelling assumptions (e.g. perfect hydraulic connectivity between geological units) over a 200 year period. Based upon these conservative modelling predictions, after a period of 200 years post-mining groundwater drawdown may affect up to 19 bores located beyond the project site during the long-term. Groundwater monitoring will be conducted over the 50 year life of the mine to confirm the actual extent of groundwater impacts and validate the conservative predictions. The results of the groundwater monitoring conducted over the life of the mine will be used to inform the reassessment of potential post-mining groundwater impacts and identification of any bores that will potentially be impacted in the long-term post mining. As part of mine closure planning, the proponent will enter into agreements with landholders of any potentially impacted bores. The groundwater monitoring program is described in Section 9.

Modelling predictions indicate that three bores are also predicted to have been impacted by the Carmichael Coal Mine Project. Cumulative impacts on groundwater users are discussed in Section 8.6.

8.5.4 Mining impacts on surface waters

8.5.4.1 Mining impacts on springs

The closest springs to the project site are the Doongmabulla Spring Complex, 22 km to the south of the proposed mining area. The Doongmabulla Spring Complex is registered under the GAB ROP as the closest spring that could support significant cultural and environmental values.

The Clematis Sandstone is the source aquifer for the springs. During mining the drawdown in this unit is not predicted to extend significantly beyond the project site (Figure 43). This is because the project does not directly impact on the Clematis Sandstone in the south of the project site. Impacts on the Clematis Sandstone are limited to the upward propagation of depressurisation through the low permeability underlying Betts Creek Beds and Rewan Formation. In addition, the Clematis Sandstone is largely dry and unsaturated at its margins, including in the south-west of the project site adjacent the proposed mining areas (Figure 22).

The maximum predicted extent of depressurisation extends to 4 km from the project site during mining and 11 km post mining. This means that depressurisation impacts associated with the project remains at least 11 km from the Doongmabulla Spring Complex during or post mining and therefore no impacts on the springs are predicted.

Figure 43 shows the extent of drawdown, both during and post mining in the Clematis Sandstone in relation to the springs.

8.5.4.2 Mining impacts on Lake Buchanan

Lake Buchanan is located 17 km to the west of the proposed mining area and is considered to be an area of groundwater discharge and evaporation. The maximum predicted zone of depressurisation during project operations and post closure does not extend to the lake, remaining between 6 km and 17 km away post mining. The project will therefore not impact the groundwater levels in the Lake Buchanan area.

8.5.4.3 Mining impacts on surface drainage

No watercourses as defined under the Water Act are located on the project site.

As discussed in Section 7, groundwater levels in the vicinity of the project site are at significant depth, typically between 25 and 100 m below the ground surface. This is because the project site is located in the headwaters of the catchment where the topography is elevated and recharge relatively low. The surface drainages have only short duration highly ephemeral flows following rainfall. Within the predicted extents of drawdown, the groundwater table is at least 15 m below the base of any drainage feature, and typically greater than 20 m. Groundwater therefore does not provide baseflow to surface drainages, but instead moves underground to the west and east away from the project site. Therefore, the depressurisation predicted to occur in the groundwater system will not impact on surface drainages as there is no direct interconnection between these systems.

8.6 Cumulative mining and coal seam gas impacts

The following activities also extract groundwater and therefore require consideration of the potential for cumulative impacts with the project:

- agricultural stock bores;
- coal seam gas projects; and
- coal mining projects.

No coal seam gas projects are currently proposed in the vicinity of the project site.

Private bores are relatively sparsely spread in the region, and records indicate yields from the bores are relatively low at typically less than six litres per second. The total extraction volumes of groundwater are low and this pumping has negligible effect upon the regional groundwater levels. Therefore, the pumping from private bores will not contribute significantly to cumulative groundwater impacts.

There are currently five coal mines in the early stages of development in the Galilee Basin; Carmichael Coal Mine Project, Kevins Corner Mine, Alpha Mine, China First Mine and South Galilee Coal Project. Only the Carmichael Coal Mine Project is located within relatively close proximity to the project with the remainder between 125 km and 200 km to the south of the project site. Only the Carmichael Coal Mine Project has the potential to generate a cumulative impact on groundwater levels.

As discussed in Section 3.2, the project site adjoins the Carmichael Coal Mine Project site, a large scale underground and open cut coal mine. The Carmichael Coal Mine Project is approved but has not yet commenced construction. Given the close proximity of this project site there is the potential for the two projects to generate a cumulative impact on groundwater levels.

The method of superimposition has been adopted for assessing cumulative groundwater impacts associated with the Carmichael Coal Mine Project. This involves presenting drawdown contours reported for each project from the same unit on a single map and determining where they overlap. The cumulative impact occurs within the overlapping zone (Figure 44 to Figure 49). By comparing the mining and post mining scenarios for each mine, this approach provides a conservative assessment of the cumulative worst-case in terms of changes to groundwater levels. Predictions relating to the Carmichael Coal Mine Project were sourced from the Carmichael Coal Mine Project EIS and Supplementary EIS documents. The 1 m drawdown contour has been taken as the limit of impact for each project.

This cumulative assessment shows (by stratigraphic unit):

- Quaternary Sediments are typically absent at the project site and may be present as thin, dry sediments in the downstream drainage features. More extensive Quaternary Sediments are present in the adjacent Carmichael River catchment which contains a significant watercourse. The sediments of the Carmichael River may be saturated, however impacts from the project site do not extend this far and therefore there is no cumulative impact during mining, or post mining (Figure 27);
- Tertiary Sediments – no cumulative impact during mining, but a cumulative impact post mining;
- Clematis Sandstone – no cumulative depressurisation during or post mining; and
- Betts Creek Beds:
 - A/B Seam – cumulative impact during and post mining; and
 - D Seam – cumulative impact during and post mining.

Figure 44 to Figure 49 demonstrates these results for the four stratigraphic units. The figures show the cumulative impact increases post mining and occurs in the area where the project and Carmichael Coal Mine Project are in close proximity, i.e. in the northern part of Carmichael Coal Mine Project site and southern portion of Project China Stone site.

During mining the zone of cumulative drawdown within the Tertiary Sediments do not overlap. Post mining, the project increases the drawdown predicted for Carmichael Coal Mine Project by up to 20 m. There are no private bores located within this zone (Figure 44 and Figure 45).

The Carmichael Coal Mine Project does not directly mine the Clematis Sandstone within the open cut mines, or fracture it in the underground mines. The Carmichael Coal Mine Project groundwater model therefore predicts no significant depressurisation of the Clematis Sandstone greater than 1 m during mining and post closure. The model for Project China Stone therefore predicts no cumulative impacts on the Clematis Sandstone. While the Doongmabulla Spring Complex is fed by the Clematis Sandstone aquifer, the springs are beyond any zone of cumulative influence and therefore there will be no cumulative impact on these springs.

The cumulative impact is most extensive in the coal seams targeted by the mining operations, and occurs with drawdown overlapping in the A Seam and D Seam by the end of mining. The project effects on groundwater level are most extensive within the Southern Underground, which is directly mined, where over 100 m of additional depressurisation could occur during mining. Post mining the cumulative impact reduces as the mined workings flood with water. Outside this area the project could add between 1 m to 50 m to the drawdown predicted for the Carmichael Coal Mine Project.

The project impacts on the C Seam are shown on Figure 32 and Figure 40 and discussed in Section 8.4. However, the Carmichael Coal Mine Project EIS or Supplementary EIS (GHD, 2013) do not provide any predictions of groundwater impacts in the C Seam.

It is anticipated that the Carmichael Coal Mine Project groundwater impacts on the C Seam would be comparable to the Carmichael Coal Mine Project impacts on the D Seams. On this basis, the cumulative C Seam impacts of the Carmichael Coal Mine Project (based on D Seam impacts) and Project China Stone (Figure 48 and Figure 49) are anticipated to be equivalent to those presented for the D Seam.

The zone of cumulative impact is concentrated largely in the area where the two projects adjoin. Groundwater use is very limited in this area, with only three private bores potentially experiencing a cumulative impact. These are:

- Allens bore on 'Dooyne';
- RN132938 on 'Moray Downs'; and
- RN103875 on 'Hyde Park'.

The Allens bore is predicted to be impacted by the Carmichael Coal Mine Project and is therefore likely to be subject to a make good agreement with Adani Mining Pty Ltd. RN103875 is within the project site and will be effectively dealt with by the land access agreement for the mining lease application. RN1329385 is owned by Adani Mining Pty Ltd and is within the Carmichael Coal Mine Project site and will be impacted by the Carmichael Coal Mine Project.

8.7 Impact on groundwater quality

The project will involve the construction of mine infrastructure, mainly within the eastern portion of the project site. Key infrastructure is outlined in Section 1.

Seepage associated with mine waste storage facilities and hydrocarbon and chemical storage is the main potential source of groundwater contamination. Rainfall runoff associated with mine infrastructure is addressed in the EIS Surface Water Section.

Potential groundwater quality impacts associated with these contamination sources are addressed in the following sections. The potential for impacts to groundwater quality have been determined using information on seepage water quality and the conceptual design of mine waste storage facilities derived from the EIS Geochemistry Report and the EIS Mine Waste Storage Facility Conceptual Design Report, respectively.

Overburden, coal (including rejects and tailings) and power station waste runoff quality is based upon geochemical testing and analysis presented in the EIS Geochemistry Report. However, it should be recognised that direct application of geochemical data can be misleading. Using sample pulps (ground to passing 75 μm) provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. As such, the results of geochemical tests on water extract solutions represent an assumed 'worst case' scenario for undiluted leachate from tested materials. The quality of actual runoff and/or seepage water from these materials would be better than these results due to the less optimum conditions for leaching and the significant dilution from fresh rainfall runoff. The results are therefore not representative of water quality and for the purpose of this assessment, geochemical test results are a highly conservative representation of water quality.

8.7.1 *Overburden emplacement areas and final void lakes*

Initial overburden will be stored in out-of-pit overburden emplacement areas to the east of the open cut mining area. Once the open cut pits have been developed, overburden will be placed in-pit. The overburden emplacement areas will be rehabilitated progressively as the mine develops using proven rehabilitation techniques.

Kinetic Leach Columns (KLC) testing of samples of interburden and overburden recorded a median EC value in the leachate of 346 $\mu\text{S}/\text{cm}$ and a slightly alkaline pH. The open cut voids will form a permanent sink post mining, with water leaching through the spoils moving into the lake formed within the final void. The geochemical test work indicates that the risk of saline surface leachate from spoil material is low in the short term and is expected to diminish with time as soluble salts are leached from this material. The EIS Geochemistry Report also shows that the concentration of soluble metals and major ions in runoff and seepage from overburden is likely to remain within applied water quality guideline criteria and is unlikely to present any significant environmental risks for on-site or downstream water quality.

The EIS surface water assessment determined the water levels within the final void would recover to an equilibrium level of 255 mAHD. This level is well below the pre-mining groundwater levels and means the final void will act as a sink to groundwater flow. Water will evaporate from the lake surface, and draw in groundwater from the surrounding geological units. Evaporation from the lake surface will concentrate salts in the lake slowly over time. This gradually increasing salinity will not pose a risk to the surrounding groundwater systems as the final void will remain a permanent sink.

8.7.2 *Tailings storage facility*

As discussed in Section 1, tailings generated by the project will be stored in an out of pit TSF. The TSF is located to the east of the open cut mining areas (Figure 2). The underlying geology comprises Tertiary sediments overlying the Joe Joe Group, and is relatively distant from the GAB units. Two bores (MB 20 and MB 32) were drilled in this area to investigate the potential for a shallow water table and the nature of the underlying strata. Both holes were terminated in dry sandstone at 25 m below the surface. Subsequent measurements indicated the water table is deeper than 25 m below the ground surface in the area of the TSF. Groundwater samples collected from other bores screened within saturated Tertiary sediments recorded EC values between 500 $\mu\text{S}/\text{cm}$ and 1,000 $\mu\text{S}/\text{cm}$.

Geochemical testing on tailings materials reporting to the TSF was undertaken for the EIS Geochemistry Report. The testing included measuring pH and EC in KLC. Static and kinetic leachate test results presented in the geochemical assessment concluded that coal rejects and tailings are likely to generate low to moderate salinity runoff with a median KLC EC of 279 $\mu\text{S}/\text{cm}$.

The geochemical testing indicates any leachate from the TSF is likely to be better quality than the Tertiary groundwater so degradation of groundwater quality is improbable should any seepage from the TSF occur. There is only one bore in proximity to the TSF (RN36400), and this bore will be removed during construction of the TSF, so therefore the risk to groundwater users is considered low.

Leachate results indicate that seepage generated by the storage of tailings at the TSF is likely to be pH neutral to alkaline, again similar to the in-situ groundwater in the Tertiary sediments. The concentration of soluble metals and major ions in TSF seepage is predicted to be low. The exception was selenium that was recorded in two KLC columns with composite coal rejects marginally above the stock watering guideline. Dissolved metals in the Tertiary groundwater samples do not exceed guidelines for stock water.

The work indicates the water table at the site of the proposed TSF is relatively deep, and that the leachate generated from the facility will of a similar quality to the Tertiary groundwater. The facility will be designed to minimise leachate generation, however were seepage to occur a degradation in groundwater quality is unlikely. There are no private bores within close proximity to the proposed TSF so the risks to the groundwater regime are low.

8.7.3 Power station waste storage facility

The proposed power station waste has been tested as part of the EIS Geochemistry Report. KLC testing indicates this material is likely to generate waters with neutral pH and a median EC of approximately 907 $\mu\text{S}/\text{cm}$. Concentrations of fluoride, molybdenum and selenium exceeded stock watering guidelines in initial leaches, but reduced to below guideline levels after 26 weeks.

The proposed PSWSF is adjacent the proposed TSF, where groundwater investigations shows the water table to be at depth. Leachate generated from the power station waste storage facility will of a similar quality to the groundwater within the underlying Tertiary sediments. The power station waste storage facility will be designed to minimise leachate generation, however were seepage to occur a degradation in groundwater quality is unlikely. There are no private bores within close proximity to the proposed TSF so the risks to groundwater users are unlikely.

8.7.4 Hydrocarbons

There is potential for groundwater contamination to occur as a result of hydrocarbon and metals contamination from workshops and fuel storage areas. However, adequate bunding and immediate clean-up of spills which is standard practice and a legislated requirement at mine sites should prevent the contamination of the groundwater regime.

9. Groundwater monitoring and management plan

9.1.1 *Ongoing Pre-Mining Baseline Monitoring*

The established groundwater monitoring network comprises 31 monitoring bores and 12 VWP's at 24 locations across the project site and surrounding area (Figure 12). Data from this monitoring network enabled confirmation of baseline groundwater levels and quality from representative hydrogeological units.

The groundwater monitoring network established as part of EIS groundwater investigations will be maintained throughout the life of the project. Any monitoring bores or VWP's that are removed by mining during the life of the project will be replaced, where necessary.

Recording of groundwater levels from existing monitoring bores and VWP's will continue until the commencement of project construction. This will provide a long-term dataset that will enable natural water level fluctuations (such as responses to rainfall) to be distinguished from potential water level impacts due to depressurisation resulting from mining activities.

Groundwater quality monitoring will also continue until the commencement of project construction. This will establish a robust, long-term baseline groundwater quality that can be used to determine site-specific groundwater contaminant trigger levels and detect any changes in groundwater quality arising from mining activities during and post mining.

This baseline groundwater and level data will be reviewed prior to project construction to establish which water quality parameters should continue to be monitored and the frequency of the groundwater monitoring. All determinations of groundwater quality and levels will be undertaken by an appropriately qualified person.

9.1.2 *Operations Phase Groundwater Monitoring*

An operations phase groundwater monitoring program is required to identify any significant departure from baseline conditions or the EIS model predictions that could result in significant impacts to water resources, water users and environmental values. The proposed monitoring program will monitor groundwater levels and quality in relation to:

- Groundwater take from the GAB;
- Groundwater take from the Greater Western Sub-Artesian Area;
- Drawdown impacts on private water supply bores;
- Indirect depressurisation impacts on the water table in the Tertiary sediments; and
- Water quality impacts arising from mine waste storage facilities.

An operations phase monitoring program has been developed to meet these monitoring objectives and confirm the project effects on groundwater throughout the project operations phase. Details of the proposed operations phase groundwater monitoring program are provided in the EIS Environmental Management Section.

The existing monitoring bores will operate as groundwater compliance points. Site-specific reference conditions for the groundwater regime will be derived from ongoing pre-mining baseline monitoring and EIS groundwater model predictions.

The basis of calculation of groundwater quality triggers and limits is documented in the EIS Environmental Management Section. All proposed groundwater quality triggers and limits will be determined prior to project construction using long-term baseline data collected from the ongoing monitoring program. Monitoring data will be reconciled with the proposed groundwater quality triggers and limits on a quarterly basis to identify any deviations from long-term baseline groundwater quality. In accordance with the model EA conditions, the proponent will investigate any exceedance of the proposed groundwater quality triggers.

Groundwater level trigger thresholds have also been developed for each of the proposed monitoring bores. Groundwater level trigger thresholds are set at 90% of the predicted maximum water level change at each bore to allow for early identification of any unexpected impacts on groundwater levels, as shown in the EIS Environmental Management Section. Groundwater level monitoring data will be reconciled with the proposed groundwater level trigger thresholds on a quarterly basis to identify any deviations from the modelled predictions. In accordance with the model EA conditions, the proponent will investigate any exceedance of the proposed groundwater level trigger thresholds to determine whether there is a significant departure from the modelled predictions.

The proponent will also comply with any additional monitoring and reporting requirements under the Water Act water licensing regime, as discussed in Section 2.2.

10. References

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11. Abbreviations

AGE	Australasian Groundwater and Environmental Consultants Pty Ltd
ALS	ALS Environmental Laboratories
ANZECC	Australian and New Zealand Environment and Conservation Council
BoM	Bureau of Meteorology
CHPP	Coal Handling and Preparation Plant
CRD	Cumulative Rainfall Departure
EC	electrical conductivity
DotE	Department of the Environment
DME	Department of Mines and Energy
DNRM	Department of Natural Resources and Mines
EIS	Environmental Impact Assessment
EPBC Act	Environment Protection and Biodiversity Conservation Act
EPP	Environmental Protection Policy
EPP Water	Environmental Protection Policy Water
GAB	Great Artesian Basin
GAB ROP	Great Artesian Basin Resource Operations Plan
GAB WRP	The Water Resource (Great Artesian Basin) Plan
GMA	Groundwater Management Area
GSQ	Geological Survey of Queensland
GWDB	DNRM Groundwater Database
L/s	litres per second
m	metres
MA	Management Areas
mAHD	metres above Australian height datum
m/day	metres per day
MBGS	McElroy Bryan Geological Services
ML	megalitres
ML/year	million litres per year
mm/yr	millimetres per year
MNES	Matters of National Environmental Significance
Mtpa	Million tonnes per annum
MU	Management Units
NATA	National Association of Testing Authorities
No.	number
PSWSF	Power station waste storage facility

RMS	root mean square
ROM	Run of Mine
ROP	Resource Operations Plan
TDS	total dissolved solids
the project	Project China Stone
TSF	Tailings Storage Facility
VWP	vibrating wire piezometer
Water Act	Queensland Water Act 2000
Water Reform Act	Water Reform and Other Legislation Amendment Act 2014
WRP	Water Resources Plan
µS/cm	microsiemens per centimetre
%	percentage

12. Glossary

Alluvium - Sediment (gravel, sand, silt, clay) transported by water (i.e. deposits in a stream channel or floodplain).

Aquiclude - A low-permeability unit that forms either the upper or lower boundary of a ground-water flow system.

Aquifer - Rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, confined - An aquifer that is overlain by a confining bed. The confining bed has a significantly lower hydraulic conductivity than the aquifer.

Aquifer, perched - A region in the unsaturated zone where the soil may be locally saturated because it overlies a low-permeability unit.

Aquifer, semi-confined - An aquifer confined by a low-permeability layer that permits water to slowly flow through it. During pumping of the aquifer, recharge to the aquifer can occur across the confining layer. Also known as a leaky artesian or leaky confined aquifer.

Aquifer, unconfined - An aquifer in which there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer. Water-table aquifer is a synonym.

Aquitard - A low-permeability unit than can store ground water and also transmit it slowly from one aquifer to another.

Colluvium - Sediment (gravel, sand, silt, clay) transported by gravity (i.e. deposits at the base of a slope).

Cone of Depression - The depression in the water table around a well or excavation defining the area of influence of the well. Also known as cone of influence.

Drawdown - A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping of ground water from wells or excavations.

Hydraulic Conductivity - A measure of the rate at which water moves through a soil/rock mass. It is the volume of water that moves within a unit of time under a unit hydraulic gradient through a unit cross-sectional area that is perpendicular to the direction of flow.

Hydraulic gradient - The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Infiltration - The flow of water downward from the land surface into and through the upper soil layers.

K - Hydraulic conductivity.

Model calibration - The process by which the independent variables of a digital computer model are varied in order to calibrate a dependent variable such as a head against a known value such as a water-table map.

Packer test - An aquifer test performed in an open borehole; the segment of the borehole to be tested is sealed off from the rest of the borehole by inflating seals, called packers, both above and below the segment.

Piezometer - A non-pumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface. A piezometer generally has a short well screen through which water can enter.

Porosity - The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric surface - A surface that represents the level to which water will rise in tightly cased wells. If the head varies significantly with depth in the aquifer, then there may be more than one potentiometric surface. The water table is a particular potentiometric surface for an unconfined aquifer.

Pumping Test - A test made by pumping a well for a period of time and observing the response/change in hydraulic head in the aquifer.

Slug Test - A test made by the instantaneous addition, or removal, of a known volume of water to or from a well. The subsequent well recovery is measured.

Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

Storativity - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer, per unit change in head.

Transmissivity - A measure of the rate at which water moves through an aquifer of unit width under a unit hydraulic gradient.

Unsaturated zone - The zone between the land surface and the water table. It includes the root zone, intermediate zone, and capillary fringe. The pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched ground water, may exist in the unsaturated zone. Also called zone of aeration and vadose zone.

Water budget - An evaluation of all the sources of supply and the corresponding discharges with respect to an aquifer or a drainage basin.

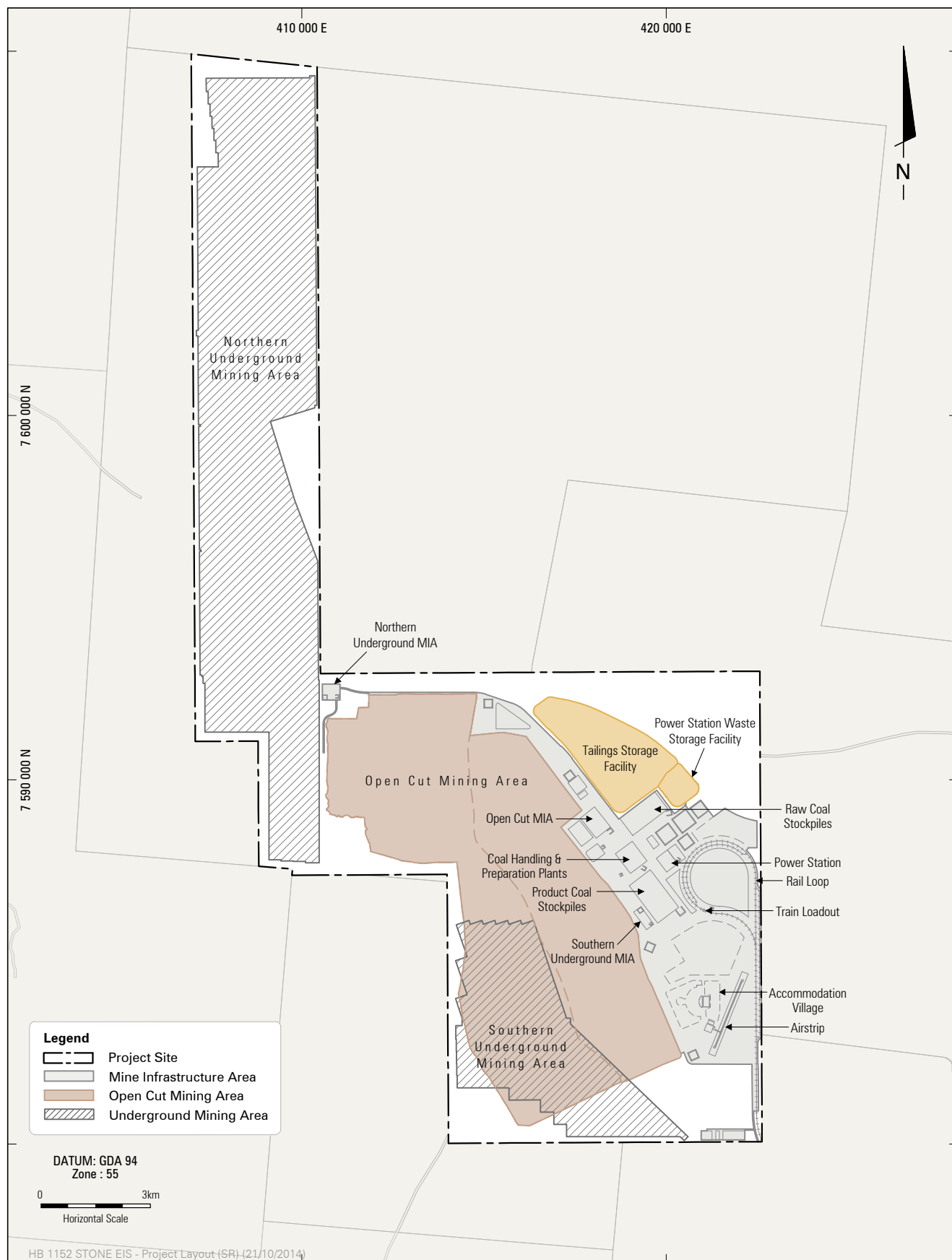
Water table - The water table is the surface where the water pressure head is equal to the atmospheric pressure. It represents the top of the zone where subsurface strata are saturated with groundwater.

List of figures

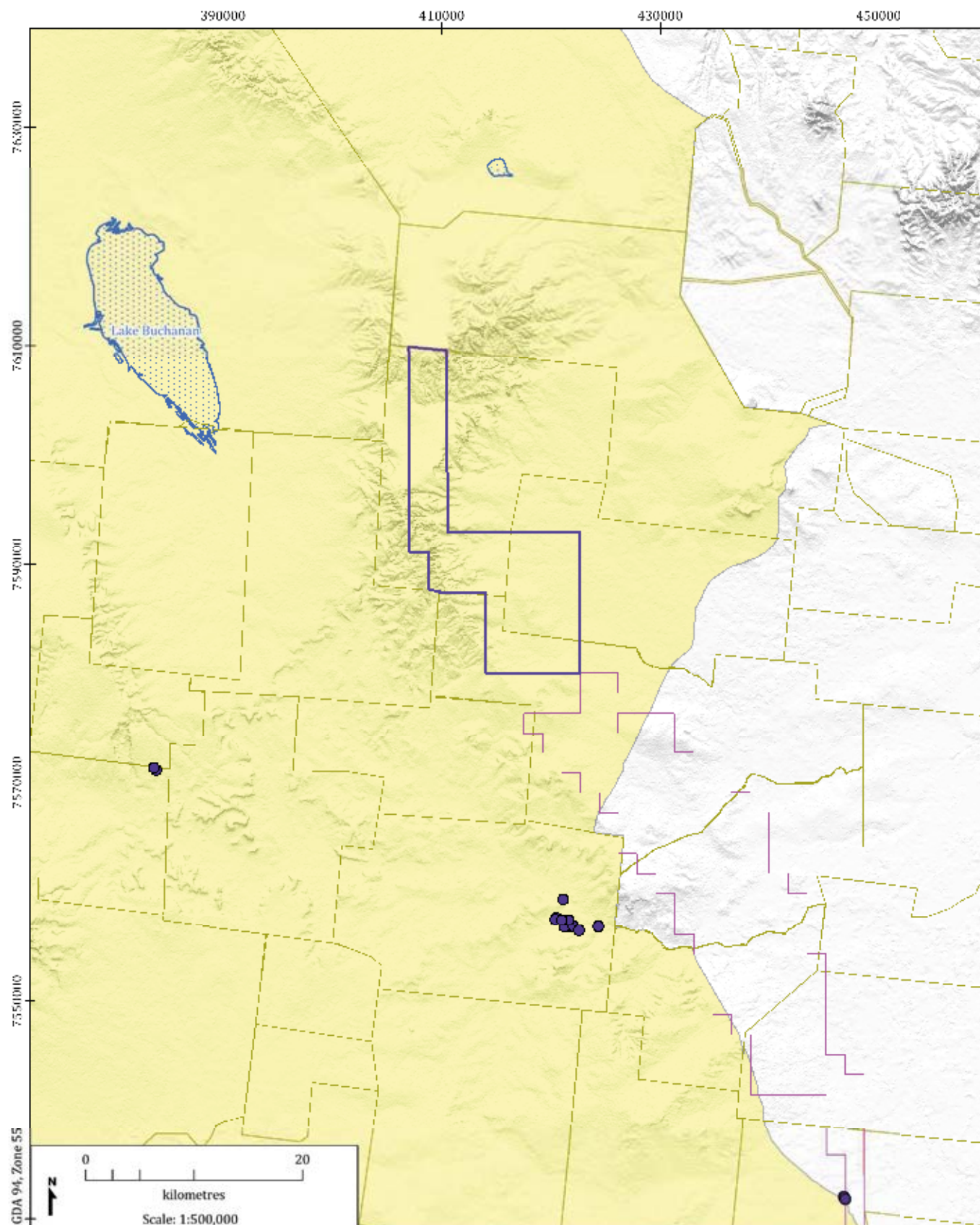




PROJECT CHINA STONE



PROJECT CHINA STONE

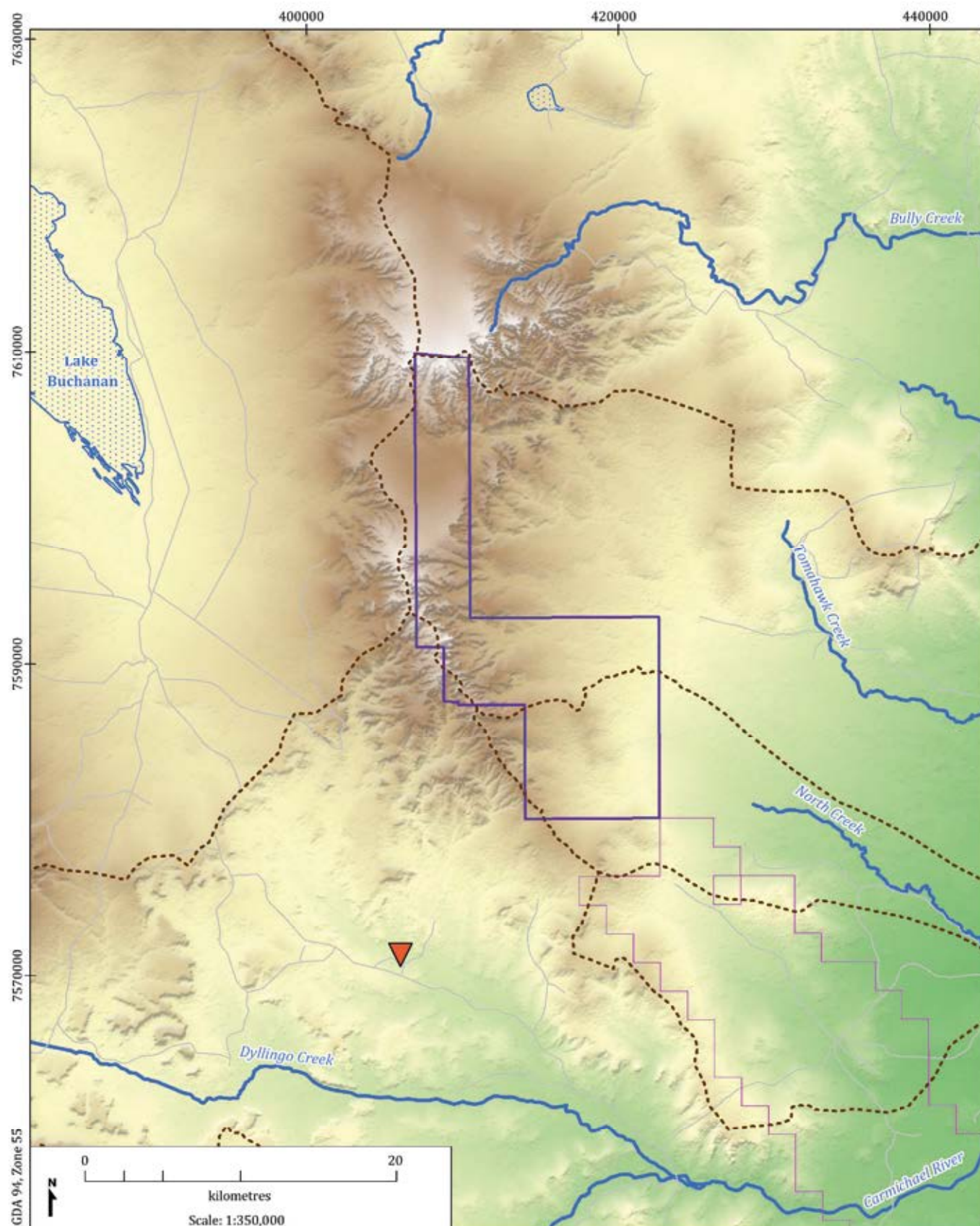


LEGEND:

- Project site
- Carmichael Coal Mine Project
- Barcaldine North Management Area
- GAB Springs (Fensham and Fairfax (2006) Springs of Queensland)
- Property boundaries
- Surface water feature

Project China Stone (G1587)

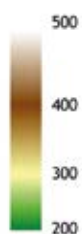
**Water Resource (Great Artesian Basin)
Plan 2006 Area**DATE:
24/6/2015FIGURE No:
3



LEGEND:

- Project site
- Carmichael Coal Mine Project
- Catchment boundary
- Major drainage
- Road
- ▲ Carmichael weather station (036122)
- Surface water feature

Elevation (mAHD)



Project China Stone (G1587)

Topography and drainage



DATE:
24/6/2015

FIGURE No:
4

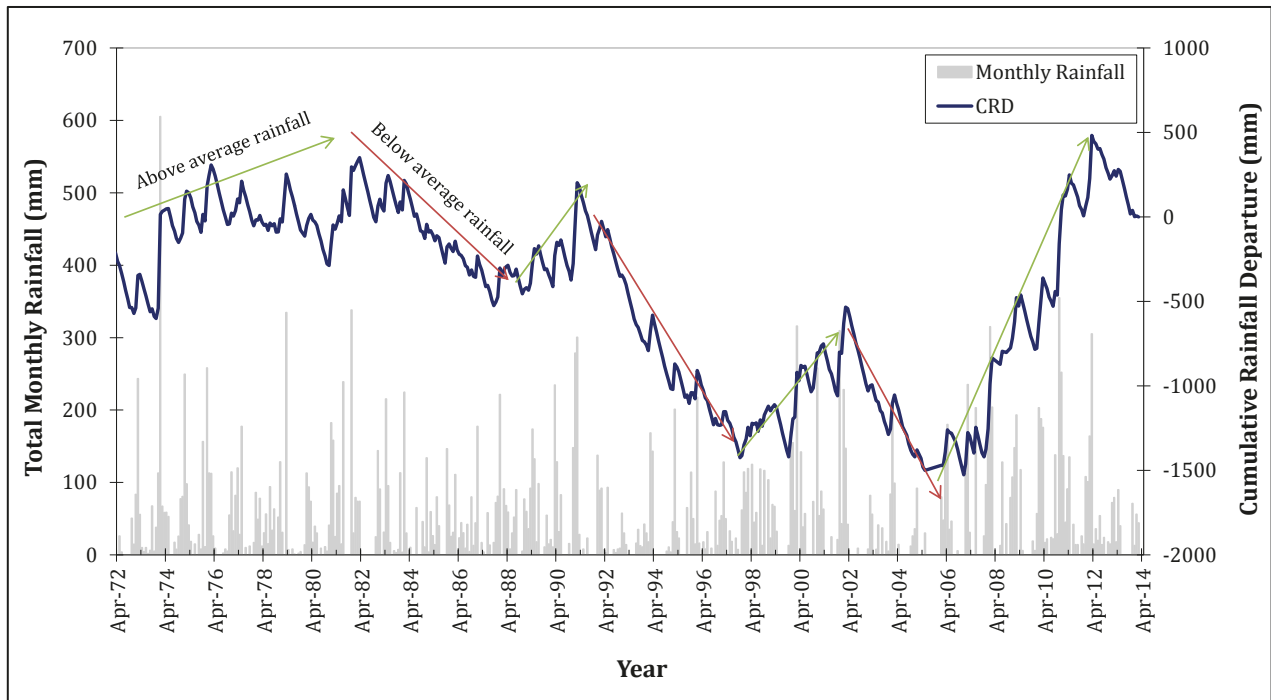
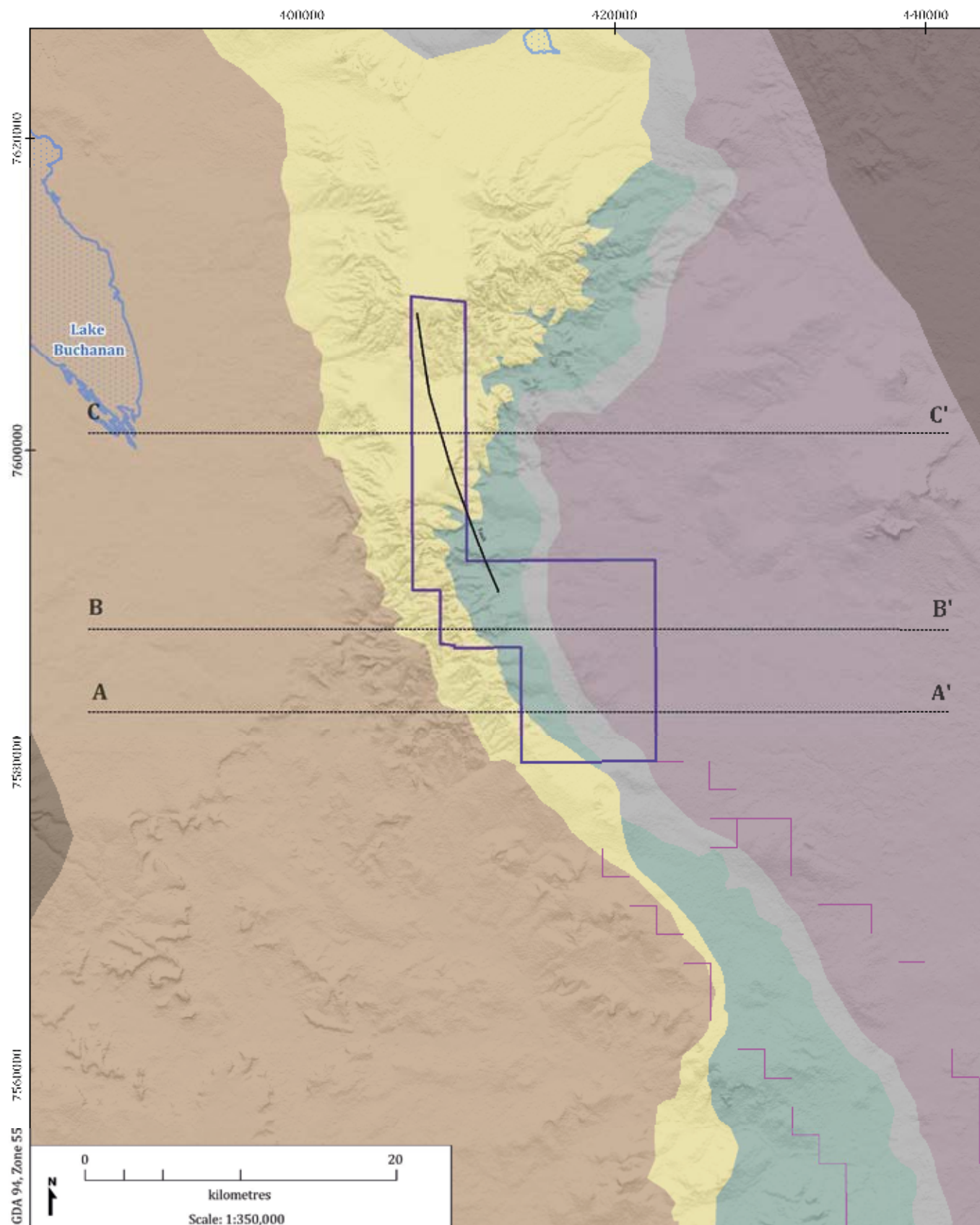


Figure 5 Cumulative rainfall departure



LEGEND:

- Project site
- Carmichael Coal Mine Project
- Fault
- Cross-section
- Surface water feature

- Carboniferous - Drummond Basin
- Permian - Joe Joe Group
- Permian - Betts Creek Beds
- Triassic - Rewan Formation
- Triassic - Clematis Sandstone
- Triassic - Moolayember Formation
- Jurassic - Ronlow Beds

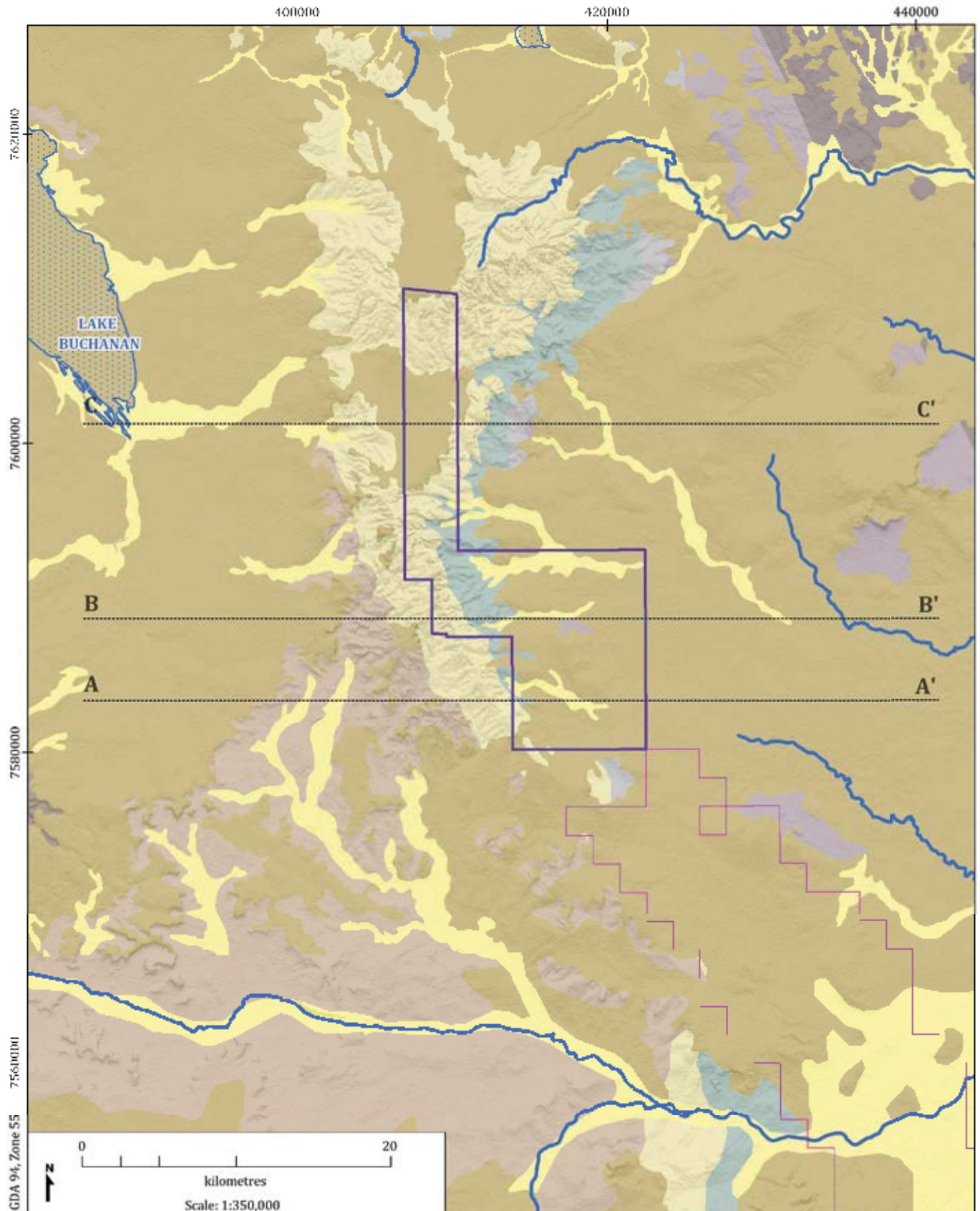
Project China Stone (G1587)

Geological units sub-cropping under Tertiary/Quaternary sediments



DATE:
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FIGURE No:
6



Project China Stone (G1587)

Surface geology

DATE:
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7

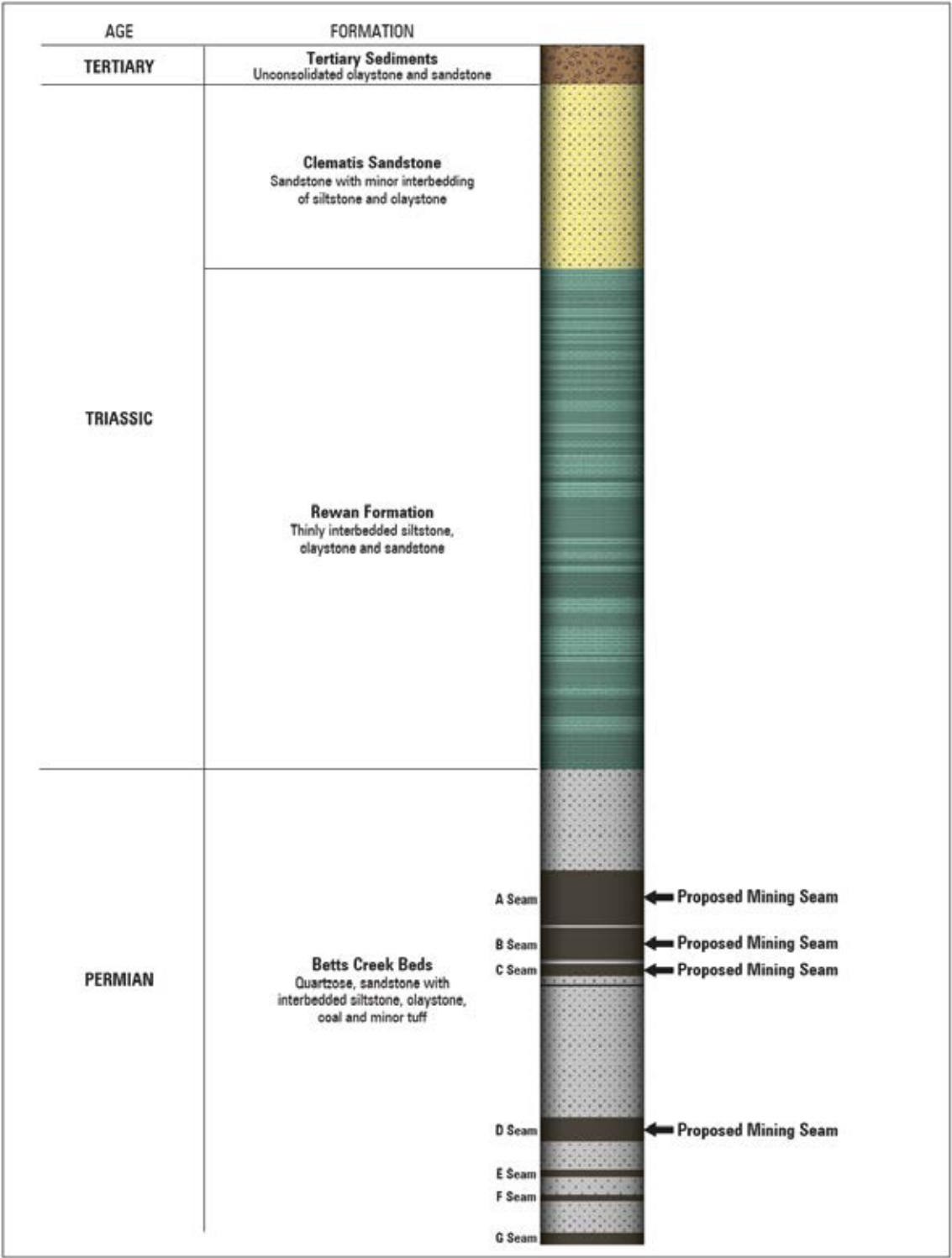


Figure 8 Stratigraphic column (source Hansen Bailey)

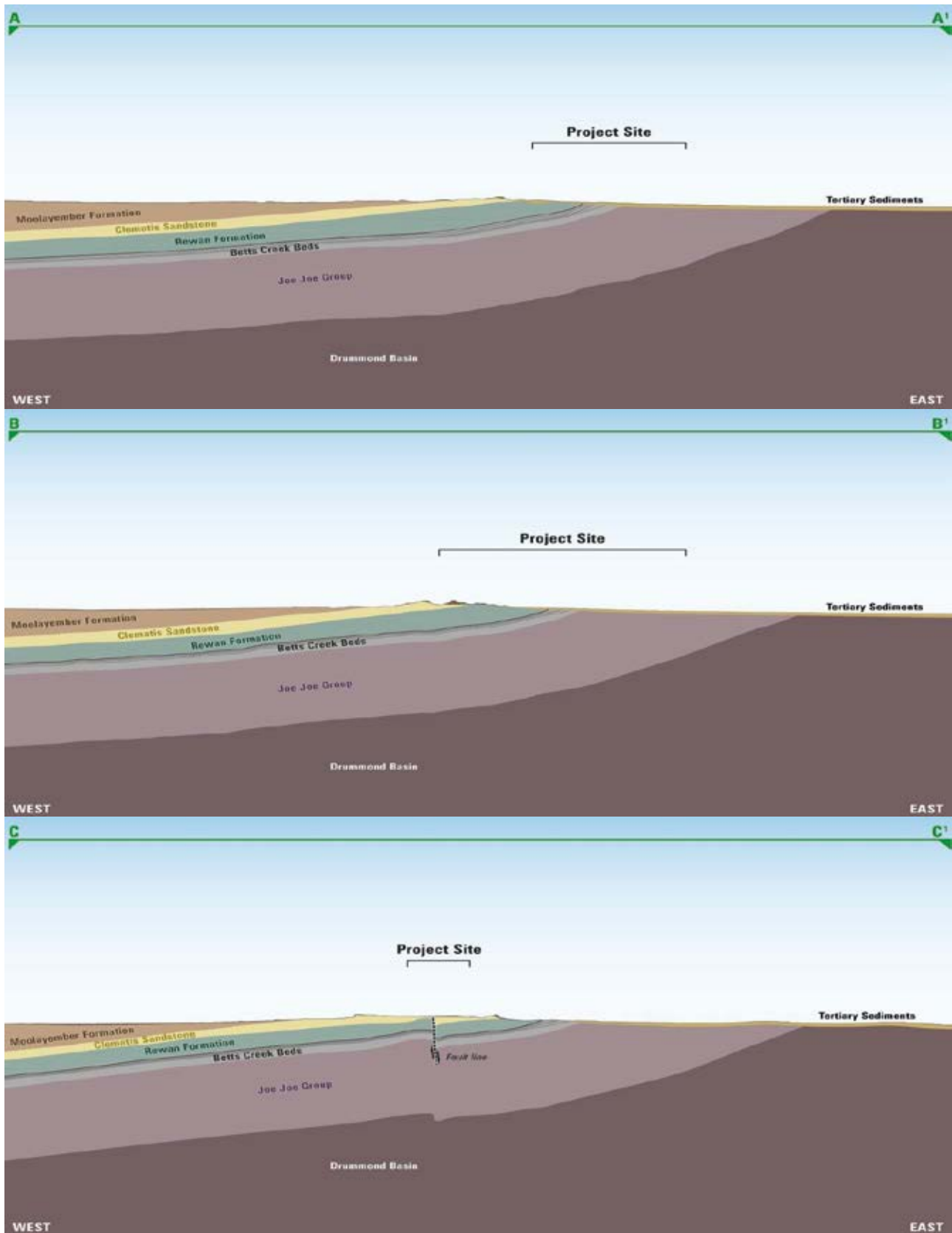
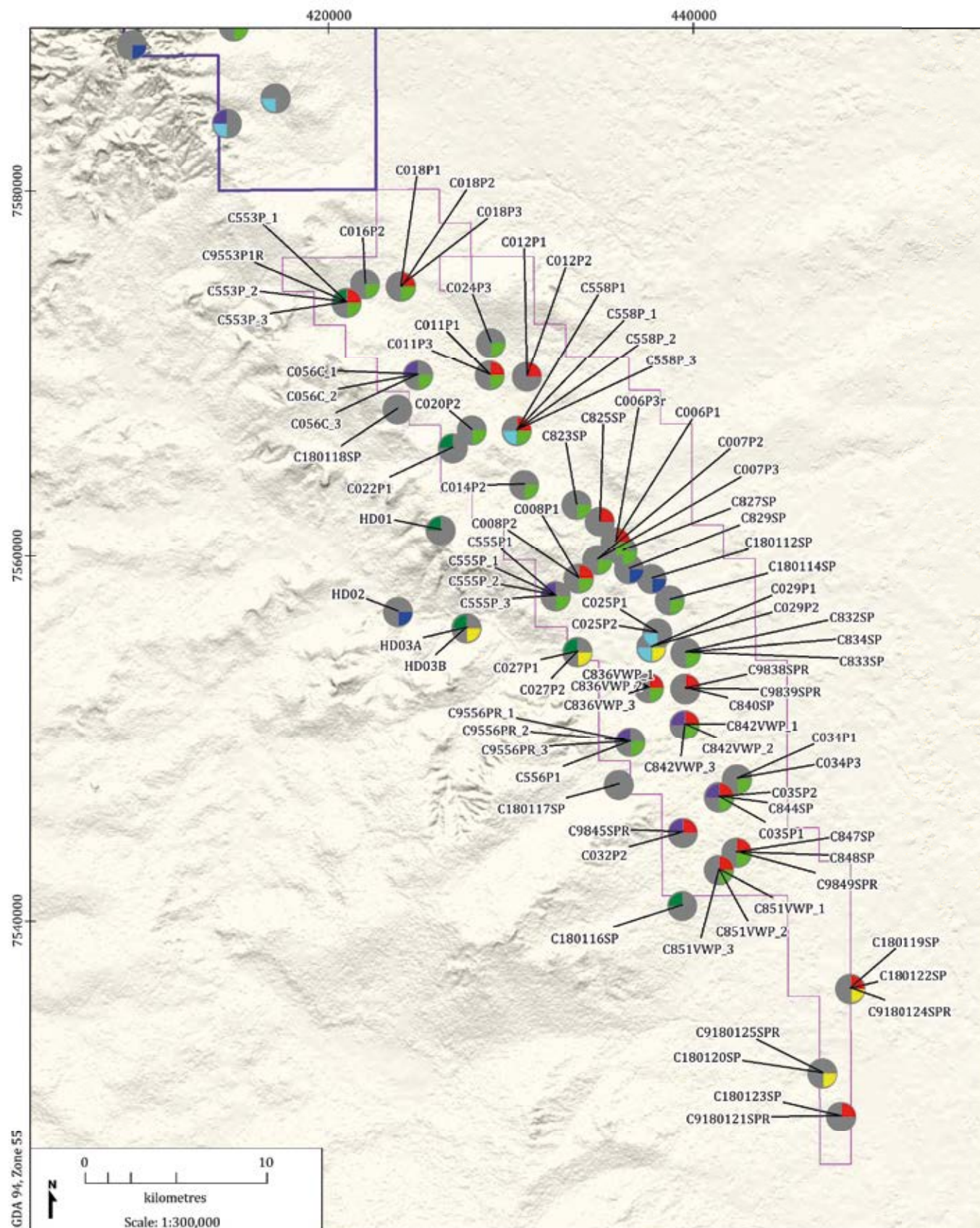


Figure 9 Geological Cross Sections (source Hansen Bailey)



LEGEND:

- Project site
- Carmichael Coal Mine Project

Monitoring bores by Geology

- Betts Creek Beds Interburden
- Betts Creek Beds Coal Seam
- Clematis Sandstone
- Dunda Beds
- Quaternary Alluvium
- Rewan Formation
- Tertiary Sediments

Project China Stone (G1587)

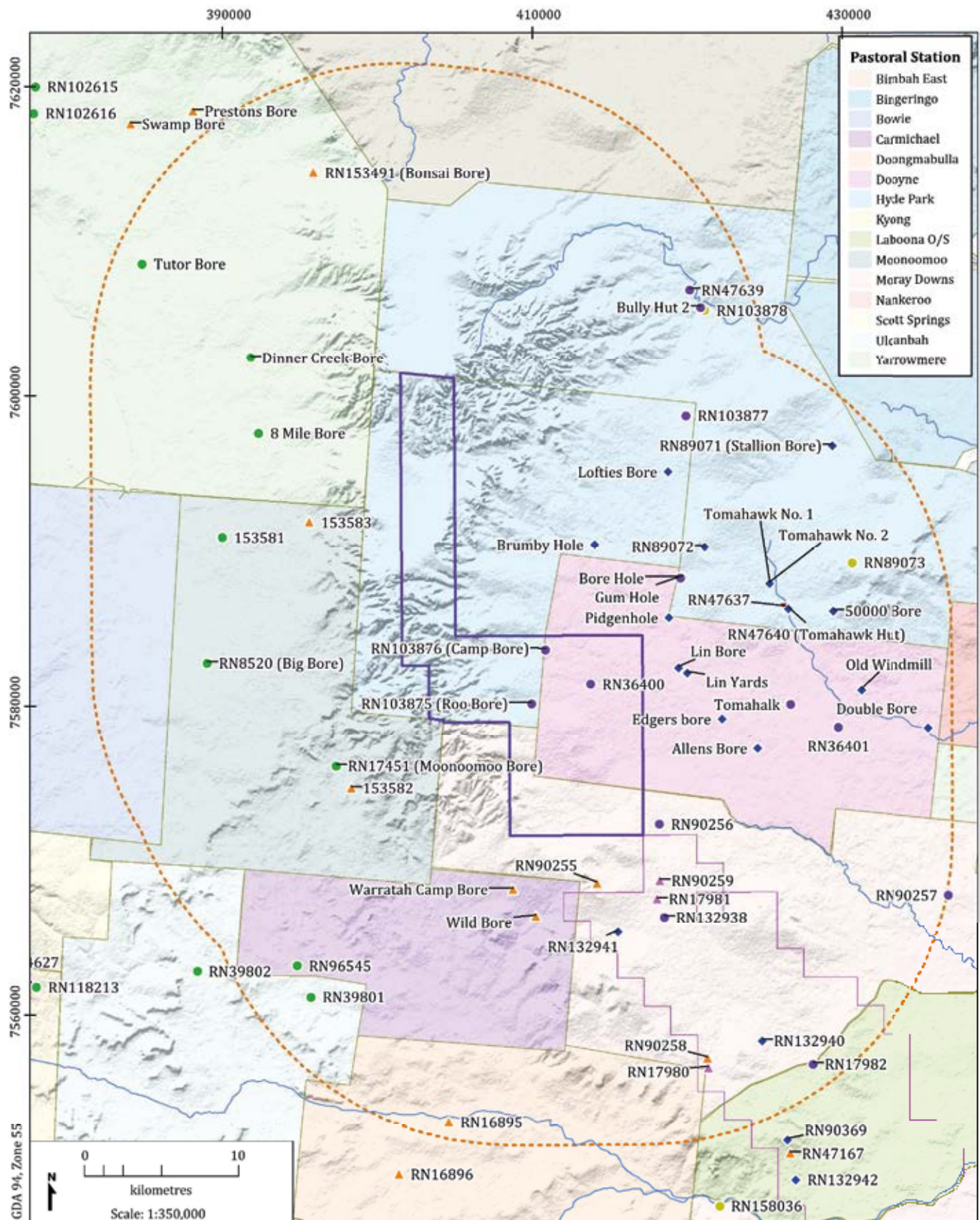
Carmichael Coal Mine Monitoring Bores



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FIGURE No:

10



LEGEND:

Private bore by stratigraphy intersected:

- Quaternary Sediments
- ◆ Tertiary Sediments
- Moolayember Formation
- Dunda Beds
- ◆ Ronlow Beds
- ▲ Clematis Sandstone
- ▲ Rewan Formation
- Betts Creek Beds and Joe Joe Group
- ▼ Basement Volcanics

- Project site
- Carmichael Coal Mine Project
- Major drainage
- 10km from Project site
- 20km from Project site

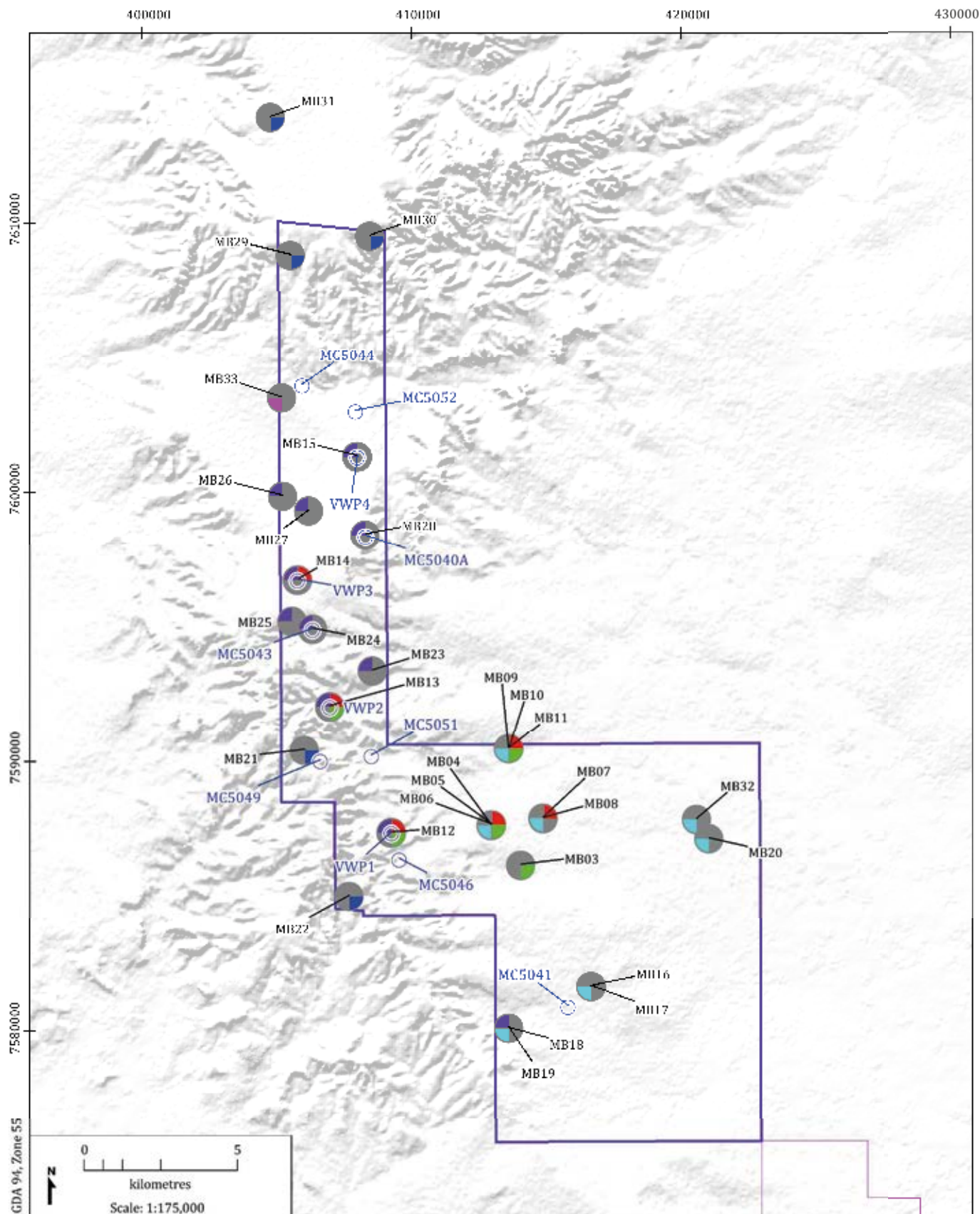
Project China Stone (G1587)

Private Bores



DATE:
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FIGURE No. **11**



LEGEND:

Monitoring bores by Geology

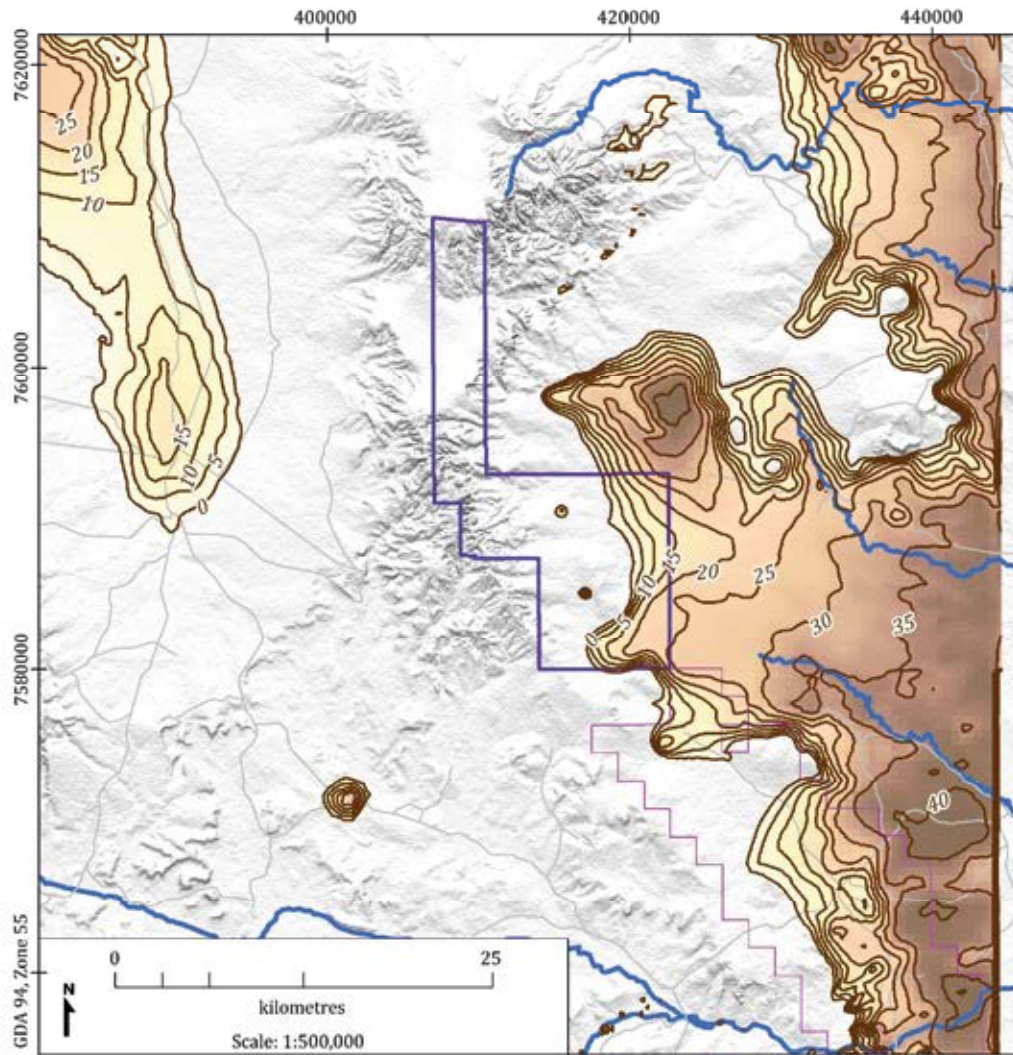
- | | |
|------------------------------|-------------------------------|
| Betts Creek Beds Interburden | Clematis Sandstone / Rewan Fm |
| Betts Creek Beds Coal Seam | Rewan Formation |
| Clematis Sandstone | Tertiary Sediments |
| Packer test completed | Project site |
| | Carmichael Coal Mine Project |

Project China Stone (G1587)

Field investigation bores

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12

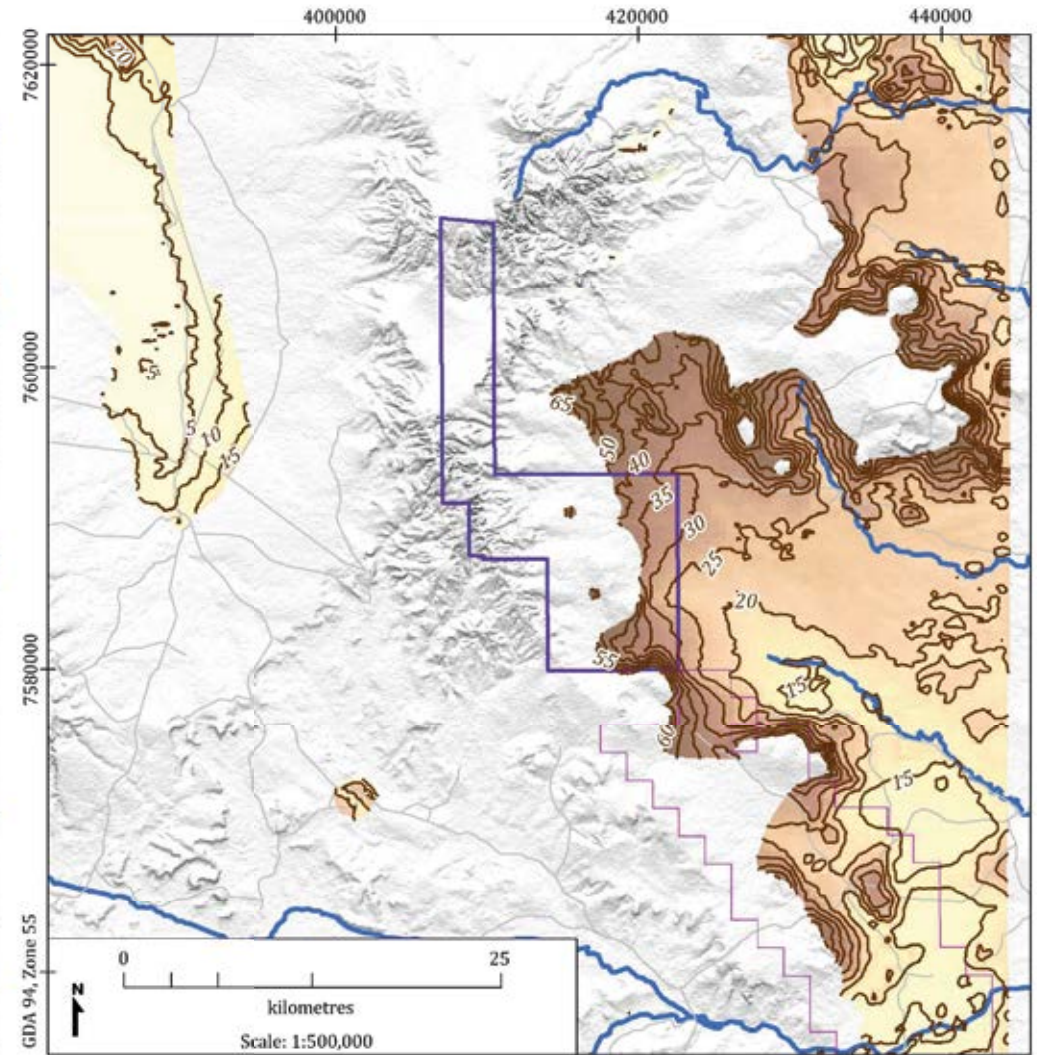
Tertiary Sediments - saturated thickness (m)



LEGEND:

- saturated thickness (5m interval, m)
- Depth to water (5m interval, mBGL)
- Project site
- Carmichael Coal Mine Project

Tertiary Sediments - depth to water (mBGL)



Project China Stone (G1587)

**Tertiary Sediments - saturated thickness
and depth to potentiometric surface**

DATE:
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FIGURE No:

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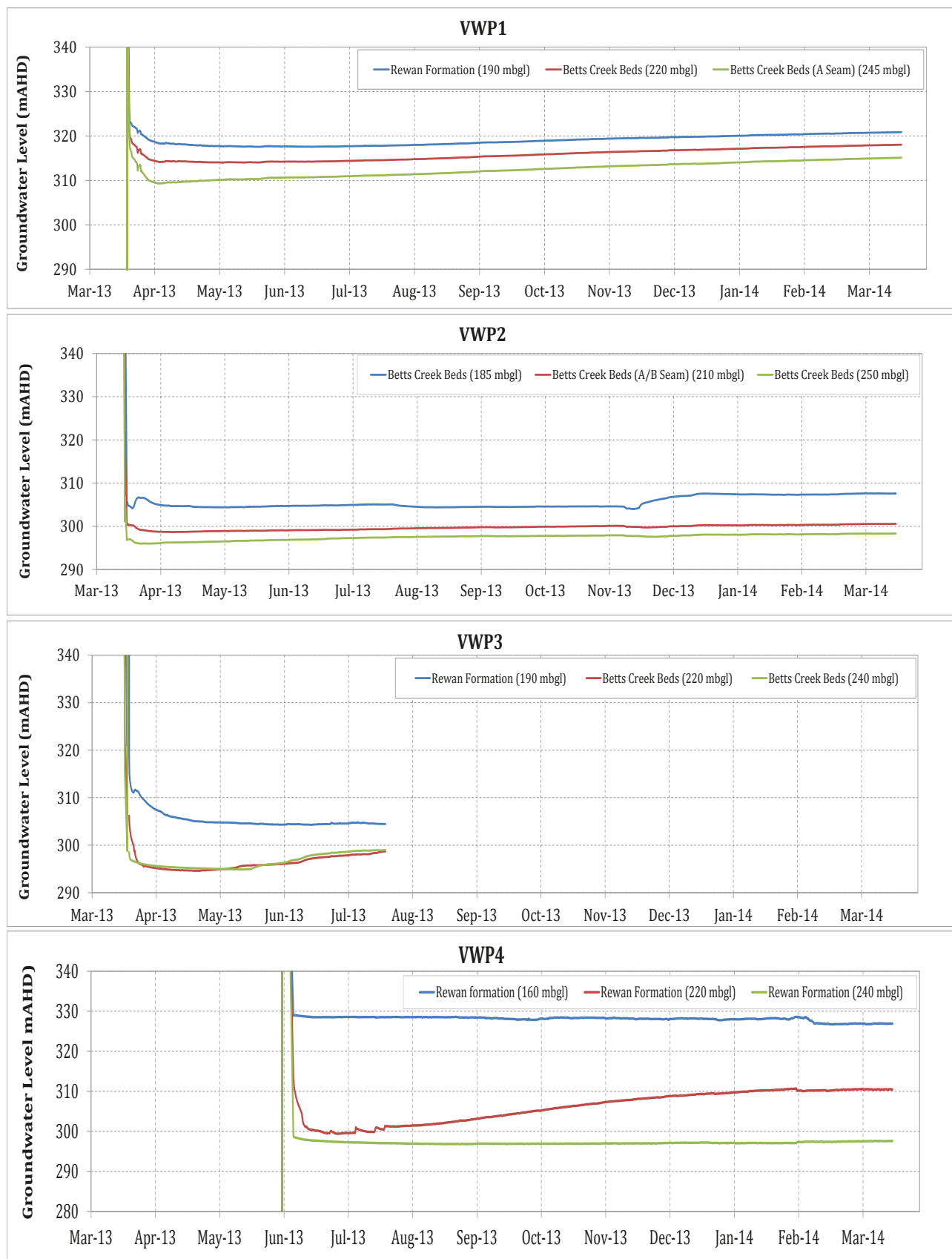


Figure 14 VWP hydrographs

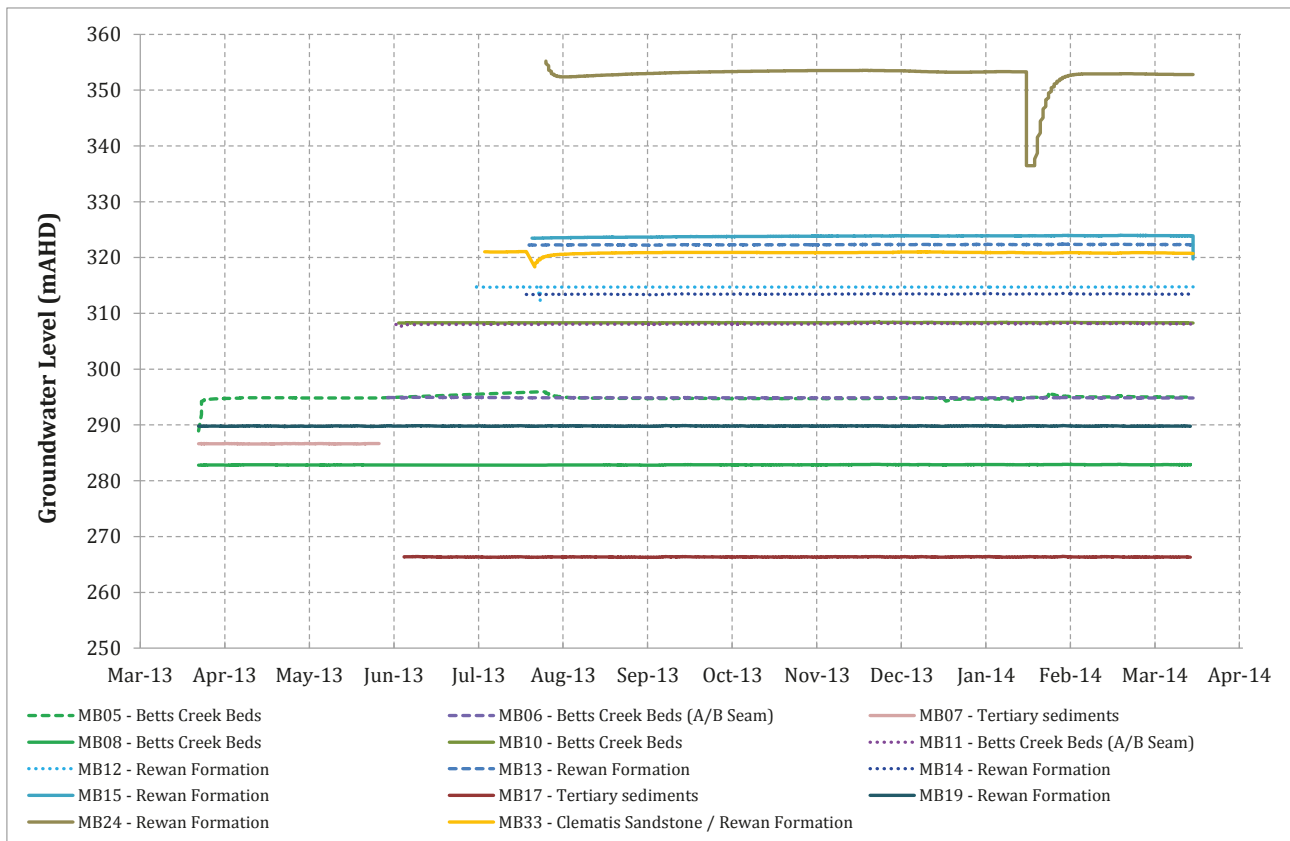
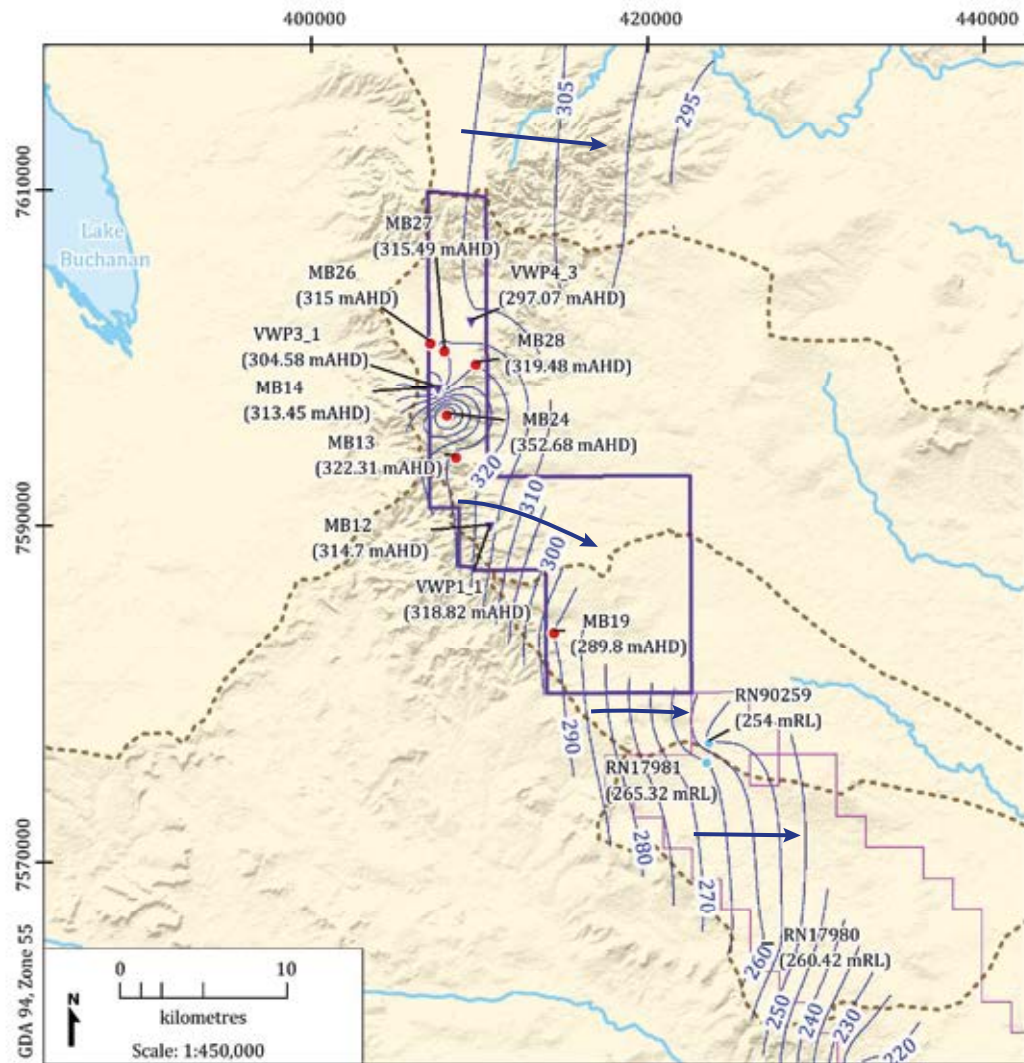


Figure 15 Groundwater level hydrographs

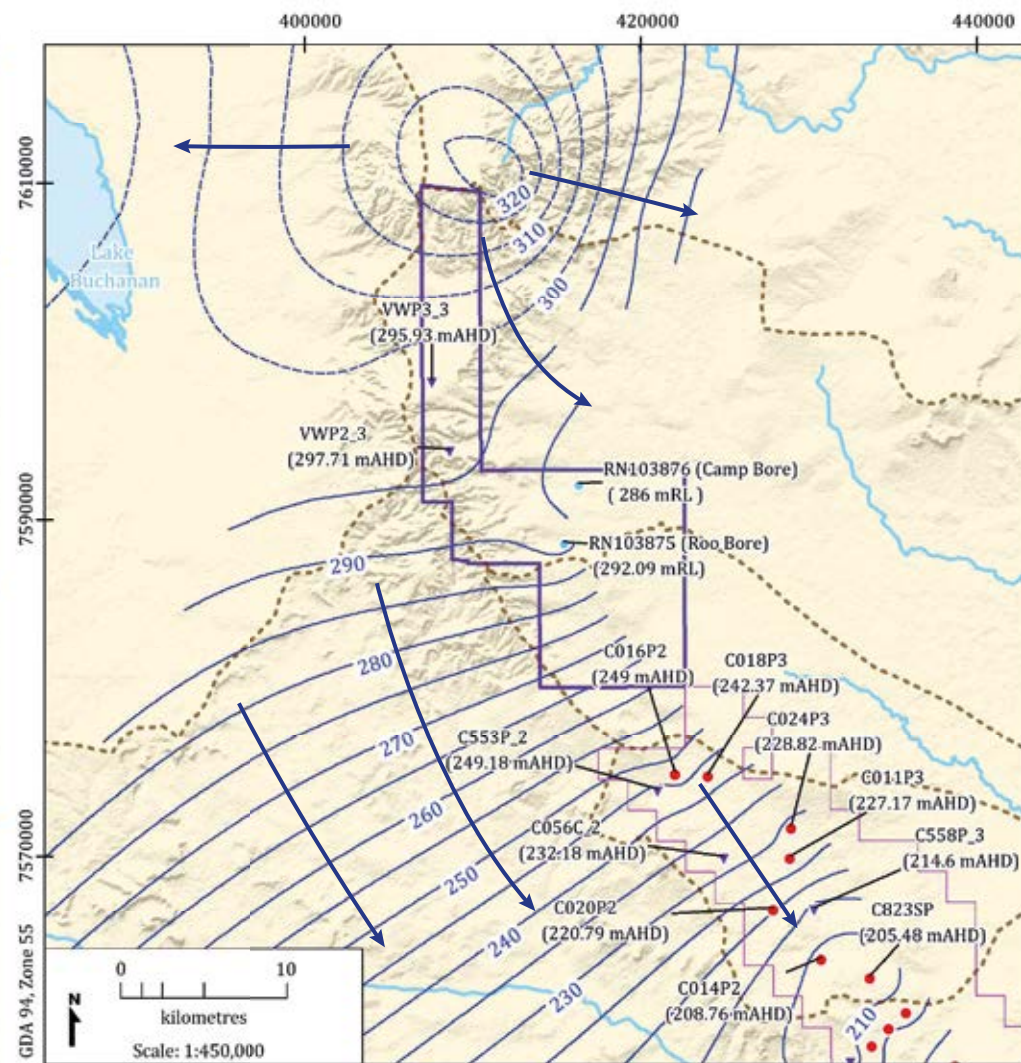
Groundwater Level Contours - Rewan Formation



LEGEND:

- Monitoring bore (groundwater level mAHd)
- ▼ VWP (groundwater level mAHd)
- Private bore (groundwater level mAHd)
- Inferred 5m groundwater level contour (mAHd)
- *** Catchment
- Project site
- Carmichael Coal Mine Project
- Groundwater flow direction

Groundwater Level Contours - Permian stratigraphy



Project China Stone (G1587)

Groundwater Levels
Rewan Formation and Permian stratigraphyDATE:
25/6/2015

FIGURE No:

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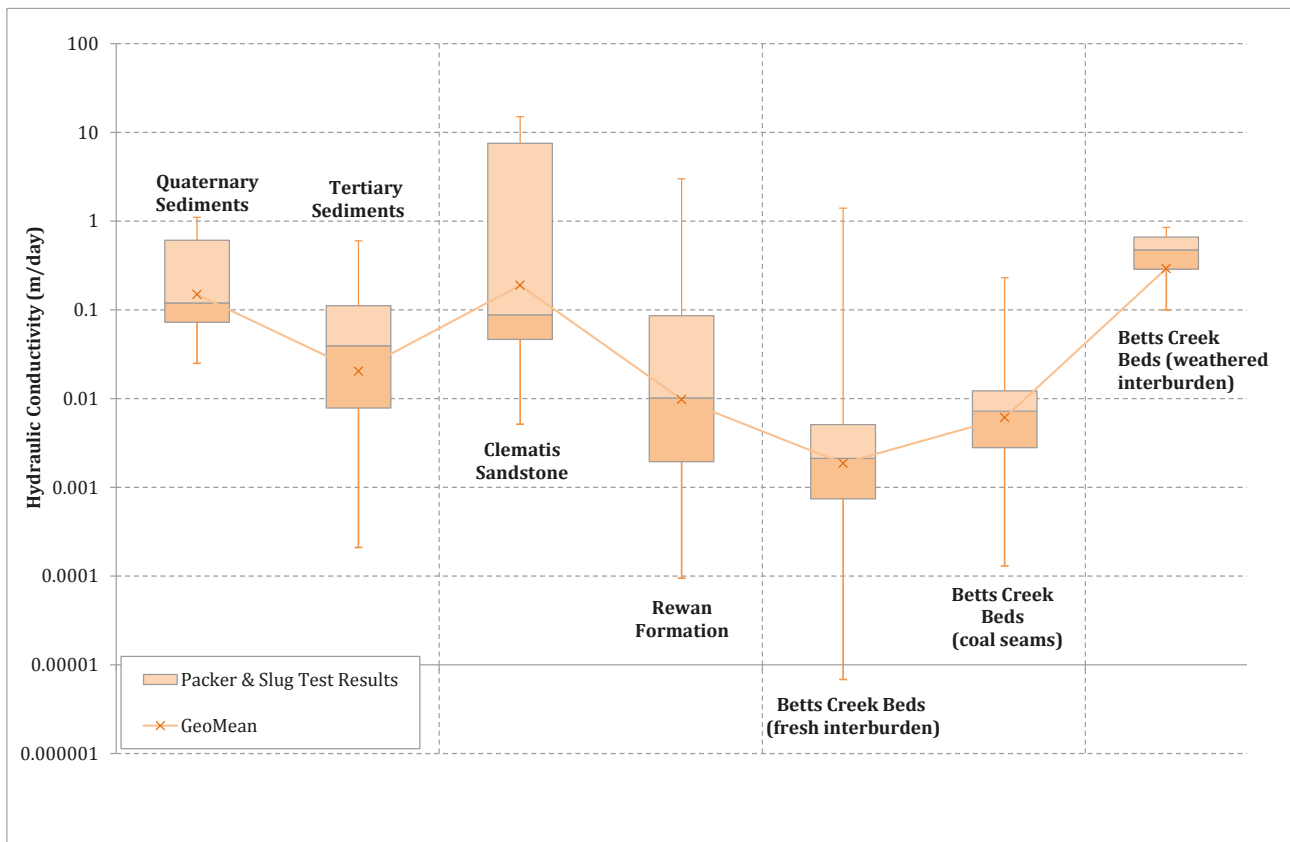


Figure 17 Hydraulic conductivity data

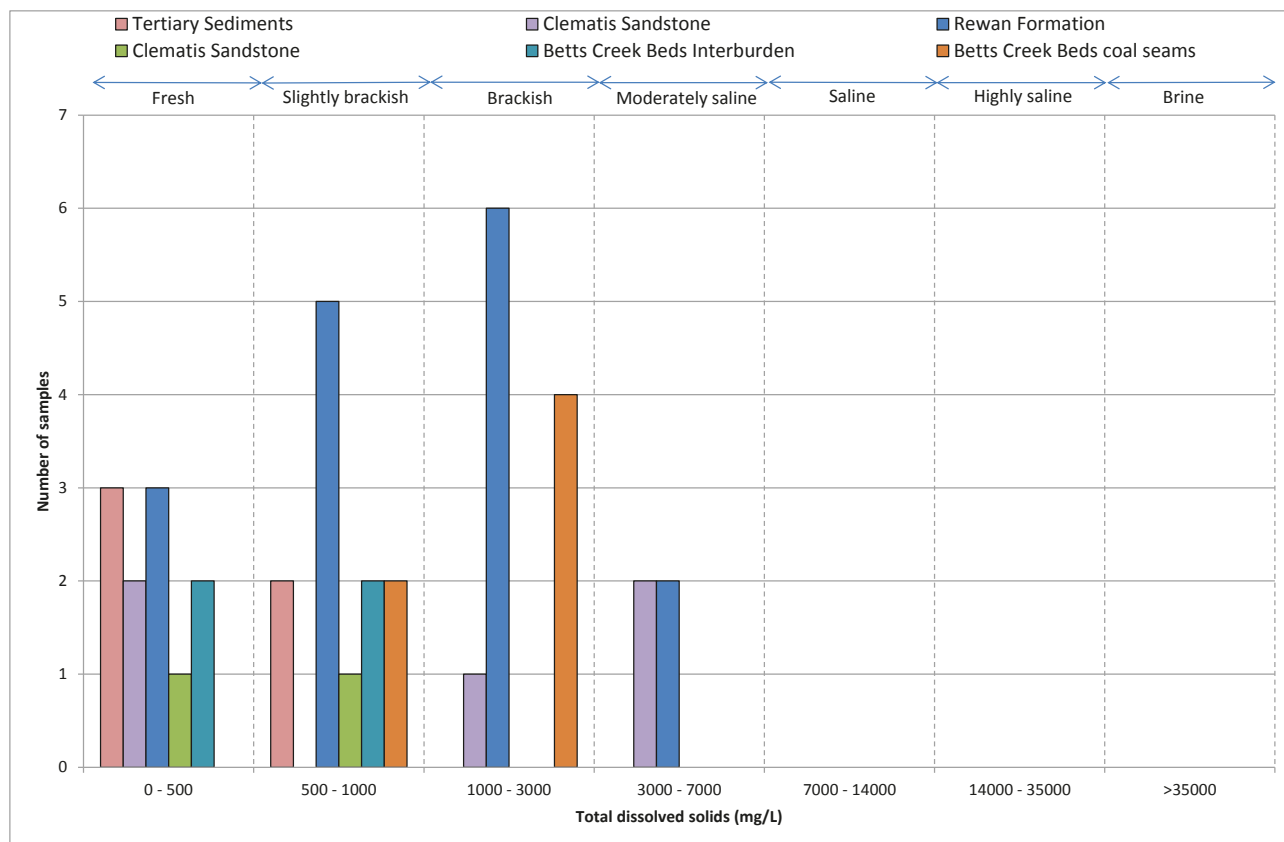
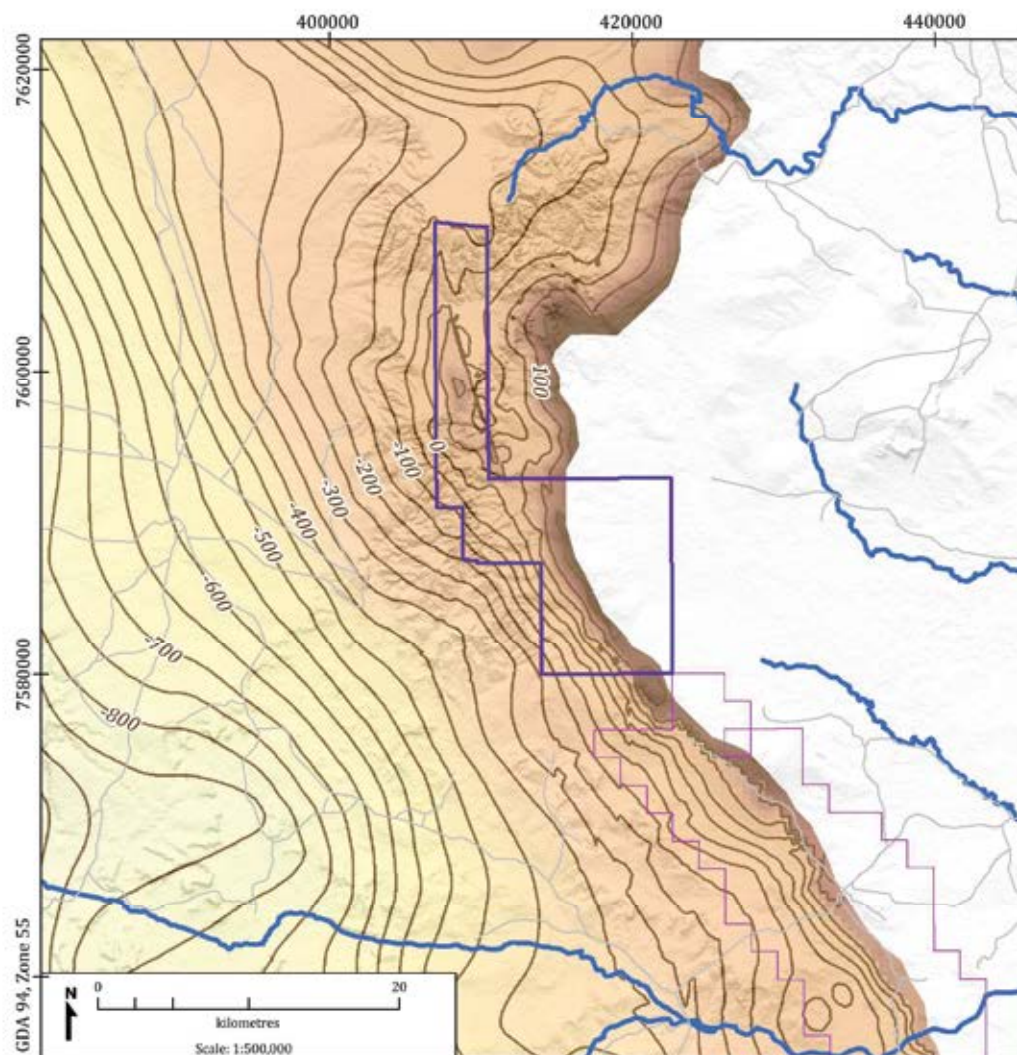
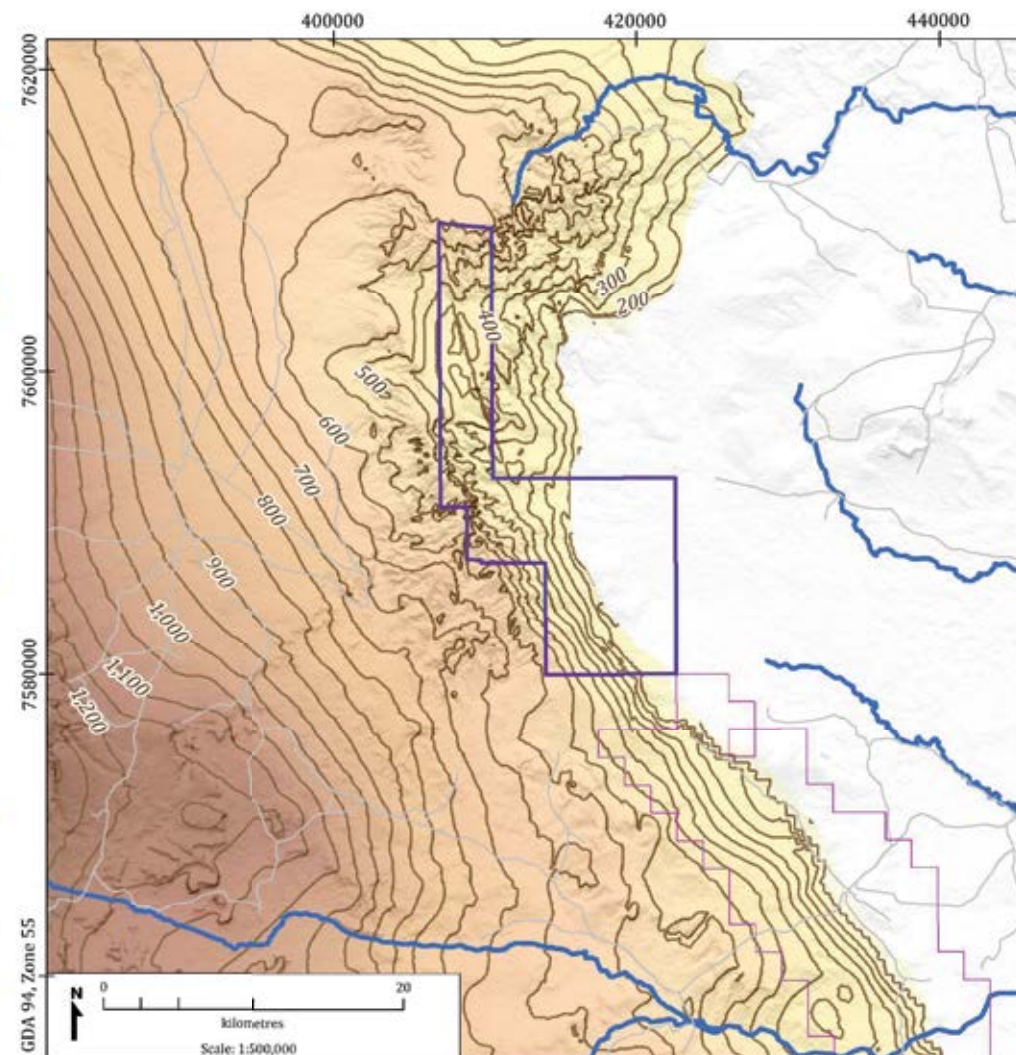


Figure 18 TDS Histogram – all geological units

Permian Betts Creek Beds - structure of base (mAHD)



Permian Betts Creek Beds - depth to base (mBGL)



LEGEND:

- Structure of base contour (50m interval, mAHD)
- Depth to base contour (50m interval, mBGL)
- Project site
- Carmichael Coal Mine Project



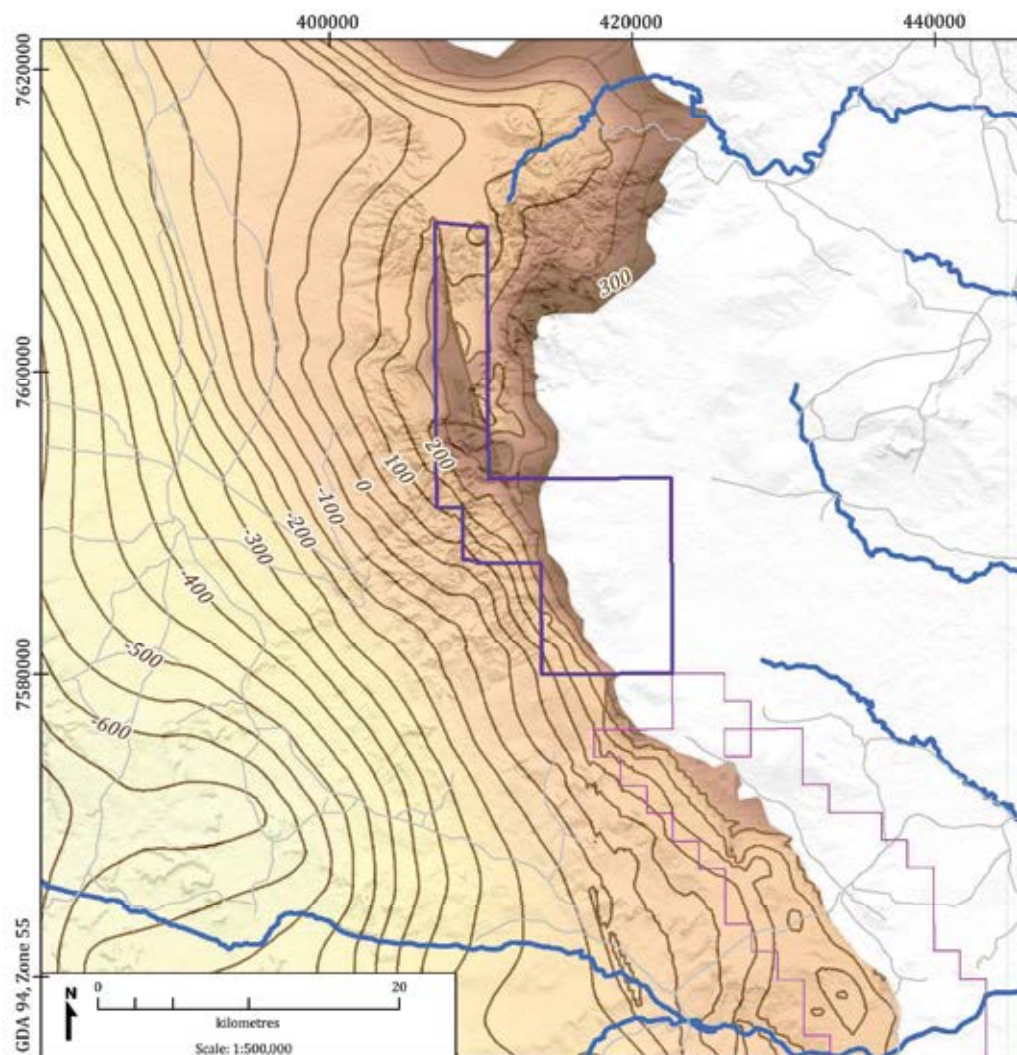
Project China Stone (G1587)

**Permian Betts Creek Beds - structure of base
and depth to base**

DATE:
24/6/2015

HGL/E No:
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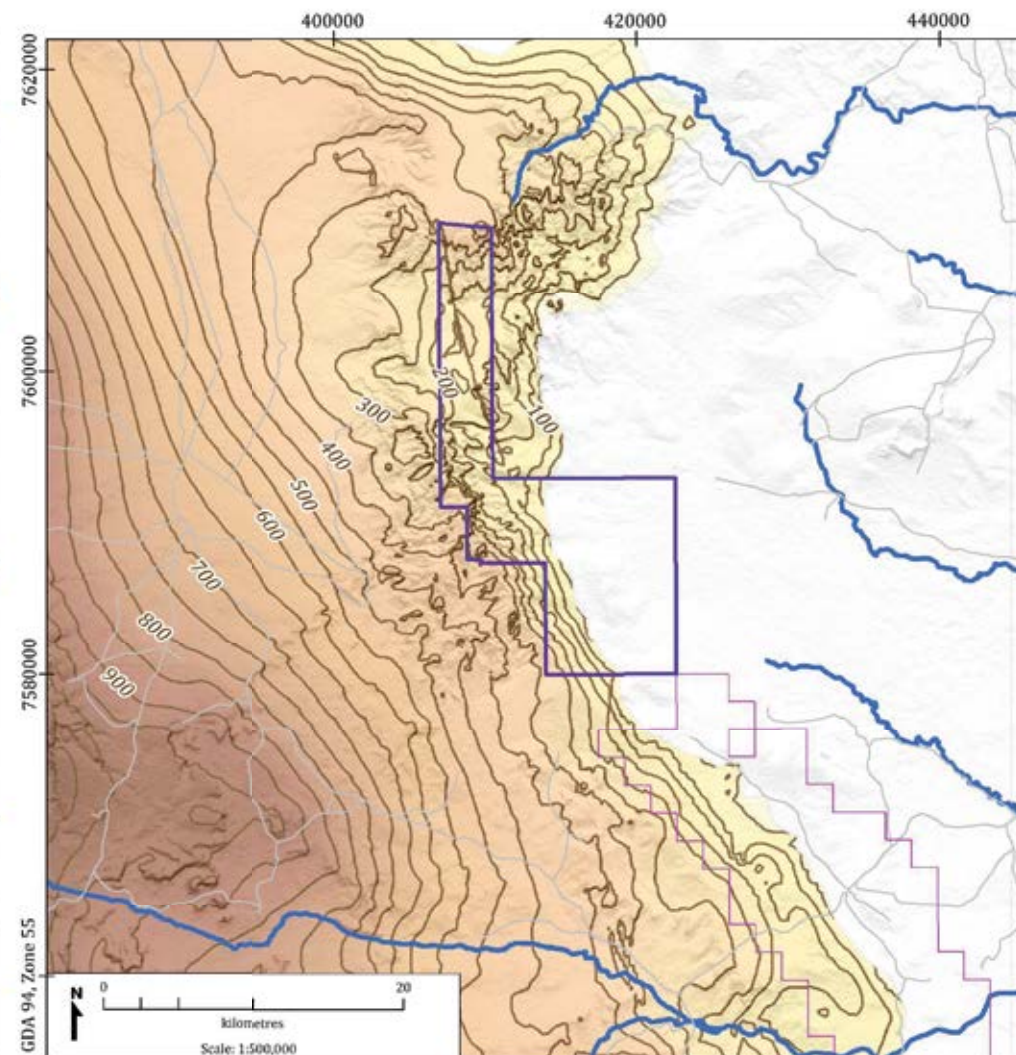
Rewan Formation - structure of base (mAHD)



LEGEND:

- Structure of base contour (50m interval, mAHD)
- Depth to base contour (50m interval, mBGL)
- Project site
- Carmichael Coal Mine Project

Rewan Formation - depth to base (mBGL)



Project China Stone (G1587)

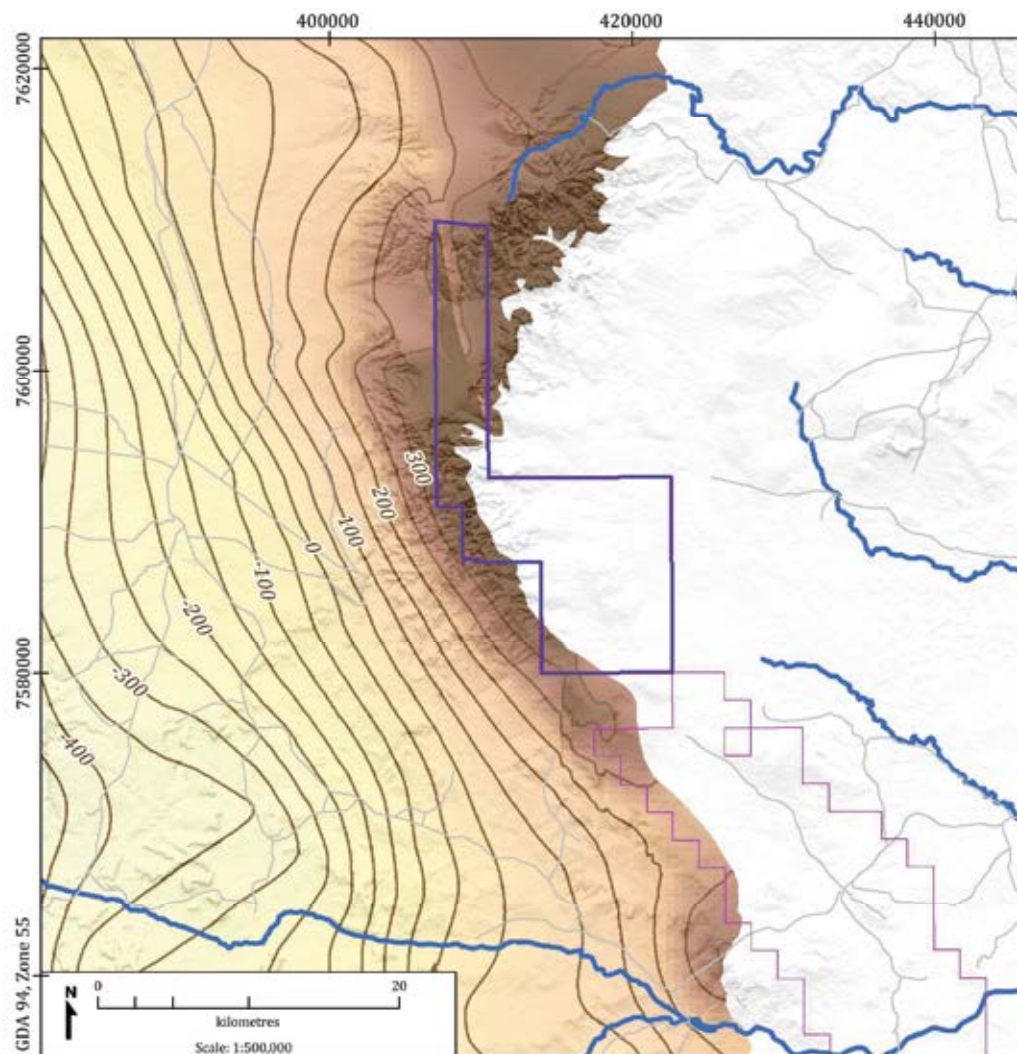


**Rewan Formation - structure of base
and depth to base**

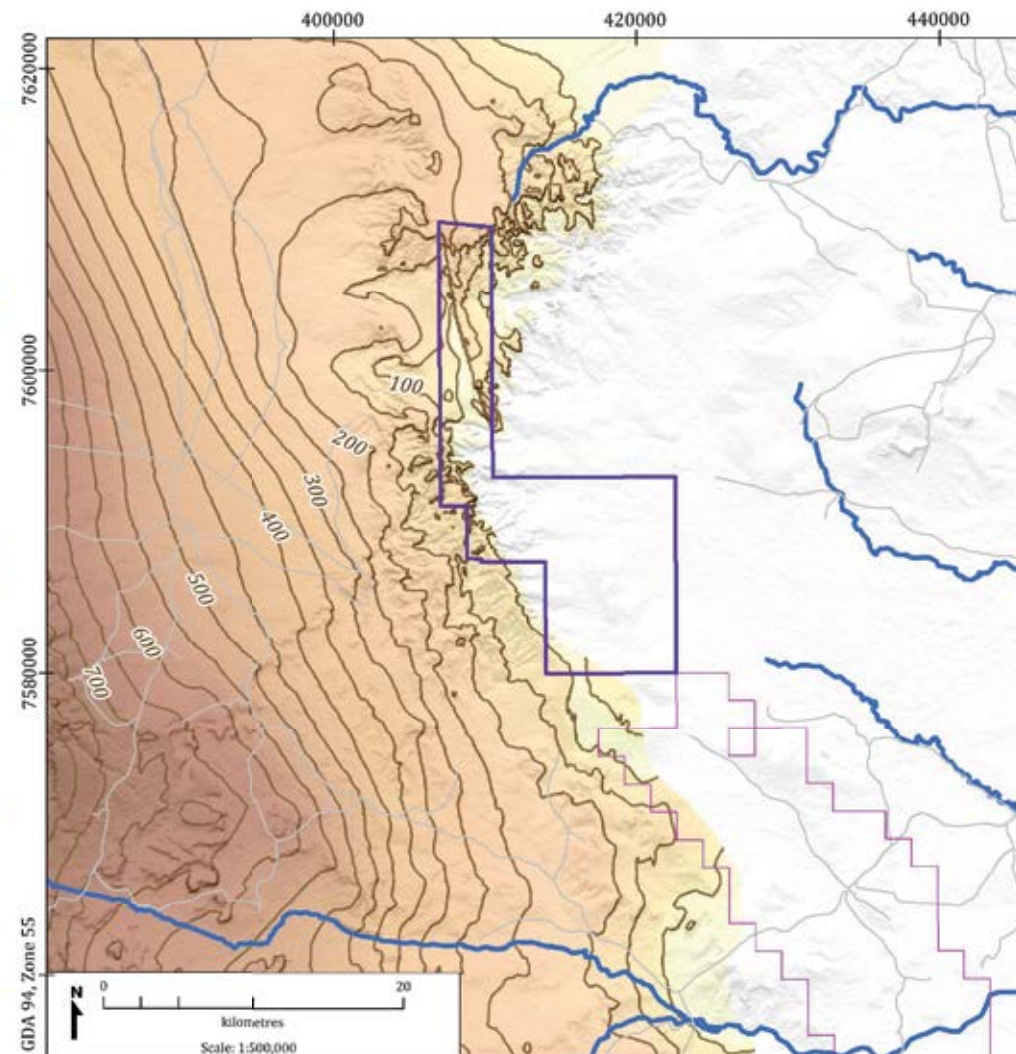
DATE:
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HGLRE No:
20

Clematis Sandstone - structure of base (mAHD)



Clematis Sandstone - depth to base (mBGL)



LEGEND:

- Structure of base contour (50m interval, mAHD)
- Depth to base contour (50m interval, mBGL)
- Project site
- Carmichael Coal Mine Project

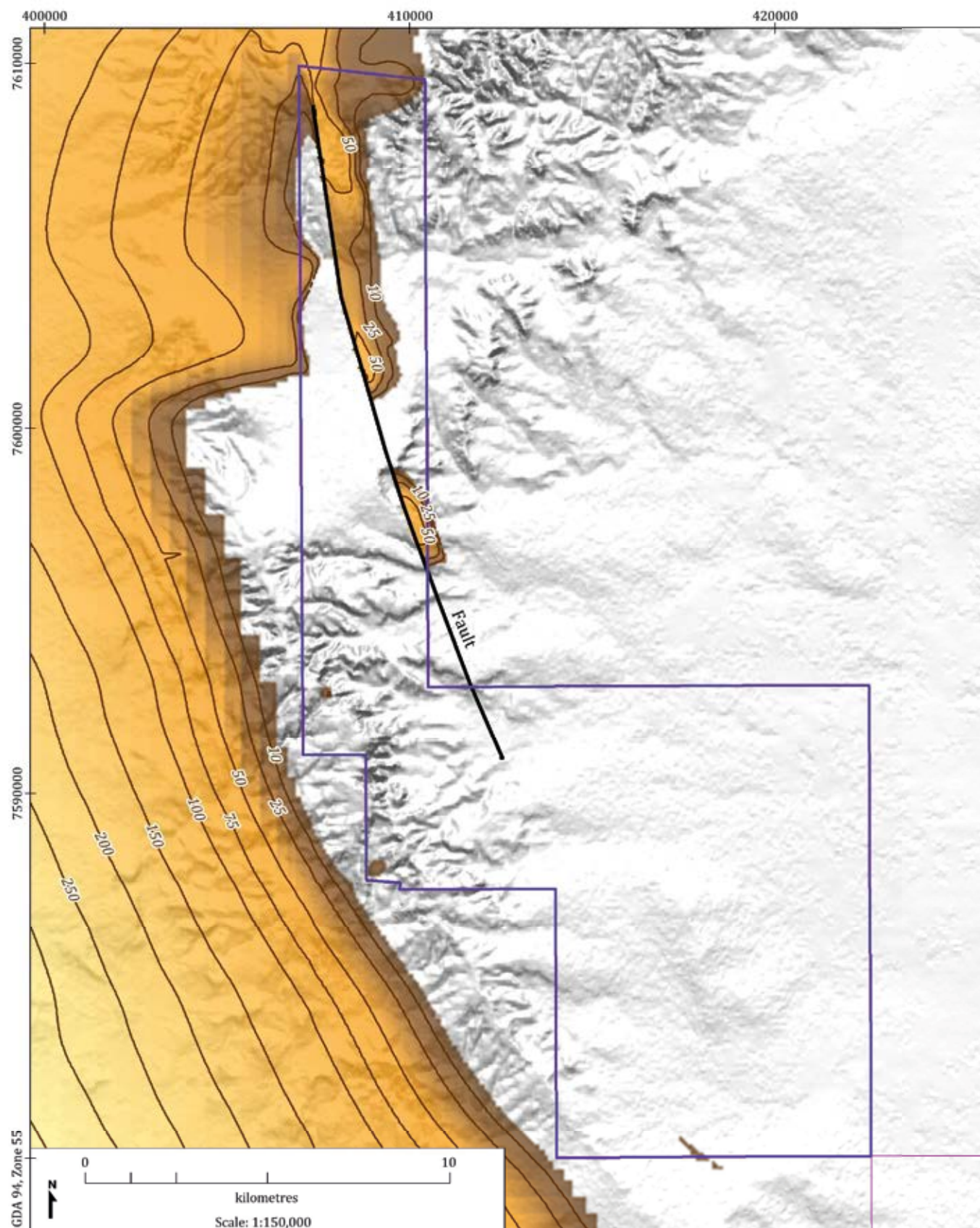


Project China Stone (G1587)

**Clematis Sandstone - structure of base
and depth to base**

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LEGEND:

- Contours
- Fault
- Project site
- Carmichael Coal Mine Project

Project China Stone (G1587)

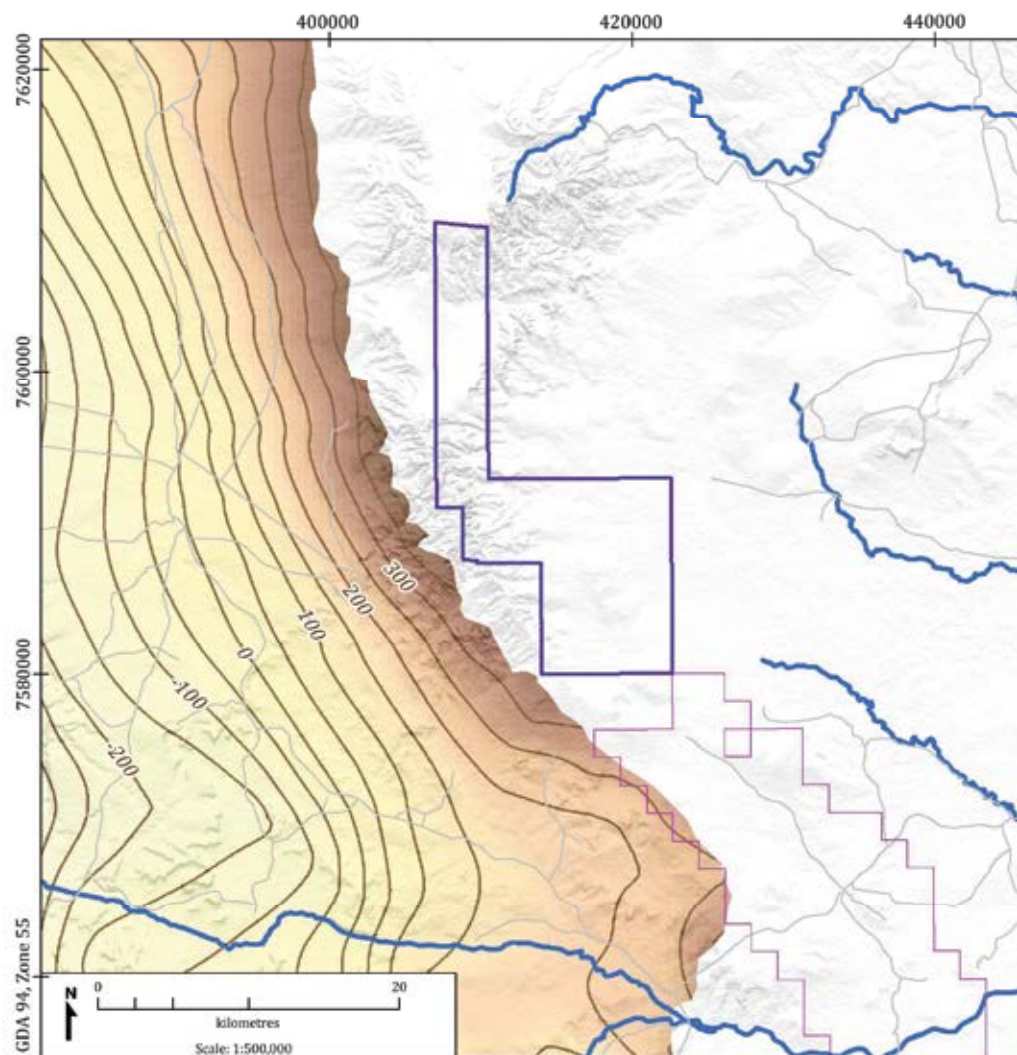
Saturated thickness of Clematis Sandstone



DATE:
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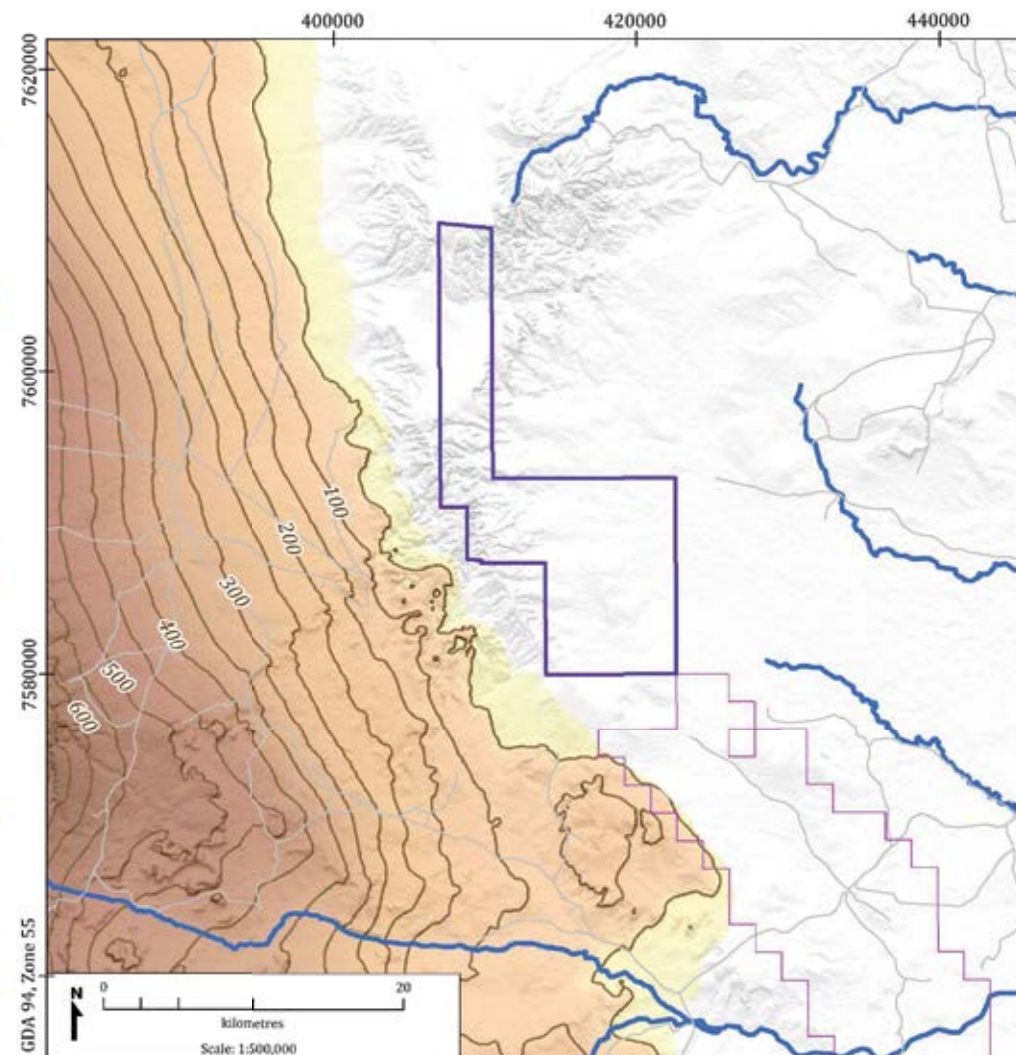
Moolayember Formation - structure of base (mAHD)



LEGEND:

- Structure of base contour (50m interval, mAHD)
- Depth to base contour (50m interval, mBGL)
- Project site
- Carmichael Coal Mine Project

Moolayember Formation - depth to base (mBGL)



Project China Stone (G1587)

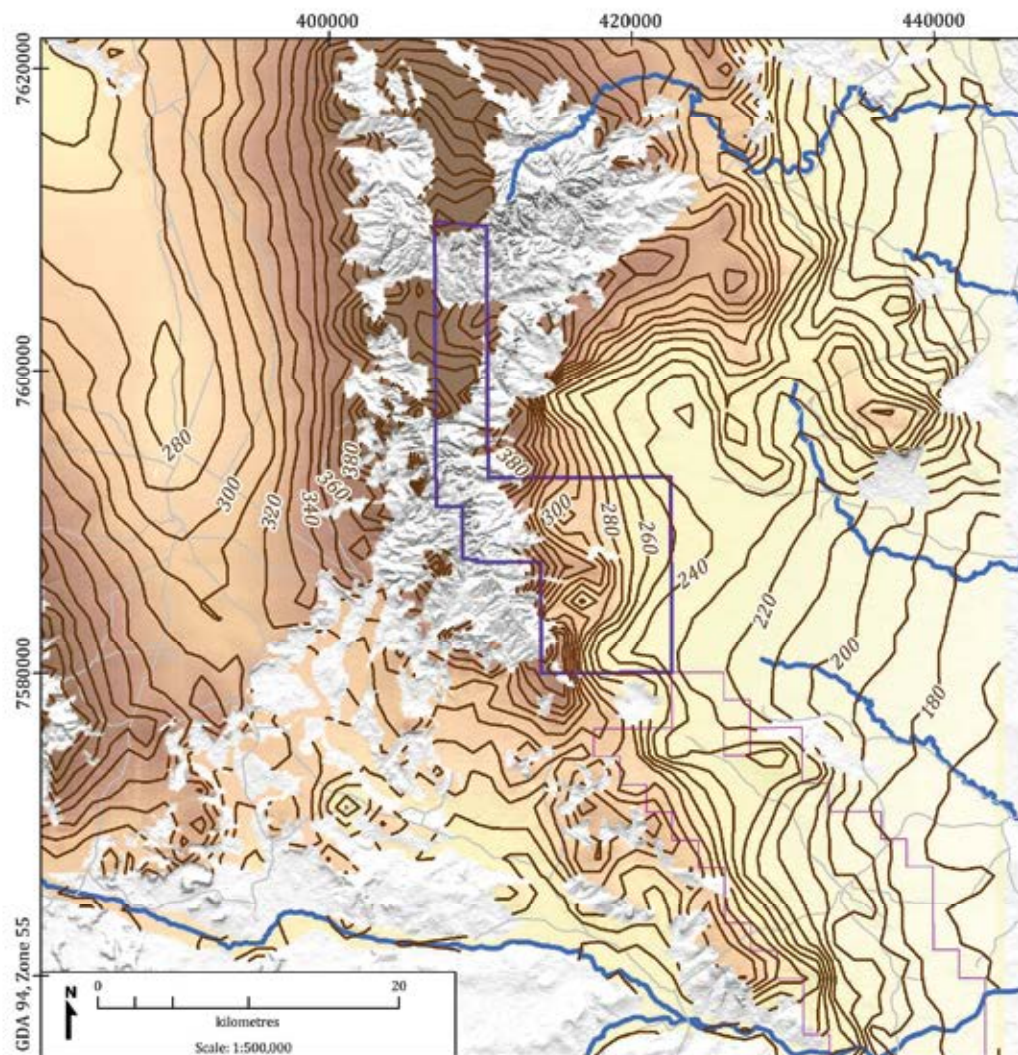


**Moolayember Formation - structure of base
and depth to base**

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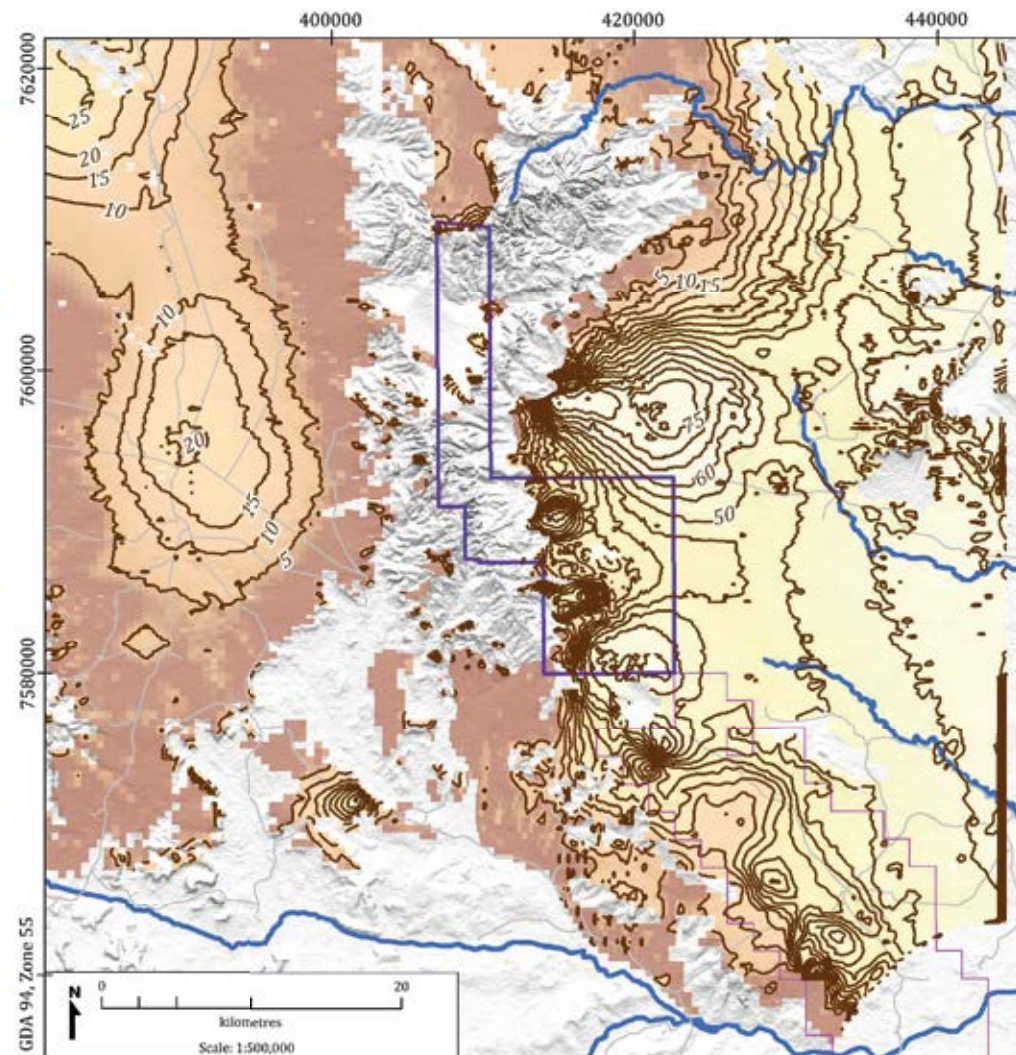
Tertiary Sediments - structure of base (mAHD)



LEGEND:

- Structure of base contour (10m interval, mAHD)
- Depth to base contour (5m interval, m)
- Project site
- Carmichael Coal Mine Project

Tertiary Sediments - depth to base (m)



Project China Stone (G1587)



**Tertiary Sediments - structure of base
and depth to base**

DATE:
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FIGURE No:
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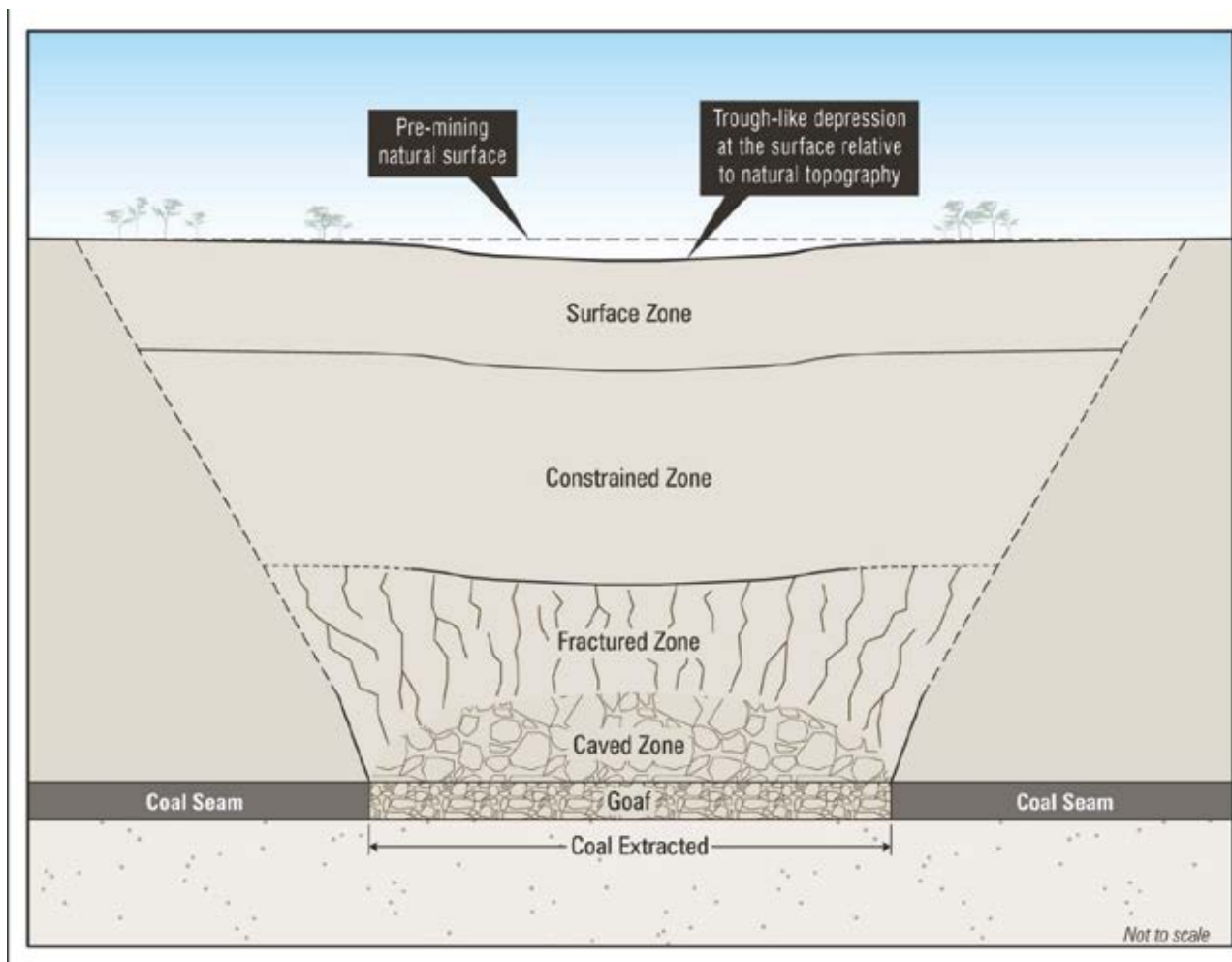
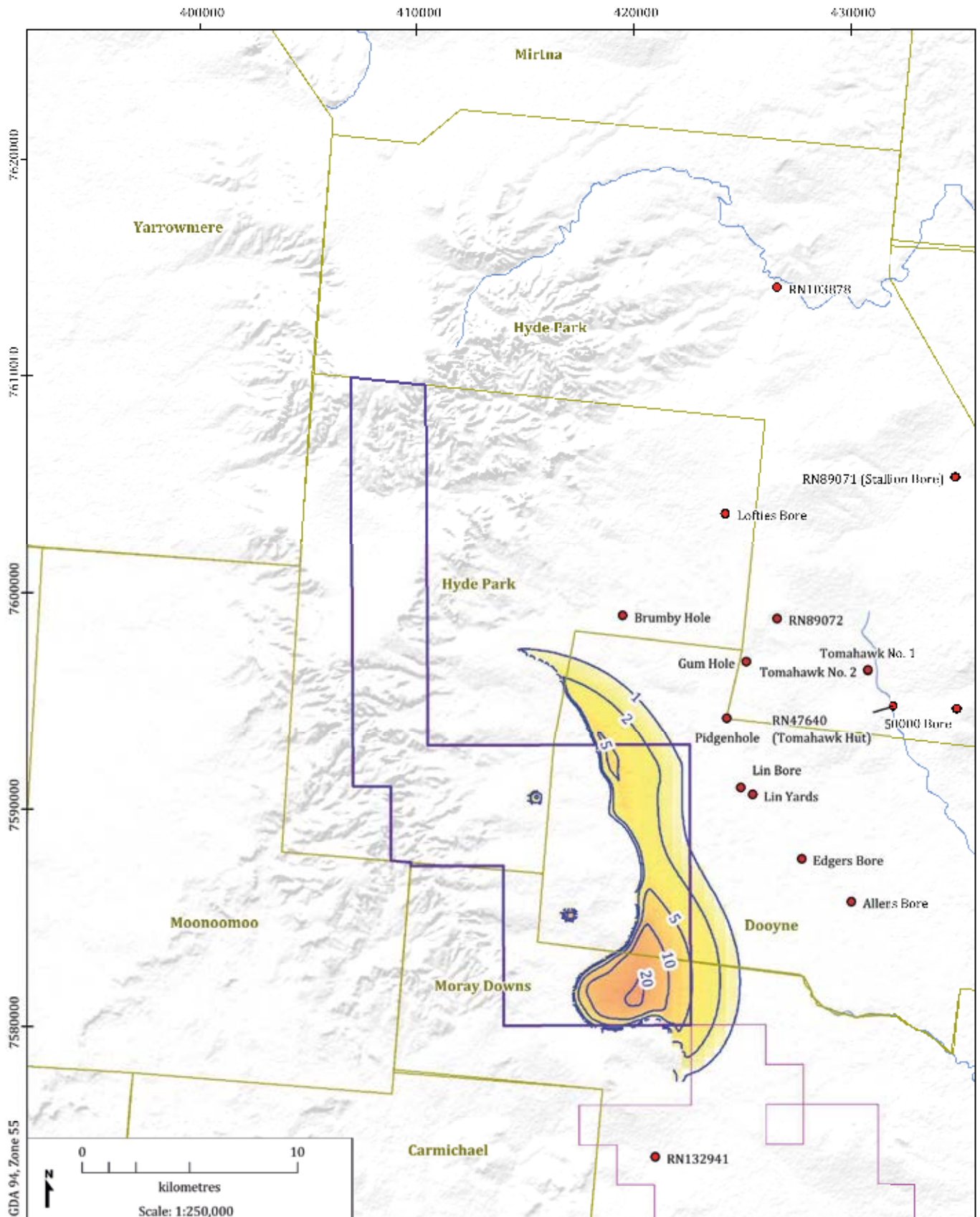


**Figure 26 Conceptual model of caving and the nature of fracturing above a mine excavation
(source Hansen Bailey)**



LEGEND:

- Maximum Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

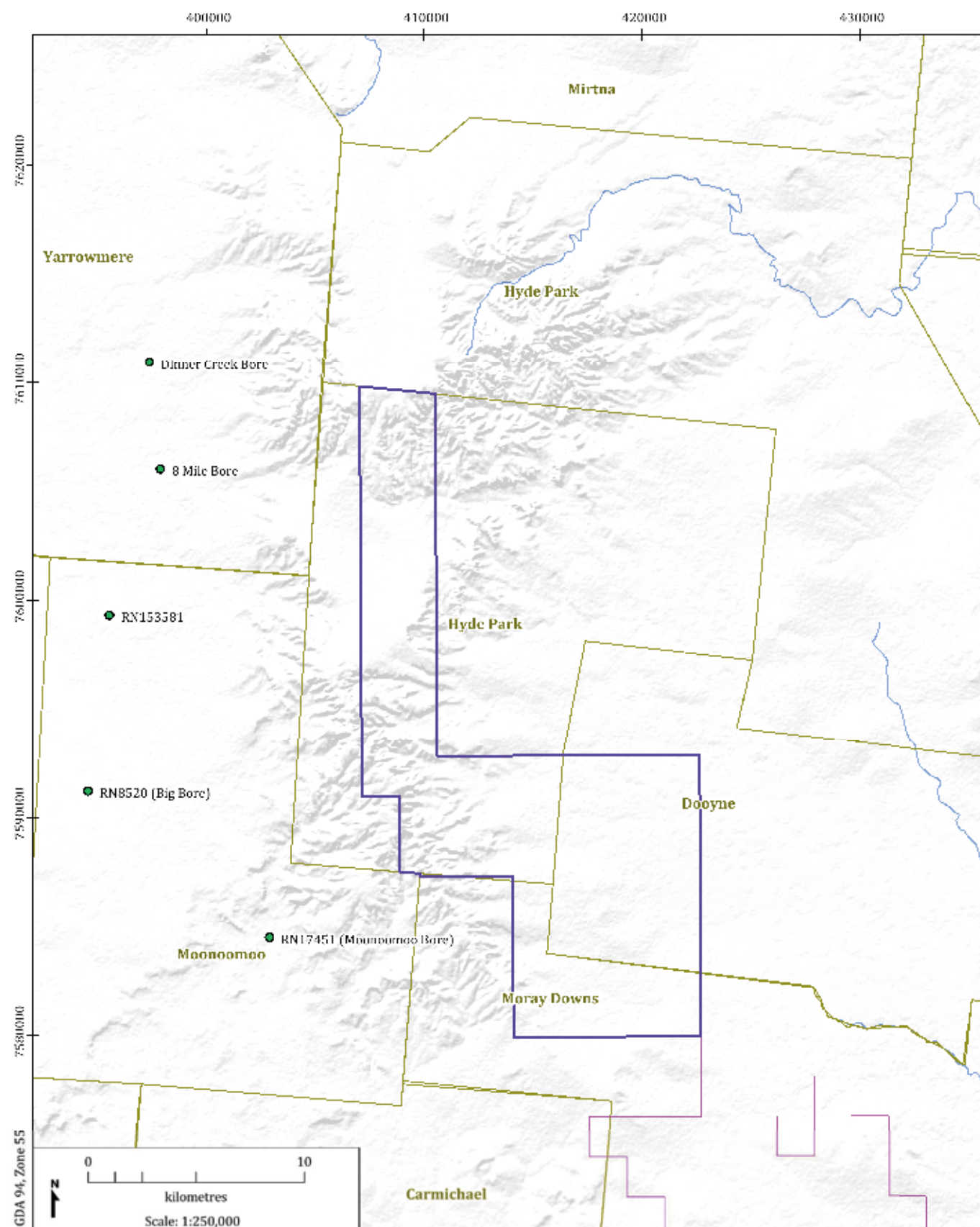
Project China Stone (G1587)

Maximum zone of depressurisation during mining - Tertiary Sediments



DATE:
24/6/2015

FIGURE No:
27



LEGEND:

(No contour for this layer)

- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

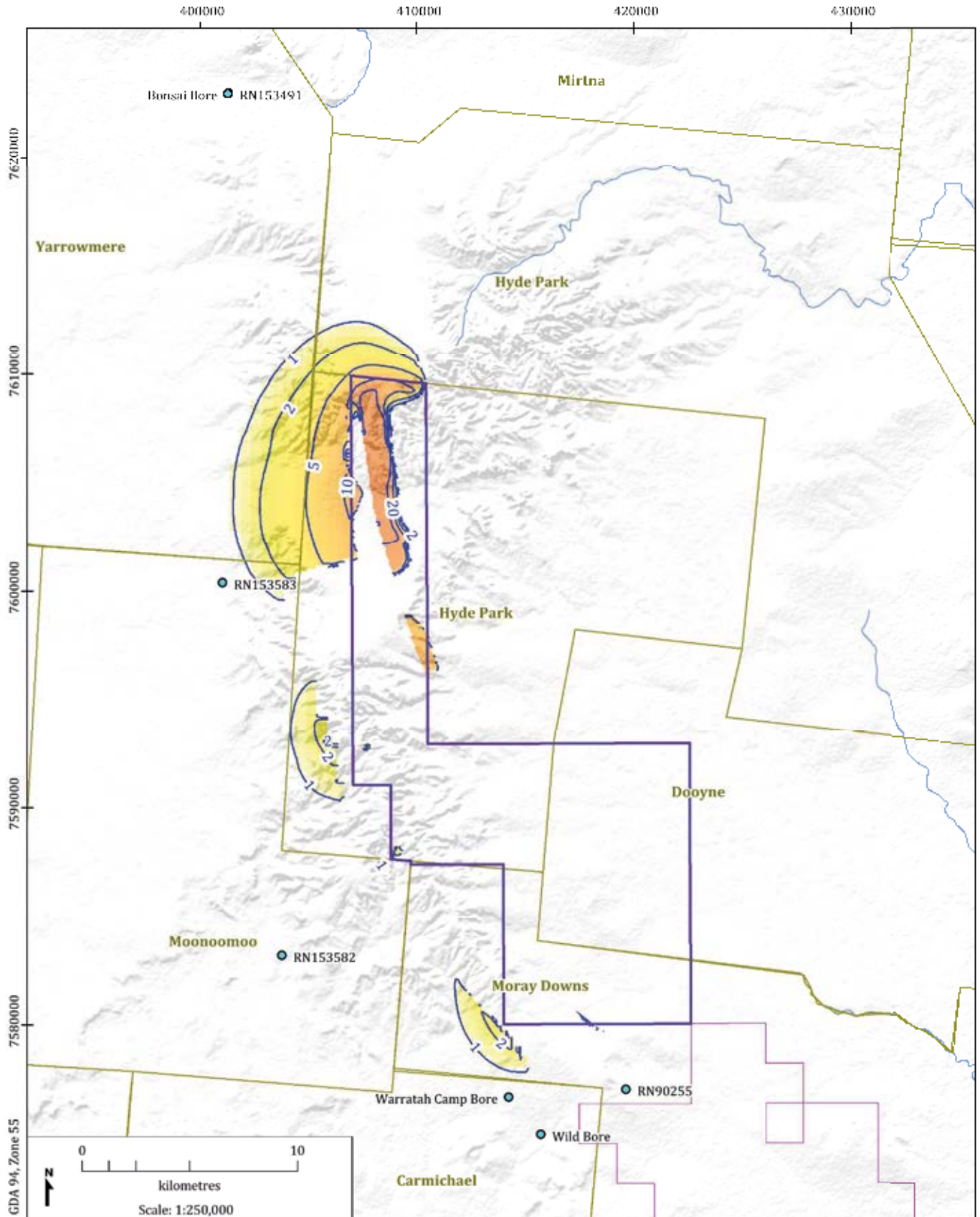
Project China Stone (G1587)

Maximum zone of depressurisation during mining - Moolayember Formation



DATE:
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FIGURE No:
28



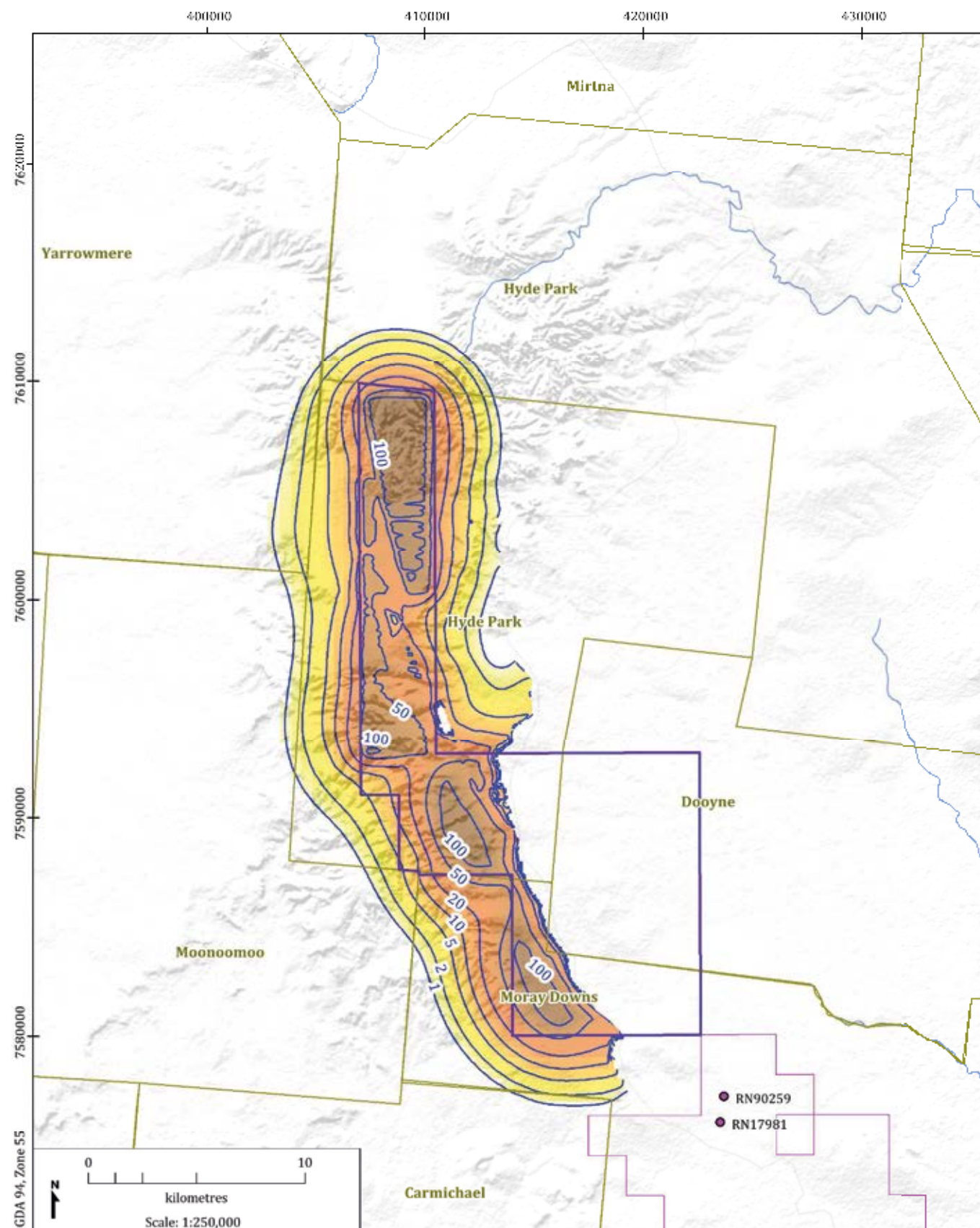
Project China Stone (G1587)

Maximum zone of depressurisation during mining - Clematis Sandstone



DATE:
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FIGURE No. **29**



LEGEND:

- Maximum Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

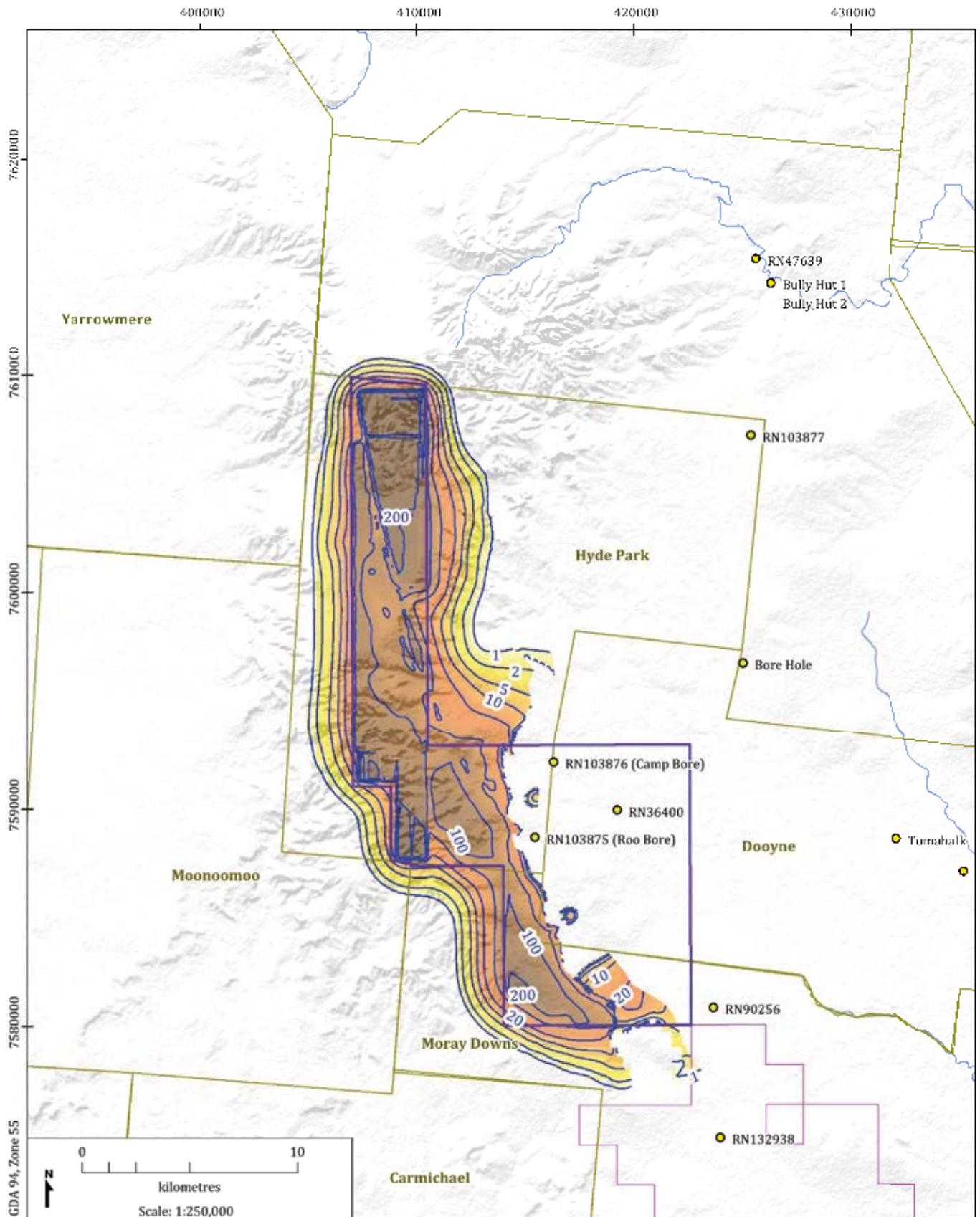
Project China Stone (G1587)

Maximum zone of depressurisation during mining - Rewan Formation



DATE:
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FIGURE No:
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LEGEND:

- Maximum Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

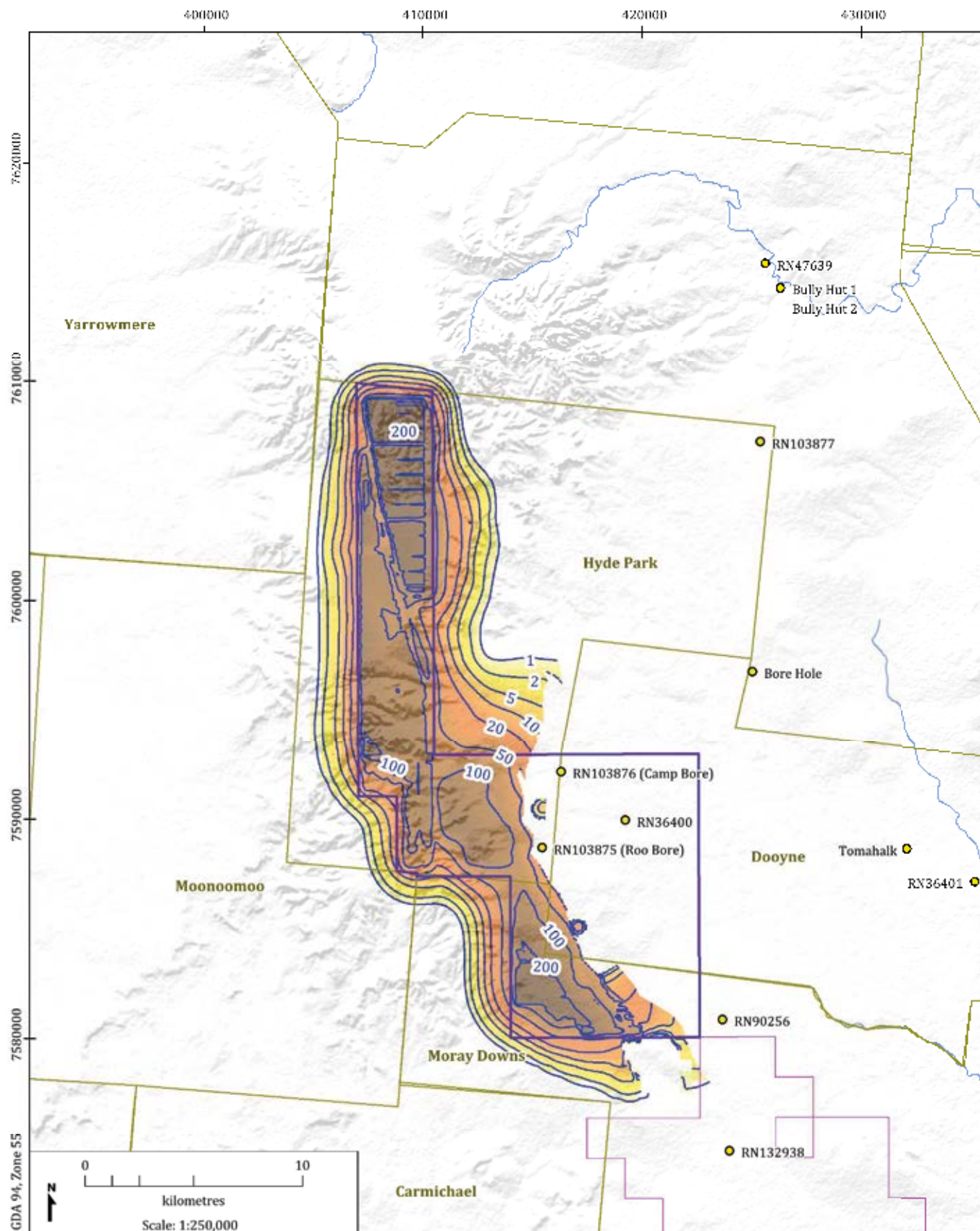
Project China Stone (G1587)

Maximum zone of depressurisation during mining - A seam and Betts Creek Beds



DATE:
24/6/2015

FIGURE No:
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LEGEND:

— Maximum Drawdown contour (m)

◆ Private bore

— Project site

— Carmichael Coal Mine Project

— Major drainage

— Cadastre

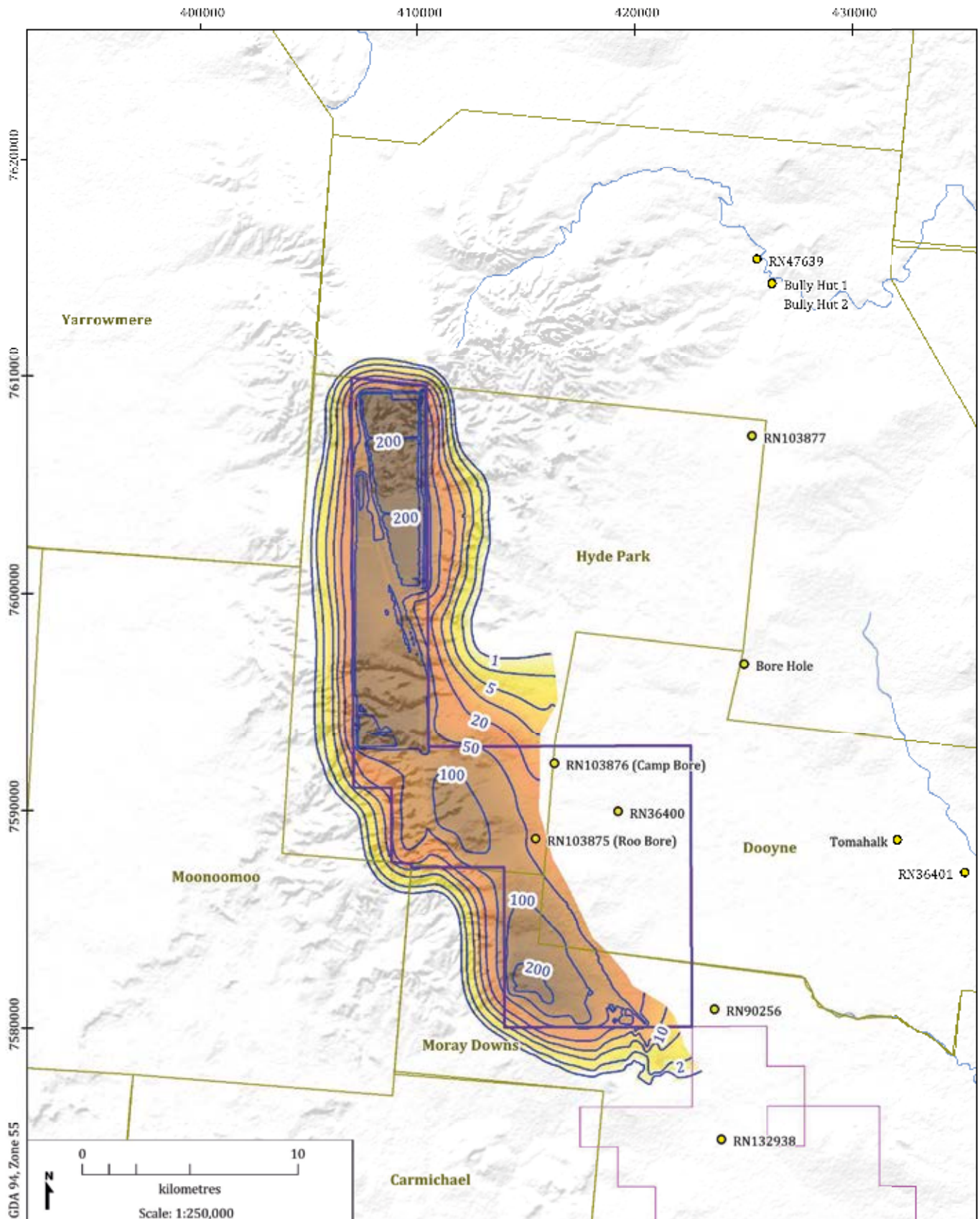
Project China Stone (G1587)

**Maximum zone of depressurisation
during mining - C seam/Betts Creek Beds**



DATE:
24/6/2015

FIGURE No:
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LEGEND:

— Maximum Drawdown contour (m)

● Private bore

— Project site

— Carmichael Coal Mine Project

— Major drainage

□ Cadastre

Project China Stone (G1587)

**Maximum zone of depressurisation
during mining - D seam/Betts Creek Beds**



DATE:
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FIGURE No:

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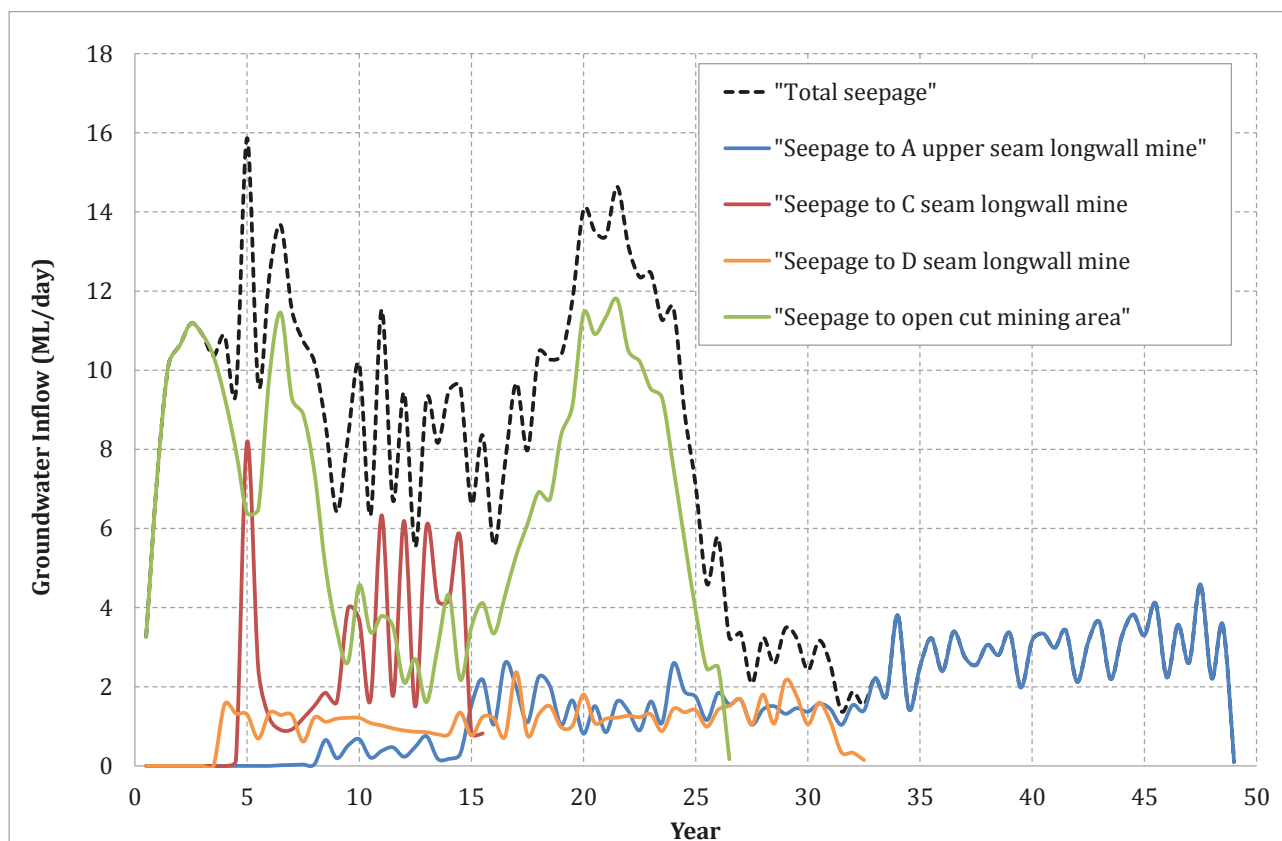
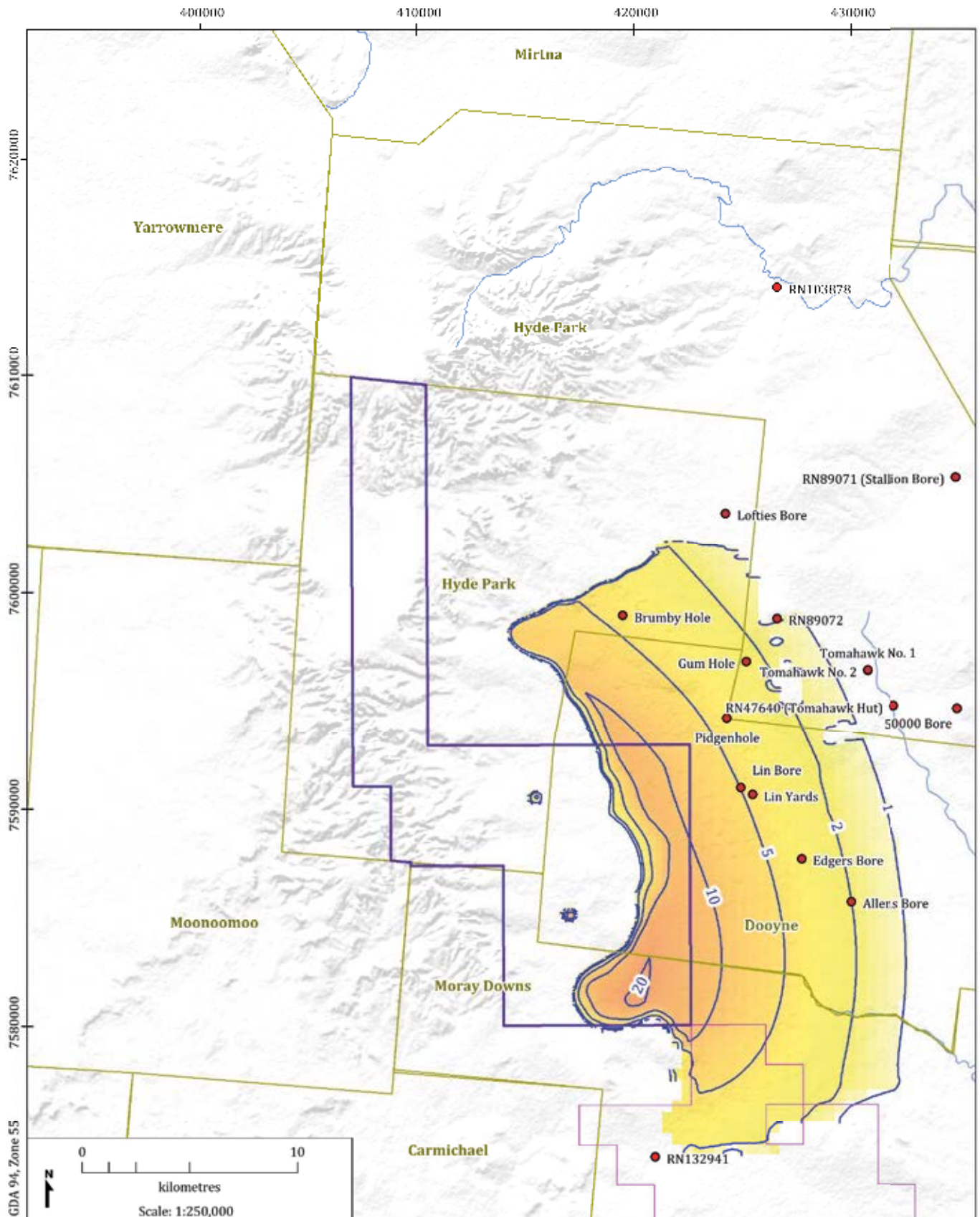


Figure 34 Simulated seepage into proposed mining areas



LEGEND:

- Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

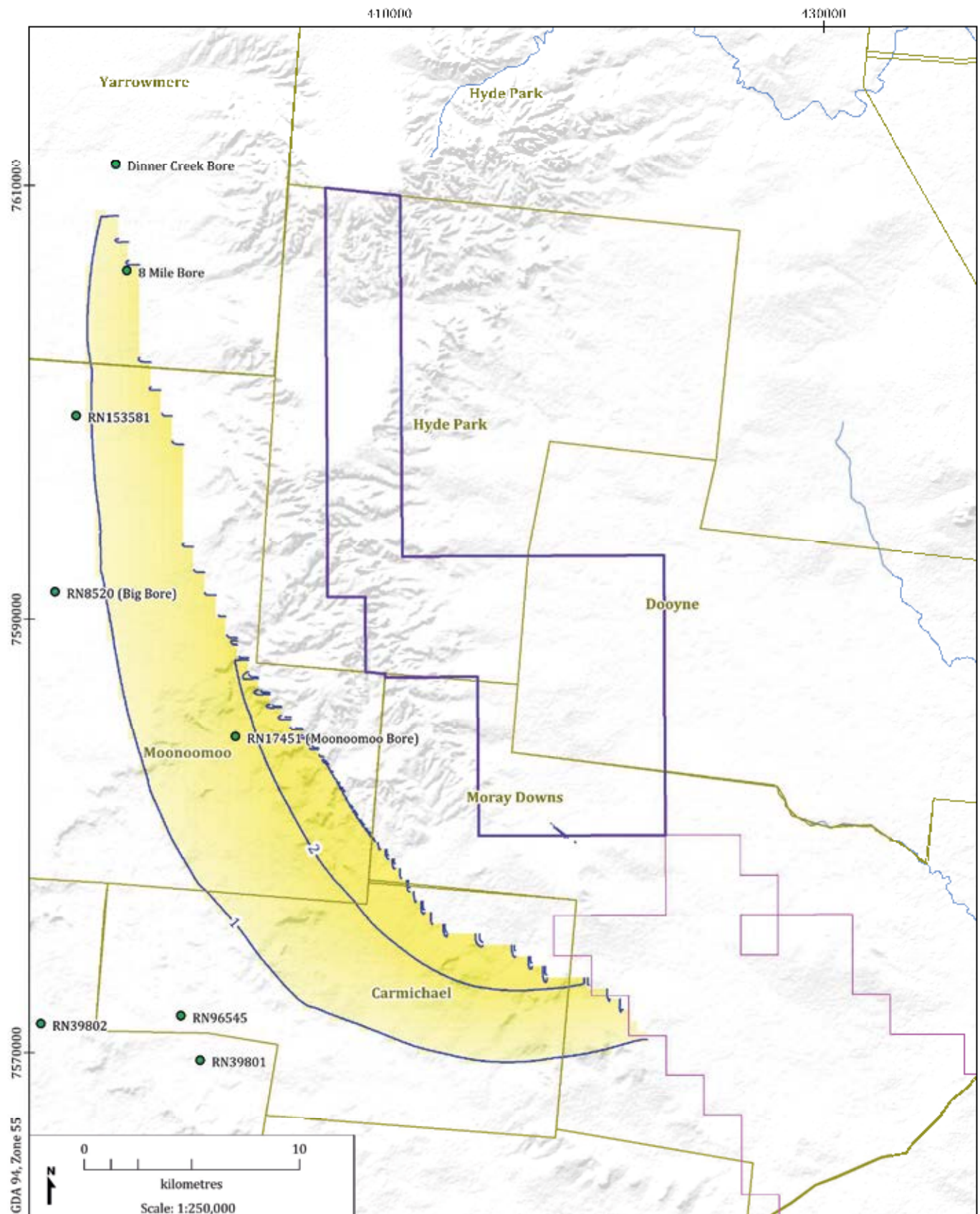
Project China Stone (G1587)

Zone of depressurisation - Tertiary Sediments - post mining



DATE:
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FIGURE No:
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LEGEND:

- Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

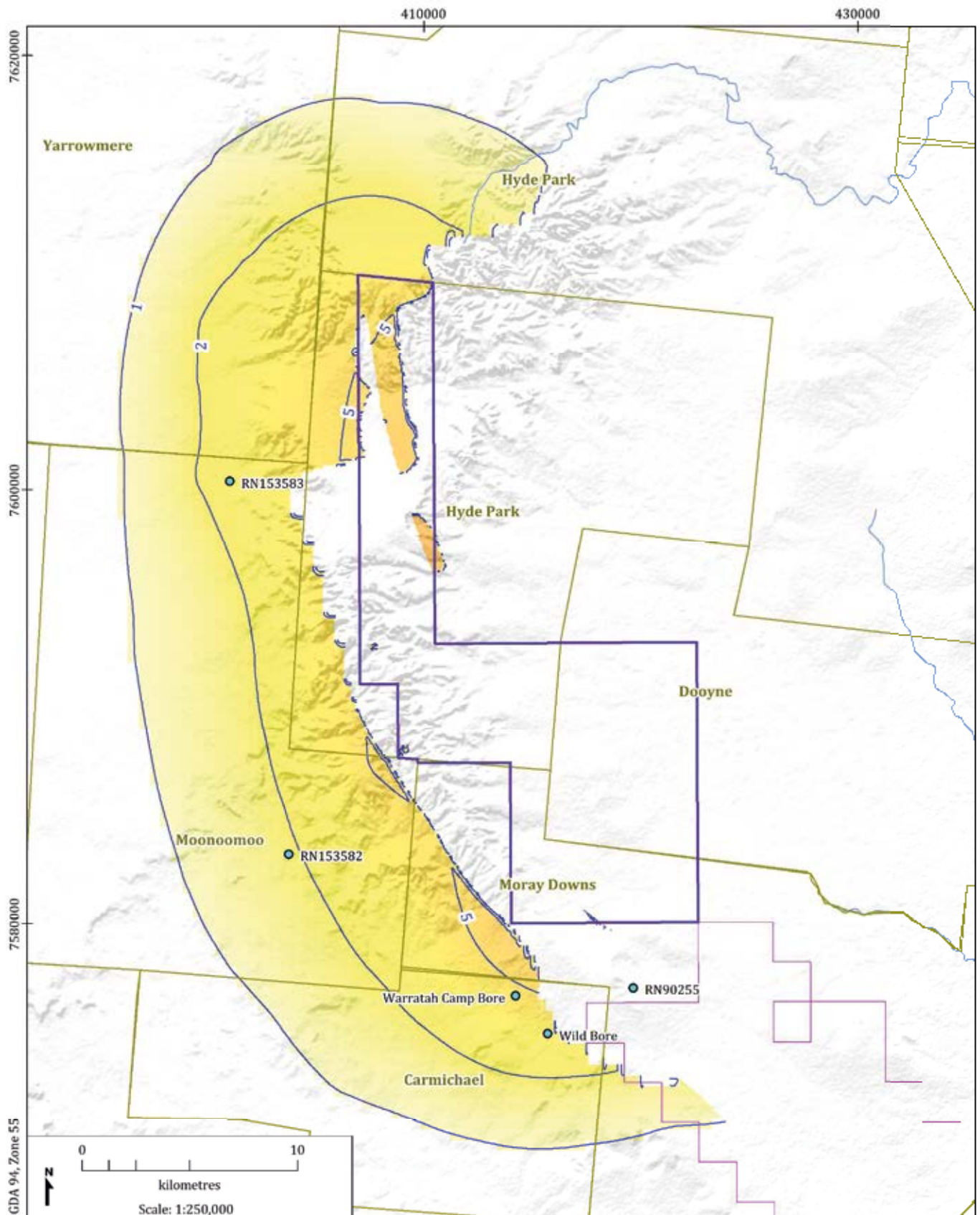
Project China Stone (G1587)

**Zone of depressurisation - Moolayember
Formation - post mining**



DATE:
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FIGURE No:
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LEGEND:

- Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

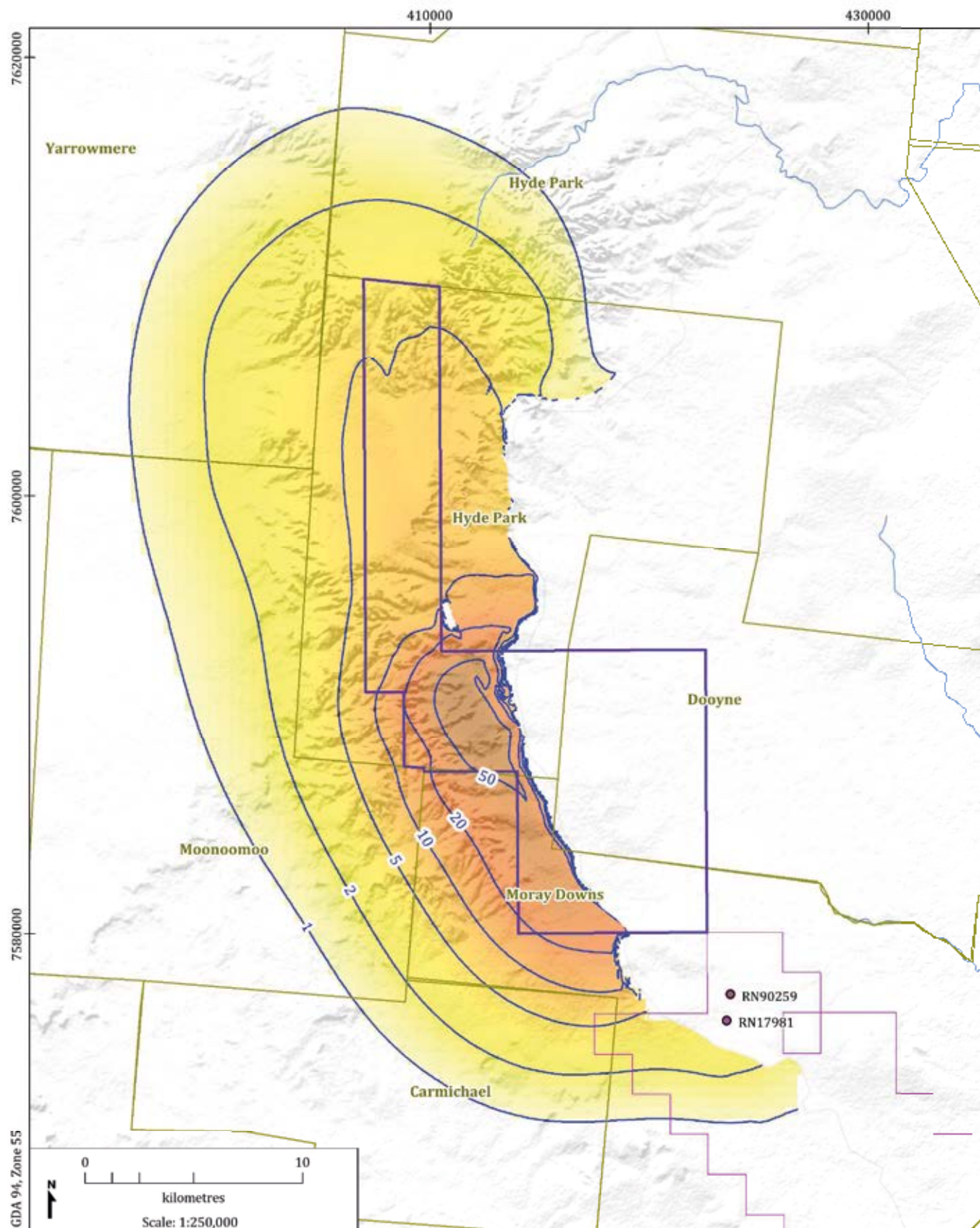
Project China Stone (G1587)

Zone of depressurisation - Clematis Sandstone - post mining



DATE:
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FIGURE No:
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LEGEND:

- Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

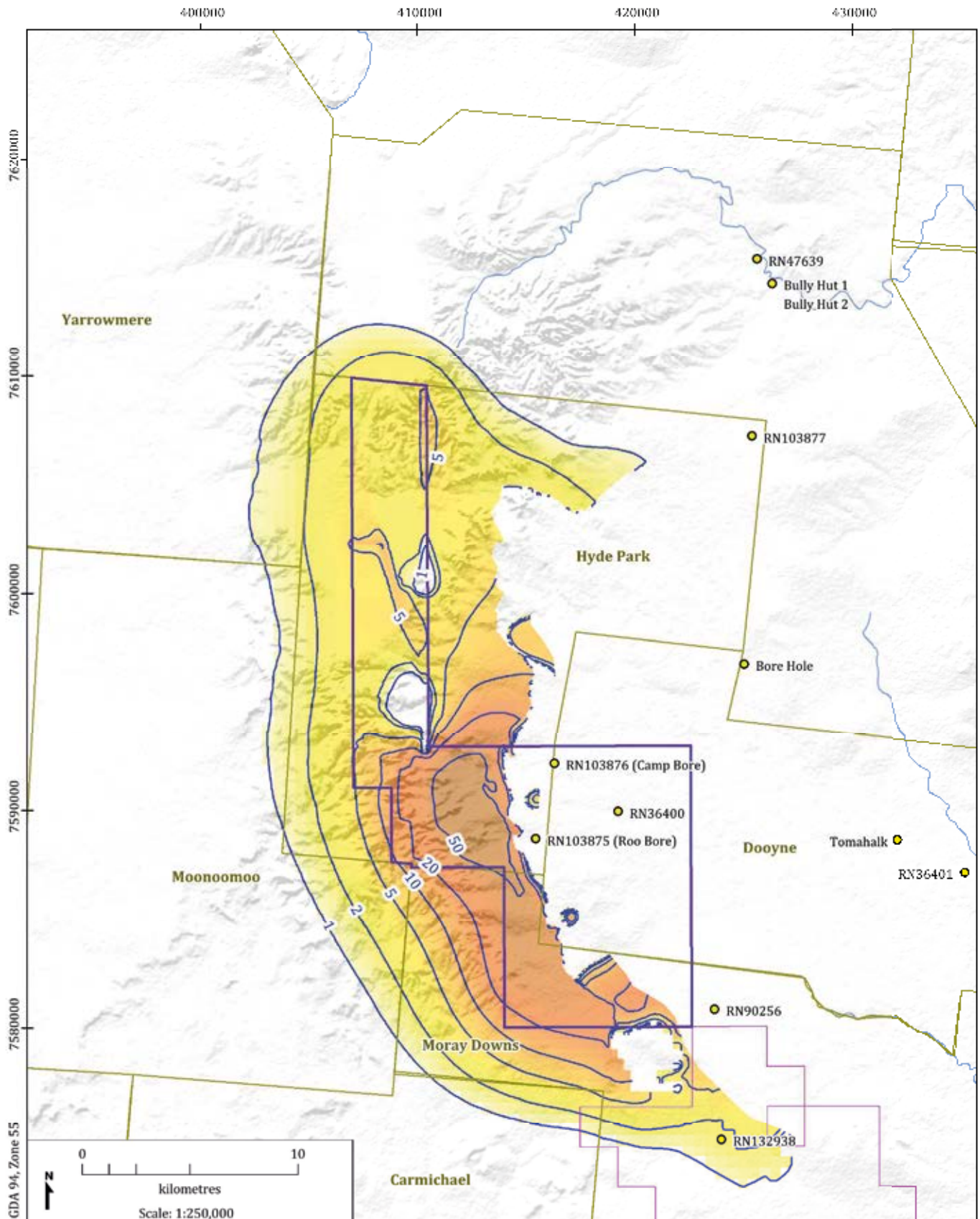
Project China Stone (G1587)

Zone of depressurisation - Rewan Formation - post mining



DATE:
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FIGURE No:
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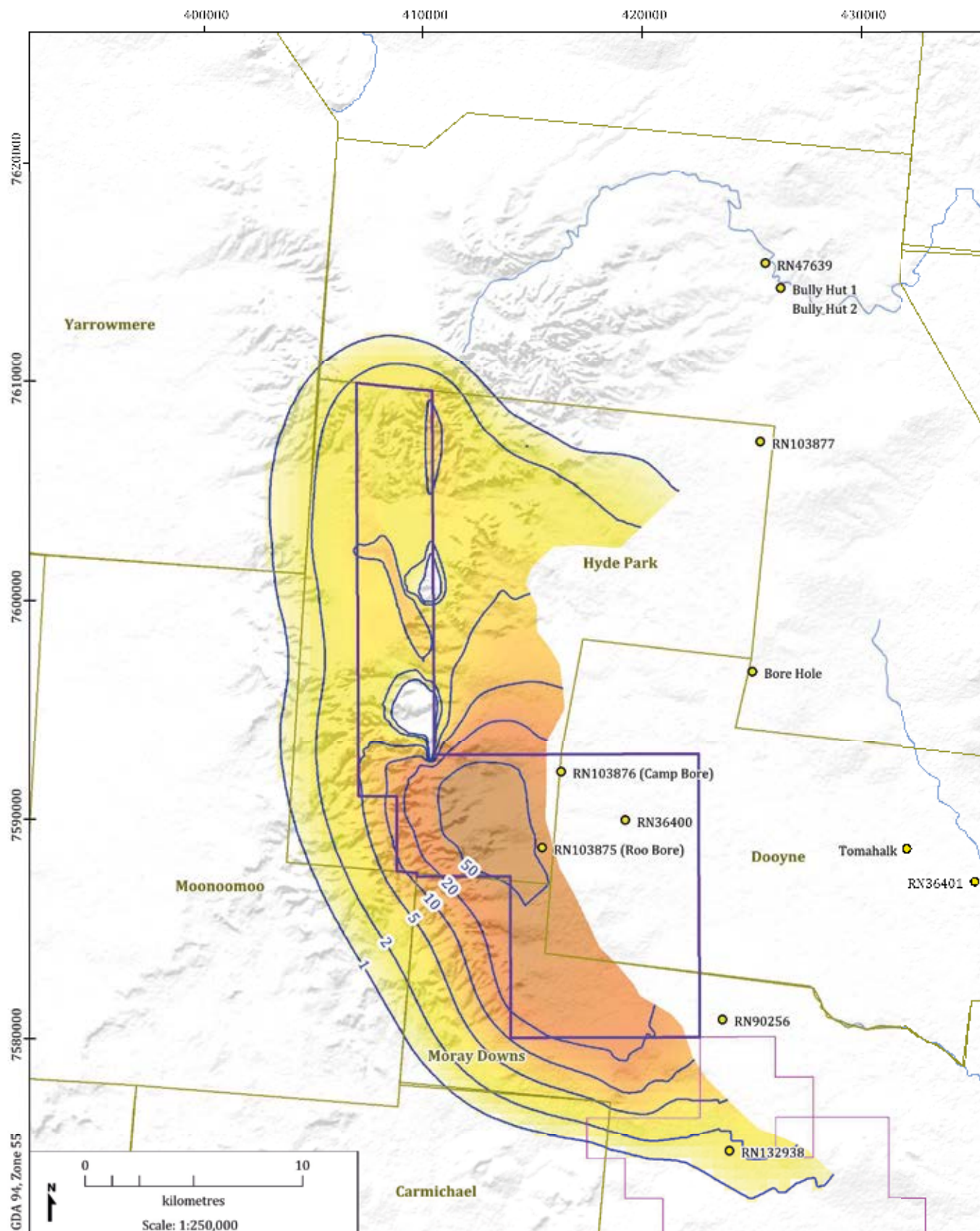
Project China Stone (G1587)

Zone of depressurisation - A seam post mining



DATE:
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FIGURE No:
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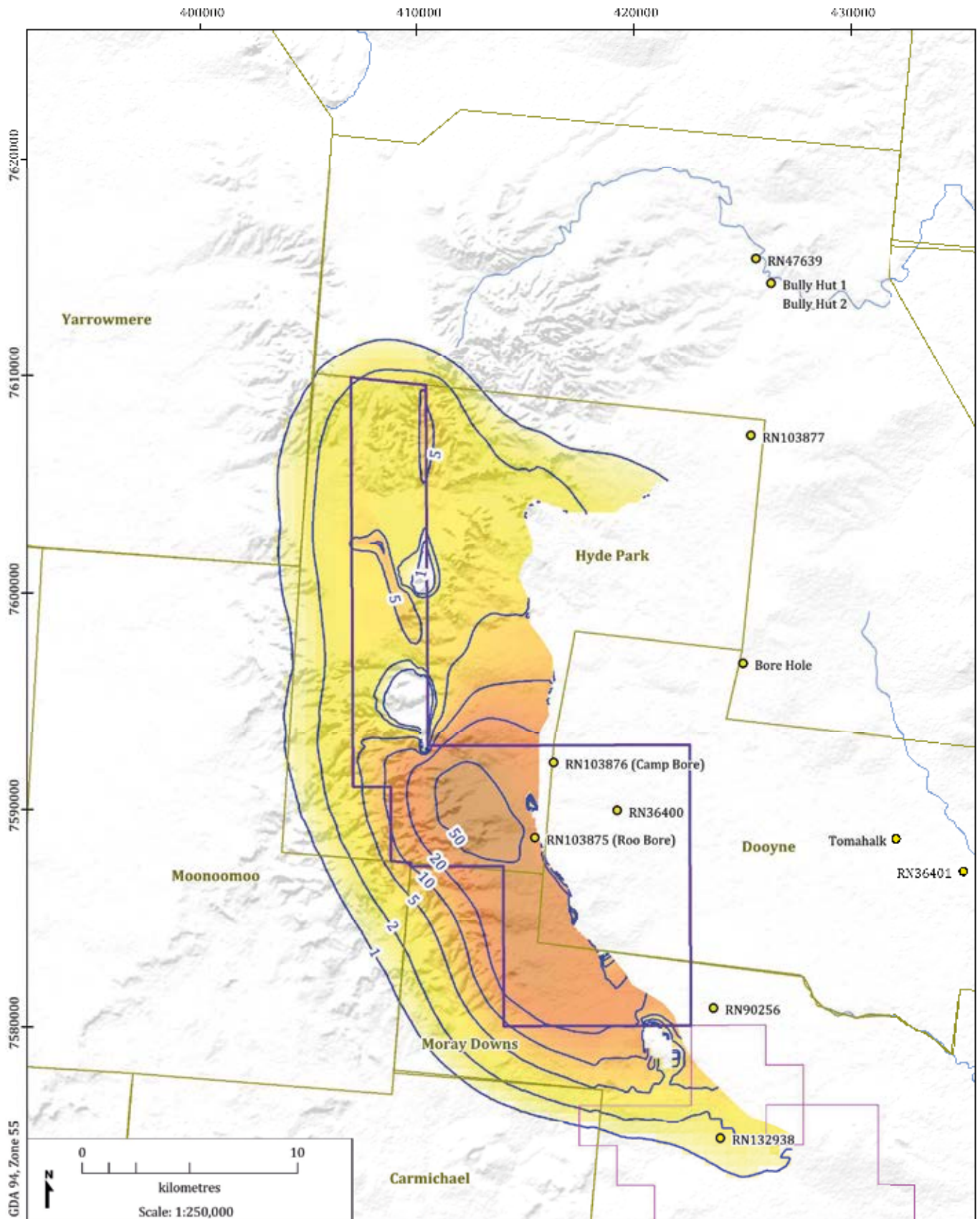
LEGEND:

- Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

Project China Stone (G1587)

Zone of depressurisation - C seam post mining

DATE:
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LEGEND:

- Drawdown contour (m)
- Private bore
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastral

Project China Stone (G1587)

Zone of depressurisation - D seam post mining

DATE:
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41

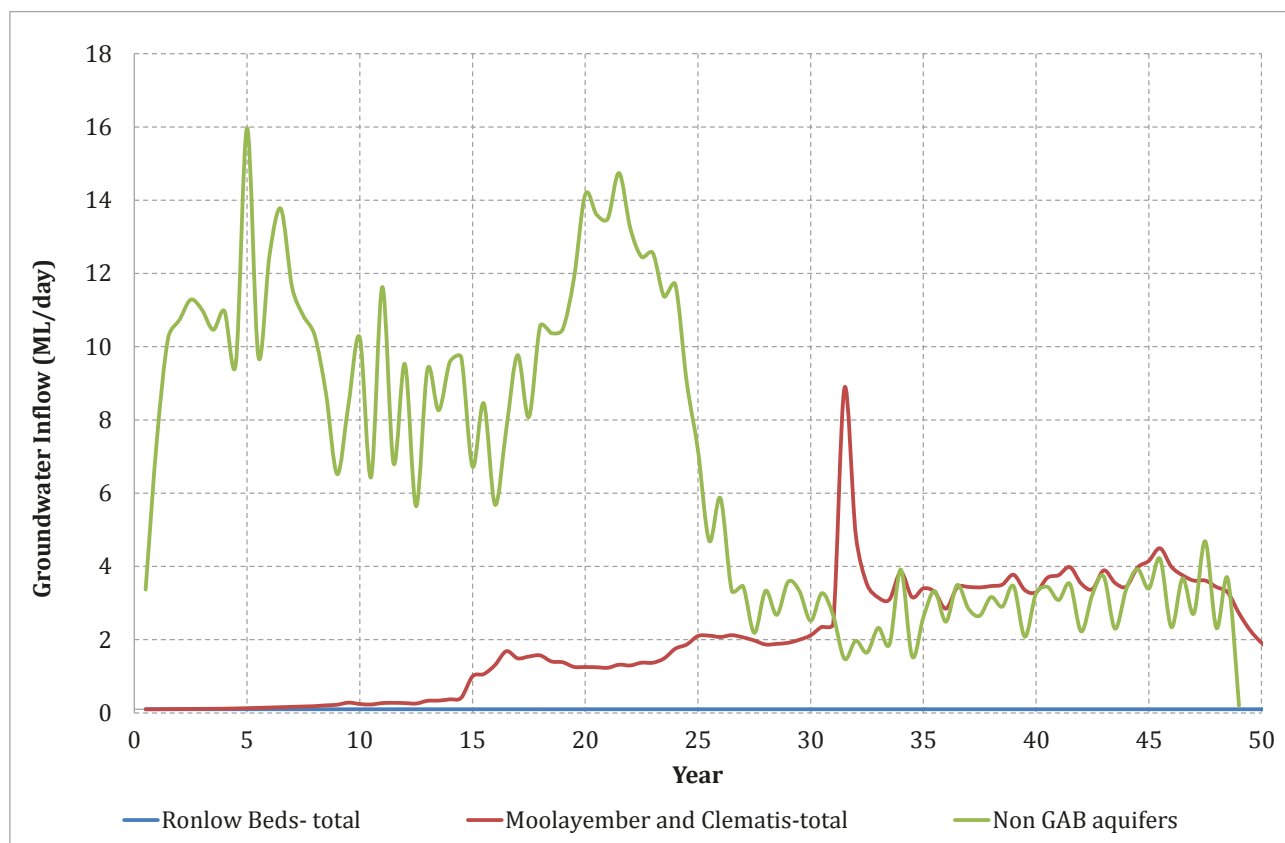
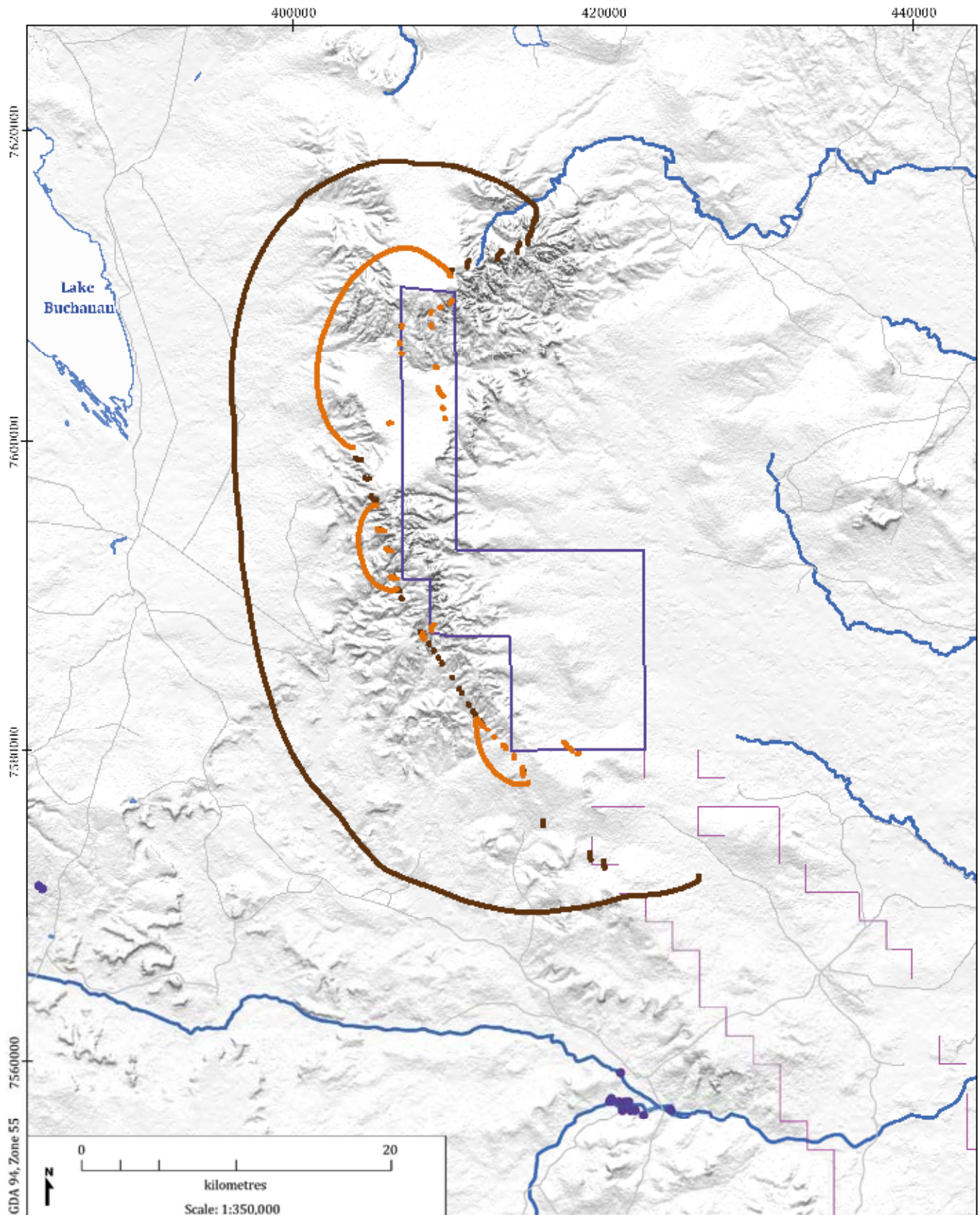


Figure 42 'Water take' - during mining

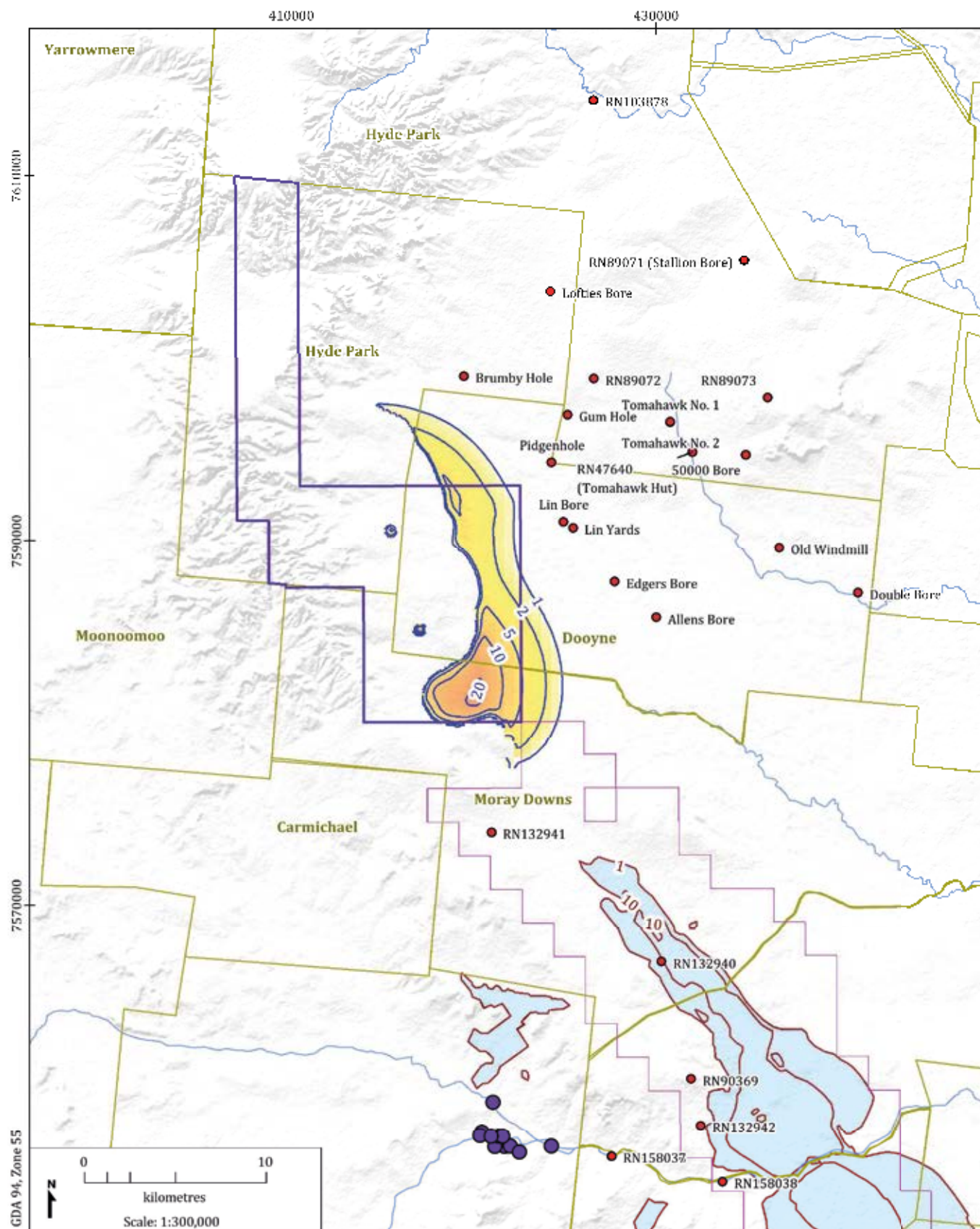


LEGEND:

- Project site
- Carmichael Coal Mine Project
- GAB Springs
- Major features
- Road
- Maximum drawdown during mining - 1m contour
- Drawdown post mining - 1m contour

Project China Stone (G1587)

**Groundwater interaction
with surface water**DATE:
24/6/2015FIGURE No:
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Project China Stone (G1587)

Cumulative drawdown - Tertiary Sediments - end of mining

DATE:
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44

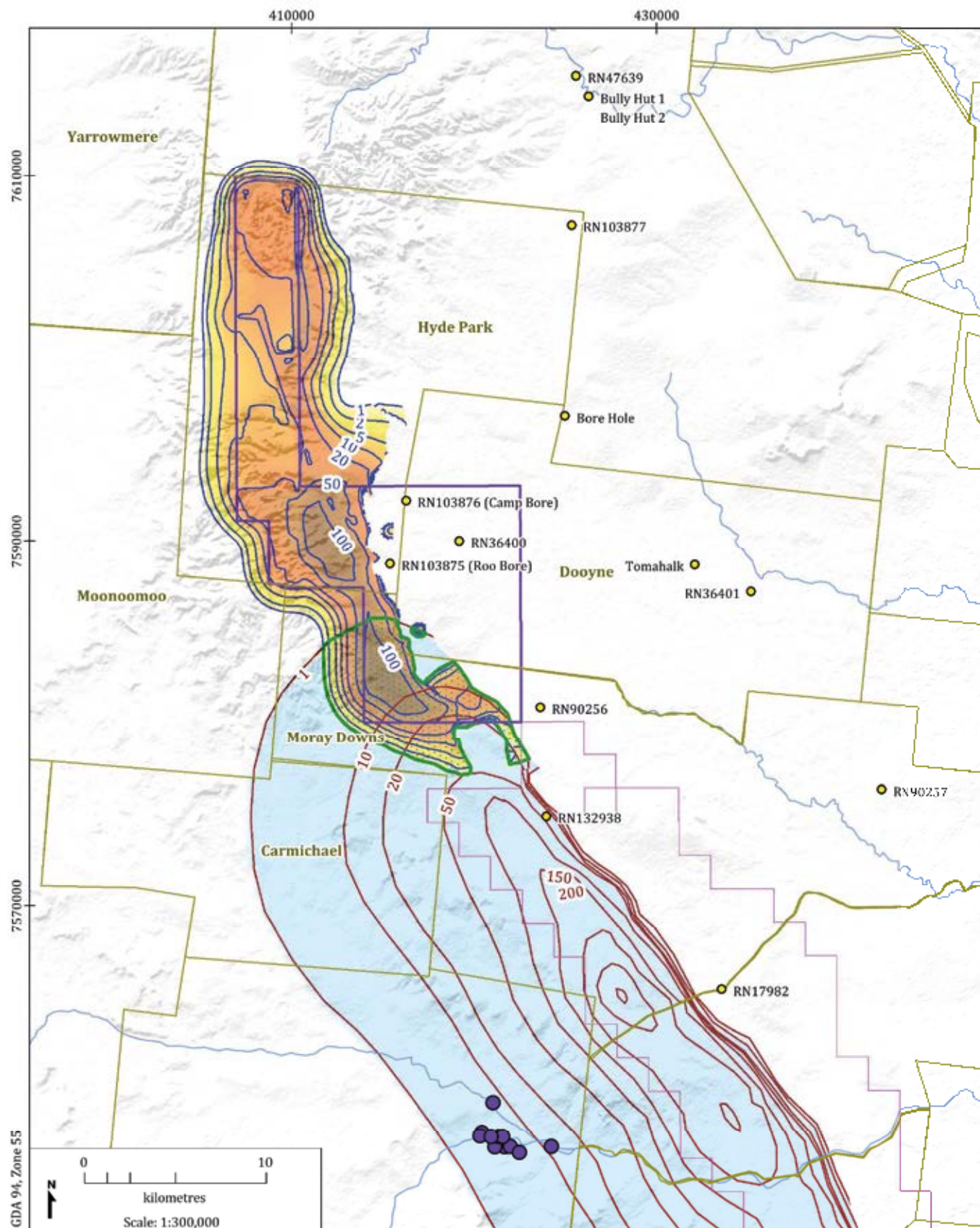


- Drawdown contour (m)
- Private bore
- GAB Springs (Fensham and Fairfax (2006) Springs of Queensland)
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre

Zone of drawdown - Carmichael
Coal Mine Project

**Cumulative drawdown - Tertiary
Sediments - post mining**





LEGEND:

— Drawdown contour (m)

● Private bore

● GAB Springs (Fensham and Fairfax (2006)
Springs of Queensland)— Project site
— Carmichael Coal Mine Project

— Major drainage

— Cadastre

— Drawdown contour - Carmichael
Coal Mine Project (m)— Zone of drawdown - Carmichael
Coal Mine Project

— Zone of cumulative impact

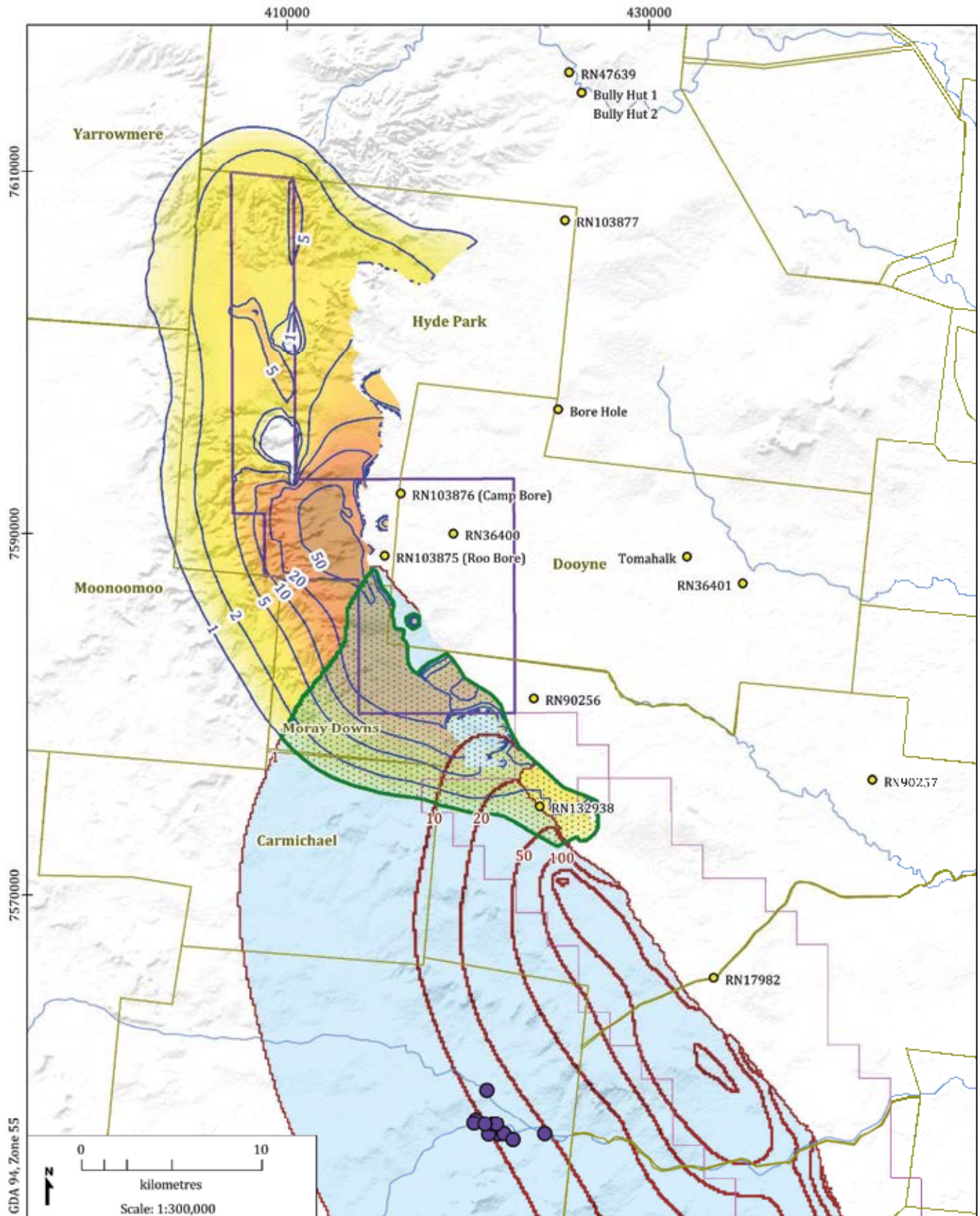
Project China Stone (G1587)

**Cumulative drawdown – Coal seams
(A China Stone - A/B Carmichael)
- end of mining**



DATE:
24/6/2015

FIGURE No:
46



LEGEND:

- Drawdown contour (m)
- Private bore
- GAB Springs (Fensham and Fairfax (2006) Springs of Queensland)
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre
- Drawdown contour - Carmichael Coal Mine Project (m)
- Zone of drawdown - Carmichael Coal Mine Project
- Zone of cumulative impact

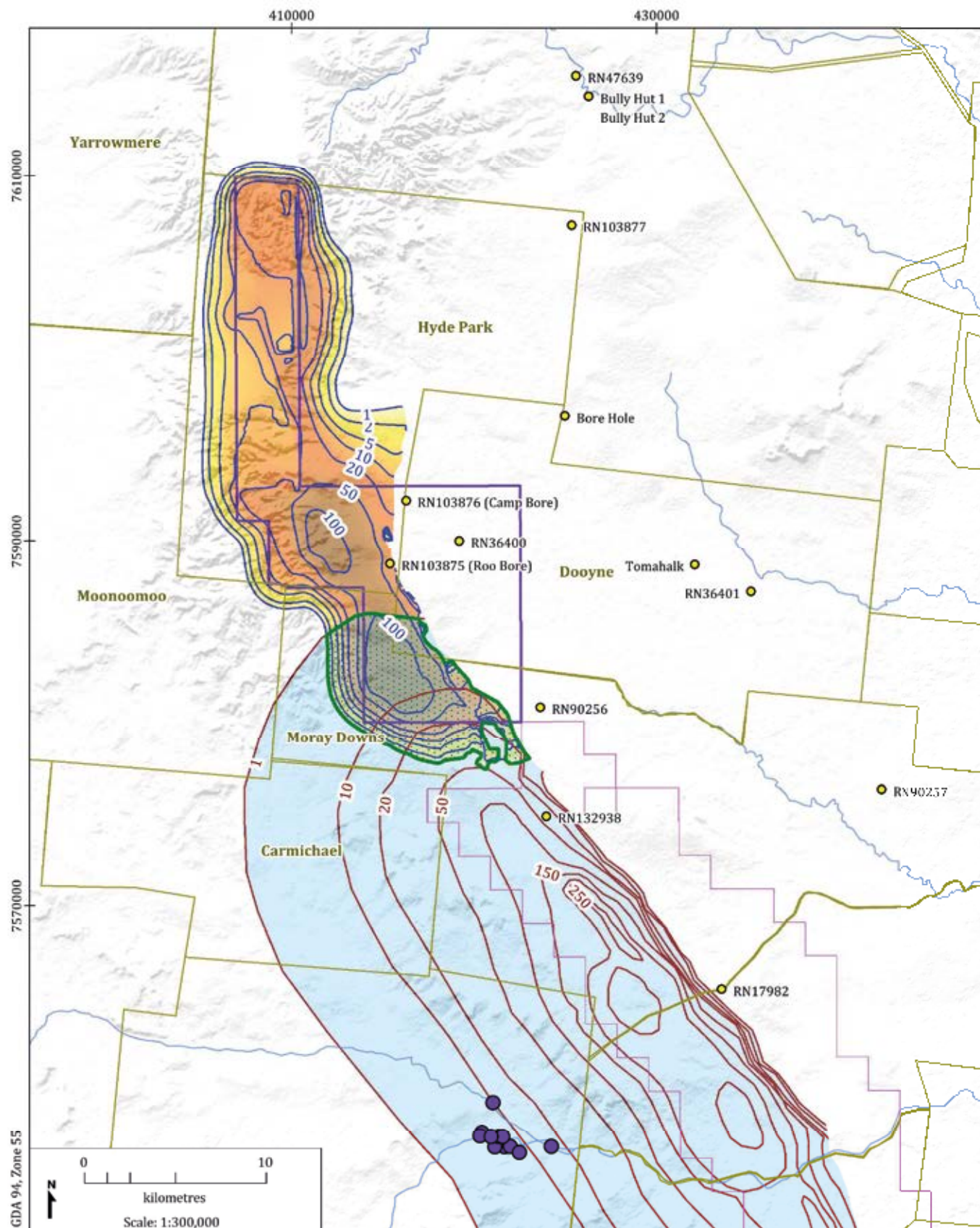
Project China Stone (G1587)

**Cumulative drawdown – Coal seams
(A China Stone - A/B Carmichael)
- post mining**



DATE:
24/6/2015

FIGURE No:
47



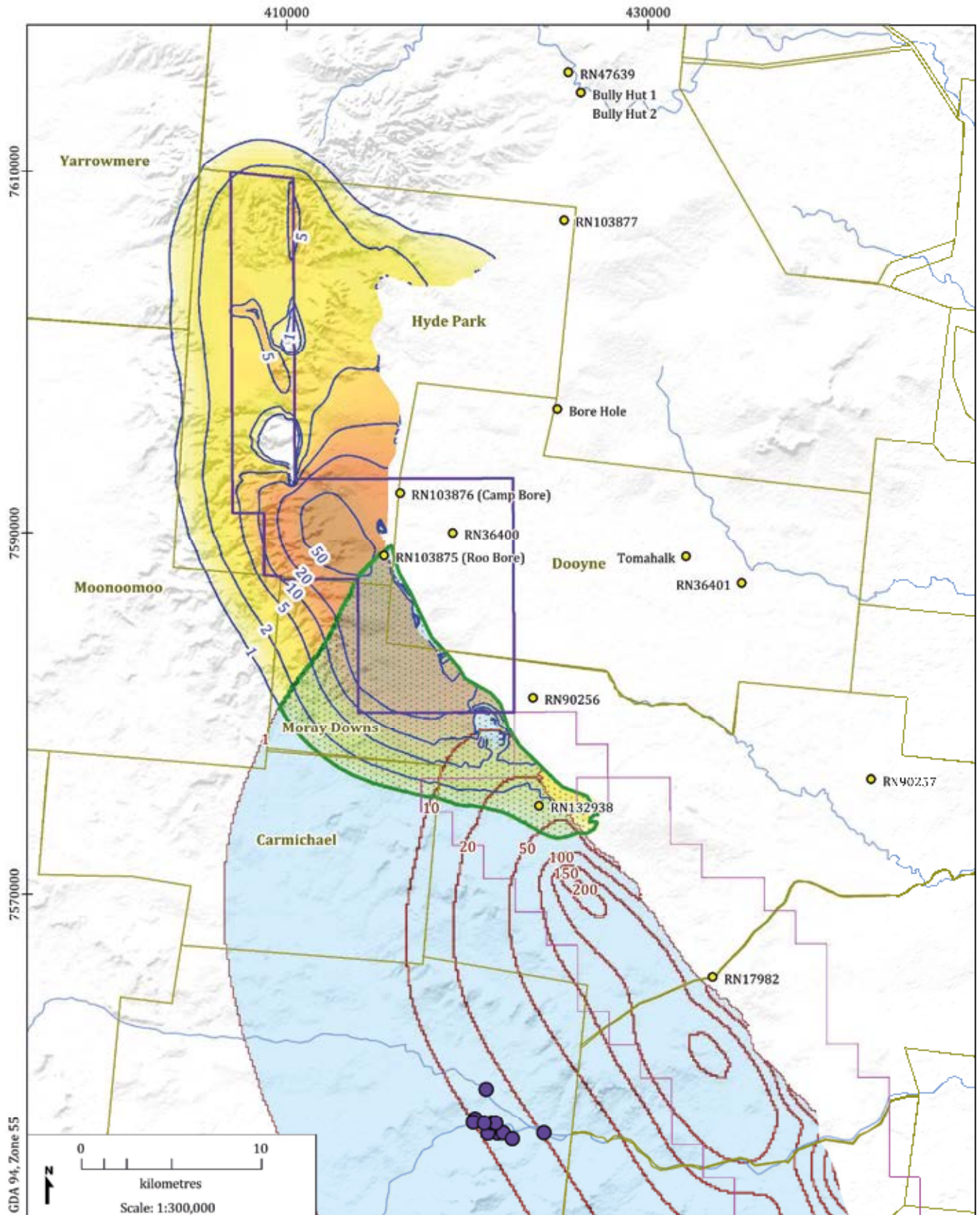
LEGEND:

- Drawdown contour (m)
- Private bore
- GAB Springs (Fensham and Fairfax (2006) Springs of Queensland)
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre
- Drawdown contour - Carmichael Coal Mine Project (m)
- Zone of drawdown - Carmichael Coal Mine Project
- Zone of cumulative impact

Project China Stone (G1587)

Cumulative drawdown - Coal seams (D seam) - end of mining

DATE:
24/6/2015FIGURE No:
48



LEGEND:

- Drawdown contour (m)
- Private bore
- GAB Springs (Fenham and Fairfax (2006) Springs of Queensland)
- Project site
- Carmichael Coal Mine Project
- Major drainage
- Cadastre
- Drawdown contour - Carmichael Coal Mine Project (m)
- Zone of drawdown - Carmichael Coal Mine Project
- Zone of cumulative impact

Project China Stone (G1587)

Cumulative drawdown - Coal seams (D seam) - post miningDATE:
24/6/2015FIGURE No:
49

Appendix A

Field investigation report

A1. Field investigations

Field investigations into the hydrogeology of the project site were undertaken between December 2012 and August 2013 and included:

- Drilling and constructing a groundwater monitoring network;
- Post-drilling field measurements of groundwater distribution, water quality, hydraulic properties including falling head and packer testing; and
- A bore census to confirm the extent of existing groundwater use and surface expression of groundwater.

A2. Groundwater drilling

Groundwater drilling comprised:

- drilling and construction of 31 groundwater monitoring bores;
- drilling and construction of 4 vibrating wire piezometer (VWP) arrays; and
- drilling 8 HQ core hole for the purpose of packer testing.

The drilling layout and construction details are discussed in the following sections.

A2.1 Groundwater monitoring bores

A total of 31 groundwater monitoring bores were drilled and constructed between December 2012 and August 2013 and installed by a licenced water bore driller.

Appendix A-1 provides a summary of the construction details for each groundwater monitoring bore drilled at the project site. Appendix A-2 provides composite logs outlining the stratigraphy and lithology, bore construction, and drilling details for each groundwater monitoring bore. All bores were logged by a Macmines geologist; an AGE hydrogeologist provided guidance on the bore design.

The groundwater monitoring bores were located to allow monitoring of major geological units at the project site and provide a robust coverage of the project area. Six sites consist of multiple bores screened at different depths to measure the vertical gradient between formations, these include:

- MB04, MB05, and MB06;
- MB07, and MB08;
- MB09, MB10, and MB11;
- MB16, and MB17;
- MB18, and MB19; and
- MB20, and MB32.

Monitoring bores were drilled using open-hole rotary drilling techniques. The monitoring bores were supervised by a hydrogeologist or geologist and constructed with 50 mm diameter, flush threaded, Class 18 uPVC with Class 18 machine slotted (0.4 mm aperture) uPVC screen. The screen aperture was opened to a 1 mm slot for every metre of screen to align with stygofauna monitoring requirements. Stygofauna monitoring is discussed in the EIS aquatic ecology report.

A filter pack of clean rounded to sub-rounded gravel of 3 mm to 6 mm diameter was placed in the annulus above the screen. A layer of bentonite pellets (1 m to 2 m) was placed above the filter pack to form a seal to hydraulically isolate the screened section. A cement/bentonite grout was used to seal the remaining bore annulus. A steel lockable protector was cemented around the protruding casing at the surface.

All holes were drilled and constructed according to the guidelines presented in the '*Minimum Construction Requirements for Water Bores in Australia*'¹. The following sections document the drilling and construction of the monitoring bores.

A2.2 Bore development

Bores were airlift developed to remove drilling fines and enhance hydraulic conductivity within the surrounding aquifer. Developing continued until all fines were removed and field water quality parameters (for pH and electrical conductivity) had stabilised.

Where monitoring bores did not yield sufficient flow to enable adequate development a powered bailer (similar to a small cable tool drilling rig) was used to remove fluid in the bore until the pH stabilised.

A2.3 Groundwater levels and logger installations

Groundwater levels were measured manually using a water level dipper for all monitoring bores throughout the field investigation. Groundwater level data is discussed in detail in Section 6.1 of the main report.

Solinst levelloggers were installed in all monitoring bores and set to record at 6-hourly intervals. A barometric logger was placed inside the protective collar of MB06 and set to record concurrently with the other data loggers.

A2.4 Survey bore locations

On completion of the drilling program all bores were surveyed by a licensed surveyor to accurately measure their position and height. Appendix A-1 presents the surveyed bore coordinates and elevations for each bore. Figure 15 in the main body of the report shows the location of each bore. Table A 1 summarises the construction of each bore.

¹ National Uniform Drillers Licensing Committee (2013) "*Minimum Construction Requirements for Water Bores in Australia*" Ed.3 Revised February 2013.

Table A 1 Groundwater monitoring bores – construction details

Hole ID	Age	Geological unit	Screened lithology	Elevation (mAHD)		Base of hole (mAHD)	Total drilled depth (mbGL)	Screen (mAHD)	Gravel pack (mAHD)	Mean static water level (mAHD)
				ToC	Ground					
MB07	Tertiary	Tertiary Sediments	clay	343.47	343.01	283	60	289 - 283	299 - 283	286.6
MB17	Tertiary	Tertiary Sediments	sand	329.54	329.04	252.4	76.65	258.3 - 252.3	262.3 - 252.3	266.3
MB18	Tertiary	Tertiary Sediments	sand	341.91	341.54	288.9	52.6	294.9 - 288.9	298.9 - 288.9	dry
MB20	Tertiary	Tertiary Sediments	sand	297.84 ^A	297.34	272.3	25	275.3 - 272.3	277.3 - 272.3	dry
MB32	Tertiary	Tertiary Sediments	sand	302.56 ^A	302.06	277.1	25	280.1 - 277.1	283.1 - 277.1	dry
MB04	Tertiary	Tertiary Sediments	silt and gravel	366.95	366.25	340.8	25.5	346.8 - 340.8	350.8 - 340.8	dry
MB16	Tertiary	Tertiary Sediments	silt and sand	329.63	329.03	304	25	307 - 304	309 - 304	dry
MB09	Tertiary and Permian	Tertiary Sediments and Betts Creek Beds	sand, silt and weathered sandstone	342.86	342.21	318.9	23.35	324.9 - 318.7	325.4 - 318.9	dry
MB31	Triassic	Clematis Sandstone	unknown	unknown	468.55	319.2	149.4	unknown	unknown	dry
MB21	Triassic	Clematis Sandstone	weathered sandstone	470.9 ^A	470.4	339.9	130.5	345.9 - 339.9	349.9 - 339.9	dry
MB29	Triassic	Clematis Sandstone	weathered sandstone	496.62 ^A	496.12	347.1	149	354.1 - 348.1	359.1 - 347.1	dry
MB30	Triassic	Clematis Sandstone	weathered sandstone	484.11 ^A	483.61	334.3	149.3	340.3 - 334.3	346.3 - 334.3	dry
MB22	Triassic	Clematis Sandstone	weathered sandstone	388.45 ^A	387.95	280.5	107.5	286.5 - 280.5	298.5 - 280.5	dry
MB23	Triassic	Rewan Formation	unknown	unknown	415.67	325.7	90	unknown	unknown	dry
MB24	Triassic	Rewan Formation	claystone	440.75	440	309	131	316 - 310	321.5 - 310	352.7
MB25	Triassic	Rewan Formation	claystone and siltstone	462.8	462	336.6	125.4	324.5 - 318.5	328.5 - 318.5	dry
MB12	Triassic	Rewan Formation	sandstone	377.57	376.92	275.9	101	280.9 - 274.9	286.9 - 274.9	314.7

Hole ID	Age	Geological unit	Screened lithology	Elevation (mAHD)		Base of hole (mAHD)	Total drilled depth (mbGL)	Screen (mAHD)	Gravel pack (mAHD)	Mean static water level (mAHD)
				ToC	Ground					
MB13	Triassic	Rewan Formation	sandstone	389.66	389.09	287.1	102	293.5 - 287.5	295.1 - 287.1	322.3
MB14	Triassic	Rewan Formation	sandstone	447.07	446.34	296.3	150	306.3 - 300.3	308.3 - 300.3	313.5
MB26	Triassic	Rewan Formation	sandstone	411.26	410.56	291	119.6	297.6 - 291.6	303.6 - 291.1	314.8
MB27	Triassic	Rewan Formation	sandstone and claystone	415.74	415.24	301.6	113.6	309.2 - 302.2	313.6 - 301.6	316.1
MB28	Triassic	Rewan Formation	sandstone and claystone	437a	436.5	298.5	138	304.5 - 298.5	310.5 - 298.5	319.5
MB19	Triassic	Rewan Formation	siltstone and claystone	341.96	341.51	258	83.5	267 - 261	273 - 258	289.8
MB15	Triassic	Rewan Formation	siltstone and sandstone	409.35	408.7	289.3	119.4	299.3 - 293.3	305.3 - 289.3	323.8
MB33	Triassic	Rewan Formation	weathered claystone	418.46	417.8	268.4	149.4	273.8 - 267.8	279.8 - 267.8	320.8
MB06	Permian	Betts Creek Beds	coal - A & B seams	366.42	366.02	226.5	139.5	241 - 232	261 - 229	294.8
MB11	Permian	Betts Creek Beds	coal - A & B seams	342.59	341.91	257.9	84	264.9 - 258.9	274.9 - 257.9	308.1
MB03	Permian	Betts Creek Beds	coal - A Seam	347.2	346.67	254.9	91.75	260.9 - 254.9	264.9 - 254.9	287.3
MB05	Permian	Betts Creek Beds	sandstone	366.79	366.14	258.1	108	264.1 - 258.1	274.1 - 258.1	294.7
MB08	Permian	Betts Creek Beds	weathered sandstone and siltstone	343.42 ^A	342.92	252.9	90	260.8 - 254.8	270.8 - 254.8	282.9
MB10	Permian	Betts Creek Beds	weathered claystone	342.74	342.12	284.8	57.35	290.8 - 284.8	291.8 - 284.8	308.3

Notes:

Co-ordinates GDA94, Zone 55

mAHD = metres above height datum

mbGL = metres below ground level

^AToC elevation an estimate, data not supplied by

A2.5 Vibrating wire piezometers

A total of four VWP arrays were constructed during March and June 2013. The bores were drilled using the same drilling techniques used for the groundwater monitoring program. The installation of all VWPs was supervised by an AGE hydrogeologist.

Each VWP site was nested with an open standpipe monitoring bore which screened the Rewan overburden. These, along with the three sensors in each VWP array, provide the ability to assess any vertical differences in groundwater pressures between geological units.

Table A 2 shows the depths and target geological units for each VWP sensor.

Table A 2 Vibrating wire piezometers – construction details

Hole ID	Nested monitoring bore	Ground level (mAHD)	Base of hole (mAHD)	Total drilled depth (mbGL)	Age	Geological unit	Sensor lithology	Depth of gauge (mAHD)	Groundwater pressure head (mAHD)
VWP1	MB12	385	34.2	350.8	Triassic	Rewan Formation	siltstone	195	318.82
					Permian	Betts Creek Beds	sandstone	165	315.68
					Permian	Betts Creek Beds	coal - A Seam	140	312.4
VWP2	MB13	398	91.5	306.5	Permian	Betts Creek Beds	sandstone	213	304.75
					Permian	Betts Creek Beds	coal - A Seam	188	299.79
					Permian	Betts Creek Beds	sandstone	148	297.71
VWP3	MB14	458	109.7	348.3	Triassic	Rewan Formation	siltstone	268	304.58
					Permian	Betts Creek Beds	sandstone	238	295.86
					Permian	Betts Creek Beds	siltstone	218	295.93
VWP4	MB15	418	168	250	Triassic	Rewan Formation	siltstone	258	347.84
					Triassic	Rewan Formation	sandstone	218	327.8
					Triassic	Rewan Formation	siltstone	178	298.98

Notes: mAHD = metres above height datum

A3. In-situ permeability testing

A3.1 Falling head tests

As a part of the investigation, 18 falling head tests were completed on 16 bores. The testing was designed to evaluate the hydraulic conductivity of aquifer material surrounding the bore screen. Falling head tests involve rapidly displacing the head of water in the bore and measuring the rate of recovery; from this the hydraulic conductivity of the aquifer is calculated.

The bores were analysed using either the Cooper-Bredehoeft-Papadopoulos (1967)² method for leaky confined aquifers or the Hvorslev (1953)³ method for confined aquifers.

Tests were completed by either NRC in March 2013 or an AGE Hydrogeologist in June and July 2013. Table A 3 shows the details for each test. Section 6.1 in the main report summarises all hydraulic test data for the different groundwater units.

Table A 3 Falling head test details

Bore No.	Geological unit	Age	Unit	Lithology	Method	Hydraulic conductivity (m/day)	Test completed by
MB03	Coal - A Seam	Permian	Betts Creek Beds	Coal - A Seam	Hvorslev	0.04	AGE
MB05	Betts Creek Beds (Permian overburden)	Permian	Betts Creek Beds	sandstone	Hvorslev	0.0001	NRC
MB06	Coal - A & B Seams	Permian	Coal - A & B Seams	Coal - A & B seams	Hvorslev	0.04	AGE
MB07	Tertiary sediments	Tertiary	Tertiary sediments	clay	Hvorslev	0.01	AGE
MB07	Tertiary sediments	Tertiary	Tertiary sediments	clay	Hvorslev	0.04	NRC
MB08	Weathered Betts Creek Beds (Permian overburden)	Permian	Betts Creek Beds	claystone, siltstone, and sandstone	Hvorslev	0.9	AGE
MB08	Weathered Betts Creek Beds (Permian overburden)	Permian	Betts Creek Beds	claystone, siltstone, and sandstone	Hvorslev	0.02	NRC
MB10	Weathered Betts Creek Beds (Permian overburden)	Permian	Betts Creek Beds	claystone	Hvorslev	0.1	AGE
MB11	Coal - A & B Seams	Permian	Betts Creek Beds	Coal - A & B Seams	Hvorslev	0.2	AGE
MB12	Rewan Group (sandstone)	Triassic	Rewan Formation	sandstone	Hvorslev	0.002	AGE
MB13	Rewan Group (sandstone)	Triassic	Rewan Formation	sandstone	Hvorslev	0.2	AGE
MB17	Tertiary sediments	Tertiary	Tertiary sediments	sandstone	Hvorslev	0.6	AGE

² Cooper, H.H., Bredehoeft, J.D., and Papadopoulos, S.S., (1967) 'Response of a finite-diameter well to an instantaneous charge of water', Water Resources Research, vol. 3, no. 1, pp. 263-269.

³ Hvorslev, M.J., (1951), *Time lag and soil permeability in ground-water observations*, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50.

Bore No.	Geological unit	Age	Unit	Lithology	Method	Hydraulic conductivity (m/day)	Test completed by
MB19	Rewan Group (siltstone/claystone)	Triassic	Rewan Formation	siltstone and claystone	Hvorslev	0.08	AGE
MB22	Weathered Clematis Sandstone	Triassic	Clematis Sandstone	sandstone	Hvorslev	0.09	NRC
MB24	Rewan Group (claystone)	Triassic	Rewan Formation	claystone	Cooper-Bredehoeft-Papadopulos	0.02	NRC
MB27	Rewan Group (sandstone and claystone)	Triassic	Rewan Formation	sandstone and claystone	Cooper-Bredehoeft-Papadopulos	0.09	NRC
MB28	Rewan Group (sandstone and claystone)	Triassic	Rewan Formation	sandstone and claystone	Hvorslev	0.06	NRC
MB33	Weathered Rewan Group (upper claystone)	Triassic	Rewan Formation	claystone	Hvorslev	0.0005	AGE

A3.2 Packer tests

Packer tests consist of isolating a section of a bore hole with inflatable packers so aquifer tests can be conducted on a discrete zone or feature (e.g. a coal seam or fault). The Lugeon (1933)⁴ method was used to estimate the hydraulic conductivity of the test interval. The Lugeon Test is similar to a constant head test where water is injected into the test interval at a constant pressure and the flow rate is measured. Generally the test is conducted over 5 stages at different pressures. During each stage the average pressure and flow rate are recorded, this data is used to calculate the hydraulic conductivity for each stage.

A total of 68 packer tests were carried out in the project site within eight drill holes between July and October 2013 using a Sigra inflatable straddle packer. Each test was supervised by either an AGE hydrogeologist or Macmines geologist. Table A 4 presents the packer test details for all tests. Appendix A-2 contains the bore logs for each packer test hole.

Table A 4 Packer test details

Hole ID	Test interval (mbGL)	Age	Unit	Lithology	Test No.	Interpreted hydraulic conductivity (m/day)
MC5040A	198.5 - 203.5	Triassic	Rewan Formation	siltstone and sandstone	4	0.001
	225.5 - 230.5	Permian	Betts Creek Beds	sandstone	3	0.007
	250 - 255	Permian	Betts Creek Beds	sandstone	2	0.002
	262 - 357.2	Triassic	Rewan and Betts Creek Beds	siltstone, sandstone, and coal	1	0.006
MC5041	72.9 - 77.9	Permian	Betts Creek Beds	siltstone	14	0.002
	78 - 83	Permian	Betts Creek Beds	siltstone and claystone	13	0.001
	89.8 - 94.8	Permian	Betts Creek Beds	coal - AU Seam	12	0.002

⁴ Lugeon, M., (1933) '*Barrage et Géologie*', Dunod, Paris

Hole ID	Test interval (mbGL)	Age	Unit	Lithology	Test No.	Interpreted hydraulic conductivity (m/day)
	98.8 - 103.8	Permian	Betts Creek Beds	coal - AL Seam	11	0.002
	107.8 - 112.8	Permian	Betts Creek Beds	coal - B Seam	10	0.002
	117 - 122	Permian	Betts Creek Beds	siltstone	9	0.003
	123.7 - 128.7	Permian	Betts Creek Beds	coal - C4 / C3 Seam	8	0.015
	131.5 - 134.5	Permian	Betts Creek Beds	coal - C2 Seam	7	0.005
	137.8 - 142.8	Permian	Betts Creek Beds	sandstone	6	0.002
	145.5 - 149.5	Permian	Betts Creek Beds	siltstone	5	0.002
	150.5 - 155.5	Permian	Betts Creek Beds	coal - D Seam	4	0.003
	159.5 - 164.5	Permian	Betts Creek Beds	coal - E Seam	3	0.013
	165.6 - 169.6	Permian	Betts Creek Beds	coal - F Seam	2	0.01
	172 - 176	Permian	Betts Creek Beds	coarse sandstone	1	0.004
MC5043	148 - 153	Triassic	Rewan Formation	siltstone	10	0.002
	202 - 207	Permian	Betts Creek Beds	sandstone and siltstone	9	0.002
	247 - 252	Permian	Betts Creek Beds	coal - Au2/Au1 Seam	8	0.002
	271 - 276	Permian	Betts Creek Beds	coal - B2/B1 Seam	7	0.002
	279 - 283	Permian	Betts Creek Beds	coal - C5 Seam	6	0.002
	291 - 295	Permian	Betts Creek Beds	sandstone and siltstone	5	0.002
	294.8 - 299.8	Permian	Betts Creek Beds	coal - D Seam	4	0.021
	309 - 313	Permian	Betts Creek Beds	coal - E Seam	3	0.005
	318 - 322	Permian	Betts Creek Beds	coal - F Seam	2	0.003
	324 - 329	Permian	Betts Creek Beds	coarse sandstone	1	0.005
MC5044	148 - 153	Triassic	Rewan Formation	sandstone and siltstone	11	0.005
	175 - 180	Triassic	Rewan Formation	sandstone and siltstone	10	0.009
	259 - 264	Permian	Betts Creek Beds	carbonaceous siltstone	9	0.006
	274 - 278	Permian	Betts Creek Beds	coal - AU1 - Seam	8	0.005
	280 - 285	Permian	Betts Creek Beds	coal - AL- Seam	7	0.008
	292 - 297	Permian	Betts Creek Beds	coal - B-Seam	6	0.009
	310 - 315	Permian	Betts Creek Beds	coal - C-Seam	5	0.004
	318 - 323	Permian	Betts Creek Beds	sandstone and siltstone	4	0.009
	324.5 - 329.5	Permian	Betts Creek Beds	coal - D2-Seam	3	0.008
	336 - 339	Permian	Betts Creek Beds	coal - E Seam	2	0.008
	343 - 345	Permian	Betts Creek Beds	coal - F Seam	1	0.002
MC5046	280 - 285	Permian	Betts Creek Beds	coal - AL- Seam	6	0.003
	289 - 294	Permian	Betts Creek Beds	coal - B2-Interburden	5	0.002

Hole ID	Test interval (mbGL)	Age	Unit	Lithology	Test No.	Interpreted hydraulic conductivity (m/day)
	320.9 - 324.9	Permian	Betts Creek Beds	sandstone and siltstone	4	0.004
	324.5 - 329.5	Permian	Betts Creek Beds	coal - D2-Seam	3	0.008
	336 - 339	Permian	Betts Creek Beds	coal - E-Seam	2	0.007
	343 - 345	Permian	Betts Creek Beds	coal - F-Seam	1	0.011
MC5049	403 - 407	Permian	Betts Creek Beds	coal - D2-Seam	3	0.002
	418 - 421	Permian	Betts Creek Beds	coal - E-Seam	2	0.003
	427 - 430	Permian	Betts Creek Beds	coal - F-Seam	1	0.005
MC5051	175 - 180	Permian	Betts Creek Beds	sandstone	10	0.01
	192 - 194	Permian	Betts Creek Beds	coal - AL- Seam	6	0.007
	203 - 205	Permian	Betts Creek Beds	coal - C-Seam	5	0.006
	211 - 213	Permian	Betts Creek Beds	sandstone and siltstone	4	0.007
	248 - 250	Permian	Betts Creek Beds	coal - D2-Seam	3	0.025
	259 - 264	Permian	Betts Creek Beds	coal - E-Seam	9	0.007
	261 - 263	Permian	Betts Creek Beds	coal - E-Seam	2	0.007
	267 - 269	Permian	Betts Creek Beds	coal - F-Seam	1	0.009
	274 - 278	Permian	Betts Creek Beds	sandstone	8	0.006
MC5052	181 - 184	Triassic	Rewan Formation	sandstone	10	0.044
	292 - 296	Permian	Betts Creek Beds	sandstone	9	0.008
	310 - 313	Permian	Betts Creek Beds	coal - AU1 - Seam	8	0.04
	320.4 - 323.4	Permian	Betts Creek Beds	coal - AL- Seam	7	0.007
	328 - 331	Permian	Betts Creek Beds	coal - B-Seam	6	0.01
	337 - 340	Permian	Betts Creek Beds	coal - C-Seam	5	0.004
	354 - 358	Permian	Betts Creek Beds	sandstone and siltstone	4	0.002
	367 - 369	Permian	Betts Creek Beds	coal - D1-Seam	3	0.017
	374 - 377	Permian	Betts Creek Beds	coal - E-Seam	2	0.012
	382 - 384	Permian	Betts Creek Beds	coal - F-Seam	1	0.004

A4. Groundwater quality sampling

A4.1 Water quality sampling method

A total of 38 groundwater samples collected over two rounds were collected from 21 groundwater monitoring bores between March 2013 and April 2014. Prior to purging, groundwater depth was measured with a water level dipper. Generally, samples were collected by purging bores of a minimum three bore volumes until field parameters (pH, electrical conductivity and temperature) had stabilised. For those bores that purged dry, samples were collected once the bore recovered sufficiently to collect a sample. The monitoring bores were purged and sampled using a combination of bailer and Bennett sampling pumps.

Each sample was collected in laboratory-supplied containers. Samples requiring dissolved metal analysis were filtered in the field, using a 0.45 micron filter, prior to being transferred to the laboratory. All samples were itemised on a Chain of Custody Form, which accompanied the samples to the laboratory. The water samples were submitted to ALS Environmental Laboratories (ALS) for analysis. ALS is National Association of Testing Authorities (NATA) accredited.

A4.2 Lab water quality analysis

The water samples were analysed for the following suite of parameters:

- Physical parameters (pH, electrical conductivity, total dissolved solids, total hardness);
- Major anions (CO₃, HCO₃, Cl, SO₄);
- Major cations (Ca, Mg, Na, K);
- Minor ions (F);
- A suite of 49 dissolved and total metals and metalloids; and
- Nutrients (ammonia, nitrite, nitrate, nitrite + nitrate, TKN, total nitrogen, total phosphorus).

Section 6.3 in the main report summarises major ion concentrations for the different groundwater units. Appendix A-3 includes the complete set of laboratory data compared against the ANZECC (2000)⁵ guidelines for irrigation and livestock drinking water, as well as Australian drinking water guidelines (NHMRC, 2011)⁶.

A4.3 Field water quality sampling

Field water quality measurements were recorded during each sampling event, including electrical conductivity (EC) and pH. Appendix A-3 provides the measured parameters for each sampling event. Table A 5 summarises the water quality data.

⁵ ANZECC (2000) '*Australia and New Zealand guidelines for fresh and marine water quality*', National water quality management strategy; no.4, October 2000

⁶ NHMRC, NRMCC (2011) '*Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy*', National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra, Version 2.0, updated December 2013

Table A 5 Summary of water quality results – all geological units

Parameter	Statistic	Tertiary Sediments	Clematis Sandstone	Rewan Formation	Clematis/Rewan	Betts Creek Beds Interburden	Betts Creek Beds coal seams
EC @ 25°C (µS/cm)	Avg.	724	3310	1765	618	895	2005
	Min.	506	387	295	332	713	1020
	Max.	989	6900	5290	904	1090	3180
Total Dissolved Solids (mg/L)	Avg.	470	2151	1148	402	582	1305
	Min.	329	252	192	216	463	663
	Max.	643	4480	3440	588	708	2070
pH (pH units)	Avg.	8.13	9.24	8.68	9.19	7.74	8.03
	Min.	7.93	5.77	7.62	9.02	6.74	7.80
	Max.	8.50	12.40	10.10	9.36	8.20	8.44
Calcium (mg/L)	Avg.	16	234	52	15	13	36
	Min.	7	2	2	5	10	16
	Max.	35	578	246	24	16	70
Magnesium (mg/L)	Avg.	13	21	31	8	17	35
	Min.	7	8	2	2	16	16
	Max.	20	44	109	13	18	58
Sodium (mg/L)	Avg.	100	160	260	103	134	312
	Min.	60	53	49	56	103	144
	Max.	159	275	635	150	163	494
Bicarbonate (mg/L)	Avg.	103	66	146	116	94	151
	Min.	58	12	29	44	67	72
	Max.	209	158	323	188	125	290
Chloride (mg/L)	Avg.	137	164	431	85	195	512
	Min.	85	34	35	46	159	243
	Max.	191	540	1350	124	233	743
Sulphate (mg/L)	Avg.	20	10	46	13	26	57
	Min.	10	6	2	6	21	6
	Max.	47	16	288	19	36	101
Number of Samples		5	5	16	2	4	6

A5. Bore census

A bore census was carried out between December 2012 and June 2013 at the project site and surrounding properties. The bore census was designed to identify private bores surrounding the project site that could potentially be impacted by the project. In addition, findings from a bore census conducted by GHD as part of the groundwater investigation for Carmichael Coal Mine. were also used in the assessment.

A total of 90 private bores were identified through the DNRM GWDB and through the bore census of surrounding properties. Section 6.4 of the main report outlines the results from the bore census; Appendix A-1 provides details of all of the landholder bores surrounding the project site within the domain of the groundwater model. Figure 21 in the main body of the report shows the locations of all known landholder bores surrounding the project site

Appendix A-1
Bore details



Type	Bore ID	Bore Type	Easting	Northing	Surface (mAHD)	Ending Depth (mAHD)	Bore Depth (mbgl)	Target Unit	Model Layer	Yield (incl. air lifts)	Packer Testing	Head Test	Pumping Test	Field Water Quality
Project China Stone	MB03	SP	414830	7589056	346.7	254.9	91.8	A Seam	10	Y	N	Y	N	Y
Project China Stone	MB04	SP	413863	7590355	366.3	341.0	25.3	Tertiary	2	N	N	N	N	N
Project China Stone	MB05	SP	413873	7590356	366.1	258.3	107.8	Betts Creek Beds	9	N	N	Y	N	N
Project China Stone	MB06	SP	413874	7590369	366.0	229.0	137.0	A/B Seams	12	N	N	Y	N	N
Project China Stone	MB07	SP	415547	7590584	343.0	283.2	59.8	Tertiary	2	Y	N	Y	N	Y
Project China Stone	MB08	SP	415553	7590570	342.9	255.0	87.9	Betts Creek Beds	9	Y	N	Y	N	Y
Project China Stone	MB09	SP	414434	7592831	342.2	319.1	23.2	Tertiary	2	N	N	N	N	N
Project China Stone	MB10	SP	414439	7592830	342.1	285.0	57.2	Betts Creek Beds	9	Y	N	Y	N	Y
Project China Stone	MB11	SP	414442	7592837	341.9	258.8	83.1	A/B Seams	12	Y	N	Y	N	Y
Project China Stone	MB12	SP	410626	7590113	376.9	274.9	102.0	Rewan Formation	8	N	N	Y	N	N
Project China Stone	MB13	SP	408638	7594223	389.1	287.7	101.4	Rewan Formation	8	Y	N	Y	N	Y
Project China Stone	MB14	SP	407589	7598323	446.3	300.3	146.0	Rewan Formation	8	Y	N	Y	N	Y
Project China Stone	MB15	SP	409522	7602328	408.7	293.5	115.2	Rewan Formation	8	N	N	Y	N	N
Project China Stone	MB16	SP	417115	7585134	329.0	304.2	24.8	Tertiary	2	N	N	N	N	N
Project China Stone	MB17	SP	417118	7585137	329.0	252.3	76.7	Tertiary	2	N	N	Y	N	N
Project China Stone	MB18	SP	414442	7583778	341.5	289.1	52.4	Tertiary	2	N	N	N	N	N
Project China Stone	MB19	SP	414446	7583780	341.5	261.2	80.3	Rewan Formation	8	Y	N	Y	N	Y
Project China Stone	MB20	SP	420926	7589917	297.3	272.5	24.8	Tertiary	2	N	N	N	N	N
Project China Stone	MB21	SP	407809	7592771	470.4	340.0	130.4	Clematis Sandstone	5	N	N	N	N	N
Project China Stone	MB22	SP	409254	7588046	388.0	280.6	107.4	Clematis Sandstone	5	N	N	Y	N	N
Project China Stone	MB23	SP	410019	7595392	415.7	325.7	90.0	Rewan Formation	8	N	N	N	N	N
Project China Stone	MB24	SP	408081	7596736	440.0	310.2	129.8	Rewan Formation	8	N	N	Y	N	N
Project China Stone	MB25	SP	407410	7596980	462.0	318.7	143.3	Rewan Formation	8	N	N	N	N	N
Project China Stone	MB26	SP	407115	7601043	410.6	291.8	118.8	Rewan Formation	8	Y	N	N	N	Y
Project China Stone	MB27	SP	407959	7600572	415.2	302.2	113.0	Rewan Formation	8	N	N	Y	N	N
Project China Stone	MB28	SP	409796	7599783	436.5	298.7	137.8	Rewan Formation	8	N	N	Y	N	N
Project China Stone	MB29	SP	407367	7608867	496.1	348.1	148.0	Clematis Sandstone	5	N	N	N	N	N
Project China Stone	MB30	SP	409939	7609491	483.6	334.3	149.3	Clematis Sandstone	5	N	N	N	N	N
Project China Stone	MB31	SP	406705	7613342	468.6	318.6	150.0	Clematis Sandstone	5	N	N	N	N	N
Project China Stone	MB32	SP	420524	7590538	302.1	277.3	24.8	Tertiary	2	N	N	N	N	N
Project China Stone	MB33	SP	407079	7604221	417.8	268.0	149.8	Clematis SS / Rewan Fm	7	N	N	Y	N	N
Project China Stone	VWP1_1	VWP	410643	7590108	385.0	-	-	Rewan Formation	8	N	Y	N	N	N
Project China Stone	VWP1_2	VWP	410643	7590108	385.0	-	-	Betts Creek Beds	9	N	Y	N	N	N
Project China Stone	VWP1_3	VWP	410643	7590108	385.0	-	-	AU Seam	10	N	Y	N	N	N
Project China Stone	VWP2_1	VWP	408642	7594211	398.0	-	-	Betts Creek Beds	9	N	Y	N	N	N
Project China Stone	VWP2_2	VWP	408642	7594211	398.0	-	-	A Seam	10	N	Y	N	N	N
Project China Stone	VWP2_3	VWP	408642	7594211	398.0	-	-	Betts Creek Beds	11	N	Y	N	N	N
Project China Stone	VWP3_1	VWP	407578	7598319	458.0	-	-	Rewan Formation	8	N	Y	N	N	N
Project China Stone	VWP3_2	VWP	407578	7598319	458.0	-	-	Betts Creek Beds	9	N	Y	N	N	N
Project China Stone	VWP3_3	VWP	407578	7598319	458.0	-	-	Betts Creek Beds	9	N	Y	N	N	N
Project China Stone	VWP4_1	VWP	409533	7602316	418.0	-	-	Rewan Formation	8	N	Y	N	N	N
Project China Stone	VWP4_2	VWP	409533	7602316	418.0	-	-	Rewan Formation	8	N	Y	N	N	N
Project China Stone	VWP4_3	VWP	409533	7602316	418.0	-	-	Rewan Formation	8	N	Y	N	N	N

Note: Coordinates are in GDA 94 Zone 55

SP : Standpipe

VWP : Vibrating wire piezometer

LHB : Landholder bore



Appendix A-1 - Bore Details

Type	Bore ID	Bore Type	Easting	Northing	Surface (mAHD)	Ending Depth (mAHD)	Bore Depth (mbgl)	Target Unit	Model Layer	Yield (incl. air lifts)	Packer Testing	Head Test	Pumping Test	Field Water Quality
Private bore	RN2207	LHB	391027	7549656	295.5	-	-	Tertiary?	2	N	N	N	N	-
Private bore	RN2221	LHB	374085	7551274	378.6	-	-	Tertiary?	2	N	N	N	N	-
Private bore	RN2229	LHB	374193	7553480	386.8	-	-	Tertiary?	2	N	N	N	N	-
Private bore	RN5965	LHB	381254	7550613	325.3	247.9	77.4	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN6150	LHB	397931	7547994	289.0	151.8	137.2	Ronlow Beds	3	N	N	N	N	-
Private bore	RN8506	LHB	393044	7555350	301.0	-	-	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN16371	LHB	370461	7574850	352.0	275.8	76.2	Ronlow Beds	3	N	N	N	N	-
Private bore	RN16830	LHB	394117	7545745	289.4	130.9	158.5	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN16895	LHB	410061	7561628	257.4	159.9	97.5	Clematis Sandstone	5	N	N	N	N	-
Private bore	RN16896	LHB	406868	7558257	272.5	149.1	123.4	Clematis Sandstone	5	N	N	N	N	-
Private bore	RN17980	LHB	426849	7565142	278.7	223.8	54.9	Rewan Formation	8	N	N	N	N	-
Private bore	RN17981	LHB	423527	7576054	289.7	228.7	61.0	Rewan Formation	8	N	N	N	N	-
Private bore	RN17982	LHB	433592	7565399	240.7	189.6	51.1	Betts Creek Beds	17	N	N	N	N	-
Private bore	RN22367	LHB	394416	7545886	289.4	-56.9	346.3	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN25500	LHB	378076	7563350	327.8	-	-	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN32980	LHB	376195	7595709	378.2	349.3	28.9	Ronlow Beds	3	N	N	N	N	-
Private bore	RN36400	LHB	419234	7589965	311.9	-	-	Joe Joe Group	9	N	N	N	N	-
Private bore	RN36401	LHB	435204	7587181	257.0	194.5	62.5	Joe Joe Group	9	N	N	N	N	-
Private bore	RN39801	LHB	401187	7569715	292.2	200.7	91.5	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN39802	LHB	393849	7571397	294.7	120.3	174.4	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN44485	LHB	438998	7546581	261.2	-	-	Tertiary?	2	Y	N	N	N	-
Private bore	RN47167	LHB	432099	7559599	269.3	222.1	47.2	Clematis Sandstone	5	N	N	N	N	-
Private bore	RN47637	LHB	431780	7594906	273.2	-	-	Basement Volcanics	17	N	N	N	N	-
Private bore	RN47639	LHB	425622	7615420	295.5	291.2	4.3	Betts Creek Beds	9	N	N	N	N	-
Private bore	RN54627	LHB	382895	7570700	341.2	339.2	2.0	Tertiary	2	N	N	N	N	-
Private bore	RN62623	LHB	442969	7545554	236.5	169.5	67.0	Dunda Beds	6	Y	N	N	N	-
Private bore	RN62624	LHB	439404	7546336	256.0	202.0	54.0	Tertiary	2	Y	N	N	N	-
Private bore	RN62754	LHB	418833	7548212	266.3	-	-	Tertiary?	2	N	N	N	N	-
Private bore	RN70308	LHB	439280	7619223	264.0	-	-	Tertiary?	2	N	N	N	N	-
Private bore	RN76888	LHB	377991	7563196	327.8	245.5	82.3	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN89072	LHB	426589	7598813	326.4	283.7	42.7	Tertiary	2	N	N	N	N	-
Private bore	RN89073	LHB	436107	7597782	341.1	290.8	50.3	Alluvium	1	N	N	N	N	-
Private bore	RN90255	LHB	419633	7577047	330.3	235.3	95.0	Clematis Sandstone	5	N	N	N	N	-
Private bore	RN90256	LHB	423671	7580878	280.0	162.6	117.4	Joe Joe Group	9	Y	N	N	N	-
Private bore	RN90257	LHB	442360	7576313	231.2	111.2	120.0	Joe Joe Group	17	N	N	N	N	-
Private bore	RN90258	LHB	426775	7565785	282.2	206.9	75.3	Clematis Sandstone	5	Y	N	N	N	-
Private bore	RN90259	LHB	423688	7577246	290.0	185.0	104.9	Rewan Formation	8	N	N	N	N	-
Private bore	RN90260	LHB	436157	7551360	260.0	169.0	91.0	Rewan Formation	8	N	N	N	N	-
Private bore	RN90369	LHB	431919	7560469	281.1	202.1	79.0	Tertiary	2	Y	N	N	N	-
Private bore	RN96545	LHB	400295	7571749	293.6	59.6	234.0	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN100185	LHB	381554	7554876	330.6	327.6	3.0	Tertiary	2	N	N	N	N	-
Private bore	RN102615	LHB	383407	7628532	310.0	234.3	75.8	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN102616	LHB	383296	7626814	301.6	238.0	63.6	Moolayember Fmt	4	N	N	N	N	-
Private bore	RN103877	LHB	425379	7607254	331.4	241.4	90.0	Betts Creek Beds	9	N	N	N	N	-
Private bore	RN103878	LHB	426591	7614110	290.6	228.7	61.8	Alluvium	1	Y	N	N	N	-
Private bore	RN118213	LHB	383472	7570354	325.4	237.6	87.8	Moolayember Fmt	4	Y	N	N	N	-
Private bore	RN118253	LHB	389570	7554808	309.0	307.0	2.0	Tertiary	2	Y	N	N	N	-
Private bore	RN118645	LHB	374942	7547465	355.3	353.3	2.0	Ronlow Beds	3	Y	N	N	N	-
Private bore	RN132938	LHB	423989	7574860	285.8	138.8	147.0	Betts Creek Beds	9	Y	N	N	N	-
Private bore	RN132939	LHB	442391	7547815	230.8	121.8	109.0	Betts Creek Beds?	9	Y	N	N	N	-
Private bore	RN132940	LHB	430302	7566901	252.6	209.2	43.4	Tertiary	2	N	N	N	N	-
Private bore	RN132941	LHB	420989	7573964	297.6	231.6	66.0	Tertiary	2	Y	N	N	N	-
Private bore	RN132942	LHB	432461	7557893	246.8	180.8	66.0	Tertiary	2	Y	N	N	N	-
Private bore	RN132943	LHB	436542	7549885	266.3	193.1	73.2	Tertiary	2	Y	N	N	N	-
Private bore	RN153491 (Bonsai bore)	LHB	401317	7622968	366.3	281.3	85.0	Clematis Sandstone	5	Y	N	N	N	-
Private bore	RN153581	LHB	395472	7599422	-	100.0	100.0	Clematis Sandstone?	5	Y	N	N	N	-
Private bore	RN153582	LHB	403774	7583208	-	121.0	121.0	Clematis Sandstone?	5	Y	N	N	N	-
Private bore	RN153583	LHB	401055	7600393	-	97.0	97.0	Clematis Sandstone?	5	Y	N	N	N	-
Private bore	RN158036	LHB	427560	7556220	237.9	-	-	Alluvium?	1	N	N	N	N	-
Private bore	RN158037	LHB	427565	7556214	237.9	-	-	Alluvium?	1	N	N	N	N	-
Private bore	RN158038	LHB	433645	7554823	234.2	-	-	Alluvium?	1	N	N	N	N	-
Private bore	50000 Bore	LHB	434904	7594662	302.5	254.9	47.6	Tertiary	2	Y	N	N	N	-
Private bore	8 Mile Bore	LHB	397808	7606133	338.7	-	-	Moolayember Fmt	4	Y	N	N	N	-
Private bore	Allens Bore	LHB	430014	7585765	265.6	-	-	Tertiary?	2	N	N	N	N	-
Private bore	RN8520 (Big Bore)	LHB	394499	7591314	323.4	95.4	228.0	Moolayember Fmt	4	N	N	N	N	-
Private bore	Bore Hole	LHB	425018	7596787	301.7	-	-	Joe Joe Group	9	N	N	N	N	-
Private bore	Brumby Hole	LHB	419476	7598953	331.0	248.4	82.6	Tertiary/ Joe Joe Group	2	Y	N	N	N	-
Private bore	Bully Hut 1	LHB	426317	7614304	290.9	271.9	19.1	Joe Joe Group	9	Y	N	N	N	-
Private bore	Bully Hut 2	LHB	426317	7614304	290.9	238.6	52.3	Joe Joe Group	9	N	N	N	N	-
Private bore	RN103876 (Camp Bore)	LHB	416315	7592174	333.1	259.0	74.1	Betts Creek Beds	9	N	N	N	N	-
Private bore	Dinner Creek Bore	LHB	397286	7611035	343.3	-	-	Moolayember Fmt	4	N	N	N	N	-
Private bore	Double Bore	LHB	441061	7587115	240.2	-	-	Tertiary?	2	N	N	N	N	-
Private bore	Edgers Bore	LHB	427723	7587725	275.6	-	-	Tertiary?	2	N	N	N	N	-
Private bore	Gum Hole	LHB	425174	7596844	307.0	263.1	43.9	Tertiary	2	Y	N	N	N	-
Private bore	Lane Bore	LHB	374411	7603855	344.8	284.8	60.0	Moolayember Fmt	4	Y	N	N	N	-
Private bore	Lin Bore	LHB	424923	7591009	288.6	-	-	Tertiary?	2	N	N	N	N	-
Private bore	Lin Yards	LHB	425457	7590678	286.0	-	-	Tertiary?	2	N	N	N	N	-
Private bore	Lofties Bore	LHB	424220	7603658	323.8	240.8	83.0	Tertiary/ Joe Joe Group	2	Y	N	N	N	-
Private bore	RN17451 (Moonoomoo Bore)	LHB	402814	7584618	322.0	256.2	65.8	Moolayember Fmt	4	Y	N	N	N	-
Private bore	Old Windmill	LHB	436733	7589584	255.9	-	-	Tertiary?	2	N	N	N	N	-
Private bore	Pidgenhole	LHB	424286	7594242	298.1	-	-	Tertiary?	2	N	N	N	N	-
Private bore	Prestons Bore	LHB	393555	7626959	337.1	275.5	61.7	Clematis Sandstone	5	N	N	N	N	-
Private bore	RN103875 (Roo Bore)	LHB	415439	7588709	343.0	264.7	78.3	Betts Creek Beds	9	N	N	N	N	-
Private bore	RN89071 (Stallion Bore)	LHB	434834	7605336	271.2	227.9	43.3	Tertiary	2	Y	N	N	N	-
Private bore	Swamp Bore	LHB	389547	7626125	321.0	266.0	55.0	Clematis Sandstone	5	Y	N	N	N	-
Private bore	Tomahawk	LHB	432126	7588667	266.8	-	-	Joe Joe Group	9	N	N	N	N	-
Private bore	Tomahawk No. 1	LHB	430781	7596452	279.0	-	-	Tertiary?	2	N	N	N	N	-
Private bore	Tomahawk No. 2	LHB	430781	7596446	279.0	258.4	20.6	Tertiary	2	Y	N	N	N	-
Private bore	RN47640 (Tomahawk Hut)	LHB	431986	7594800	273.2	251.5	21.7	Tertiary	2	Y	N	N	N	-
Private bore	Tutor Bore	LHB	390274	7617085	308.9	185.5	123.4	Moolayember Fmt	4	N	N	N	N	-
Private bore	Wild Bore	LHB	415707	7574936	303.4	-	-	Clematis Sandstone?	5	N	N	N	N	-

Note: Coordinates are in GDA 94 Zone 55

SP : Standpipe

VWP : Vibrating wire piezometer

LHB : Landholder bore



Type	Bore ID	Bore Type	Easting	Northing	Surface (mAHD)	Ending Depth (mAHD)	Bore Depth (mbgl)	Target Unit	Model Layer	Yield (incl. air lifts)	Packer Testing	Head Test	Pumping Test	Field Water Quality
Private bore	Warratah Camp Bore	LHB	414226	7576678	316.0	238.0	78.0	Clematis Sandstone	5	Y	N	N	N	-
Carmichael bore	C006P1	SP	435726	7560833	233.7	-	-	Interburden	15	-	-	-	-	-
Carmichael bore	C006P3r	SP	435734	7560826	233.9	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C007P2	SP	434726	7559864	238.1	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C007P3	SP	434728	7559862	238.1	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C008P1	SP	433710	7558830	238.1	-	-	Permian	9	-	-	-	-	-
Carmichael bore	C008P2	SP	433708	7558827	238.1	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C011P1	SP	428843	7569953	254.5	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C011P3	SP	428846	7569955	254.4	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C012P1	SP	430888	7569874	247.3	-	-	Permian Overburden	9	-	-	-	-	-
Carmichael bore	C012P2	SP	430887	7569877	247.3	-	-	Permian Overburden	9	-	-	-	-	-
Carmichael bore	C014P2	SP	430731	7563976	256.0	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C016P2	SP	422017	7574974	294.5	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C018P1	SP	423982	7574850	281.3	-	-	Permian Overburden	9	-	-	-	-	-
Carmichael bore	C018P2	SP	423988	7574849	281.3	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C018P3	SP	423978	7574853	281.2	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C020P2	SP	427846	7566932	263.1	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C022P1	SP	426813	7565962	273.8	-	-	Dunda Beds	6	-	-	-	-	-
Carmichael bore	C024P3	SP	428909	7571761	258.6	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C025P1	SP	438016	7555846	227.5	-	-	Tertiary	2	-	-	-	-	-
Carmichael bore	C025P2	SP	438010	7555845	227.5	-	-	Tertiary	2	-	-	-	-	-
Carmichael bore	C027P1	SP	433643	7554818	227.0	-	-	Alluvium	1	-	-	-	-	-
Carmichael bore	C027P2	SP	433648	7554819	227.6	-	-	Dunda Beds	6	-	-	-	-	-
Carmichael bore	C029P1	SP	437691	7555082	225.4	-	-	Tertiary	2	-	-	-	-	-
Carmichael bore	C029P2	SP	437688	7555081	225.4	-	-	Alluvium	1	-	-	-	-	-
Carmichael bore	C032P2	SP	439404	7544896	256.2	-	-	Permian Overburden	9	-	-	-	-	-
Carmichael bore	C034P1	SP	442386	7547816	227.4	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C034P3	SP	442389	7547814	227.4	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C035P1	SP	441404	7546824	236.3	-	-	Rewan Formation	8	-	-	-	-	-
Carmichael bore	C035P2	SP	441402	7546828	236.2	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C555P1	SP	432450	7557881	241.2	-	-	Rewan Formation	8	-	-	-	-	-
Carmichael bore	C556P1	SP	436524	7549882	260.6	-	-	Rewan Group	8	-	-	-	-	-
Carmichael bore	C558P1	SP	430312	7566903	250.1	-	-	Tertiary / Permian	2	-	-	-	-	-
Carmichael bore	C9553P1R	SP	421010	7573975	294.1	-	-	Dunda Beds	6	-	-	-	-	-
Carmichael bore	HD01	SP	426146	7561468	-	-	-	Dunda Beds	6	-	-	-	-	-
Carmichael bore	HD02	SP	423823	7557008	240.0	-	-	Clematis Sandstone	5	-	-	-	-	-
Carmichael bore	HD03A	SP	427565	7556120	229.4	-	-	Dunda Beds	6	-	-	-	-	-
Carmichael bore	HD03B	SP	427559	7556119	229.4	-	-	Alluvium	1	-	-	-	-	-
Carmichael bore	C553P_1	VWP	420993	7573965	294.6	-	-	D1 Seam	16	-	-	-	-	-
Carmichael bore	C553P_2	VWP	420993	7573965	294.6	-	-	AB1 Seam	10	-	-	-	-	-
Carmichael bore	C553P_3	VWP	420993	7573965	294.6	-	-	Permian Overburden	9	-	-	-	-	-
Carmichael bore	C555P_1	VWP	432450	7557881	241.2	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C555P_2	VWP	432450	7557881	241.2	-	-	AB1 Seam	10	-	-	-	-	-
Carmichael bore	C555P_3	VWP	432450	7557881	241.2	-	-	Rewan Group	8	-	-	-	-	-
Carmichael bore	C9556PR_1	VWP	436543	7549885	260.4	-	-	D2 Seam	16	-	-	-	-	-
Carmichael bore	C9556PR_2	VWP	436543	7549885	260.4	-	-	AB1 Seam	10	-	-	-	-	-
Carmichael bore	C9556PR_3	VWP	436543	7549885	260.4	-	-	Rewan Group	8	-	-	-	-	-
Carmichael bore	C056C_1	VWP	424920	7569970	283.9	-	-	D1 Seam	16	-	-	-	-	-
Carmichael bore	C056C_2	VWP	424920	7569970	283.9	-	-	AB1 Seam	10	-	-	-	-	-
Carmichael bore	C056C_3	VWP	424920	7569970	283.9	-	-	Rewan Group	6	-	-	-	-	-
Carmichael bore	C558P_1	VWP	430312	7566903	250.1	-	-	Overburden	17	-	-	-	-	-
Carmichael bore	C558P_2	VWP	430312	7566903	250.1	-	-	D1 Seam	16	-	-	-	-	-
Carmichael bore	C558P_3	VWP	430312	7566903	250.1	-	-	AB1 Seam	10	-	-	-	-	-
Carmichael bore	C823SP	SP	433605	7562875	245.9	-	-	C Seam	14	-	-	-	-	-
Carmichael bore	C825SP	SP	434868	7561960	238.1	-	-	D Seam Underburden	17	-	-	-	-	-
Carmichael bore	C827SP	SP	436101	7560334	231.7	-	-	E Seam	17	-	-	-	-	-
Carmichael bore	C829SP	SP	436463	7559356	238.1	-	-	Colinlea sandstone	17	-	-	-	-	-
Carmichael bore	C180112SP	SP	437715	7558820	226.2	-	-	Colinlea sandstone	17	-	-	-	-	-
Carmichael bore	C180114SP	SP	438687	7557649	225.0	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C832SP	SP	439570	7554788	223.1	-	-	C Seam	14	-	-	-	-	-
Carmichael bore	C833SP	SP	439559	7554779	223.1	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C834SP	SP	439577	7554764	223.1	-	-	D Seam Underburden	17	-	-	-	-	-
Carmichael bore	C836VWP_1	VWP	437567	7552869	236.8	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C836VWP_2	VWP	437567	7552869	236.8	-	-	AB Seam	10	-	-	-	-	-
Carmichael bore	C836VWP_3	VWP	437567	7552869	236.8	-	-	Overburden	9	-	-	-	-	-
Carmichael bore	C9838SPR	SP	439558	7552813	228.6	-	-	Overburden	9	-	-	-	-	-
Carmichael bore	C9839SPR	SP	439567	7552797	228.3	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C840SP	SP	439546	7552839	228.7	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C842VWP_1	VWP	439502	7550839	238.8	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C842VWP_2	VWP	439502	7550839	238.8	-	-	AB Seam	12	-	-	-	-	-
Carmichael bore	C842VWP_3	VWP	439502	7550839	238.8	-	-	Rewan Group	8	-	-	-	-	-
Carmichael bore	C844SP	SP	441392	7546840	235.6	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C9845SPR	SP	439412	7544904	255.2	-	-	Rewan Group	8	-	-	-	-	-
Carmichael bore	C847SP	SP	442385	7543809	236.8	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C848SP	SP	442364	7543815	236.7	-	-	D Seam	16	-	-	-	-	-
Carmichael bore	C9849SPR	SP	442357	7543819	236.9	-	-	Below D Seam	17	-	-	-	-	-
Carmichael bore	C851VWP_1	VWP	441383	7542878	244.7	-	-	Interburden	13	-	-	-	-	-
Carmichael bore	C851VWP_2	VWP	441383	7542878	244.7	-	-	AB3	12	-	-	-	-	-
Carmichael bore	C851VWP_3	VWP	441383	7542878	244.7	-	-	Permian Overburden	9	-	-	-	-	-
Carmichael bore	C180119SP	SP	448587	7536354	219.0	-	-	Claystone	9	-	-	-	-	-
Carmichael bore	C180122SP	SP	448581	7536351	219.0	-	-	Claystone	9	-	-	-	-	-
Carmichael bore	C9180124SPR	SP	448600	7536358	219.0	-	-	Alluvium	1	-	-	-	-	-
Carmichael bore	C180120SP	SP	447057	7531730	227.1	-	-	Alluvium	1	-	-	-	-	-
Carmichael bore	C9180125SPR	SP	447040	7531739	227.1	-	-	Alluvium	1	-	-	-	-	-
Carmichael bore	C9180121SPR	SP	448086	7529364	229.8	-	-	Mudstone	9	-	-	-	-	-
Carmichael bore	C180123SP	SP	448079	7529358	229.9	-	-	Claystone	9	-	-	-	-	-
Carmichael bore	C180116SP	SP	439394	7540911	260.7	-	-	Dunda Beds	6	-	-	-	-	-
Carmichael bore	C180117SP	SP	435917	7547523	278.6	-	-	-	-	-	-	-	-	-
Carmichael bore	C180118SP	SP	423799	7568089	305.6	-	-	-	-	-	-	-	-	-

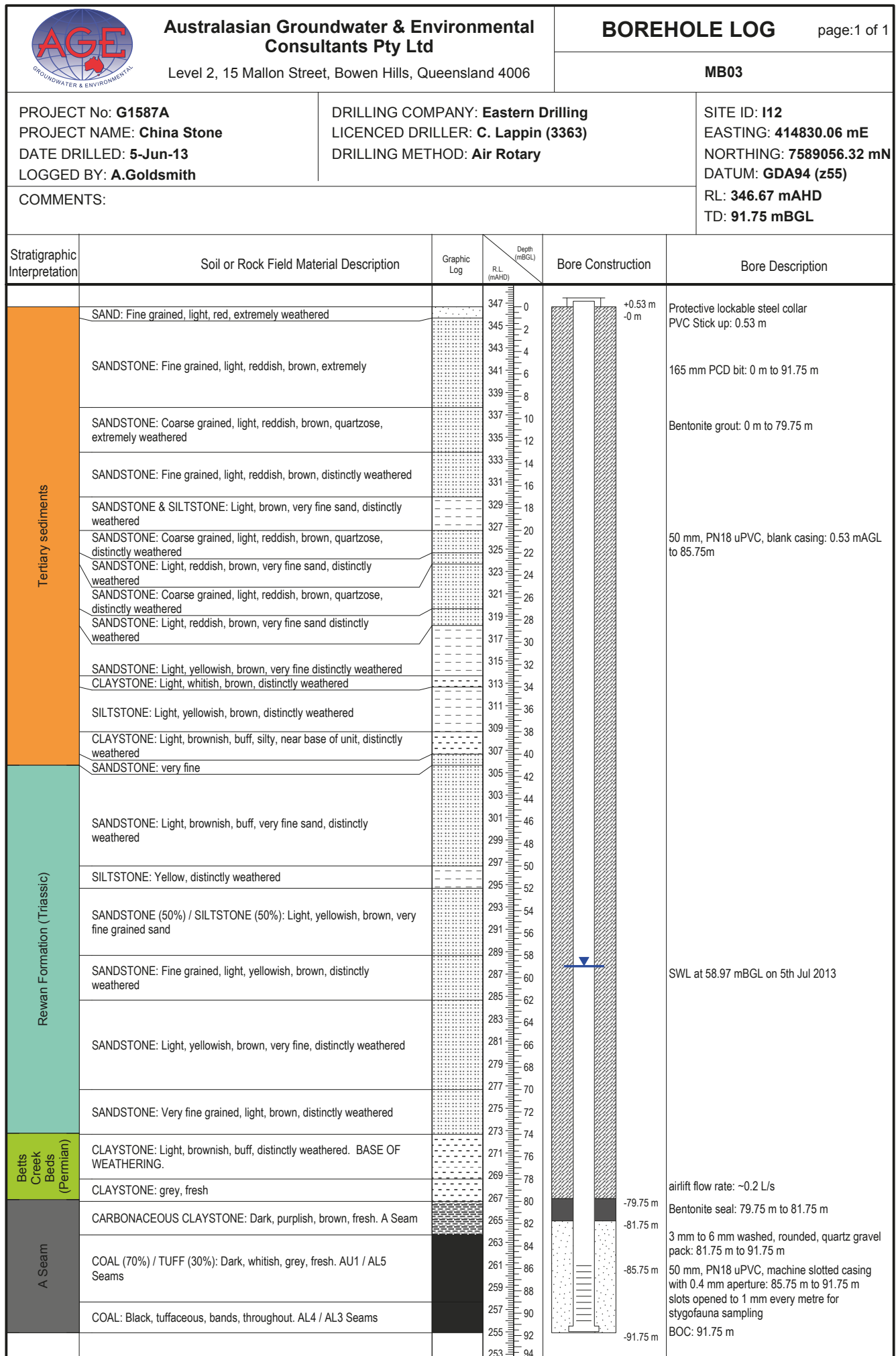
Note: Coordinates are in GDA 94 Zone 55

SP : Standpipe

VWP : Vibrating wire piezometer

LHB : Landholder bore

Appendix A-2
Bore construction logs




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BOREHOLE LOG

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MB04

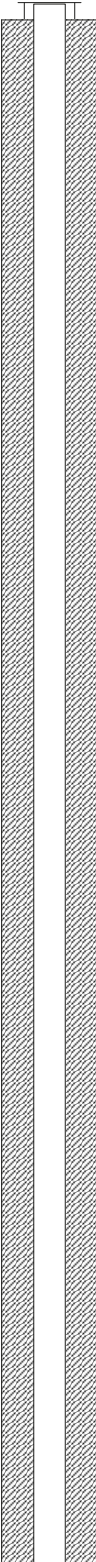
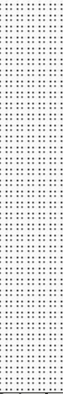
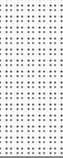
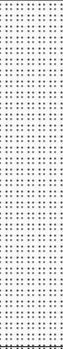
PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **6-Jan-13**
 LOGGED BY: **S. Miller**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **M. Rhook (3342)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **J14.5**
 EASTING: **413863.27 mE**
 NORTHING: **7590355.23 mN**
 DATUM: **GDA94 (z55)**
 RL: **366.25 mAHD**
 TD: **25.5 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments			367 0	+0.7 m -0 m	Protective lockable steel collar PVC Stick up: 0.7 m
	SOIL: Orangey, red, quartzose, weathered to soil				
	GRAVEL CONGLOMERATE: Orangey, red, highly weathered		365 2 363 4 361 6 359 8 357 10 355 12 353 14 351 16	165 mm PCD bit: 0 m to 25.5 m Bentonite grout: 0 m to 14.5 m Bentonite seal: 14.5 m to 15.5 m	
	GRAVEL CONGLOMERATE: Orangey, red, quartzose, fragments, throughout, highly weathered		349 18 347 20	3 mm to 6 mm washed, rounded, quartz gravel pack: 15.5 m to 25.6 m 50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 19.5 m	
	SILTSTONE: Orangey, red, quartzose, fragments, silty matrix		345 22 343 24 341 26	50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 19.5 m to 25.5 m slots opened to 1 mm every metre for stygofauna sampling bore dry at the time of drilling, still dry on the 19th March 2014 BOC: 25.5 m	

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006			BOREHOLE LOG page: 1 of 2		
			MB05		
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 16-Dec-12 LOGGED BY: S.Miller / H.Donovan		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: M. Rhook (3342) DRILLING METHOD: Air Rotary		SITE ID: J14.5 EASTING: 413873.45 mE NORTHING: 7590356.35 mN DATUM: GDA94 (z55) RL: 366.14 mAHD TD: 108 mBGL	
COMMENTS:					
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments	SAND: Dark red/orange, completely weathered		368 366 364 362 360 358 356 354 352 350 348 346 344 342 340 338 336 334 332 330 328 326 324 322 320 318 316 314	+0.65 m -0 m 	Protective lockable steel collar PVC Stick up: 0.65 m 165 mm PCD bit: 0 m to 108 m Bentonite grout: 0 m to 91 m 50 mm, PN18 uPVC, blank casing: 0.65 mAGL to 102 m
	SANDSTONE: Medium red/orange, lithic, fractured, gravelly, completely weathered				
	GRAVEL CONGLOMERATE: Medium grey/brown, highly weathered				
	SANDSTONE: Light red/brown, minor lithic, fractured, highly weathered				
	SANDSTONE: mottled red/cream, highly weathered laterite				
	SANDSTONE: Very fine grained, light creamy red, highly weathered				
	SILTSTONE: Light cream red, clayey, highly weathered				
	SANDSTONE: Light cream white, highly weathered				
	SILTSTONE: Light cream red, sandy in parts, highly weathered				
	CLAYSTONE: Light creamy brown, silty in parts, moderately weathered				


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Consultants Pty Ltd**

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BOREHOLE LOG

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MB05

 PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **16-Dec-12**
 LOGGED BY: **S.Miller / H.Donovan**

 DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **M. Rhook (3342)**
 DRILLING METHOD: **Air Rotary**

 SITE ID: **J14.5**
 EASTING: **413873.45 mE**
 NORTHING: **7590356.35 mN**
 DATUM: **GDA94 (z55)**
 RL: **366.14 mAHD**
 TD: **108 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments			312 54 310 56 308 58 306 60 304 62 302 64 300 66 298 68 296 70 294 72 292 74 290 76 288 78 286 80 284 82 282 84 280 86 278 88 276 90 274 92 272 94 270 96 268 98 266 100 264 102 262 104 260 106 258 108		
Rewan Formation (Triassic)	CLAYSTONE: Light yellow/brown, moderately weathered				
	CLAYSTONE: Medium purplish brown, slightly weathered				SWL at 71.26 mBGL on 3rd Jul 2013
	SILTSTONE: Medium blueish grey, slightly weathered				
	CLAYSTONE: Medium blueish grey, slightly weathered				
	SILTSTONE: Medium blueish grey, fresh				
Betts Creek Beds (Permian)	CLAYSTONE: Medium grey				slots opened to 1 mm every metre for stygofauna sampling
	SILTSTONE: Medium grey				Bentonite seal: 91 m to 92 m
	CLAYSTONE: Medium grey				3 mm to 6 mm washed, rounded, quartz gravel pack: 92 m to 108 m
	SANDSTONE: Very fine grained, light grey, clayey matrix				50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 102 m to 108 m
	COAL: Dark, brown. AU4 Seam				BOC: 108 m

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MB06

DRILLING COMPANY: **Eastern Drilling**
LICENCED DRILLER: **C.Lappin (3363)**
DRILLING METHOD: **Mud Rotary / Core**

SITE ID: **J14.5**
EASTING: **413873.53 mE**
NORTHING: **7590368.99 mN**
DATUM: **GDA94 (z55)**
RL: **366.02 mAHD**
TD: **139.5 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	R.L. (mAHD)	Depth (mBSL)	Bore Construction	Bore Description
			368			
	SAND: Medium to dark, orange, brown, extremely, weathered.		366	0	+0.4 m -0 m	Protective lockable steel collar PVC Stick up: 0.4 m
	SANDSTONE: Medium, orange, distinctly weathered.		364	2		
	SANDSTONE: Fine grained, light to medium, creamy, green, distinctly weathered.		362	4		
	SANDSTONE: Medium to coarse grained, medium, brown, distinctly weathered.		360	6		123 mm PCD bit: 0 m to 86.3 m
	SANDSTONE: Fine grained, light to medium, reddish, brown, distinctly weathered.		358	8		
	SILTSTONE: Mottled, blackish, brown, distinctly weathered.		356	10		HQ core: 86.3 m to 139.5 m
	SANDSTONE: Fine grained, light to medium, creamy, red.		354	12		
	FERRICRETE: Medium to dark, brownish, red, distinctly, weathered, abundant, quartz.		352	14		
	SILTSTONE: Creamy, brown, sandy, distinctly weathered.		350	16		Reamed using 123 mm PCD bit to 139.5 m
	SILTSTONE: Brownish, red, sandy, lithic, distinctly, weathered.		348	18		
	FERRICRETE: Dark, brownish, black, altered, distinctly, weathered.		346	20		
	SILTSTONE: Light to medium, reddish, brown, sandy, distinctly weathered.		344	22		
	SANDSTONE: Fine grained, reddish, brown, silty, lithic, altered, distinctly weathered.		342	24		
			340	26		Bentonite grout: 0 m to 105 m
			338	28		
			336	30		
	SANDSTONE: Fine to medium grained, mottled, reddish, brown, to creamy, white, silty, distinctly weathered.		334	32		
			332	34		
			330	36		50 mm, PN18 uPVC, blank casing: 0.4 mAGL to 125 m
			328	38		
	SILTSTONE: Mottled, purplish, red, to creamy, white, clayey, lithic, distinctly weathered.		326	40		
			324	42		
			322	44		
			320	46		
	MUDSTONE: Mottled, creamy, brown, silty, lithic, distinctly weathered.		318	48		
	SILTSTONE: Mottled, yellowish, brown, clayey, distinctly, weathered.		316	50		
			314	52		
	CLAYSTONE: Light, yellowish, brown, silty, traces, distinctly weathered.		312	54		
			310	56		
			308	58		
			306	60		
			304	62		
			302	64		
	CLAYSTONE: Light, yellowish, brown, silty, traces, distinctly weathered.		300	66		
			298	68		


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BOREHOLE LOG

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MB06

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **19-Mar-13**
 LOGGED BY: **J.Ford**

DRILLING COMPANY: **Eastern Drilling**
 LICENCED DRILLER: **C.Lappin (3363)**
 DRILLING METHOD: **Mud Rotary / Core**

SITE ID: **J14.5**
 EASTING: **413873.53 mE**
 NORTHING: **7590368.99 mN**
 DATUM: **GDA94 (z55)**
 RL: **366.02 mAHD**
 TD: **139.5 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Rewan Formation (Triassic)			296 70		
	SILTSTONE: Mottled, yellowish, orange, clayey, traces, distinctly weathered.		294 72		SWL at 71.09 mBGL on 3rd Jul 2013
	SILTSTONE: Mottled, purplish, brown, clayey, slightly, weathered.		292 74		
			290 76		
	SILTSTONE: Mottled, grey, occasional, sandy, fresh.		288 78		
			286 80		
Betts Creek Beds (Permian)	CORE LOSS:		284 82		
			282 84		
	SILTSTONE: Grey, minor, sandy, phases, low strength rock, thickly laminated(6-20mm).		280 86		
	SANDSTONE: Very fine to fine grained, light, grey, silty, laminae, throughout, low strength rock, minor, calcite, in veins, carbonaceous wisps		278 88		
			276 90		
	SANDSTONE: Medium grained, light, grey, siltstone, laminae, near top of unit, low strength rock.		274 92		
			272 94		
	SANDSTONE: Fine to medium grained, light, grey, carbonaceous, laminae, siltstone, lenses, low, strength rock.		270 96		
			268 98		
	SANDSTONE: Medium grained, light, grey, carbonaceous, laminae, low strength rock.		266 100		
A Seam			264 102		
	SANDSTONE: Fine to medium grained, light, grey, carbonaceous, laminae, low strength rock.		262 104		
	SILTSTONE: Grey, low strength rock, thickly, laminated(6-20mm).		260 106		
	SANDSTONE: Fine to medium grained, light, grey, siltstone, laminae.		258 108		
	CORE LOSS:		256 110		
	SANDSTONE: Very fine to fine grained, light, grey, siltstone, phases, throughout, low strength, rock.		254 112		
			252 114		
			250 116		
			248 118		
	COAL: Dull <1% bright, AU4 / AL5 Seam		246 120		
B Seam			244 122		
			242 124		
			240 126		
			238 128		
	SILTSTONE: Light grey, carbonaceous in part, laminated		236 130		
			234 132		
	COAL: Dull <1% bright. B3 / B1 Seams		232 134		
			230 136		
			228 138		
	SILTSTONE: Light grey, carbonaceous in part, laminated		226 140		

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		MB07			
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 16-Dec-12 LOGGED BY: H.Donovan		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: M. Rhook (3342) DRILLING METHOD: Air Rotary			
COMMENTS:		SITE ID: K13 EASTING: 415547.42 mE NORTHING: 7590583.66 mN DATUM: GDA94 (z55) RL: 343.01 mAHD TD: 60 mBGL			
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments	SAND: Dark red, completely weathered. Base of Tertiary at 4 m		343 0		+0.46 m -0 m Protective lockable steel collar PVC Stick up: 0.46 m
	SANDSTONE: Fine grained, light brown, highly weathered		341 2		
	SILTSTONE: Yellow, sandy, highly weathered		339 4		152 mm PCD bit: 0 m to 60 m
	SANDSTONE: Fine grained, Yellow, highly weathered		337 6		
	SANDSTONE: Very fine grained, light, yellow/grey, highly weathered		335 8		Bentonite grout: 0 m to 43 m
	SANDSTONE: Fine grained, light cream/red, highly weathered		333 10		
	SANDSTONE: Very fine grained, light cream/grey, highly weathered		331 12		
	SANDSTONE: Fine grained, reddish cream, highly weathered		329 14		
	SANDSTONE: Fine grained, light cream/yellow, highly weathered		327 16		50 mm, PN18 uPVC, blank casing: 0.46 mAGL to 54 m
	SANDSTONE: Fine grained, light red, highly weathered		325 18		
	SILTSTONE: Red, highly weathered		323 20		
	SANDSTONE: Very fine grained, red, highly weathered		321 22		
	SILTSTONE: Light, red/cream, highly weathered		319 24		
	SILTSTONE: Light brown/red, occasional clayey sandy, highly weathered		317 26		
	SILTSTONE: Light yellow, highly weathered		315 28		
	SANDSTONE: Very fine grained, red, highly weathered		313 30		
	SILTSTONE: Light, red/cream, highly weathered		311 32		
	SILTSTONE: Light brown/red, occasional clayey sandy, highly weathered		309 34		
	SILTSTONE: Light yellow, highly weathered		307 36		
	SILTSTONE: Light brown/red, occasional clayey sandy, highly weathered		305 38		
	SILTSTONE: Light yellow, highly weathered		303 40		
SILTSTONE: Light brown/red, occasional clayey sandy, highly weathered		301 42			
SILTSTONE: Light yellow, highly weathered		299 44	-43 m -44 m	Bentonite seal: 43 m to 44 m	
CLAYSTONE: Light, white/yellow, highly weathered		297 46		3 mm to 6 mm washed, rounded, quartz gravel pack: 44 m to 60 m	
CLAYSTONE: Light, creamy pink, occasionally silty, highly weathered		295 48			
CLAYSTONE: Light, creamy pink, occasionally silty, highly weathered		293 50			
CLAYSTONE: Light, creamy pink, occasionally silty, highly weathered		291 52		SWL at 52.01 mBGL on 20th Jan 2013	
CLAYSTONE: Light, creamy pink, occasionally silty, highly weathered		289 54	-54 m	50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 54 m to 60 m slots opened to 1 mm every metre for stygofauna sampling	
CLAYSTONE: Light, creamy pink, occasionally silty, highly weathered		287 56			
CLAYSTONE: Light, creamy pink, occasionally silty, highly weathered		285 58			
CLAYSTONE: Light, creamy pink, occasionally silty, highly weathered		283 60	-60 m	BOC: 60 m	


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BOREHOLE LOG

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MB08

 PROJECT No: **G1587A**

 PROJECT NAME: **China Stone**

 DATE DRILLED: **21-Mar-13**

 LOGGED BY: **B.Diaz / H.Donovan**

 DRILLING COMPANY: **Watson Drilling**

 LICENCED DRILLER: **J.Freeman (3335)**

 DRILLING METHOD: **Air Rotary**

 SITE ID: **K13**

 EASTING: **415553.1 mE**

 NORTHING: **7590569.96 mN**

 DATUM: **GDA94 (z55)**

 RL: **342.92 mAHD**

 TD: **90 mBGL**

 COMMENTS: **redrill; grout seeped into the screen on the initial bore**

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments	SAND: Red, fine grained, weathered to soil		342 0	+0.5 m	Protective lockable steel collar
	SANDSTONE: Reddish brown, fine grained, completely weathered		340 2	-0 m	PVC Stick up: 0.5 m (estimate)
	SANDSTONE: Fine grained, yellow/brown, moderately weathered		338 4		152 mm PCD bit: 0 m to 90 m
	SANDSTONE: Medium grained, pinkish brown, moderately weathered		336 6		Bentonite grout: 0 m to 76 m
	SANDSTONE: Fine grained, light brown, moderately weathered		334 8		
	SANDSTONE: Medium grained, reddish brown		332 10		
	GRAVEL CONGLOMERATE: Light reddish brown, sandy, moderately weathered		330 12		
	SANDSTONE: Fine grained, light reddish brown, moderately weathered		328 14		
	SANDSTONE: Coarse grained, light reddish brown		326 16		
	SANDSTONE: Fine grained, light reddish brown, moderately weathered		324 18		
	SANDSTONE: Light brown, moderately weathered		322 20		50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 82.1 m
	SILTSTONE: Purplish brown, clayey, moderately weathered		320 22		
	SILTSTONE: light yellow, slightly weathered		318 24		
	SANDSTONE: Fine grained, light yellow, slightly weathered		316 26		
	SILTSTONE: Yellowish orange, slightly weathered		314 28		
	SILTSTONE: Pinkish white, slightly weathered		312 30		
	CLAYSTONE: Pinkish white, slightly weathered		310 32		
	SILTSTONE: Off white, slightly weathered		308 34		
Betts Creek Beds (Permian)	CLAYSTONE: Off white, yellow, slightly weathered		306 36		
	SILTSTONE: Cream sandy towards base of unit, slightly weathered		304 38		
	SANDSTONE: Medium grained, creamish grey, slightly weathered		302 40		
	CLAYSTONE: Creamish grey, slightly weathered		300 42		
	SILTSTONE: Grey, weathered		298 44		
	SANDSTONE: Fine to medium grained, light grey, BASE OF WEATHERING AT 86.4 m.		296 46		
			294 48		
			292 50		
			290 52		
			288 54		
			286 56		
			284 58		
			282 60		
			280 62		
			278 64		
			276 66		
			274 68		
			272 70		
			270 72		
			268 74		
			266 76		
			264 78		
			262 80		
			260 82		
			258 84		
			256 86		
			254 88		

SWL at 60.18 mBGL on 30th May 2013

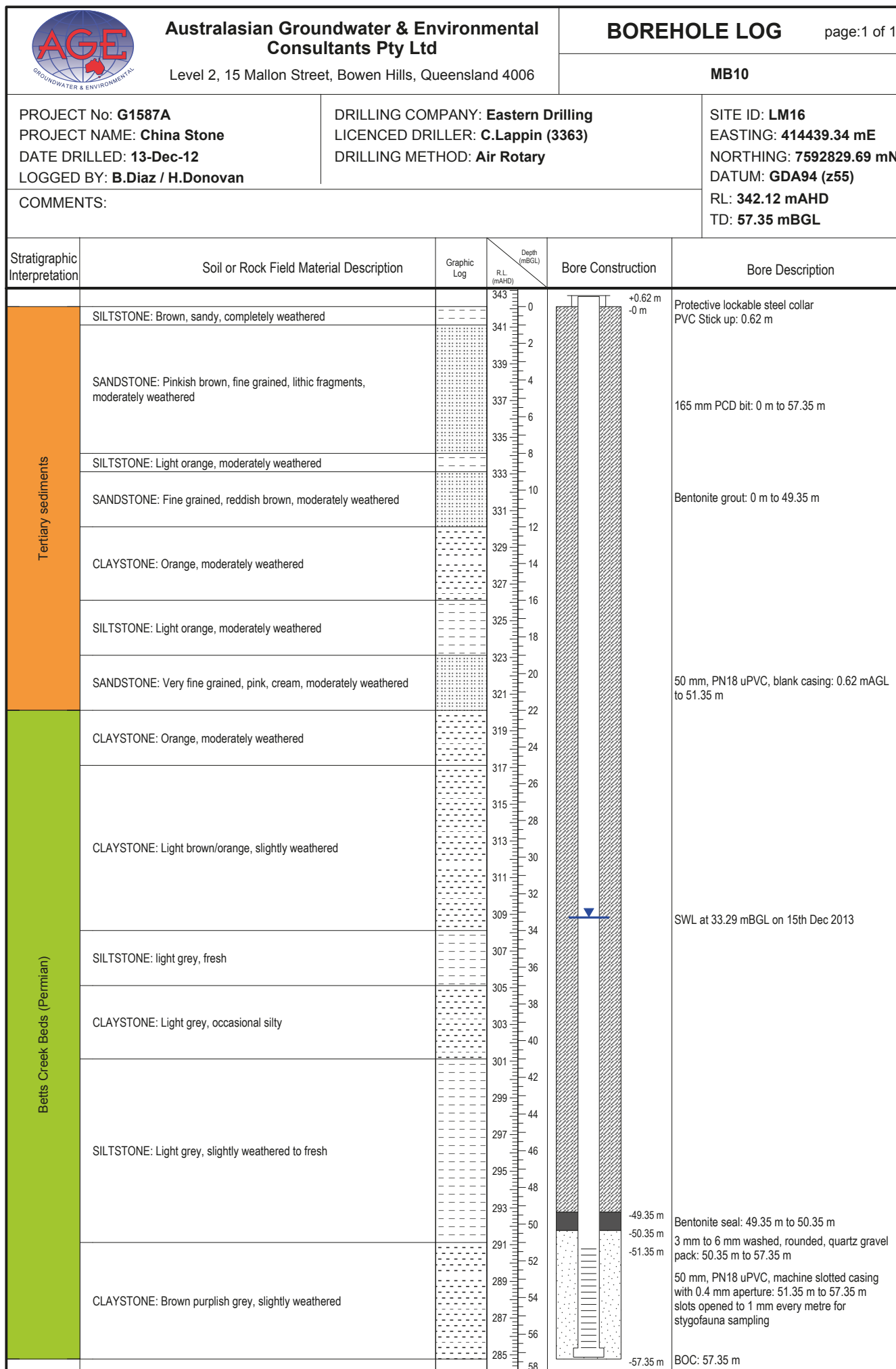
Bentonite seal: 76 m to 79 m

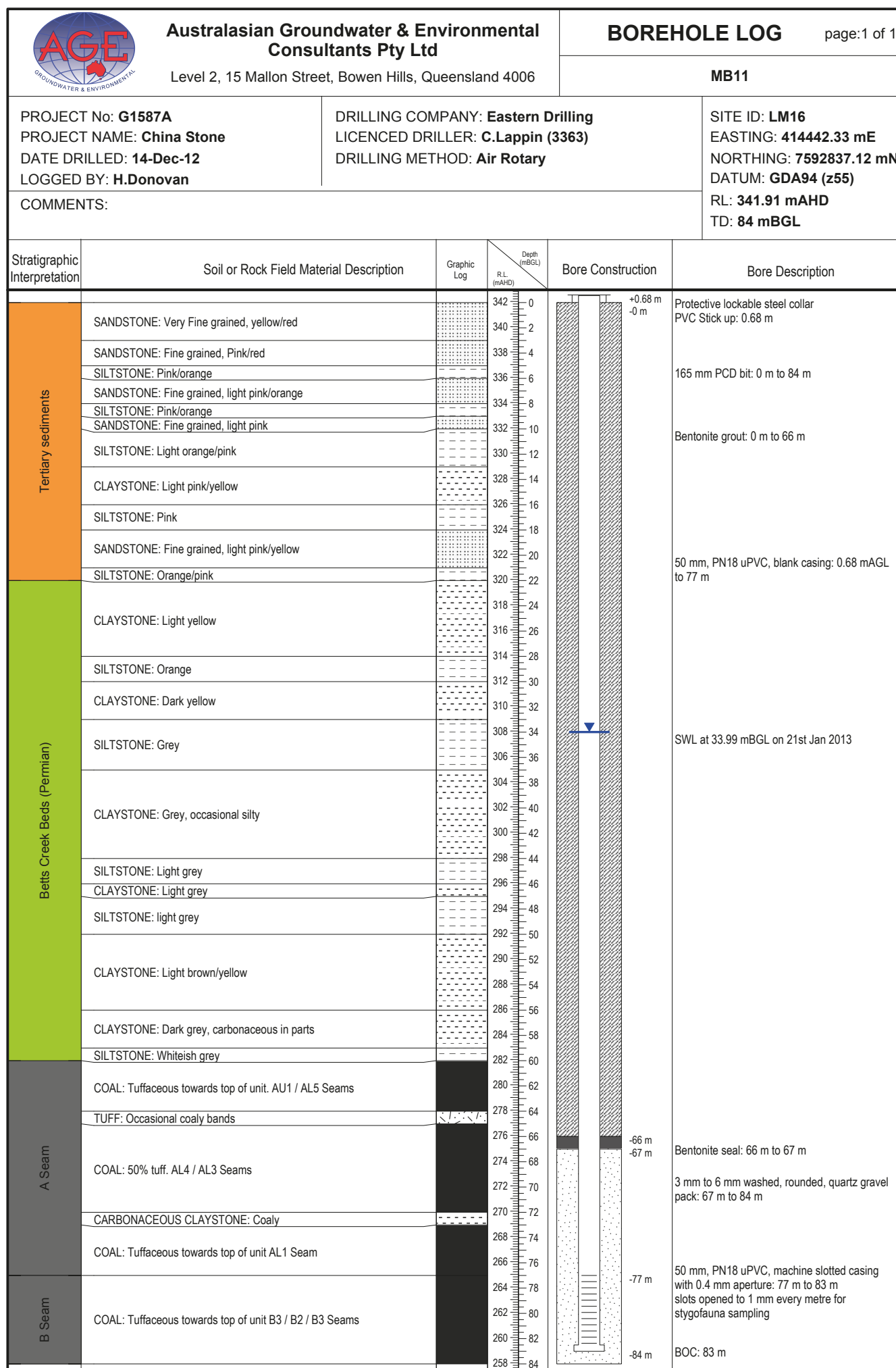
3 mm to 6 mm washed, rounded, quartz gravel pack: 79 m to 90 m

50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 82.1 m to 88.1 m slots opened to 1 mm every metre for stygofauna sampling

BOC: 88.1 m

		Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:1 of 1	
				MB09	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 12-Dec-12 LOGGED BY: B.Diaz / H.Donovan		DRILLING COMPANY: Eastern Drilling LICENCED DRILLER: C.Lappin (3363) DRILLING METHOD: Air Rotary		SITE ID: LM16 EASTING: 414433.68 mE NORTHING: 7592830.77 mN DATUM: GDA94 (z55) RL: 342.21 mAHD TD: 23.35 mBGL	
COMMENTS:					
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments			343 0	+0.65 m -0 m	Protective lockable steel collar PVC Stick up: 0.65 m
	SAND: Brown		341 2		165 mm PCD bit: 0 m to 23.5 m
	SANDSTONE: Light pinkish red, fine to medium grained, gravelly, completely weathered		339 4		Bentonite grout: 0 m to 15.8 m
			337 6		
	SILTSTONE: Light pinkish purple, slightly weathered		335 8		50 mm, PN18 uPVC, blank casing: 0.65 mAGL to 15.8 m
			333 10		
	SANDSTONE: Very fine grained, light pinkish purple, slightly weathered		331 12		bore dry at the time of drilling, still dry on the 30th May 2013
			329 14		
	CLAYSTONE: Light orange/brown, silty, slightly weathered		327 16	-15.8 m	Bentonite seal: 15.8 m to 16.8 m
			325 18	-16.8 m -17.35 m	
Berts Creek Beds (Permian)	SILTSTONE: Light orange, slightly weathered		323 20		3 mm to 6 mm washed, rounded, quartz gravel pack: 16.8 m to 23.35 m
			321 22		50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 17.35 m to 23.35 m
	SANDSTONE: Very fine grained, light orange/brown, slightly weathered		319	-23.35 m	slots opened to 1 mm every metre for stygofauna sampling BOC: 23.35 m
	CLAYSTONE: Light yellow, silty, slightly weathered				






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BOREHOLE LOG

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MB12

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **7-Jun-13**
 LOGGED BY: **B. Walker**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **H16**
 EASTING: **410626.14 mE**
 NORTHING: **7590113.24 mN**
 DATUM: **GDA94 (z55)**
 RL: **376.92 mAHD**
 TD: **101 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments	SANDSTONE: Fine grained, mottled, brown, weathered		378 0		Protective lockable steel collar PVC Stick up: 0.65 m
	SANDSTONE: Very fine to fine grained, purplish, weathered		376 2		165 mm PCD bit: 0 m to 101 m
	SANDSTONE: Very fine to fine grained, creamy, weathered		374 4		Bentonite grout: 0 m to 87 m
	SANDSTONE: Very fine to fine grained, light, brown, weathered		372 6		
	CLAYSTONE: Dark, reddish, brown, silty in part, weathered		370 8		
	SANDSTONE: Very fine to fine grained, creamy, weathered		368 10		
	CLAYSTONE: Dark, reddish, brown, weathered		366 12		
	CLAYSTONE: Pinkish, purple, weathered		364 14		
	CLAYSTONE: Dark, reddish, brown, weathered		362 16		
	CLAYSTONE: Dark, purplish, brown, silty in part, weathered		360 18		
	SANDSTONE: Very fine to fine grained, light, greenish, grey, weathered		358 20		
	SILTSTONE: Yellowish, cream, weathered		356 22		
	SANDSTONE: Very fine to fine grained, creamy, weathered		354 24		
	CLAYSTONE: Brown, silty in part, weathered		352 26		
	SANDSTONE: Very fine to fine grained, pinkish, cream, weathered		350 28		
	SILTSTONE: Pinkish, cream, weathered		348 30		
	SILTSTONE: Pinkish, weathered		346 32		
	CLAYSTONE: Brown, silty in part, weathered		344 34		
	SANDSTONE: Very fine to fine grained, light, yellowish, brown, weathered		342 36		
	SILTSTONE: Light, yellowish, brown, weathered		340 38		
	SANDSTONE: Very fine to fine grained, creamy, weathered		338 40		
	SILTSTONE: Creamy, weathered		336 42		
	SANDSTONE: Very fine to fine grained, light, pinkish, cream, weathered		334 44		
	SILTSTONE: Light, yellowish, brown, weathered		332 46		
	SILTSTONE: Pinkish, weathered		330 48		
	SANDSTONE: Very fine to fine grained, light, brownish, buff, weathered		328 50		
Rewan Formation (Triassic)	SANDSTONE: Fine to medium grained, light, brownish, buff, weathered		326 52		
	SILTSTONE: Pinkish, weathered		324 54		
	CLAYSTONE: Dark, purplish, brown, BASE OF WEATHERING.		322 56		
	SILTSTONE: Dark, pink, fresh		320 58		
	SANDSTONE: Very fine to fine grained, brown, fresh		318 60		
	CLAYSTONE: Greenish, grey, fresh		316 62		
	SILTSTONE: Greenish, grey, fresh		314 64		
	SANDSTONE: Very fine to fine grained, grey, fresh		312 66		
	SILTSTONE: Greenish, grey		310 68		
	SILTSTONE: Dark, purplish, grey		308 70		
	SANDSTONE: Very fine to fine grained, greenish, grey		306 72		
	SILTSTONE: Greenish, grey, sandy in part		304 74		
	SANDSTONE: Very fine to fine grained, grey, silty near base of unit		302 76		
	SANDSTONE: Very fine to fine grained, greenish, grey		300 78		
			298 80		
			296 82		
			294 84		
			292 86		
			290 88		
			288 90		
			286 92		
			284 94		
			282 96		
			280 98		
			278 100		
			276 102		
			274 104		

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MB13

SITE ID: **K21.5**
EASTING: **408638.04 mE**
NORTHING: **7594222.58 mN**
DATUM: **GDA94 (z55)**
RL: **389.09 mAHD**
TD: **102 mBGL**

RL: 389.09 mAHD
TD: 102 mBGL

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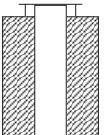
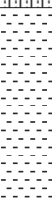
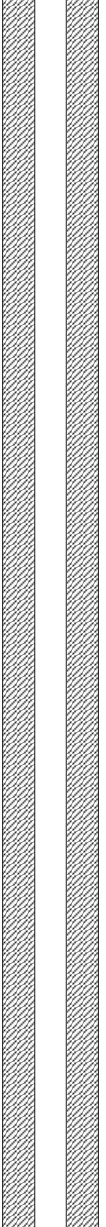
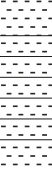
BOREHOLE LOG

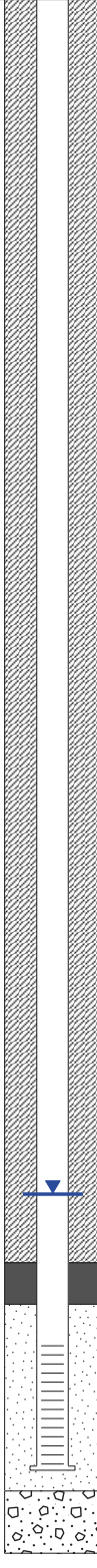
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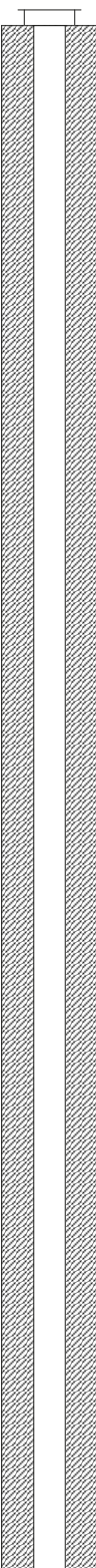
MB14

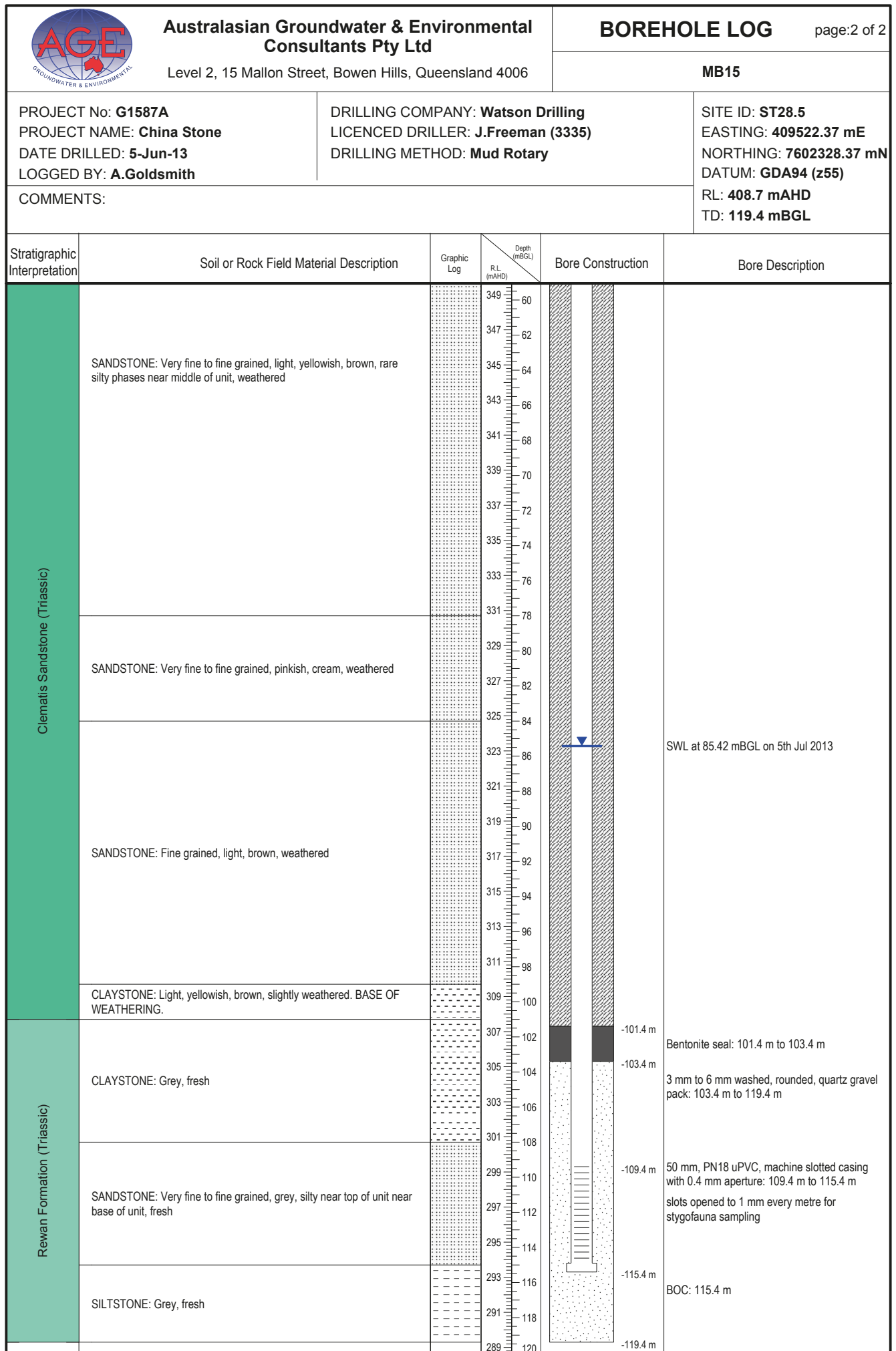
SITE ID: **NO26**
EASTING: **407588.75 mE**
NORTHING: **7598323.11 mN**
DATUM: **GDA94 (z55)**
RL: **446.34 mAHD**
TD: **150 mBGL**

RL: 446.34 mAHD
TD: 150 mBGL

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	R.L. (mAHD)	Depth (mBGL)	Bore Construction	Bore Description
			447	0		
Tertiary sediments			445	2		Protective lockable steel collar PVC Stick up: 0.73 m
	SOIL: Medium, brownish, red, sandy, clayey, extremely weathered		443	4		
			441	6		152 mm PCD bit: 0 m to 150 m
	CLAYSTONE: Medium, reddish, brown, sandy, extremely weathered		439	8		
			437	10		Bentonite grout: 0 m to 136 m
			435	12		
			433	14		
			431	16		
Renwan Formation (Triassic)	SANDSTONE: Medium grained, medium, cream, distinctly weathered		429	18		50 mm, PN18 uPVC, blank casing: 0.73 mAGL to 141 m
	CLAYSTONE: Light, cream, distinctly weathered		427	20		
	SANDSTONE: Fine grained, medium, cream, distinctly weathered		425	22		
	CLAYSTONE: Light, cream, distinctly weathered		423	24		
	SANDSTONE: Medium grained, medium, cream, distinctly weathered		421	26		
	CLAYSTONE: Light, cream, distinctly weathered		419	28		
	SILTSTONE: Medium, pink, distinctly weathered		417	30		
			415	32		
	SANDSTONE: Medium grained, medium, orange, distinctly weathered		413	34		
	CLAYSTONE: White, distinctly weathered		411	36		
	SANDSTONE: Fine grained, medium, pinkish, orange, distinctly weathered		409	38		
	SANDSTONE: Medium grained, medium, cream, distinctly weathered		407	40		
	CLAYSTONE: Medium, cream, distinctly weathered		405	42		
	CLAYSTONE: Medium, orangey, brown, distinctly weathered		403	44		
	CLAYSTONE: Medium, pink, distinctly weathered		401	46		
	CLAYSTONE: Medium, creamy, pink, sandy, distinctly weathered		399	48		
	SANDSTONE: Fine grained, medium, orangey, yellow, distinctly weathered		397	50		
	CLAYSTONE: Medium, reddish, orange, distinctly weathered		395	52		
	CLAYSTONE: Medium, pinkish, distinctly weathered		393	54		
	CLAYSTONE: Medium, reddish, orange, distinctly weathered		391	56		
	CLAYSTONE: Medium, pinkish, distinctly weathered		389	58		
	SILTSTONE: Medium, creamy, distinctly weathered		387	60		
			385	62		
	SILTSTONE: Medium, pinkish, cream, distinctly weathered		383	64		
			381	66		
	SANDSTONE: Medium, yellowish, cream, distinctly weathered		379	68		
	CLAYSTONE: Medium, pinkish, distinctly weathered		377	70		
			375	72		
	SANDSTONE: Fine grained, medium, purplish, brown, distinctly weathered		373	74		
	SANDSTONE: Fine grained, medium, yellowish, cream, distinctly weathered					

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		MB14				
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 23-Mar-13 LOGGED BY: A.Goldsmith		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: J.Freeman (3335) DRILLING METHOD: Air Rotary				
COMMENTS:		SITE ID: NO26 EASTING: 407588.75 mE NORTHING: 7598323.11 mN DATUM: GDA94 (z55) RL: 446.34 mAHD TD: 150 mBGL				
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description	
Rewan Formation (Triassic)	SANDSTONE: Fine grained, medium, yellowish, cream, distinctly weathered		371 76		SWL at 132.69 mBGL on 4th Jun 2013	
	SANDSTONE: Fine grained, medium, cream, clay, distinctly weathered		369 78			
	SANDSTONE: Fine grained, medium, brown, distinctly weathered		367 80			
	CLAYSTONE: Medium, creamy, white, distinctly weathered		365 82			
	SANDSTONE: Fine grained, medium, creamy, white, clayey, distinctly weathered		363 84			
	CLAYSTONE: Medium, creamy, grey, distinctly weathered		361 86			
	SILTSTONE: Medium, grey, d		359 88			
	SILTSTONE: Medium, greyish, cream, distinctly weathered		357 90			
	SANDSTONE: Fine to medium grained, medium, yellowish, brown, distinctly weathered		355 92			
			353 94			
			351 96			
			349 98			
	SILTSTONE: Medium, greyish, yellow, slightly weathered		347 100			
			345 102			
			343 104			
			341 106			
	SANDSTONE: Fine to medium grained, medium, yellowish, brown, distinctly weathered. BASE OF WEATHERING.		339 108			
			337 110			
			335 112			
			333 114			
	SILTSTONE: Medium, grey, fresh.		331 116			
			329 118			
			327 120			
			325 122			
	SANDSTONE: Fine grained, medium, grey		323 124			
SILTSTONE: Medium, grey		321 126				
		319 128				
		317 130				
		315 132				
SANDSTONE: Fine grained, medium, grey, fresh		313 134		3 mm to 6 mm washed, rounded, quartz gravel pack: 138 m to 147 m		
SILTSTONE: Medium, grey		311 136				
		309 138				
		307 140				
		305 142				
SANDSTONE: Fine grained, medium, grey		303 144		50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 141 m to 146 m slots opened to 1 mm every metre for stygofauna sampling BOC: 146 m Hole collapse: 147 m to 150 m		
SANDSTONE: Fine grained, medium, grey		301 146				
NOT SAMPLED: No return		299 148				
		297 150				
		295 152				

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page: 1 of 2 MB15			
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 5-Jun-13 LOGGED BY: A.Goldsmith		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: J.Freeman (3335) DRILLING METHOD: Mud Rotary			
COMMENTS:		SITE ID: ST28.5 EASTING: 409522.37 mE NORTHING: 7602328.37 mN DATUM: GDA94 (z55) RL: 408.7 mAHD TD: 119.4 mBGL			
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments	SOIL: Dark, brown, weathered		409 0	 +0.65 m -0 m 165 mm PCD bit: 0 m to 119.4 m Bentonite grout: 0 m to 101.4 m 50 mm, PN18 uPVC, blank casing: 0.65 mAGL to 109.4 m	Protective lockable steel collar PVC Stick up: 0.65m
	SANDSTONE: Fine grained, dark, brown, weathered		407 2		
	SILTSTONE: Light, yellowish, brown, weathered		405 4		
	SANDSTONE: Pink, weathered		403 6		
	SANDSTONE: Very fine to fine grained, brown, weathered		401 8		
	SILTSTONE: Pinkish, weathered		399 10		
	SANDSTONE: Very fine to fine grained, light, yellowish, brown, weathered		397 12		
	SILTSTONE: Light, pinkish, brown, weathered		395 14		
	SANDSTONE: Fine grained, creamy, weathered		393 16		
	SILTSTONE: Mottled, purplish, brown, weathered		391 18		
	SANDSTONE: Mottled, pinkish, brown, minor silty bands near middle of unit, weathered		389 20		
	SILTSTONE: Dark, reddish, brown, clayey in part, weathered		387 22		
Clematis Sandstone (Triassic)	SILTSTONE: Light, brownish, pink, weathered		385 24		
	SIDERITE: Dark, brown, weathered		383 26		
	SILTSTONE: Light, brown, weathered		381 28		
	SILTSTONE: Purplish, weathered		379 30		
	SILTSTONE: Light, creamy, brown, weathered		377 32		
	SANDSTONE: Very fine to fine grained, light, pinkish, brown, silty, in part, weathered		375 34		
			373 36		
			371 38		
			369 40		
			367 42		
		365 44			
		363 46			
		361 48			
		359 50			
		357 52			
		355 54			
		353 56			
		351 58			




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BOREHOLE LOG

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MB16

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **8-Jun-13**
 LOGGED BY: **B.Walker**

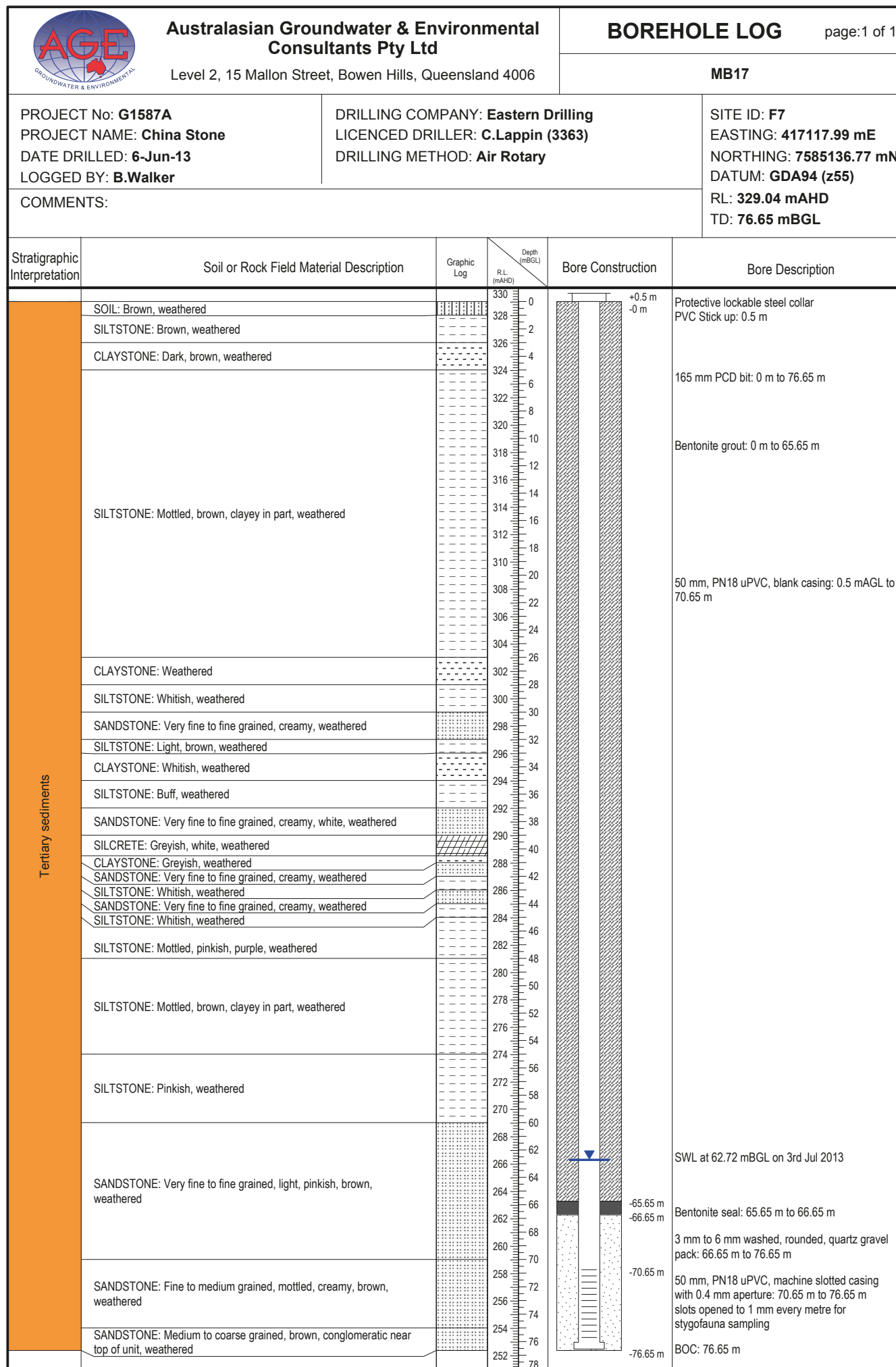
DRILLING COMPANY: **Eastern Drilling**
 LICENCED DRILLER: **C.Lappin (3363)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **DE6**
 EASTING: **417115.19 mE**
 NORTHING: **7585134.44 mN**
 DATUM: **GDA94 (z55)**
 RL: **329.03 mAHD**
 TD: **25 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			330 +0.6 m		
			0 -0 m		Protective lockable steel collar PVC Stick up: 0.6 m
	SANDSTONE: Fine grained, mottled, brown, weathered		328 2		
	CLAYSTONE: Dark, brown, weathered		326 4		
	SANDSTONE: Very fine to fine grained, creamy, weathered		324 6		152 mm PCD bit: 0 m to 25 m
	SANDSTONE: Coarse grained, light, brown, weathered		322 8		
	SANDSTONE: Very fine to fine grained, brown, silty in part, weathered		320 10		
	SANDSTONE: Fine to coarse grained, light, creamy, brown, weathered		318 12		Bentonite grout: 0 m to 19 m
	SANDSTONE: Fine to coarse grained, mottled, brown, conglomeratic in part, weathered		316 14		
			314 16		50 mm, PN18 uPVC, blank casing: 0.6 mAGL to 22 m
			312 18		bore dry at the time of drilling, still dry on the 3rd Jul 2013
	SANDSTONE: Fine grained, light, whitish, grey, silty, weathered		310 20		Bentonite seal: 19 m to 20 m
			308 22		3 mm to 6 mm washed, rounded, quartz gravel pack: 20 m to 25 m
			306 24		50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 22 m to 25 m slots opened to 1 mm every metre for stygofauna sampling
	SILTSTONE: Mottled, reddish, white, lateritic, clayey, weathered		304 25 m		BOC: 25 m

Tertiary sediments




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BOREHOLE LOG

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MB18

PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 13-Dec-12 LOGGED BY: A.Goldsmith	DRILLING COMPANY: Watson Drilling LICENCED DRILLER: M.Rhook (3342) DRILLING METHOD: Air Rotary	SITE ID: BC7.5 EASTING: 414441.65 mE NORTHING: 7583778.25 mN DATUM: GDA94 (z55) RL: 341.54 mAHD TD: 52.6 mBGL
COMMENTS:		

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments	SAND: Very fine grained, weathered to soil		342 0	+0.37 m -0 m	Protective lockable steel collar PVC Stick up: 0.37 m
	SANDSTONE: Fine to medium grained, red/orange, highly weathered		340 2		
			338 4		
	SANDSTONE: Fine grained, red/orange, highly weathered		336 6		165 mm PCD bit: 0 m to 52.6 m
			334 8		
	GRAVEL CONGLOMERATE: Pink/brown, granule sized, highly weathered, abundant quartz		332 10		Bentonite grout: 0 m to 41.6 m
			330 12		
	LATERITE: Pink, buff, coarse grained, sandy, highly weathered		328 14		
			326 16		
	LATERITE: Mottled, pink, silty, highly weathered		324 18		
			322 20		50 mm, PN18 uPVC, blank casing: 0.37 mAGL to 46.6 m
			320 22		
	LATERITE: Dark pink, clayey, highly weathered		318 24		
			316 26		
			314 28		
			312 30		
			310 32		
	SILTSTONE: Yellow/pink, highly weathered		308 34		
			306 36		
	CLAYSTONE: Dark pink, highly weathered		304 38		
			302 40		
	SANDSTONE: Very fine to fine grained, pink/yellow, moderately weathered		300 42		
			298 44	-41.6 m -42.6 m	Bentonite seal: 41.6 m to 42.6 m 3 mm to 6 mm washed, rounded, quartz gravel pack: 42.6 m to 52.6 m
	SANDSTONE: Fine to medium grained, pink, moderately weathered		296 46		
	SANDSTONE: Very fine to fine grained, pink/yellow, moderately weathered		294 48	-46.6 m	50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 46.6 m to 52.6 m slots opened to 1 mm every metre for stygofauna sampling
	CLAYSTONE: Mottled pink, moderately weathered		292 50		bore dry at the time of drilling SWL at 51.83 mBGL on 15th Dec 2013
			290 52		
	SANDSTONE: Very fine to fine grained, light, buff, moderately weathered		288 54	-52.6 m	BOC: 52.6 m


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BOREHOLE LOG

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MB19

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **13-Dec-12**
 LOGGED BY: **H.Donovan**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **M.Rhook (3342)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **BC7.5**
 EASTING: **414445.77 mE**
 NORTHING: **7583780.44 mN**
 DATUM: **GDA94 (z55)**
 RL: **341.51 mAHD**
 TD: **83.5 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments	SOIL: Red/orange, residual soil		342 0		Protective lockable steel collar PVC Stick up: 0.45 m
	SANDSTONE: Dark red/brown, moderately weathered		340 2		
	GRAVEL CONGLOMERATE: Red/orange, ferruginous, ferricrete, moderately weathered		338 4		165 mm PCD bit: 0 m to 83.5 m
	SANDSTONE: Medium grained, red/orange, quartzose fragments, gravelly, moderately weathered		336 6		Bentonite grout: 0 m to 67 m
	SILTSTONE: Red/pink, moderately weathered		334 8		
	SILTSTONE: Pink/red, moderately weathered		332 10		
	SILTSTONE: Orange, moderately weathered		330 12		
	SILTSTONE: Cream pink, clayey, moderately weathered		328 14		50 mm, PN18 uPVC, blank casing: 0.45 mAGL to 74.5 m
	CLAYSTONE: Pink/red, moderately weathered		326 16		
	CLAYSTONE: Light pink/yellow, moderately weathered		324 18		
	SANDSTONE: Very fine grained, light yellow/orange, moderately weathered		322 20		
	SANDSTONE: Very fine grained, light yellow/pink, silty in parts, clayey towards base of unit, moderately weathered		320 22		
	CLAYSTONE: Red/brown, moderately weathered		318 24		
	SANDSTONE: Very fine grained, light brown, moderately weathered		316 26		
	CLAYSTONE: Yellow, moderately weathered		314 28		
	SANDSTONE: Very fine grained, light creamy pink, moderately weathered		312 30		
	CLAYSTONE: Dark brown/red, moderately weathered		310 32		
Revan Formation (Triassic)	CLAYSTONE: Yellow, moderately weathered		308 34		
	SILTSTONE: Red/brown, moderately weathered		306 36		
	CLAYSTONE: Dark brown/red, moderately weathered		304 38		
	CLAYSTONE: Yellow, moderately weathered		302 40		
	SILTSTONE: Red/brown, moderately weathered		300 42		
	CLAYSTONE: Dark brown/red, moderately weathered		298 44		
	CLAYSTONE: Yellow, moderately weathered		296 46		
	SILTSTONE: Red/brown, moderately weathered		294 48		
	CLAYSTONE: Dark brown/red, moderately weathered		292 50		
	CLAYSTONE: Yellow, moderately weathered		290 52		bore dry at the time of drilling SWL at 51.67 mBGL on 15th Dec 2013
			288 54		
			286 56		
			284 58		
			282 60		
			280 62		
			278 64		
			276 66		
			274 68		
			272 70		
			270 72		
			268 74		
			266 76		
			264 78		
			262 80		
			260 82		
			258 84		


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BOREHOLE LOG

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MB20

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **31-May-13**
 LOGGED BY: **A.Goldsmith**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **S.Colles (3313)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **M9**
 EASTING: **420926.08 mE**
 NORTHING: **7589917.13 mN**
 DATUM: **GDA94 (z55)**
 RL: **297.34 mAHD**
 TD: **25 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			298	+0.5 m	
			0	-0 m	Protective lockable steel collar PVC Stick up: 0.5 m (estimate)
	SOIL: Brown, sandy, extremely weathered				
	GRAVEL CONGLOMERATE: Light, brown, quartzose, iron stained, extremely weathered		296		
			2		
	SANDSTONE: Medium to coarse grained, orange, quartzose, extremely weathered		294		
			4		
	GRAVEL CONGLOMERATE: Light, brownish, orange, quartzose, extremely weathered		292		165 mm PCD bit: 0 m to 25 m
			6		
	GRAVEL CONGLOMERATE: Light, whitish, pink, distinctly weathered		290		
			8		
	SANDSTONE: Fine grained, light, whitish, pink, silty, in part, distinctly weathered		288		
			10		Bentonite grout: 0 m to 18 m
	GRAVEL CONGLOMERATE: Medium grained, light, orangey, brown, quartzose, distinctly weathered		286		
			12		
	SANDSTONE: Fine grained, light, red, quartzose, distinctly weathered		284		
			14		
	GRAVEL CONGLOMERATE: Mottled, grey, distinctly weathered		282		50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 22 m
			16		
			18	-18 m	
	SANDSTONE: Fine to medium grained, light, brown, pebbles, In part, quartzose, distinctly weathered		278	-20 m	Bentonite seal: 18 m to 20 m
			20		3 mm to 6 mm washed, rounded, quartz gravel pack: 20 m to 25 m
			276	-22 m	
			22		50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 22 m to 25 m slots opened to 1 mm every metre for stygofauna sampling BOC: 25 m
	SANDSTONE: Fine grained, red, distinctly weathered		274		bore dry at the time of drilling
			24		
			272	-25 m	

Tertiary sediments

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page: 1 of 2 MB21	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 27-Aug-13 LOGGED BY: MBGS Geologist		DRILLING COMPANY: Eastern Drilling LICENCED DRILLER: C.Lappin (3363) DRILLING METHOD: Air Rotary	
COMMENTS:		SITE ID: I21 EASTING: 407808.81 mE NORTHING: 7592771.38 mN DATUM: GDA94 (z55) RL: 470.4 mAHD TD: 130.5 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Bore Construction
		Depth (mBGL) R.L. (mAHD)	Bore Description
Clematis Sandstone (Triassic)	SANDSTONE: Very fine grained, light, yellowish, orange, quartzose.	470 0 468 2 466 4 464 6 462 8 460 10 458 12 456 14 454 16 452 18 450 20 448 22 446 24 444 26 442 28 440 30 438 32 436 34 434 36 432 38 430 40 428 42 426 44 424 46 422 48 420 50 418 52 416 54 414 56 412 58 410 60 408 62 406 64	+0.5 m -0 m Protective lockable steel collar PVC Stick up: 0.5 m (estimate) 165 mm PCD bit: 0 m to 130.5 m Bentonite grout: 0 m to 119.5 m 50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 124.5 m
	SANDSTONE (80%) / SILTSTONE (20%): Very fine grained, light, purplish, red.		
	SANDSTONE: Very fine grained, light, yellow, quartzose.		
	SANDSTONE: Very fine grained, light, orangy, yellow, quartzose, minor, micaceous.		
	SANDSTONE: Very fine to fine grained, light, whitish, yellow, quartzose, siltstone, throughout.		
	SANDSTONE: Very fine grained, light, orangy, yellow, siltstone		
	SANDSTONE: Fine grained, light, whitish, yellow, quartzose.		
	SANDSTONE: Very fine to fine grained, dark, purplish, red, siltstone		
	SANDSTONE: Very fine grained, light, orangy, yellow, siltstone, claystone.		
	CLAYSTONE: Light, purplish, red, sandstone.		
	SILTSTONE (50%) / SILTSTONE (50%): Mottled, purplish, yellow. Very fine grained.		
	SANDSTONE: Very fine grained, dark, yellowish, orange, quartzose.		

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		MB21	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 27-Aug-13 LOGGED BY: MBGS Geologist		DRILLING COMPANY: Eastern Drilling LICENCED DRILLER: C.Lappin (3363) DRILLING METHOD: Air Rotary	
COMMENTS:		SITE ID: I21 EASTING: 407808.81 mE NORTHING: 7592771.38 mN DATUM: GDA94 (z55) RL: 470.4 mAHD TD: 130.5 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)
Clematis Sandstone (Triassic)	SANDSTONE: Very fine grained, mottled, purplish, brown, siltstone, throughout, quartzose, fragments.		66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100 102 104 106 108 110 112 114 116 118 120 122 124 126 128 130
	SANDSTONE: Very fine grained, dark, yellowish, orange, quartzose.		
	SANDSTONE: Very fine grained, light, pinkish, grey, siltstone, in part, distinctly weathered.		
	SANDSTONE: Very fine grained, light, orangy, grey, siltstone, in part, distinctly weathered.		
	SANDSTONE: Very fine grained, medium to dark, reddish, grey, distinctly weathered.		
	SANDSTONE: Very fine grained, medium to dark, reddish, grey, distinctly weathered.		
	SANDSTONE: Very fine grained, medium to dark, reddish, grey, distinctly weathered.		
	SANDSTONE: Very fine grained, light, orangy, grey, siltstone, in part, slightly weathered.		
	SANDSTONE: Very fine grained, medium, orangy, grey, distinctly weathered.		
	SANDSTONE: Very fine grained, light, orangy, grey, siltstone, in part, slightly weathered.		
	SANDSTONE: Very fine grained, light, yellowish, grey, distinctly weathered.		
	SANDSTONE: Very fine grained, light to medium, pinkish, grey, siltstone, in part, distinctly weathered.		
	SANDSTONE: Very fine grained, medium, orangy, grey, distinctly weathered.		
	SANDSTONE: Very fine grained, medium, reddish, grey, distinctly weathered.		
	SANDSTONE: Very fine grained, light, orangy, grey.		
		Bore Construction Bore Description	
		bore dry at the time of drilling Bentonite seal: 119.5 m to 120.5 m 3 mm to 6 mm washed, rounded, quartz gravel pack: 120.5 m to 130.5 m 50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 124.5 m to 130.5 m slots opened to 1 mm every metre for stygofauna sampling BOC: 130.5 m	

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MB22

SITE ID: **E15**
EASTING: **409253.62 mE**
NORTHING: **7588045.6 mN**
DATUM: **GDA94 (z55)**
RL: **387.95 mAHD**
TD: **107.5 mBGL**

RL: 387.95 mAHD
TD: 107.5 mBGL

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL)	Bore Construction	Bore Description
			R.L. (mAHD)		
			388 0		+0.5 m
			386 2		-0 m
	SANDSTONE: Very fine to fine grained, mottled, creamy, red, lithic, minor, quartzose, extremely weathered.		384 4		Protective lockable steel collar PVC Stick up: 0.5 m (estimate)
	SANDSTONE: Very fine grained, creamy, pink, extremely weathered.		382 6		BOC: 107.5 m
			380 8		
	SANDSTONE: Very fine to fine grained, dark, orangy, red, quartzose, throughout, minor, micaceous, extremely weathered.		378 10		152 mm PCD bit: 0 m to 107.5 m
			376 12		
			374 14		
	SANDSTONE: Very fine to fine grained, light, pinkish, yellow, quartzose, throughout, extremely weathered.		372 16		
			370 18		
	SANDSTONE: Fine to medium grained, light, pinkish, yellow, quartzose, extremely weathered.		368 20		
			366 22		
	SANDSTONE: Very fine to fine grained, light, creamy, yellow, quartzose, extremely weathered.		364 24		
			362 26		
			360 28		
	SANDSTONE: Very fine grained, light, creamy, yellow, quartzose, fragments, throughout, extremely weathered.		358 30		
			356 32		
			354 34		
	SANDSTONE: Very fine to fine grained, medium to dark, orangy, brown, quartzose, extremely weathered.		352 36		
			350 38		
	SANDSTONE: Very fine grained, medium to dark, pinkish, brown, extremely weathered.		348 40		
			346 42		
	SANDSTONE: Very fine to fine grained, dark, brownish, red, extremely weathered.		344 44		
	SANDSTONE: Very fine grained, dark, orangy, yellow, extremely weathered.		342 46		
			340 48		
	SANDSTONE: Very fine grained, light, creamy, yellow, extremely weathered.		338 50		
			336 52		
	SANDSTONE: Very fine grained, dark, brownish, red.				


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MB22

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **29-Sep-13**
 LOGGED BY: **A.Tarr**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **E15**
 EASTING: **409253.62 mE**
 NORTHING: **758045.6 mN**
 DATUM: **GDA94 (z55)**
 RL: **387.95 mAHD**
 TD: **107.5 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)	SANDSTONE: Very fine grained, medium to dark, yellowish, brown.		334 54		
	SANDSTONE: Very fine grained, dark, reddish, brown.		332 56		
			330 58		
	SANDSTONE: Very fine grained, light, creamy, yellow.		328 60		
			326 62		
	SANDSTONE: Very fine grained, dark, reddish, brown.		324 64		
	SANDSTONE: Very fine grained, light, pinkish, brown.		322 66		
			320 68		
	SANDSTONE: Very fine grained, light, orangy, brown, extremely weathered.		318 70		
			316 72		
	SANDSTONE: Very fine grained, light, orangy, brown, minor, micaceous, extremely weathered.		314 74		
			312 76		
	SANDSTONE: Very fine grained, light, pinkish, brown, quartzose, fragments, extremely weathered.		310 78		
	SANDSTONE: Very fine grained, dark, brown, minor, micaceous, extremely weathered.		308 80		
	SANDSTONE: Very fine grained, light, orangy, yellow, extremely weathered.		306 82		
	SANDSTONE: Very fine grained, dark, brown, extremely weathered.		304 84		
	SANDSTONE: Very fine grained, dark, reddish, brown, extremely weathered.		302 86		
	SANDSTONE: Very fine grained, dark, brown, extremely weathered.		300 88		
	SANDSTONE: Very fine to fine grained, dark, orangy, yellow, extremely weathered.		298 90		
	SANDSTONE: Very fine to fine grained, light, brownish, grey, extremely weathered.		296 92		
	SANDSTONE: Very fine to fine grained, light, brownish, orange, extremely weathered.		294 94		
	SANDSTONE: Very fine grained, dark, reddish, brown, extremely weathered.		292 96		
	SANDSTONE: Very fine to fine grained, light, brownish, orange, quartzose, extremely weathered.		290 98		
	SANDSTONE: Very fine grained, dark, reddish, brown, extremely weathered.		288 100		
			286 102		
	SANDSTONE: Very fine grained, light, brownish, orange, minor, quartzose.		284 104		
			282 106		
			280 108		

Bentonite seal: 87.5 m to 89.5 m

3 mm to 6 mm washed, rounded, quartz gravel pack: 89.5 m to 107.5 m

50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 101.5 m to 107.5 m slots opened to 1 mm every metre for stygofauna sampling

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		MB23	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 13-Sep-13 LOGGED BY: T. Womack		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: D.Quinlan (3084) DRILLING METHOD: Air Rotary	
COMMENTS: no construction details from client		SITE ID: M22 EASTING: 410019.27 mE NORTHING: 7595391.94 mN DATUM: GDA94 (z55) RL: 415.67 mAHD TD: 90 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)
Clematis Sandstone (Triassic)	SANDSTONE: Fine to medium grained, light to medium, creamy, orange, distinctly weathered, low strength rock.		415 0
	SANDSTONE: Very fine grained, light, pinkish, grey, d, low strength rock.		413 2
	SANDSTONE: Very fine grained, medium to dark, reddish, grey, distinctly weathered, very low strength rock		411 4
	SANDSTONE: Very fine grained, medium to dark, pinkish, grey, distinctly weathered, low strength rock.		409 6
	SANDSTONE: Very fine grained, light, grey, slightly weathered, low strength rock.		407 8
	SANDSTONE: Very fine grained, light, pinkish, grey, slightly weathered, low strength rock.		405 10
	SANDSTONE: Very fine grained, light, grey, slightly weathered, low strength rock.		403 12
	CLAYSTONE: Dark, greyish, brown, distinctly weathered, extremely low strength rock.		401 14
	SANDSTONE: Very fine to fine grained, light to medium, yellowish, orange, distinctly weathered, extremely low strength rock.		399 16
	SANDSTONE: Very fine grained, light, orangy, grey, slightly weathered, very low strength rock.		397 18
Rewan Formation (Triassic)	SANDSTONE: Very fine grained, light to medium, greyish, orange, distinctly weathered, very low strength rock		395 20
			393 22
			391 24
			389 26
			387 28
			385 30
			383 32
			381 34
			379 36
	SILTSTONE: Greyish, slightly weathered, very low strength rock.		377 38
			375 40
			373 42
			371 44
			369 46
	SANDSTONE: Very fine grained, medium to dark, orange, siltstone, in part, distinctly weathered, very low strength rock.		367 48
			365 50
	SILTSTONE: Medium, grey, distinctly weathered, extremely low strength rock.		363 52
			361 54
	SANDSTONE: Very fine to fine grained, light to medium, greyish, orange, distinctly weathered, extremely low strength rock.		359 56
			357 58
		355 60	
		353 62	
SILTSTONE: Medium, grey, sandstone, in part, slightly weathered, extremely low strength rock.		351 64	
		349 66	
		347 68	
		345 70	
SANDSTONE: Fine grained, medium, grey, slightly weathered. Moist		343 72	
SILTSTONE: Medium, grey, sandstone, in part, slightly weathered, very low strength rock.		341 74	
SANDSTONE: Medium, greyish, orange, siltstone, in part, distinctly weathered, very low strength rock.		339 76	
		337 78	
SANDSTONE: Very fine grained, medium, greyish, orange, siltstone, in part, distinctly weathered, very low strength rock.		335 80	
		333 82	
SANDSTONE: Fine grained, medium, grey, fresh. Moist		331 84	
		329 86	
SILTSTONE: Medium, grey, sandstone, in part, low strength rock		327 88	
		325 90	


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MB24

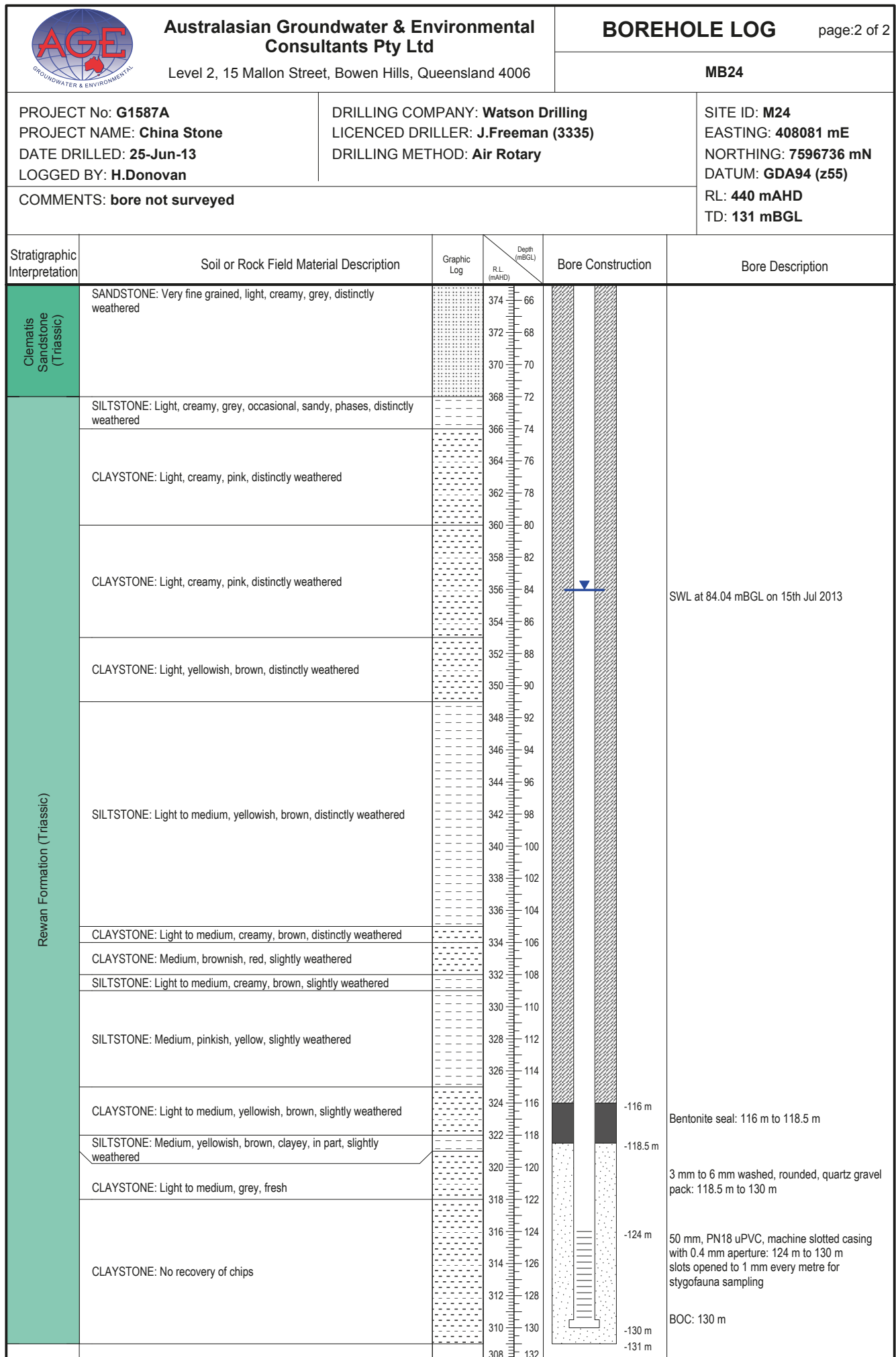
PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **25-Jun-13**
 LOGGED BY: **H.Donovan**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **J.Freeman (3335)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **M24**
 EASTING: **408081 mE**
 NORTHING: **7596736 mN**
 DATUM: **GDA94 (z55)**
 RL: **440 mAHD**
 TD: **131 mBGL**

 COMMENTS: **bore not surveyed**

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			442 440 0 438 2 436 4 434 6 432 8 430 10 428 12 426 14 424 16 422 18 420 20 418 22 416 24 414 26 412 28 410 30 408 32 406 34 404 36 402 38 400 40 398 42 396 44 394 46 392 48 390 50 388 52 386 54 384 56 382 58 380 60 378 62 376 64	+0.75 m -0 m	Protective lockable steel collar PVC Stick up: 0.75 m 152 mm PCD bit: 0 m to 131 m Bentonite grout: 0 m to 116 m 50 mm, PN18 uPVC, blank casing: 0.75 mAGL to 124 m
Clematis Sandstone (Triassic)	SAND: Light, brownish, pink, extremely weathered				
	SANDSTONE: Fine grained, medium, reddish, brown, iron stained, extremely weathered				
	SANDSTONE: Very fine to fine grained, medium, reddish, brown, iron stained, silty, in part, extremely weathered				
	SILTSTONE: Medium, reddish, brown, iron stained, occasional, sandy, extremely weathered				
	SANDSTONE: Very fine to fine grained, medium, reddish, brown, extremely weathered				
	SANDSTONE: Very fine to fine grained, light to medium, reddish, brown, occasional, siltstone, bands, distinctly weathered				




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MB25

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **6-Jul-13**
 LOGGED BY: **J.Souter**

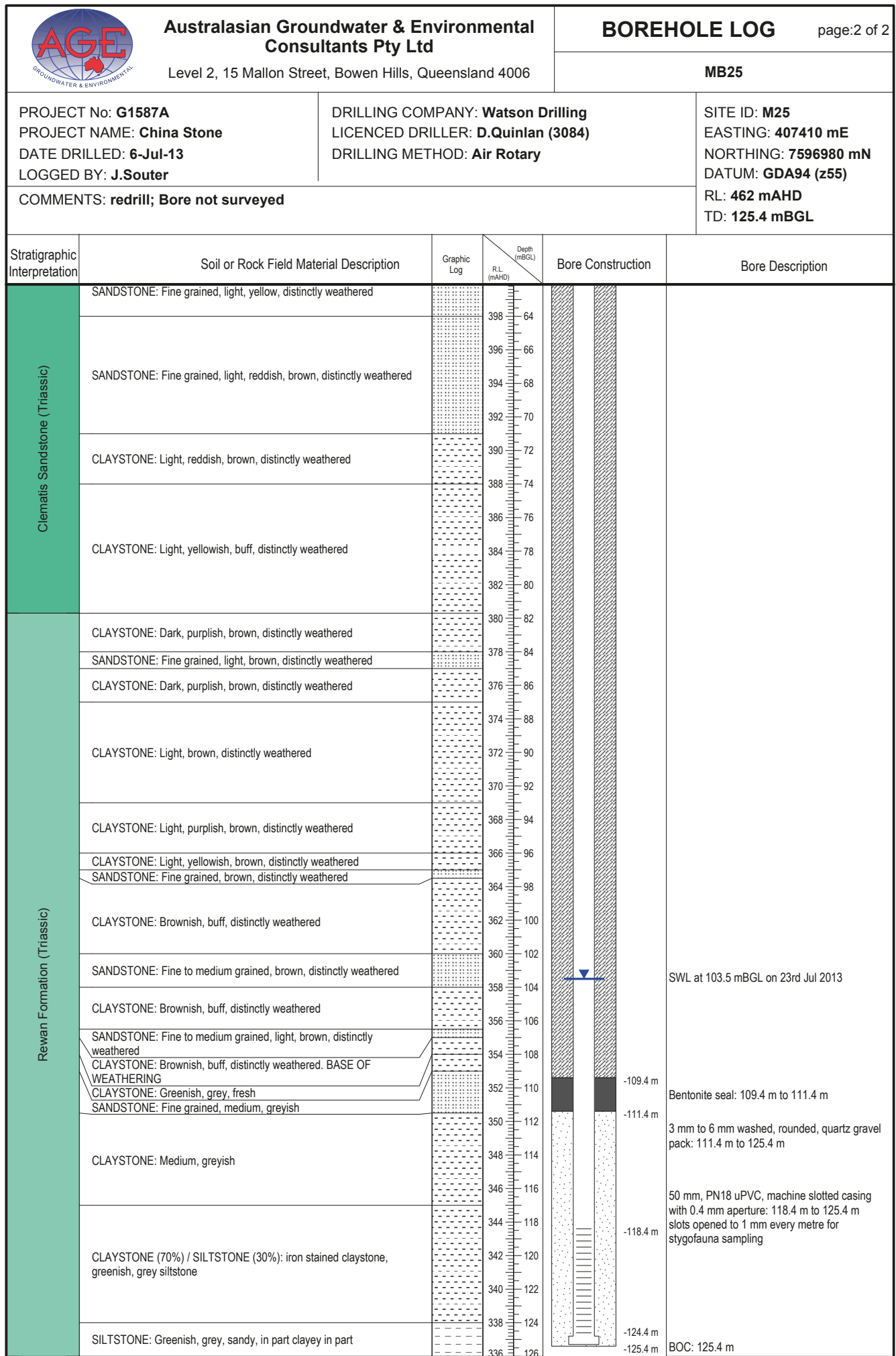
DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **M25**
 EASTING: **407410 mE**
 NORTHING: **7596980 mN**
 DATUM: **GDA94 (z55)**
 RL: **462 mAHD**
 TD: **125.4 mBGL**

 COMMENTS: **redrill; Bore not surveyed**

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			464		
	SAND: Fine grained, red, extremely weathered		462 0		Protective lockable steel collar PVC Stick up: 0.8 m
	SANDSTONE: Fine grained, red, extremely weathered		460 2		
			458 4		
			456 6		152 mm PCD bit: 0 m to 125.4 m
			454 8		
			452 10		Bentonite grout: 0 m to 109.4 m
	SANDSTONE: Medium grained, light, brownish, red, distinctly weathered		450 12		
			448 14		
			446 16		
			444 18		
			442 20		50 mm, PN18 uPVC, blank casing: 0.8 mAGL to 118.4 m
			440 22		
			438 24		
	SANDSTONE: Coarse grained, light, brownish, red, quartzose, distinctly weathered		436 26		
			434 28		
			432 30		
			430 32		
			428 34		
			426 36		
			424 38		
	SANDSTONE: Coarse grained, light, reddish, brown,		422 40		
			420 42		
			418 44		
			416 46		
			414 48		
	SANDSTONE: Coarse grained, light, reddish, brown,		412 50		
			410 52		
			408 54		
	SANDSTONE: Fine grained, light, pinkish, brown, distinctly weathered		406 56		
			404 58		
			402 60		
	SANDSTONE: Fine grained, light, yellow, distinctly weathered		400 62		

Clematis Sandstone (Triassic)




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BOREHOLE LOG

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MB26

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **2-Jul-12**
 LOGGED BY: **H.Donovan**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **Q29**
 EASTING: **407115.2 mE**
 NORTHING: **7601043.29 mN**
 DATUM: **GDA94 (z55)**
 RL: **410.56 mAHD**
 TD: **119.6 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			412 0 410 2 408 4 406 6 404 8 402 10 400 12 398 14 396 16 394 18 392 20 390 22 388 24 386 26 384 28 382 30 380 32 378 34 376 36 374 38 372		Protective lockable steel collar PVC Stick up: 0.7 m 152 mm PCD bit: 0 m to 119.6 m Bentonite grout: 0 m to 107.6 m 50 mm, PN18 uPVC, blank casing: 0.7 m AGL to 112.6 m
Clematis Sandstone (Triassic)	SAND : Very fine to fine grained, medium to dark, red, clayey, residual soil.				
	SANDSTONE: Very fine to fine grained, medium to dark, reddish, brown, extremely weathered.				
	SANDSTONE: Fine grained, medium, brownish, red, extremely weathered.				
	SANDSTONE: Fine grained, medium, brownish, red, quartzose, extremely weathered.				
	SANDSTONE: Very fine to fine grained, light to medium, brownish, yellow, extremely weathered.				
	SILTSTONE: Medium, yellowish, orange, sandy, in part, extremely weathered.				
	SANDSTONE: Fine grained, medium, yellowish, brown, extremely weathered.				
	SANDSTONE: Very fine to fine grained, medium, reddish, brown, siltstone, extremely weathered.				
	SANDSTONE: Very fine grained, light to medium, pinkish, red, extremely weathered.				
	SANDSTONE: Very fine to fine grained, light to medium, blue, extremely weathered.				
	SANDSTONE: Very fine grained, light, pinkish, cream, siltstone, in part, extremely weathered.				

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:2 of 3 MB26	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 2-Jul-12 LOGGED BY: H.Donovan		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: D.Quinlan (3084) DRILLING METHOD: Air Rotary	
COMMENTS:		SITE ID: Q29 EASTING: 407115.2 mE NORTHING: 7601043.29 mN DATUM: GDA94 (z55) RL: 410.56 mAHD TD: 119.6 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)
Clematis Sandstone (Triassic)	SANDSTONE: Very fine grained, light, pinkish, cream, siltstone, in part, extremely weathered.		40
	SILTSTONE: Light, pinkish, cream, clayey, near top of unit, extremely weathered.		42
	SANDSTONE: Very fine grained, light to medium, yellow, extremely weathered.		44
	SANDSTONE: Very fine to fine grained, light to medium, pinkish, brown, extremely weathered.		46
	CLAYSTONE: Light, pinkish, cream, distinctly weathered.		50
	SILTSTONE: Medium, yellowish, pink, distinctly weathered.		54
	SILTSTONE: Medium, pinkish, cream, distinctly weathered.		56
	SILTSTONE: Medium, yellow, distinctly weathered.		58
Rewan Formation (Triassic)	CLAYSTONE: Light, yellowish, cream, distinctly weathered.		60
	CLAYSTONE: Creamy, white, distinctly weathered.		62
	CLAYSTONE: Medium, yellowish, brown, distinctly weathered.		64
	SILTSTONE: Light to medium, yellowish, brown, clayey, near base of unit, distinctly weathered.		68
	CLAYSTONE: Light, whitish, yellow, clayey, near top of unit, distinctly weathered.		72
	SILTSTONE: Light to medium, greyish, yellow, clayey, slightly weathered.		74
	CLAYSTONE: Light to medium, yellowish, grey, siltstone, in part, slightly weathered.		76
	SILTSTONE: Light to medium, yellowish, brown, slightly weathered.		78


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BOREHOLE LOG

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MB26

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **2-Jul-12**
 LOGGED BY: **H.Donovan**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **Q29**
 EASTING: **407115.2 mE**
 NORTHING: **7601043.29 mN**
 DATUM: **GDA94 (z55)**
 RL: **410.56 mAHD**
 TD: **119.6 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Rewan Formation (Triassic)	CLAYSTONE: Light, yellowish, brown, slightly weathered.		80 330 82 328 84 326 86 324 88 322 90 320 92 318 94 316		
	SILTSTONE: Medium, greenish, grey, clayey, throughout, fresh		314 96 98 312 100 310 102 308 104 306 106 304 108 302 110 300		SWL at 95.73 mBGL on 22nd Jul 2013
	SANDSTONE: Very fine to fine grained, medium, greenish, brown, siltstone, in part.		112 298 114 296 116 294 118 292		Bentonite seal: 107.6 m to 109.6 m
	SILTSTONE: Medium to dark, greenish, grey, clayey, throughout, occasional, sandy.				3 mm to 6 mm washed, rounded, quartz gravel pack: 109.6 m to 119.6 m
	SANDSTONE: Fine grained, medium to dark, greenish, brown.				50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 112.6 m to 118.6 m slots opened to 1 mm every metre for stygofauna sampling
					BOC: 118.6 m

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MB27

SITE ID: **Q28**
EASTING: **407958.5 mE**
NORTHING: **7600572.19 mN**
DATUM: **GDA94 (z55)**
RL: **415.24 mAHD**
TD: **113.6 mBGL**

COMMENTS: **redrill; casing dropped down hole**

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)	SOIL : Light to medium, brownish, red, sandy, residual soil.		417 415 0 413 2 411 4 409 6 407 8 405 10 403 12 401 14 399 16 397 18 395 20 393 22 391 24 389 26 387 28 385 30 383 32 381 34 379 36 377 38 375 40 373 42 371 44 369 46 367 48 365 50 363 52 361 54 359 56	 +0.5 m -0 m	Protective lockable steel collar PVC Stick up: 0.5 m (estimate)
	SANDSTONE: Fine grained, light to medium, yellowish, red, iron stained, in part, extremely weathered.				152 mm PCD bit: 0 m to 113.6 m
	SANDSTONE: Fine to medium grained, light to medium, yellowish, red, extremely weathered.				Bentonite grout: 0 m to 99.6 m
	SANDSTONE: Very fine to fine grained, light to medium, reddish, yellow, extremely weathered.				50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 106 m
	SANDSTONE: Very fine to fine grained, light, pinkish, yellow, extremely weathered.				
	SANDSTONE: Very fine to fine grained, light to medium, reddish, yellow, iron stained, in part, extremely weathered.				
	SANDSTONE: Fine to medium grained, light to medium, yellow, extremely weathered.				
	SANDSTONE: Medium grained, light to medium, yellow, extremely weathered.				
	SANDSTONE: Fine grained, light to medium, pinkish, yellow, iron stained, extremely weathered.				
	SANDSTONE: Fine to medium grained, light to medium, reddish, yellow, extremely weathered.				
	SANDSTONE: Fine grained, light to medium, pinkish, yellow, iron stained, in part, extremely weathered.				


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MB27

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **7-Jul-13**
 LOGGED BY: **W.Han**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **Q28**
 EASTING: **407958.5 mE**
 NORTHING: **7600572.19 mN**
 DATUM: **GDA94 (z55)**
 RL: **415.24 mAHD**
 TD: **113.6 mBGL**

 COMMENTS: **redrill; casing dropped down hole**

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)	CLAYSTONE: Light to medium, pinkish, cream, extremely weathered.		357 58		bore dry at the time of drilling SWL at 95.36 mBGL on 6th Mar 2014 Bentonite seal: 99.6 m to 101.6 m 3 mm to 6 mm washed, rounded, quartz gravel pack: 101.6 m to 113.6 m 50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 106 m to 113 m slots opened to 1 mm every metre for stygofauna sampling BOC: 113 m
	SANDSTONE: Fine grained, light, creamy, yellow, extremely weathered.		355 60		
	SANDSTONE: Very fine to fine grained, dark, brownish, red, extremely weathered.		353 62		
	CLAYSTONE: Medium, pinkish, cream, extremely weathered.		351 64		
Rewan Formation (Triassic)			349 66		
			347 68		
			345 70		
			343 72		
			341 74		
			339 76		
			337 78		
	CLAYSTONE: Light, brownish, orange, extremely weathered.		335 80		
			333 82		
			331 84		
			329 86		
			327 88		
	CLAYSTONE: Medium, yellowish, cream, extremely weathered.		325 90		
	CLAYSTONE: Dark, yellow, extremely weathered.		323 92		
	SANDSTONE: Fine grained, medium, orange, extremely weathered.		321 94		
	CLAYSTONE: Light, greyish, cream, extremely weathered.		319 96		
	SANDSTONE: Fine grained, medium, orange, extremely weathered.		317 98		
	CLAYSTONE: Dark, orange, extremely weathered.		315 100		
	CLAYSTONE: Light, greyish, cream, distinctly weathered.		313 102		
	CLAYSTONE: Medium, greenish, grey, fresh.		311 104		
	SANDSTONE: Very fine to fine grained, medium, greenish, grey.		309 106		
	CLAYSTONE: Medium, greenish, grey.		307 108		
	SANDSTONE: Very fine to fine grained, medium, greenish, grey.		305 110		
	CLAYSTONE: Medium, greenish, grey.		303 112		
	SANDSTONE: Fine to medium grained, medium, greenish, grey, claystone, bands.		301 114		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page: 1 of 3 MB28	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 1-Jun-13 LOGGED BY: A.Goldsmith		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: S.Colles (3313) DRILLING METHOD: Mud Rotary	
COMMENTS:		SITE ID: Q26 EASTING: 409795.56 mE NORTHING: 7599782.67 mN DATUM: GDA94 (z55) RL: 436.5 mAHD TD: 138 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Bore Construction
Clematis Sandstone (Triassic)	SANDSTONE: Very fine grained, red, iron stained, extremely weathered		Protective lockable steel collar PVC Stick up: 0.5 m (estimate)
	SANDSTONE: Fine grained, dark, red, iron stained, extremely weathered		152 mm PCD bit: 0 m to 138 m
			Bentonite grout: 0 m to 124 m
			50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 132 m
	SANDSTONE: Medium grained, dark, red, iron stained, extremely weathered		
	SANDSTONE: Coarse grained, dark, red, quartzose, iron stained, distinctly weathered		
	SANDSTONE: Fine grained, red, iron stained, distinctly weathered		
	SANDSTONE: Very fine grained, light, whitish, red, iron stained, distinctly weathered		


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BOREHOLE LOG

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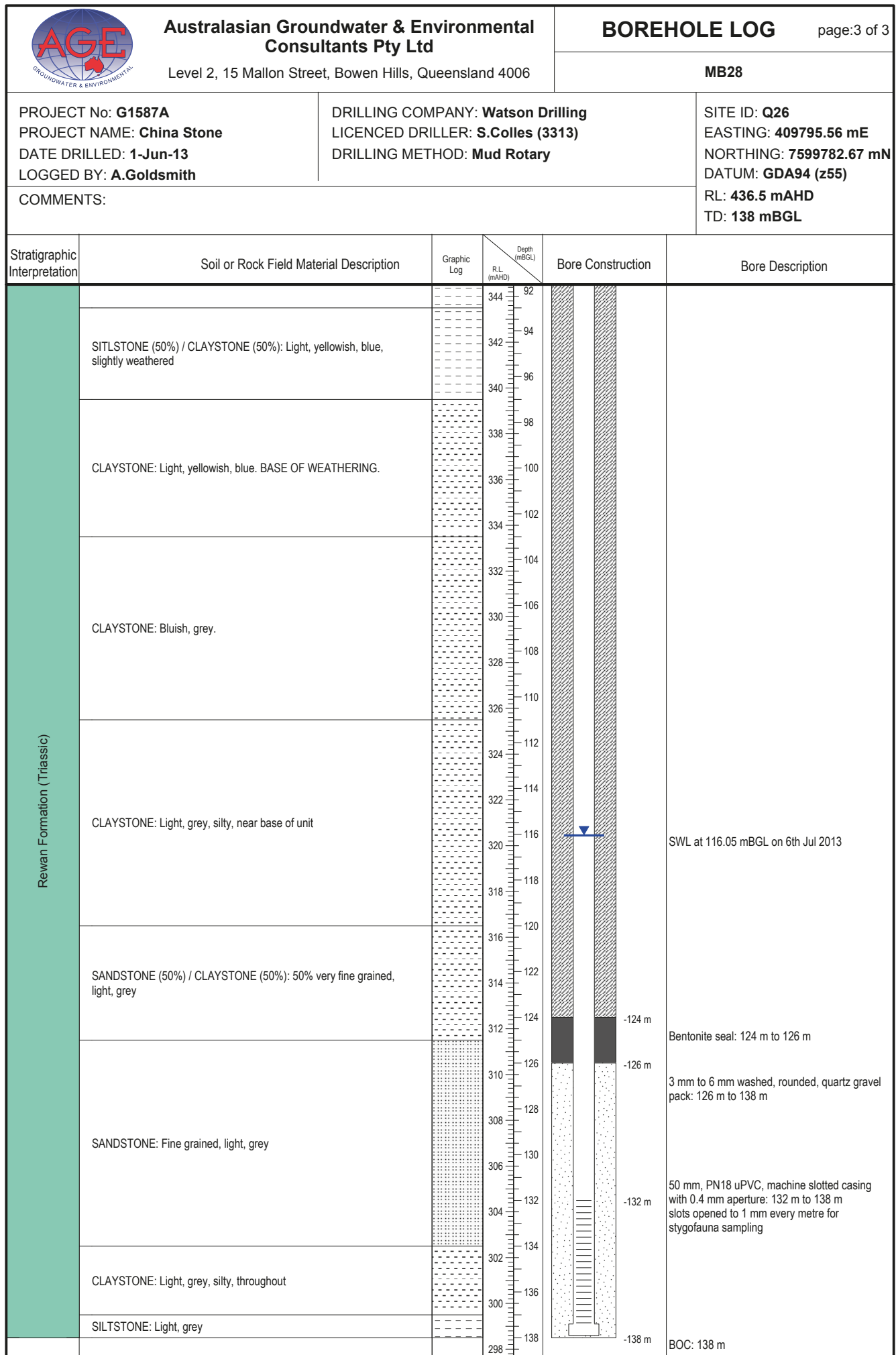
PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **1-Jun-13**
 LOGGED BY: **A.Goldsmith**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **S.Colles (3313)**
 DRILLING METHOD: **Mud Rotary**

SITE ID: **Q26**
 EASTING: **409795.56 mE**
 NORTHING: **7599782.67 mN**
 DATUM: **GDA94 (z55)**
 RL: **436.5 mAHD**
 TD: **138 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)			46		
			390		
	CLAYSTONE: Light, whitish, brown, lateritic, extremely weathered		48		
			388		
			50		
Clematis Sandstone (Triassic)			386		
			52		
			384		
	SANDSTONE: Fine grained, light, pinkish, brown, lateritic, extremely weathered		54		
			382		
			56		
			380		
	SANDSTONE: Fine grained, light, reddish, brown, iron stained, distinctly weathered		58		
			378		
			60		
Rewan Formation (Triassic)			376		
			62		
			374		
			64		
	SANDSTONE: Medium grained, light, reddish, brown, iron stained, distinctly weathered		372		
			66		
			370		
			68		
	SANDSTONE: Fine grained, light, yellowish, brown, silty, in part, distinctly weathered		368		
			70		
			366		
			72		
			364		
			74		
			362		
	SANDSTONE: Fine grained, light, reddish, brown, distinctly weathered		76		
			360		
			78		
			358		
			80		
			356		
			82		
			354		
	SANDSTONE: Very fine grained, light, yellowish, brown, distinctly weathered		84		
			352		
			86		
			350		
			88		
			348		
			90		
	SILTSTONE: Light, yellowish, brown, distinctly weathered		346		
			92		




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BOREHOLE LOG

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MB29

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **9-Sep-13**
 LOGGED BY: **A.Tarr**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Mud Rotary**

SITE ID: **Y36**
 EASTING: **407367.07 mE**
 NORTHING: **7608867.12 mN**
 DATUM: **GDA94 (z55)**
 RL: **496.12 mAHD**
 TD: **149 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
			497 0		
			495 2		
	NO RECOVERY:		493 4		
	SANDSTONE: Very fine grained, light, whitish, cream, quartzose, extremely weathered.		491 6		
	SANDSTONE: Very fine grained, dark, brownish, red, extremely weathered.		489 8		
	SANDSTONE: Very fine grained, light, whitish, cream, extremely weathered.		487 10		
	SANDSTONE: Very fine grained, light, pinkish, yellow, minor, micaceous, extremely weathered.		485 12		
	SANDSTONE: Very fine grained, light, whitish, grey.		483 14		
	SANDSTONE: Very fine grained, light, whitish, grey.		481 16		
	SANDSTONE: Very fine grained, light, whitish, grey.		479 18		
	SANDSTONE: Very fine grained, dark, brownish, red.		477 20		
	SANDSTONE: Very fine to fine grained, light, creamy, yellow, quartzose.		475 22		
	SANDSTONE: Very fine to fine grained, light, greyish, cream, quartzose, throughout.		473 24		
	SANDSTONE: Fine to medium grained, light, greyish, cream, quartzose, throughout.		471 26		
	SANDSTONE: Very fine to fine grained, light, greyish, cream, quartzose, throughout.		469 28		
	SANDSTONE: Very fine grained, light, pinkish, cream.		467 30		
	SANDSTONE: Very fine to fine grained, light, greyish, cream, quartzose, micaceous.		465 32		
	SANDSTONE: Coarse grained, light, greyish, cream, quartzose.		463 34		
			461 36		
	SANDSTONE: Granular, light, yellowish, grey, quartzose.		459 38		
			457 40		
			455 42		
			453 44		
			451 46		
			449 48		
	SANDSTONE: Coarse grained, light, greyish, yellow, quartzose, minor, micaceous.		447 50		
			445 52		
			443 54		
			441 56		
			439 58		
	SANDSTONE: Very fine to fine grained, light, yellowish, grey, claystone, bands, throughout.		437 60		
	SANDSTONE: Fine to medium grained, light, greyish, yellow, quartzose.		435 62		
			433 64		
			431 66		
	CLAYSTONE: Mottled, creamy, red.		429 68		
			427 70		
			425 72		
	SANDSTONE: Coarse grained, light, greyish, yellow, quartzose.		423 74		

Clematis Sandstone (Triassic)

 +0.5 m
-0 m

 Protective lockable steel collar
PVC Stick up: 0.5 m (estimate)

165 mm PCD bit: 0 m to 149 m

Bentonite grout: 0 m to 135 m

50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 142 m

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MB29

SITE ID: **Y36**
EASTING: **407367.07 mE**
NORTHING: **7608867.12 mN**
DATUM: **GDA94 (z55)**
RL: **496.12 mAHD**
TD: **149 mBGL**

COMMENTS:

[illegible]


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BOREHOLE LOG

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MB30

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **10-Oct-13**
 LOGGED BY: **A. Dela Cruz**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **D.Quinlan (3084)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **AA35**
 EASTING: **409938.88 mE**
 NORTHING: **7609490.59 mN**
 DATUM: **GDA94 (z55)**
 RL: **483.61 mAHD**
 TD: **149.3 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)	SOIL: Light, brownish, brown, minor, extremely weathered, stiff.		484 0	+0.5 m -0 m	Protective lockable steel collar PVC Stick up: 0.5 m (estimate)
	SANDSTONE: Very fine grained, light, white, minor, sandstone, extremely weathered, extremely low strength rock		482 2		
	SANDSTONE: Very fine grained, light, white, extremely weathered, extremely low strength rock.		480 4		
	SANDSTONE: Very fine grained, light, whitish, buff.		478 6		152 mm PCD bit: 0 m to 149.3 m
	SANDSTONE: Very fine grained, light, brown, extremely weathered, extremely low strength rock.		476 8		
	SANDSTONE: Very fine grained, light, yellowish, brown.		474 10		Bentonite grout: 0 m to 135.3 m
	SANDSTONE: Very fine grained, light to medium, brown, extremely weathered, extremely low strength rock.		472 12		
	SANDSTONE: Very fine grained, light, whitish, buff, extremely weathered, extremely low strength rock.		470 14		
	SANDSTONE: Very fine grained, buff, extremely weathered, extremely low strength rock.		468 16		50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 149.3 m
	SANDSTONE: Very fine to fine grained, medium to dark, brown, extremely weathered, extremely low strength rock.		466 18		
	CLAYSTONE: Light, cream, extremely weathered, extremely low strength rock.		464 20		
	SANDSTONE: Very fine to fine grained, light, brownish, white, extremely weathered, extremely low strength rock.		462 22		
	SANDSTONE: Very fine to fine grained, medium to dark, red, extremely weathered, extremely low strength rock.		460 24		
	CLAYSTONE: Light, brownish, cream, extremely weathered, extremely low strength rock.		458 26		
	CLAYSTONE: Light, whitish, grey, extremely weathered, extremely low strength rock.		456 28		
			454 30		
	CLAYSTONE:		452 32		
	CLAYSTONE: Light, grey, distinctly weathered, medium strength rock		450 34		
			448 36		
	CLAYSTONE: Light, brownish, cream.		446 38		
			444 40		
	SANDSTONE: Very fine to fine grained, light to dark, red, weathered, extremely low strength rock.		442 42		
			440 44		
	SANDSTONE: Very fine to fine grained, light, creamy, white, weathered, extremely low strength rock.		438 46		
			436 48		
	SANDSTONE: Fine to medium grained, light, creamy, buff, weathered, extremely low strength rock.		434 50		
	SANDSTONE: Coarse grained, light, creamy, buff, quartzose, weathered, extremely low strength rock.		432 52		
	SANDSTONE: Fine grained, light, creamy, buff, weathered, extremely low strength rock.		430 54		
	SANDSTONE: Fine grained, light, grey, distinctly weathered, extremely low strength rock.		428 56		
	SANDSTONE: Coarse grained, light, creamy, buff, quartzose, weathered, extremely low strength rock.		426 58		
	SANDSTONE: Medium to coarse grained, light, creamy, buff, quartzose, weathered, extremely low strength rock		424 60		
	SANDSTONE: Granular, light, creamy, buff, weathered, extremely low strength rock.		422 62		
	SANDSTONE: Fine grained, light, whitish, buff, weathered, extremely low strength rock.		420 64		
	SANDSTONE: Fine to medium grained, light, brown, weathered, extremely low strength rock.		418 66		
	SANDSTONE: Fine to medium grained, light to medium, brown, weathered, extremely low strength rock.		416 68		
			414 70		
	SANDSTONE: Coarse grained, light, creamy, buff, quartzose, weathered, extremely low strength rock.		412 72		
	SANDSTONE: Fine to medium grained, light, creamy, buff, weathered, extremely low strength rock.		410 74		

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MB30

SITE ID: **AA35**
EASTING: **409938.88 mE**
NORTHING: **7609490.59 mN**
DATUM: **GDA94 (z55)**
RL: **483.61 mAHD**
TD: **149.3 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.		74 408 76		
	SANDSTONE: Medium to coarse grained, light, reddish, brown, quartzose, weathered, extremely low strength rock		406 78 404 80		
	SANDSTONE: Medium to coarse grained, light, brown, weathered, extremely low strength rock.		402 82 400 84		
	SANDSTONE: Fine to medium grained, light, brown, weathered, extremely low strength rock.		398 86		
	SANDSTONE: Fine to coarse grained, light, orangy, brown.		396 88		
	SANDSTONE: Fine to medium grained, light to dark, brown, weathered, extremely low strength rock.		394 90		
	SANDSTONE: Fine to medium grained, light, yellowish, brown, weathered, extremely low strength rock.		392 92		
	SANDSTONE: Fine to medium grained, light, brownish, buff, weathered, extremely low strength rock.		390 94		
	SANDSTONE: Fine to medium grained, light, reddish, brown, weathered, extremely low strength rock.		388 96		
	SANDSTONE: Fine to medium grained, light, brown, weathered, extremely low strength rock.		386 98		
	SANDSTONE: Fine grained, light, yellowish, brown, weathered, extremely low strength rock.		384 100 382 102 380 104 378 106 376 108 374 110 372 112 370 114 368 116 366 118 364 120 362 122 360 124 358 126 356 128 354 130 352 132 350 134 348 136 346 138 344 140 342 142 340 144 338 146 336 148 334 150		
	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine to coarse grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, pinkish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine to medium grained, light, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, brownish, buff, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, medium, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, light, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine to medium grained, light to dark, reddish, brown, weathered, extremely low strength rock.				
	SANDSTONE: Fine grained, medium, reddish, brown, weathered, extremely low strength rock.				


Australasian Groundwater & Environmental Consultants Pty Ltd

Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

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MB31

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **22-Sep-13**
 LOGGED BY: **T. Womack**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **J.Freeman (3335)**
 DRILLING METHOD: **Air / Mud Rotary**

SITE ID: **CC41**
 EASTING: **406704.71 mE**
 NORTHING: **7613341.6 mN**
 DATUM: **GDA94 (z55)**
 RL: **468.55 mAHD**
 TD: **149.4 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)	SANDSTONE: Fine grained, light to medium, greyish, orange, distinctly weathered, very low strength rock.		469 0 467 2		
	SANDSTONE: Fine grained, light to medium, pinkish, orange, distinctly weathered, very low strength rock.		465 4 463 6		
	SANDSTONE: Very fine to fine grained, light, pinkish, grey, distinctly weathered, extremely low strength rock		461 8 459 10 457 12		
	SANDSTONE: Very fine grained, light, pinkish, grey, distinctly weathered, extremely low strength rock.		455 14		
	SANDSTONE: Very fine grained, light, greyish, pink, distinctly weathered, extremely low strength rock.		453 16		
	SANDSTONE: Very fine grained, light, pinkish, grey, distinctly weathered, extremely low strength rock.		451 18		
	SANDSTONE: Very fine grained, light, yellowish, grey, distinctly weathered, extremely low strength rock.		449 20 447 22 445 24		
			443 26 441 28		
	SANDSTONE: Fine grained, light, pinkish, grey, quartzose, slightly weathered.		439 30 437 32 435 34 433 36 431 38		
	SANDSTONE: Fine grained, light, pinkish, grey, quartzose, slightly weathered.		429 40 427 42 425 44		
	SANDSTONE: Coarse grained, light, orangy, grey, quartzose.		423 46 421 48 419 50 417 52		
	SANDSTONE: Very fine grained, light, orangy, grey, claystone, in part, distinctly weathered, extremely low strength rock.		415 54 413 56 411 58 409 60 407 62 405 64 403 66 401 68		
	SANDSTONE: Fine to coarse grained, light, orangy, grey, quartzose, distinctly weathered.		399 70		
	SANDSTONE: Very fine grained, light, creamy, grey, slightly weathered.		397 72		
			395 74		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:2 of 2 MB31	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 22-Sep-13 LOGGED BY: T. Womack		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: J.Freeman (3335) DRILLING METHOD: Air / Mud Rotary	
COMMENTS:		SITE ID: CC41 EASTING: 406704.71 mE NORTHING: 7613341.6 mN DATUM: GDA94 (z55) RL: 468.55 mAHD TD: 149.4 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)
Clematis Sandstone (Triassic)	SANDSTONE: Very fine to fine grained, light, pinkish, orange, distinctly weathered.		74 393 76 391 78 389 80 387 82 385 84 383 86 381 88 379 90 377 92 375 94 373 96 371 98 369 100 367 102 365 104 363 106 361 108 359 110 357 112 355 114 353 116 351 118 349 120 347 122 345 124 343 126 341 128 339 130 337 132 335 134 333 136 331 138 329 140 327 142 325 144 323 146 321 148 319 150
	SANDSTONE: Fine to coarse grained, light, orangy, grey, quartzose, slightly weathered.		
	SANDSTONE: Fine to medium grained, light to medium, orangy, grey, quartzose, distinctly weathered.		
	SANDSTONE: Fine to coarse grained, medium, greyish, orange, quartzose, distinctly weathered.		
	SANDSTONE: Very fine grained, light, pinkish, grey, slightly weathered.		
	CLAYSTONE: Medium, greyish, orange, sandstone, in part.		
	SANDSTONE: Very fine grained, light to medium, orangy, grey, occasional, claystone, fragments, distinctly weathered, very low strength		
	SANDSTONE: Very fine to fine grained, medium, orangy, grey, claystone, in part, distinctly weathered.		


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BOREHOLE LOG

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MB32

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **1-Jun-13**
 LOGGED BY: **A.Goldsmith**

DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **S.Colles (3313)**
 DRILLING METHOD: **Air Rotary**

SITE ID: **MN9.5**
 EASTING: **420523.99 mE**
 NORTHING: **7590538.25 mN**
 DATUM: **GDA94 (z55)**
 RL: **302.06 mAHD**
 TD: **25 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Tertiary sediments			303 0	+0.5 m -0 m	Protective lockable steel collar PVC Stick up: 0.5 m (estimate)
	SANDSTONE: Fine grained, light, brown, extremely weathered		301 2		
	GRAVEL CONGLOMERATE: Light, yellowish, brown, quartzose, extremely weathered		299 4		
	SANDSTONE: Fine grained, light, red, extremely weathered		297 6		165 mm PCD bit: 0 m to 25 m
	SANDSTONE: Medium to coarse grained, light, yellowish, brown, quartzose, pebbles, in part, extremely weathered		295 8 293 10		Bentonite grout: 0 m to 17 m
	SANDSTONE: Medium to coarse grained, light, yellowish, brown, quartzose, extremely weathered		291 12 289 14 287 16		50 mm, PN18 uPVC, blank casing: 0.5 mAGL to 22 m
	SANDSTONE: Medium to coarse grained, light, yellowish, brown, quartzose, extremely weathered		285 18 283 20	-17 m -19 m	Bentonite seal: 17 m to 19 m 3 mm to 6 mm washed, rounded, quartz gravel pack: 19 m to 25 m
	SANDSTONE: Fine to medium grained, red, distinctly weathered		281 22 279 24 277	-22 m -25 m	bore dry at the time of drilling, still dry on the 19th March 2014 50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 22 m to 25 m slots opened to 1 mm every metre for stygofauna sampling BOC: 25 m


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BOREHOLE LOG

page: 1 of 2

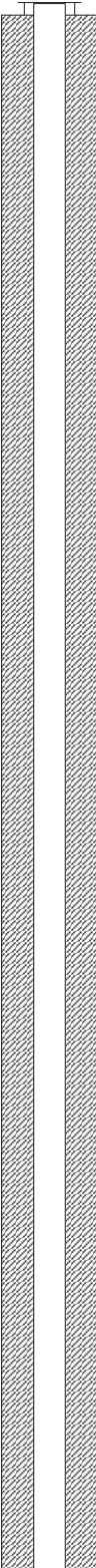
MB33

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **6-Jun-13**
 LOGGED BY: **B. Walker**

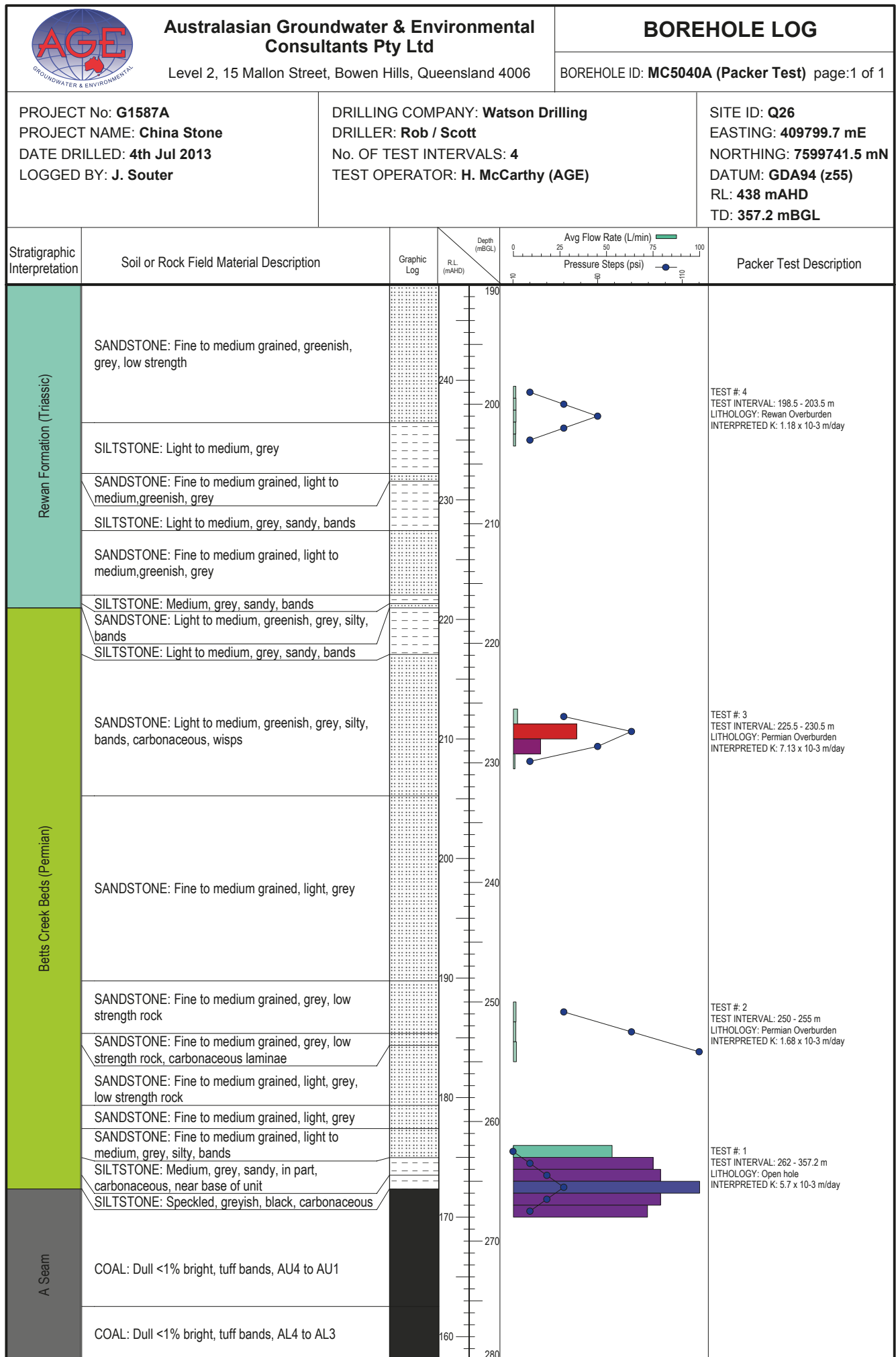
DRILLING COMPANY: **Watson Drilling**
 LICENCED DRILLER: **J.Freeman (3335)**
 DRILLING METHOD: **Mud Rotary**

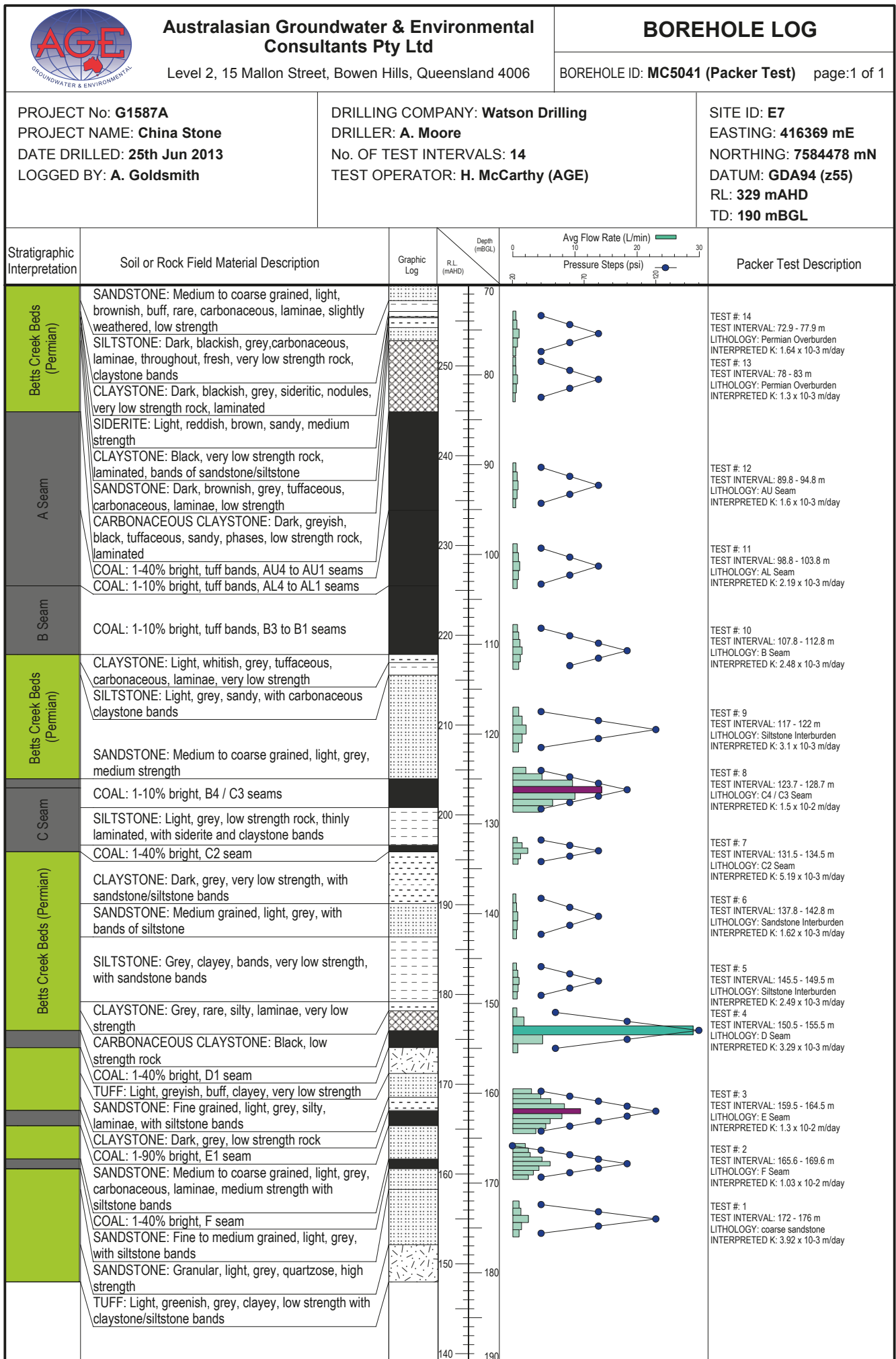
SITE ID: **T32**
 EASTING: **407078.76 mE**
 NORTHING: **7604220.71 mN**
 DATUM: **GDA94 (z55)**
 RL: **417.8 mAHD**
 TD: **149.4 mBGL**

COMMENTS:

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	Bore Construction	Bore Description
Clematis Sandstone (Triassic)	SOIL: Reddish, brown, weathered		418 0	 +0.66 m -0 m	Protective lockable steel collar PVC Stick up: 0.66 m
	SANDSTONE: Fine to medium grained, reddish, brown, weathered		416 2		
	SANDSTONE: Fine to coarse grained, reddish, brown, weathered		414 4		152 mm PCD bit: 0 m to 149.4 m
	SANDSTONE: Granular to pebbly, brown, weathered		412 6		Air rotary from 0 m to 53 m
			410 8		Mud rotary from 53 m to 149.4 m
	SANDSTONE: Very fine to fine grained, reddish, brown, weathered		408 10		Bentonite grout: 0 m to 135 m
			406 12		
			404 14		
			402 16		50 mm, PN18 uPVC, blank casing: 0.66 mAGL to 149.4 m
	SANDSTONE: Fine to coarse grained, brown, weathered		400 18		
			398 20		
			396 22		
			394 24		
			392 26		
			390 28		
			388 30		
			386 32		
			384 34		
			382 36		
			380 38		
	SANDSTONE: Granular to pebbly, brown, weathered		378 40		
			376 42		
			374 44		
			372 46		
			370 48		
			368 50		
			366 52		
			364 54		
	SANDSTONE: Fine to coarse grained, light, brownish, cream, coarser near top of unit near middle of unit, weathered		362 56		
			360 58		
			358 60		
			356 62		
			354 64		
			352 66		
			350 68		
			348 70		
			346 72		
			344 74		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG page:2 of 2		
		MB33		
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 6-Jun-13 LOGGED BY: B. Walker		DRILLING COMPANY: Watson Drilling LICENCED DRILLER: J.Freeman (3335) DRILLING METHOD: Mud Rotary		
		SITE ID: T32 EASTING: 407078.76 mE NORTHING: 7604220.71 mN DATUM: GDA94 (z55) RL: 417.8 mAHD TD: 149.4 mBGL		
COMMENTS:				
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	
Clematis Sandstone (Triassic)	SANDSTONE: Granular, mottled, brown, weathered		342 76 340 78 338 80 336 82 334 84 332 86 330 88 328 90 326 92 324 94 322 96 320 98 318 100 316 102 314 104 312 106 310 108 308 110 306 112 304 114 302 116 300 118 298 120 296 122 294 124 292 126 290 128 288 130 286 132 284 134 282 136 280 138 278 140 276 142 274 144 272 146 270 148 268 150	
	SANDSTONE: Fine to coarse grained, brown, weathered			
	SANDSTONE: Fine to coarse grained, creamy, finer near top of unit, coarser near base of unit, weathered			
	CLAYSTONE: Whitish, cream, weathered			
	LATERITE: Mottled, creamy, purple, sandy near base of unit, silty, weathered.			
	SANDSTONE: Very fine to fine grained, light, brown, minor clayey bands near base of unit, weathered			
	CLAYSTONE: Whitish, cream, weathered			
	SANDSTONE: Very fine to fine grained, light, brown, weathered			
	SILTSTONE: Light, brown, clayey in part, occasional carbonaceous bands, weathered			
	SANDSTONE: Light, brown, minor carbonaceous bands near top of unit, weathered			
	Rewan Formation (Triassic)	CLAYSTONE: Light, creamy, brown, weathered. BASE OF WEATHERING		
		CLAYSTONE: Grey, fresh		
			bore dry at the time of drilling SWL at 102.07 mBGL on 4th Jul 2013	
			Bentonite seal: 135 m to 137 m 3 mm to 6 mm washed, rounded, quartz gravel pack: 137 m to 149.4 m	
			50 mm, PN18 uPVC, machine slotted casing with 0.4 mm aperture: 143.4 m to 149.4 m slots opened to 1 mm every metre for stygofauna sampling	
			BOC: 149.4 m	

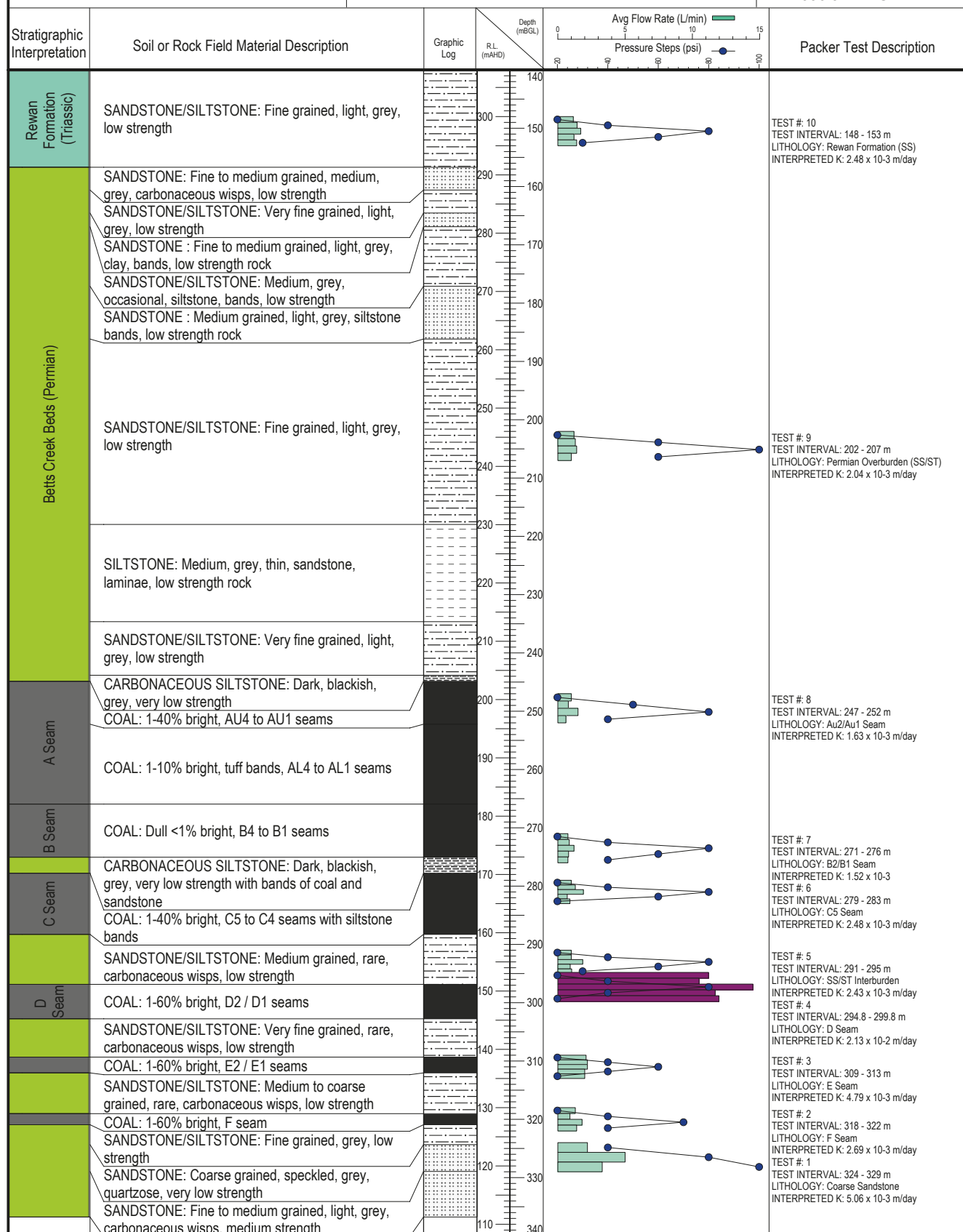




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BOREHOLE ID: MC5043 (Packer Test) page:1 of 1

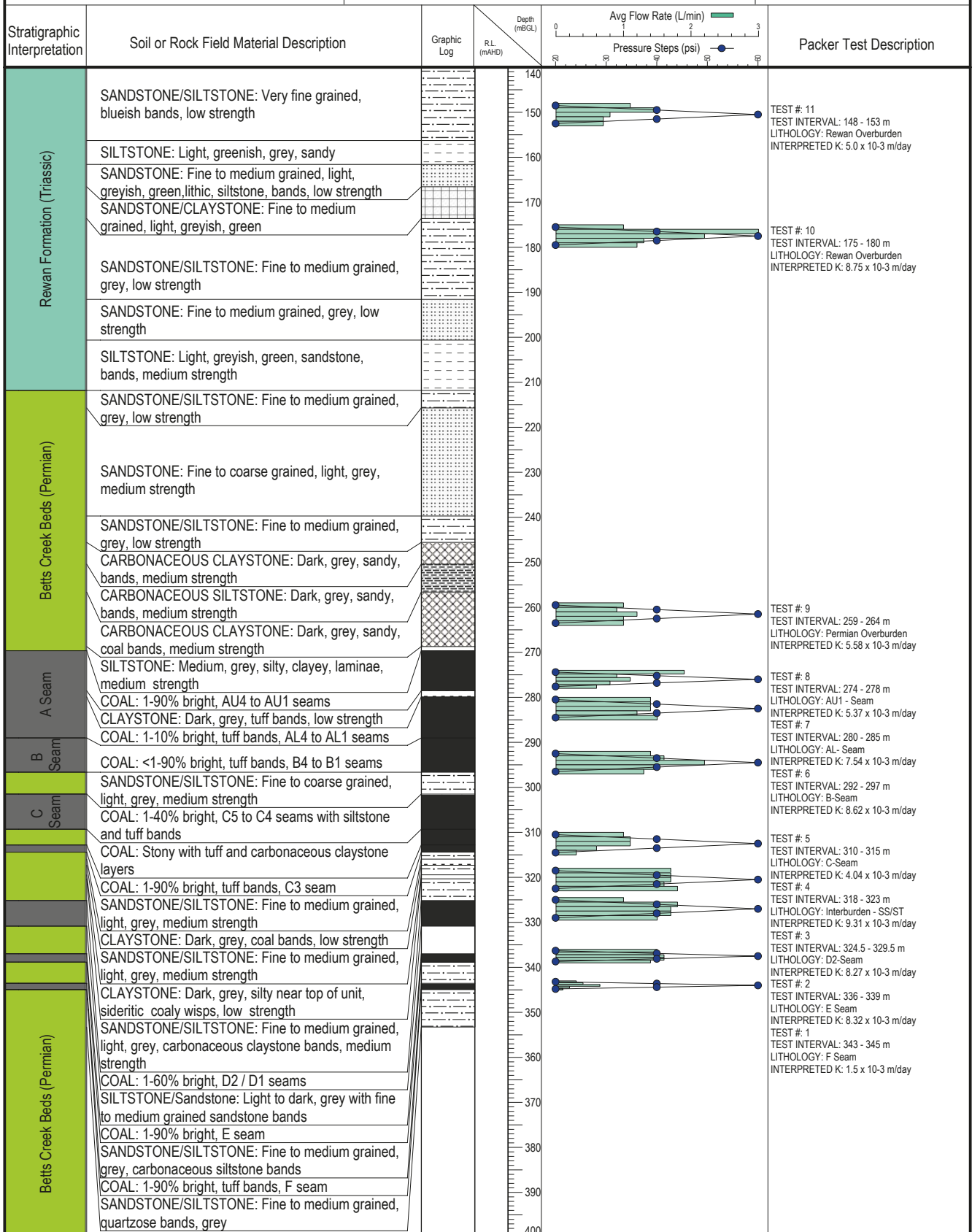
SITE ID: **M24**
EASTING: **408068 mE**
NORTHING: **7596724 mN**
DATUM: **GDA94 (z55)**
RL: **448 mAHD**
TD: **336.32 mBGL**

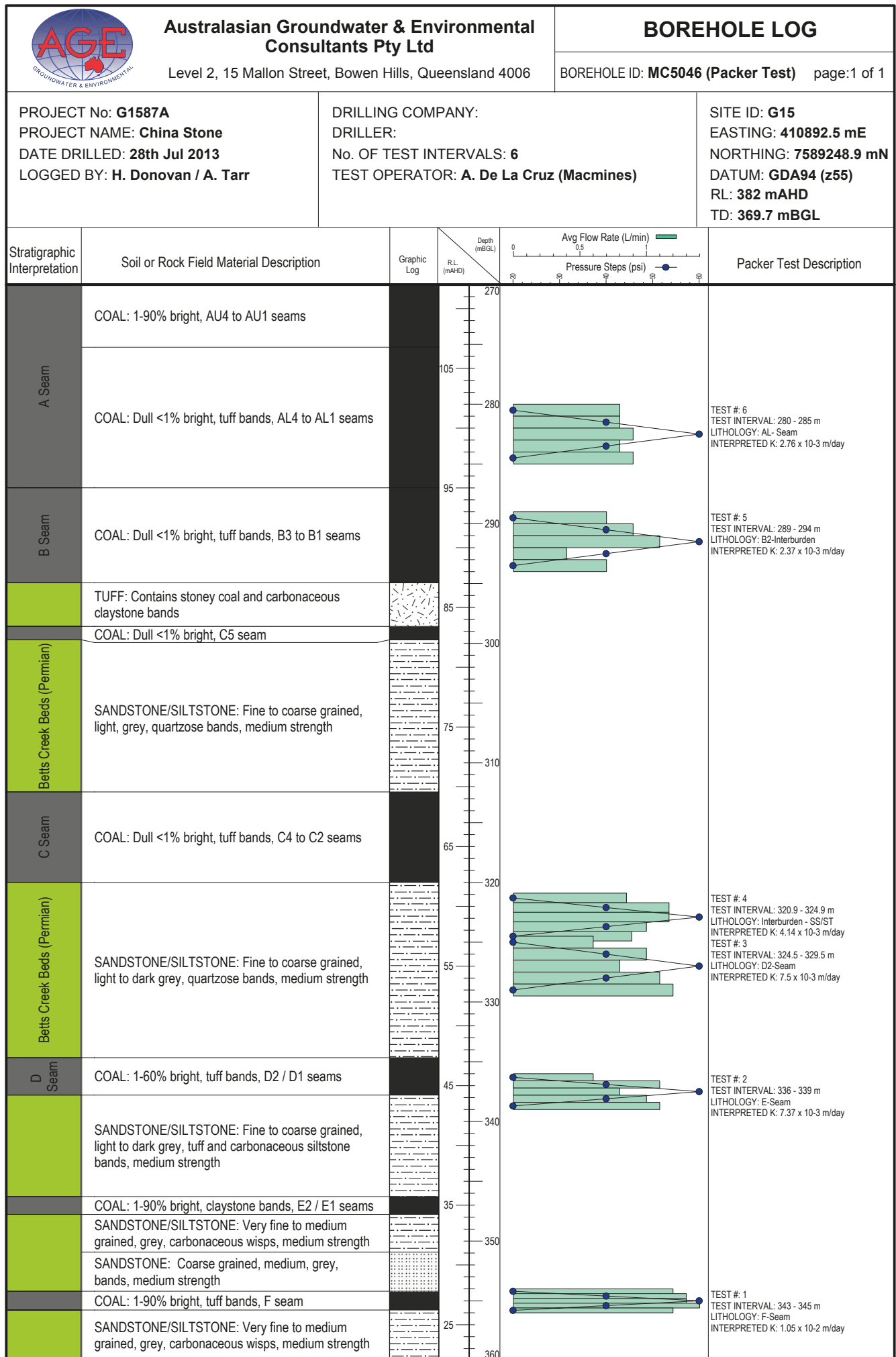


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BOREHOLE ID: MC5044 (Packer Test) page:1 of 1

SITE ID: **U32**
EASTING: **407746.7 mE**
NORTHING: **7604641.7 mN**
DATUM: **GDA94 (z55)**
RL: **mAHD**
TD: **400 mBGL**






**Australasian Groundwater & Environmental
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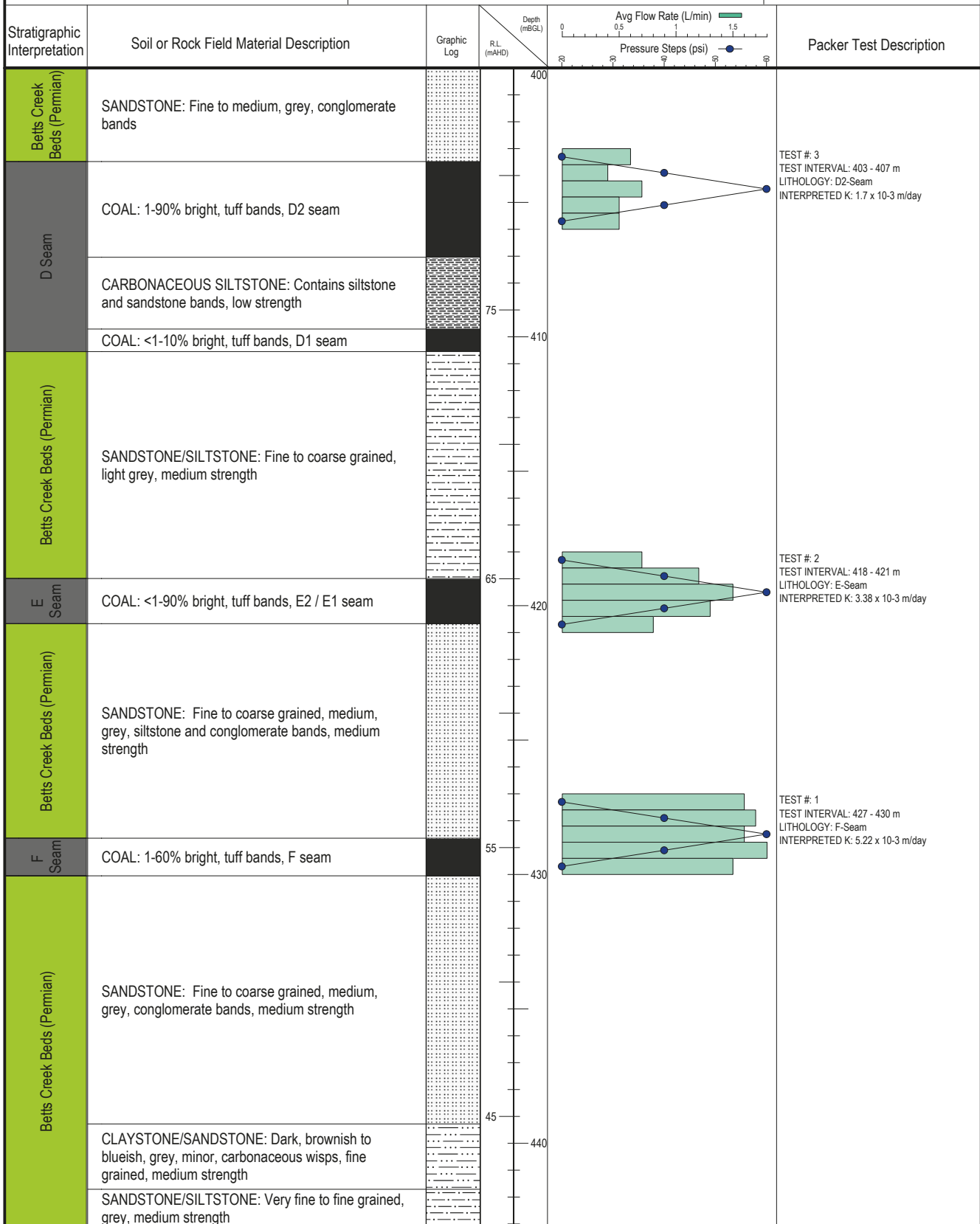
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

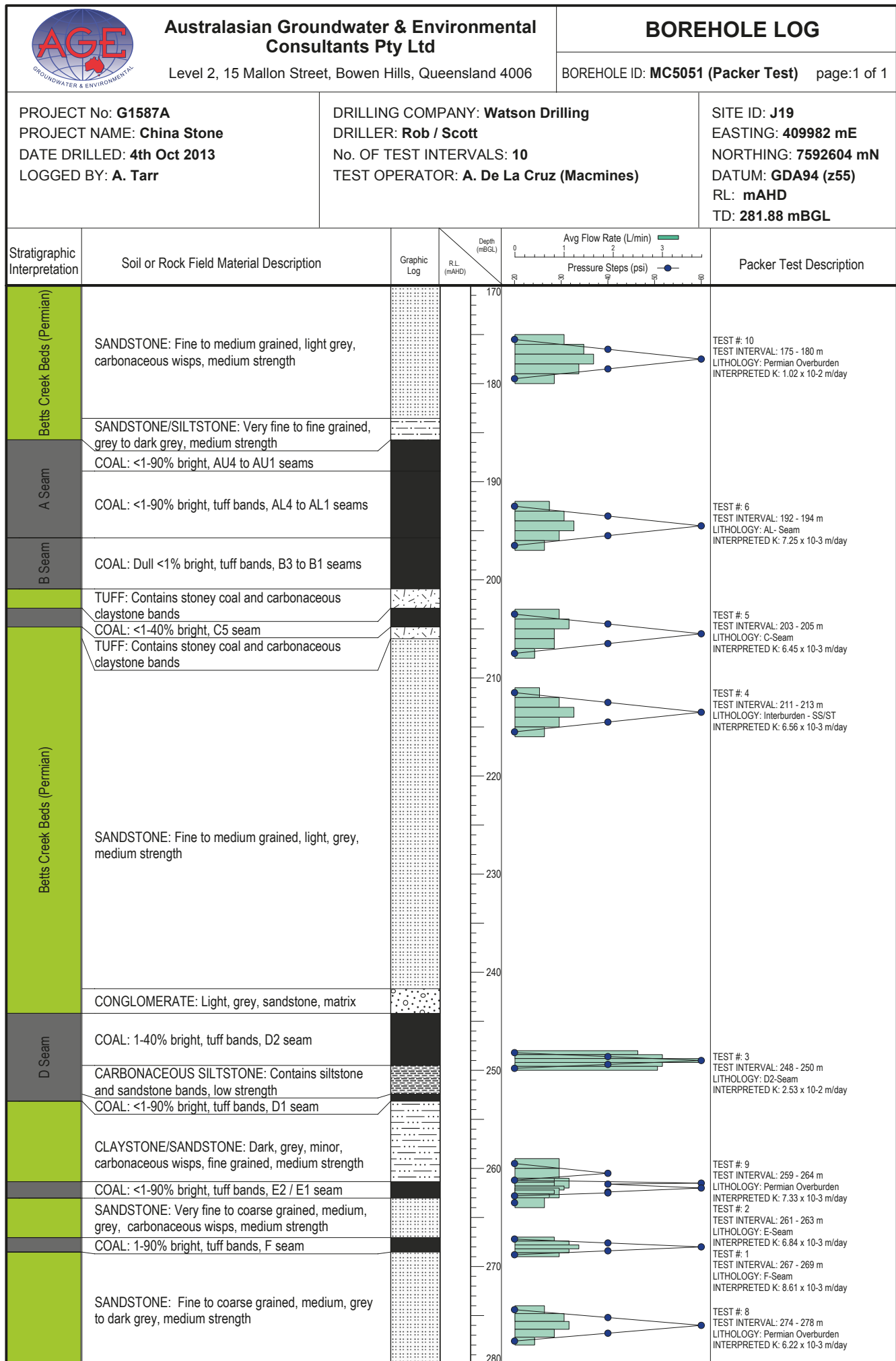
BOREHOLE LOG

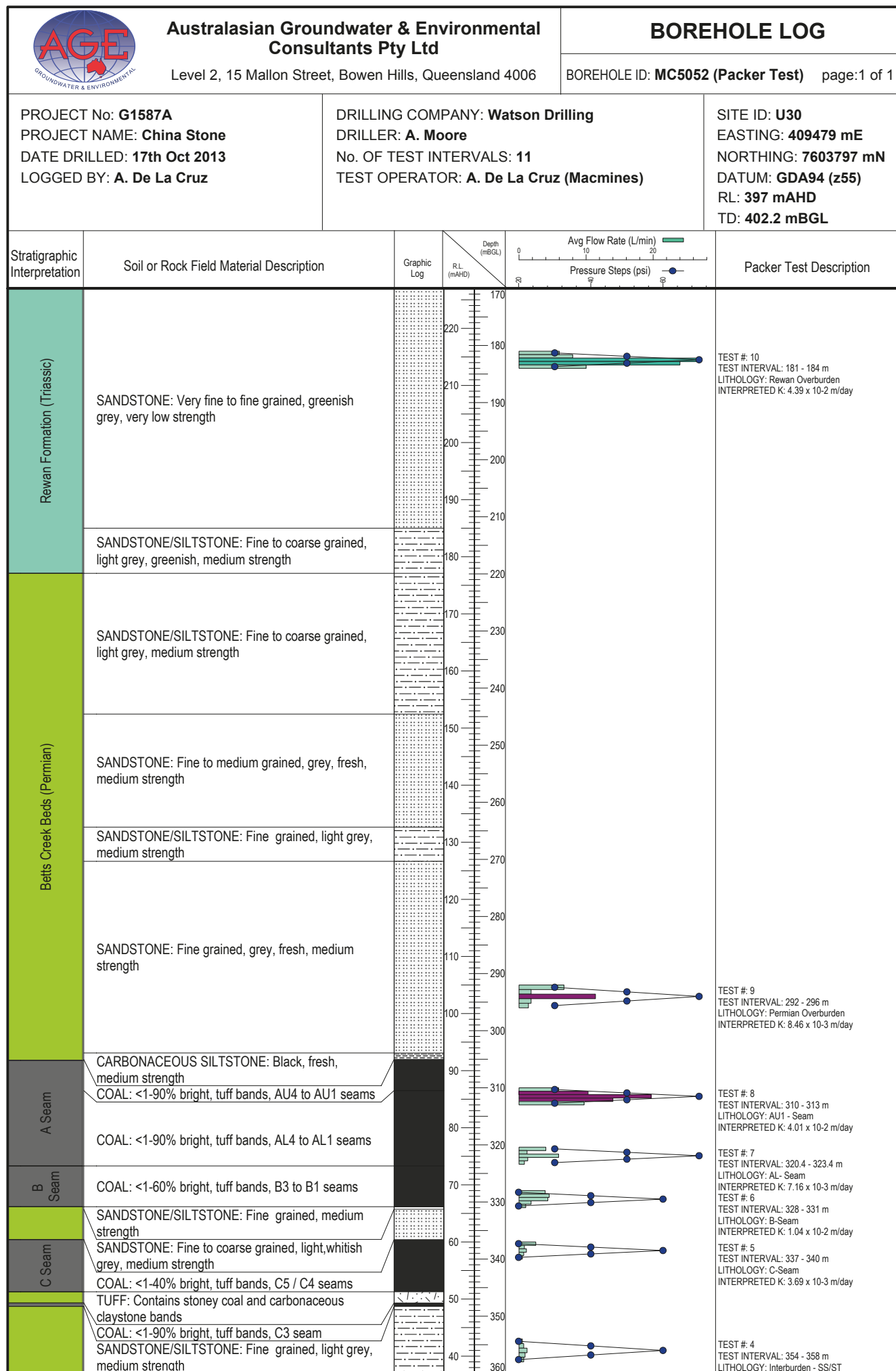
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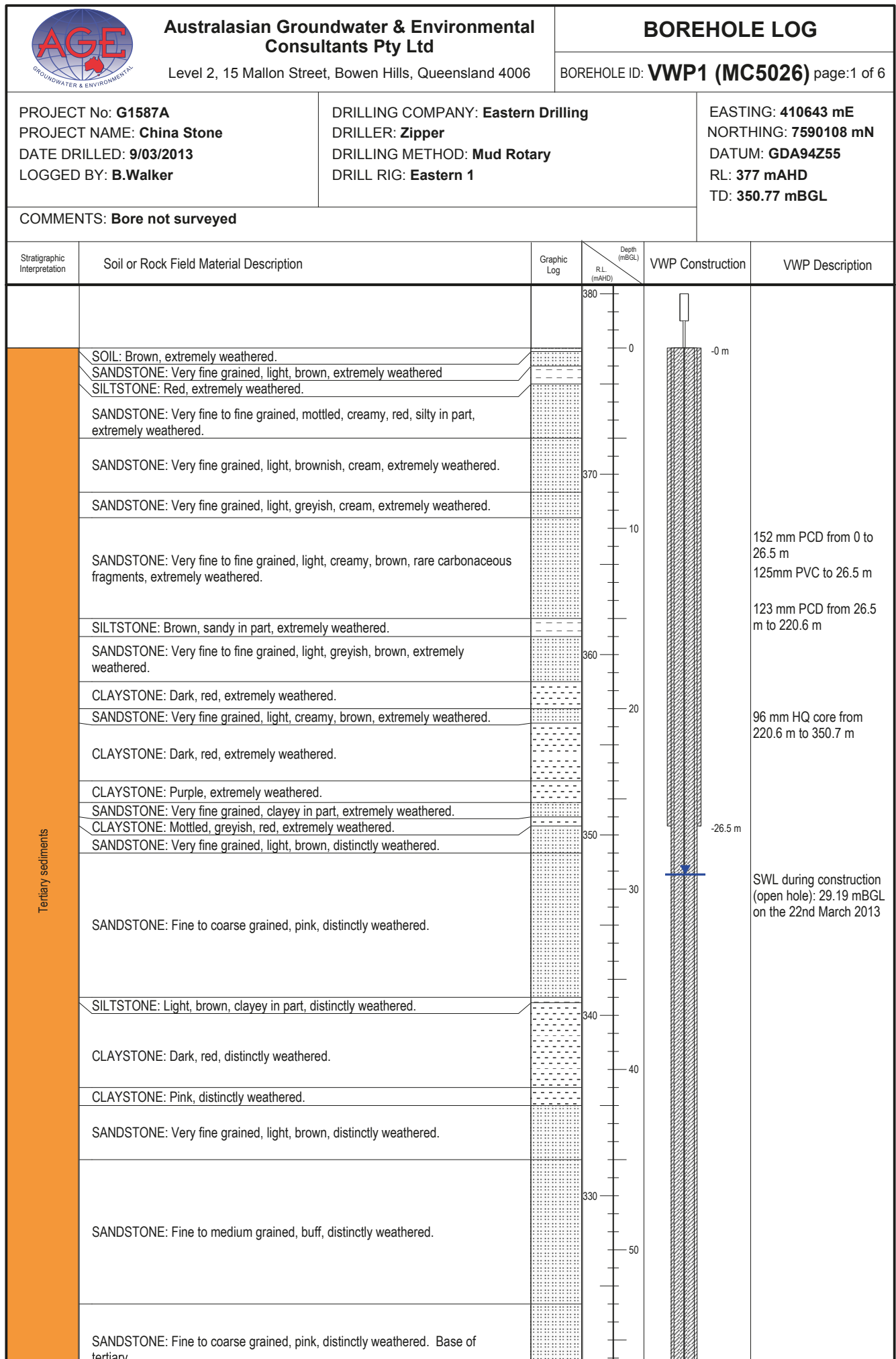
 PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **14th Sep 2013**
 LOGGED BY: **A. Tarr**

 DRILLING COMPANY:
 DRILLER: **M. Alderman**
 No. OF TEST INTERVALS: **3**
 TEST OPERATOR: **A. De La Cruz (Macmines)**

 SITE ID: **I20**
 EASTING: **408318.8 mE**
 NORTHING: **7592431.8 mN**
 DATUM: **GDA94 (z55)**
 RL: **484 mAHD**
 TD: **443.1 mBGL**


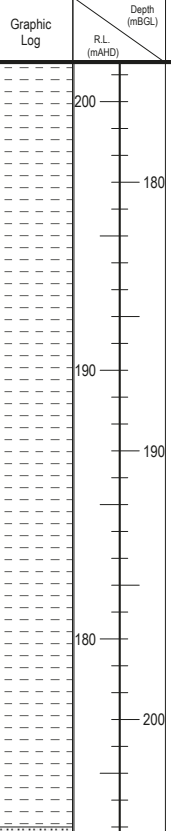
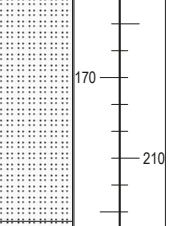
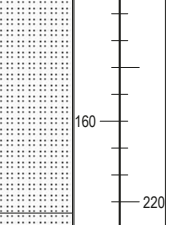
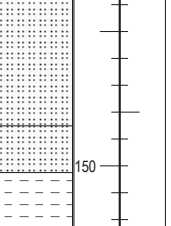
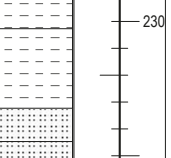


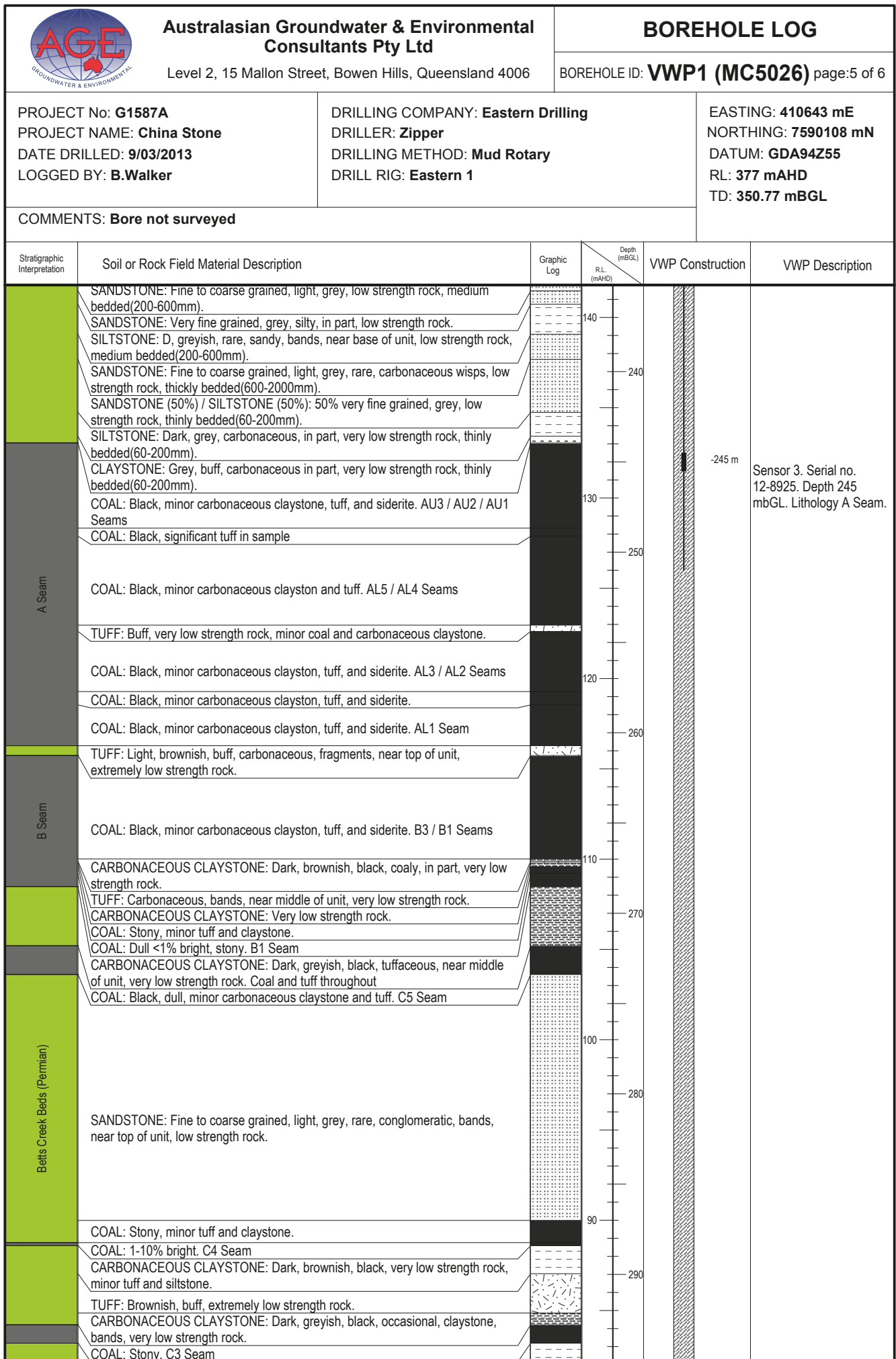




 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP1 (MC5026) page:2 of 6			
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 9/03/2013 LOGGED BY: B.Walker		DRILLING COMPANY: Eastern Drilling DRILLER: Zipper DRILLING METHOD: Mud Rotary DRILL RIG: Eastern 1			
COMMENTS: Bore not surveyed		EASTING: 410643 mE NORTHING: 7590108 mN DATUM: GDA94Z55 RL: 377 mAHD TD: 350.77 mBGL			
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	VWP Construction	VWP Description
Rewan Formation (Triassic)	SANDSTONE: Fine to coarse grained, light, brown, distinctly weathered.		320		
	SIDERITE: Dark, brown, distinctly weathered.		60		
	CLAYSTONE: Pink, distinctly weathered.				
	SILTSTONE: Light, brownish, pink, distinctly weathered.				
	SANDSTONE: Very fine grained, buff, slightly weathered.				
	CONGLOMERATE: Mottled, slightly weathered.		310		
	CLAYSTONE: Creamy, brown, slightly weathered. Base of weathering				
	CLAYSTONE: Dark, brown, fresh.				
	CLAYSTONE: Mottled, bluish, brown.		70		
	CLAYSTONE: Greyish, blue.				
	SANDSTONE: Very fine grained, grey, silty near base of unit.				
	CLAYSTONE: Purplish, brown.		300		
	SILTSTONE: Greyish, green, clayey in part.		80		
	SANDSTONE: Very fine grained, grey.				
	SILTSTONE: Grey.				
	CLAYSTONE: Brownish, grey.				
	CLAYSTONE: Grey.		290		
	SANDSTONE: Fine grained, light, greenish, grey, silty in part.		90		
	SILTSTONE: Greyish, green, clay in part.		280		
	SILTSTONE: Dark, brownish, green.		270		
SILTSTONE: Green, sandstone in part.		110			
			-114 m		

		Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP1 (MC5026) page:3 of 6	
		PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 9/03/2013 LOGGED BY: B.Walker		DRILLING COMPANY: Eastern Drilling DRILLER: Zipper DRILLING METHOD: Mud Rotary DRILL RIG: Eastern 1	
COMMENTS: Bore not surveyed					
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	VWP Construction	VWP Description
Rewan Formation (Triassic)			260		
			120		
	SANDSTONE: Greyish, green, siltstone in part.		250		
			130		
			240		
			140		
	SILTSTONE: Greyish, green, claystone in part.		230		
			150		
			220		
			160		
	SANDSTONE: Very fine grained, light to medium, bluish, grey.		210		
	SANDSTONE: Fine to medium grained, light to medium, bluish, grey, lithic.		170		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP1 (MC5026) page:4 of 6	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 9/03/2013 LOGGED BY: B.Walker		DRILLING COMPANY: Eastern Drilling DRILLER: Zipper DRILLING METHOD: Mud Rotary DRILL RIG: Eastern 1	
COMMENTS: Bore not surveyed		EASTING: 410643 mE NORTHING: 7590108 mN DATUM: GDA94Z55 RL: 377 mAHD TD: 350.77 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	VWP Construction
Rewan Formation (Triassic)	SILTSTONE: Medium, grey, minor sandy in part. Base of Triassic.		-190 m Sensor 1. Serial no. 12-8935. Depth 190 mbGL. Lithology Rewan Formation.
	SANDSTONE: Fine to medium grained, light to medium, grey, lithic.		
Belts Creek Beds (Permian)	SANDSTONE: Fine to medium grained, light to medium, grey, lithic.		-220 m Sensor 2. Serial no. 12-8927. Depth 220 mbGL. Lithology Sandstone Overburden.
	SANDSTONE: Fine to medium grained, light, grey, low strength rock, massive/absent bedding.		
	SANDSTONE (70%) / SILTSTONE (30%): 70% very fine to fine grained, light, grey, occasional, sideritic, bands, low strength rock, very thinly bedded(20-60mm).		
	SILTSTONE: Grey, occasional, sandy, bands, throughout, low strength rock, very thinly bedded(20-60mm).		
	SILTSTONE: Grey, sandy, bands, near top and base of unit, low strength rock, thinly bedded(60-200mm).		
	SANDSTONE: Very fine grained, grey, silty, in part, low strength rock, thinly bedded(60-200mm).		




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Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

 BOREHOLE ID: **VWP1 (MC5026)** page:6 of 6

 PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **9/03/2013**
 LOGGED BY: **B.Walker**

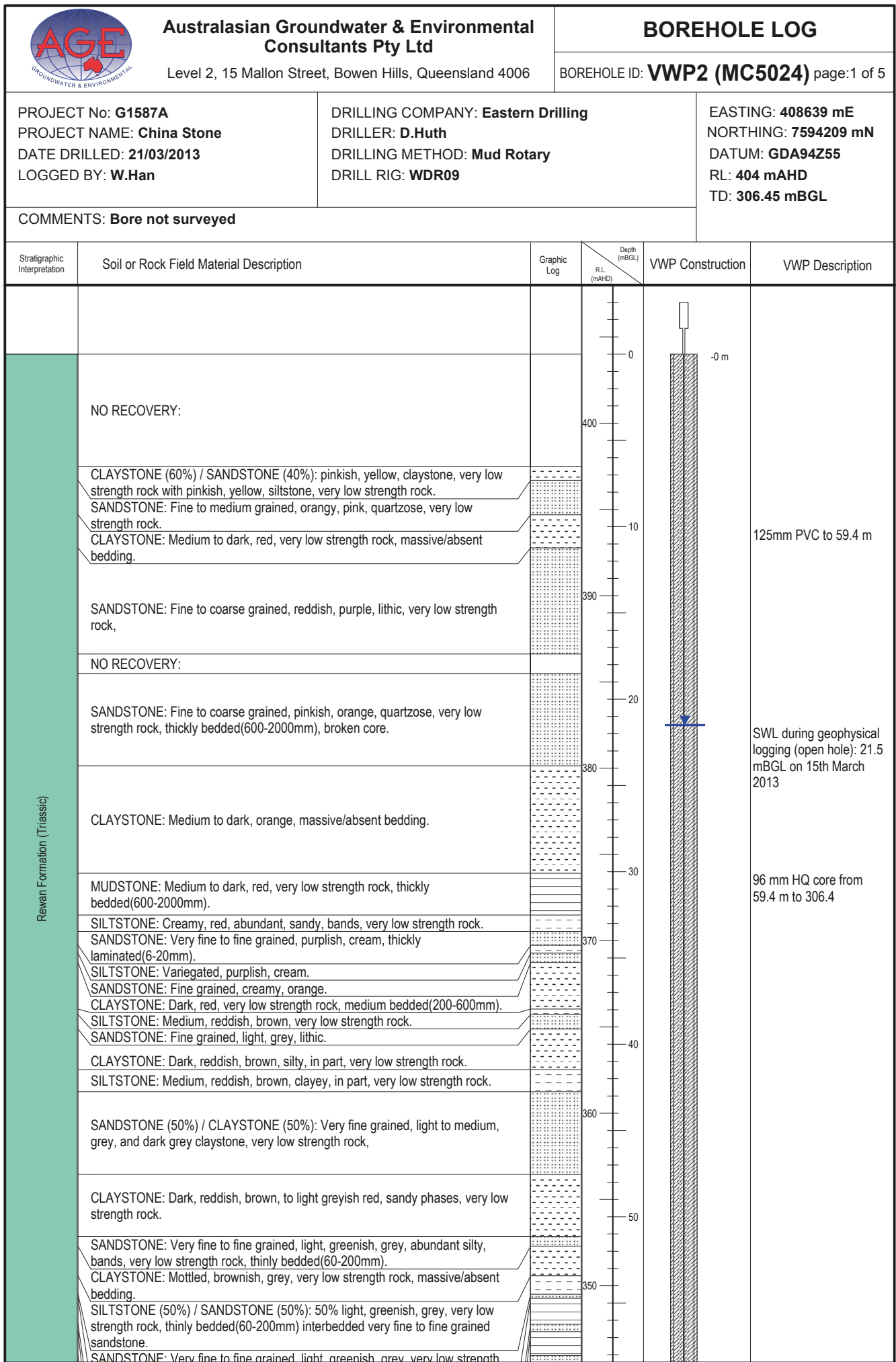
 DRILLING COMPANY: **Eastern Drilling**
 DRILLER: **Zipper**
 DRILLING METHOD: **Mud Rotary**
 DRILL RIG: **Eastern 1**

 EASTING: **410643 mE**
 NORTHING: **7590108 mN**
 DATUM: **GDA94Z55**
 RL: **377 mAHD**
 TD: **350.77 mBGL**

 COMMENTS: **Bore not surveyed**

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	VWP Construction	VWP Description
	SILTSTONE: Grey, low strength rock. SANDSTONE: Very fine to fine grained, light, grey, silty, wisps, rare coaly bands near base of unit, low strength rock, siderite at base. SANDSTONE: Fine to coarse grained, light, grey, coaly, wisps, throughout, low strength rock.		80		
	CARBONACEOUS CLAYSTONE: Dark, greyish, black, very low strength rock. COAL: Stony, C2 Seam SILTSTONE: Grey, rare coaly bands near top of unit, occasional sandstone bands throughout, very low strength rock.		300		
Belts Creek Beds (Permian)	SANDSTONE: Fine to medium grained, grey, occasional, silty, bands, throughout, low strength rock. SILTSTONE: Grey, occasional, sandy, bands, carbonaceous near base of unit, very low strength rock. CLAYSTONE: Grey, tuffaceous, in part, very low strength rock.		70 310		
D Seam	COAL: Black, carbonaceous claystone splitting plies. D2 / D1 Seam				
Belts Creek Beds (Permian)	COAL: Stony, significant siderite. SANDSTONE: Very fine to fine grained, light, greyish, grey, as, silty, bands, near top of unit, low strength rock, siderite at base. SANDSTONE: Very fine grained, grey, occasional, silty, phases, low strength rock. SILTSTONE: Grey, clayey, near base of unit, low strength rock. TUFF: Very low strength rock, siderite at base. SILTSTONE: Carbonaceous, bands, near top of unit, low strength rock, thin(<5 cm) sandstone at top of unit.		60 320		
E Seam	SANDSTONE: Fine to medium grained, grey, coarser, near top of unit, low strength rock, very thinly bedded(20-60mm). SILTSTONE: Dark, grey, low strength rock, thickly laminated(6-20mm). COAL: Black, minor carbonaceous claystone and tuff. E2 / E1 Seams				
	SANDSTONE: Fine to coarse grained, light, grey, low strength rock, medium bedded(200-600mm). COAL: 40-60% bright, minor tuff, carbonaceous claystone at base. F Seam		50 330		
Belts Creek Beds (Permian)	SANDSTONE: Fine to coarse grained, light, grey, rare carbonaceous wisps, coarser near base of unit, quartzose, low strength rock.		40 340		
	SILTSTONE: Grey, occasional sandy phases, low strength		30 350		

-350.7 m BOH: 350.7 m




Australasian Groundwater & Environmental Consultants Pty Ltd

Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

 BOREHOLE ID: **VWP2 (MC5024)** page:2 of 5

PROJECT No: **G1587A**
 PROJECT NAME: **China Stone**
 DATE DRILLED: **21/03/2013**
 LOGGED BY: **W.Han**

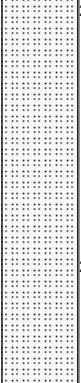
DRILLING COMPANY: **Eastern Drilling**
 DRILLER: **D.Huth**
 DRILLING METHOD: **Mud Rotary**
 DRILL RIG: **WDR09**

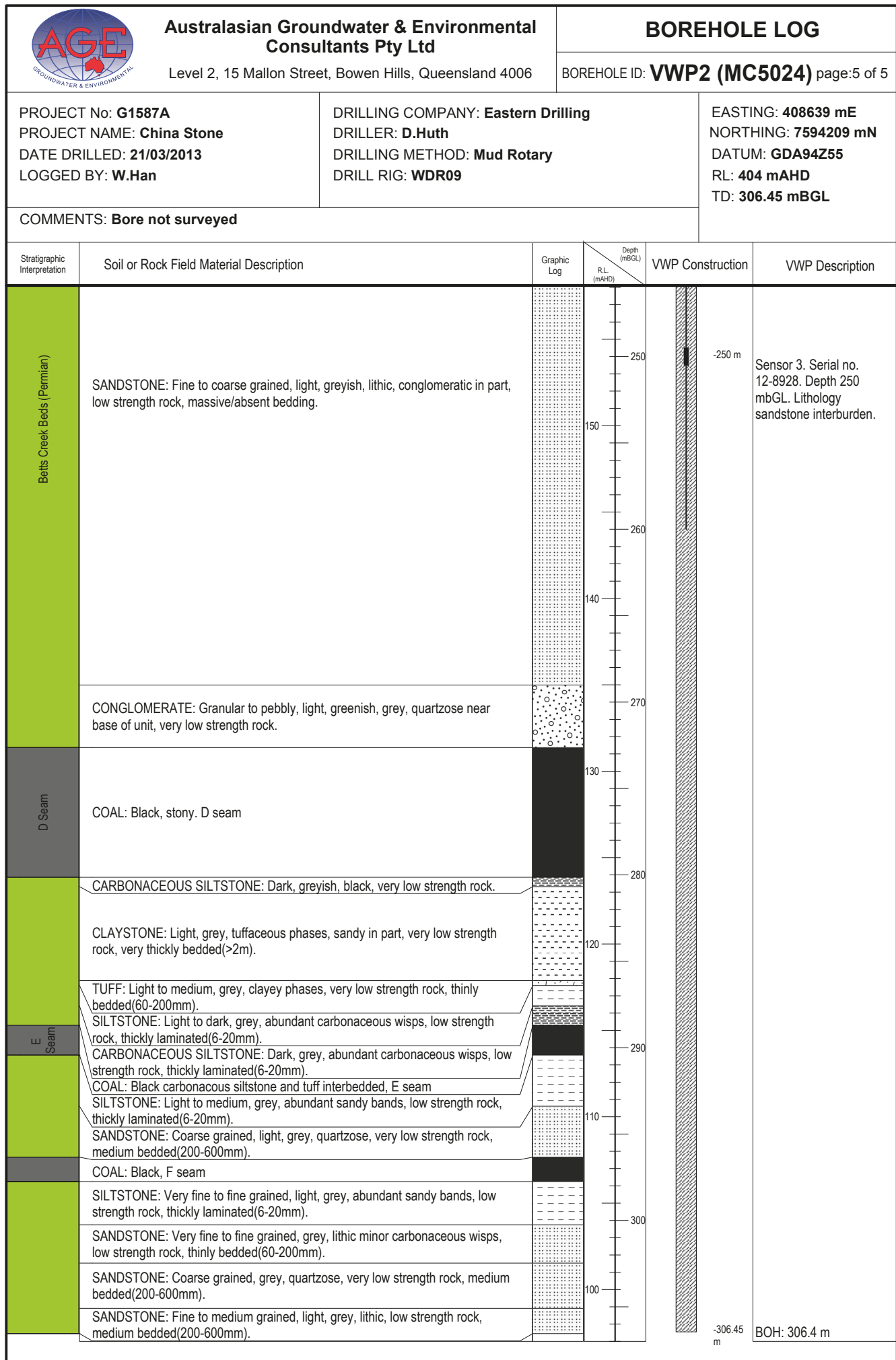
EASTING: **408639 mE**
 NORTHING: **7594209 mN**
 DATUM: **GDA94Z55**
 RL: **404 mAHd**
 TD: **306.45 mBGL**

 COMMENTS: **Bore not surveyed**

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL)	VWP Construction	VWP Description
Rewan Formation (Triassic)	rock, thickly				
	MUDSTONE: Mottled, greenish, grey, very low strength rock, massive/absent bedding.		60		-59.4 m
	SANDSTONE: Fine grained, light, greenish, grey, lithic, silty in part, very low strength rock, thickly laminated(6-20mm).		340		
	MUDSTONE: Mottled, greenish, grey, very low strength rock, massive/absent bedding, sedimentary dykes. Base of weathering				
	SANDSTONE (50%) / MUDSTONE (50%): Light, greenish, grey, with purplish green mudstone, carbonaceous, fragments, fresh, very low strength rock.		70		
	SANDSTONE: Fine to medium grained, light, greenish, grey, silty in part, fining upwards.				
	CLAYSTONE: Medium, greenish, grey, sandy in part, near top of unit sandy, bands throughout, fresh, very low		330		
	SANDSTONE: Fine grained, medium, greenish, grey, pebbles near middle of unit, near middle of unit, lithic, near base of unit, fresh, very low strength rock, medium bedded(200-600mm), fining upwards.				
	CLAYSTONE: Medium, greenish, grey, very low strength rock, massive/absent bedding.				
	CLAYSTONE: Mottled, purplish, green, low strength rock.				
	MUDSTONE: Dark, greenish, grey, abundant sandy bands, clayey, low strength rock.		80		
	SANDSTONE: Greenish, grey, low strength rock.				
	SANDSTONE: Fine to medium grained, light to medium, greenish, grey, lithic, carbonaceous, silty, pebbles near base of unit, low strength rock, thinly bedded(60-200mm).		320		
	SILTSTONE: Light to medium, greenish, grey, sandy in part near top of unit, low strength rock, thickly laminated(6-20mm).				
	SANDSTONE: Fine to medium grained, light to medium, greenish, grey, lithic, carbonaceous, silty, pebbles throughout, low strength rock, medium bedded(200-600mm).				
	MUDSTONE: Light to medium, greenish, grey, clayey, low strength rock.				
	SANDSTONE (50%) / SILTSTONE (50%): Very fine to fine grained, light, greenish, grey, low strength rock, medium bedded(200-600mm).		90		
	MUDSTONE: Greenish, grey, rare sandy bands, low strength rock, thinly bedded(60-200mm).				
	SANDSTONE: Fine to medium grained, light, greenish, grey, silty in part, low strength rock, thinly bedded(60-200mm), sedimentary dykes.		310		
	SILTSTONE: Grey, low strength rock.				
	SANDSTONE: Fine to medium grained, greenish, grey, silty bands near top of unit, low strength rock, very thinly bedded(20-60mm).				
	SILTSTONE: Light, greenish, grey, silty bands throughout, minor clay bands, low strength rock, very thinly bedded(20-60mm).		100		
	SANDSTONE (50%) / SILTSTONE (50%): Light, greenish, grey sandstone, lithic, low strength rock, medium bedded(200-600mm) interbedded with light, greenish, grey siltstone, low strength rock, very thinly bedded(20-60mm).				
	SILTSTONE: Light, greenish, grey, occasional clay bands, low strength rock, thickly laminated(6-20mm).		300		
	SANDSTONE: Fine to coarse grained, light, grey, low strength rock, thickly laminated(6-20mm), 15.				
	SILTSTONE: Light, greenish, grey, low strength rock.				
	SANDSTONE: Very fine to fine grained, light, greenish, grey, rare pebbles, low strength rock, thinly laminated(<6mm).		110		
	SANDSTONE: Fine to coarse grained, light, greenish, grey, silty in part, rare pebbles, low strength rock.				
	SILTSTONE: Light to medium, greenish, grey, low strength rock, massive/absent bedding.		290		
	SANDSTONE: very fine to coarse grained, medium, brownish, grey, lithic, rare pebbles, low strength rock/.				
	SILTSTONE: Light to medium, creamy, green.				
	SANDSTONE: Fine grained, light to medium, grey, lithic, low strength rock, massive/absent bedding.		120		
	SILTSTONE: Greenish, grey, low strength rock, massive/absent bedding.				
	MUDSTONE: Mottled, purplish, grey, clay in part, low strength rock, poorly developed bedding, calcite, on joints.				
	SANDSTONE: Very fine to fine grained, light, greenish, grey, lithic, low strength rock, massive/absent bedding.				

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP2 (MC5024) page:3 of 5			
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 21/03/2013 LOGGED BY: W.Han		DRILLING COMPANY: Eastern Drilling DRILLER: D.Huth DRILLING METHOD: Mud Rotary DRILL RIG: WDR09			
COMMENTS: Bore not surveyed		EASTING: 408639 mE NORTHING: 7594209 mN DATUM: GDA94Z55 RL: 404 mAHD TD: 306.45 mBGL			
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	VWP Construction	VWP Description
Renwan Formation (Triassic)	MUDSTONE: Medium, greenish, grey, low strength rock, massive/absent bedding.				
	SANDSTONE: Light, grey, clayey near top of unit, silty bands, low strength rock.				
	SILTSTONE: Light to medium, greenish, grey, low strength rock, thinly laminated(<6mm).		280		
	SANDSTONE: Light to medium, greenish, grey, silty bands, near base of unit, low strength rock, medium bedded(200-600mm).				
	NO RECOVERY:				
	SANDSTONE (60%) / SILTSTONE (40%): Very fine to fine grained sandstone, light, grey, low strength rock, interbedded with greenish, grey, clayey in part, low strength rock, thickly bedded(600-2000mm).		130		
	SILTSTONE: Greenish, grey, sandy bands, near middle of unit, low strength rock, medium bedded(200-600mm).				
	SANDSTONE: Fine grained, greenish, grey, carbonaceous wisps near base of unit, low strength rock, thickly bedded(600-2000mm).		270		
	SANDSTONE: Fine to coarse grained, grey, rare coaly, lenses, near top of unit, coarser near base of unit quartzose near base of unit, low strength rock, medium bedded(200-600mm).				
	SILTSTONE: Grey, sandy bands, in part, low strength rock, thinly bedded(60-200mm).				
	SANDSTONE: Light, greenish, grey, low strength rock, thickly bedded(600-2000mm).		140		
	SILTSTONE: Light, greenish, grey, low strength rock, thickly bedded(600-2000mm).				
	SANDSTONE: Fine grained, light, greenish, grey, silty bands near top of unit, low strength rock, thickly bedded(600-2000mm).		260		
	SANDSTONE: Fine to coarse grained, light, grey, occasional silty, bands near top of unit, low strength rock, massive/absent bedding.				
	SILTSTONE: Greenish, grey, clayey in part, sandy near base of unit, low strength rock, thinly bedded(60-200mm).				
SANDSTONE: Fine to coarse grained, greenish, grey, low strength rock, thickly bedded(600-2000mm).		150			
SILTSTONE: Grey, sandy in part, low strength rock, thickly bedded(600-2000mm).		250			
SANDSTONE: Fine to coarse grained, light, grey, low strength rock, thickly bedded(600-2000mm).					
SILTSTONE: Grey, low strength rock, thickly bedded(600-2000mm).		160			
SANDSTONE: Fine to medium grained, light, grey, silty bands near base of unit, low strength rock, thickly bedded(600-2000mm).					
SILTSTONE: Grey, occasional sandy bands, low strength rock, thinly bedded(60-200mm), minor siderite.		240			
SILTSTONE: Grey, occasional sandy bands, low strength rock, thinly bedded(60-200mm), minor siderite.		170			
Belts Creek Beds (Permian)			230		
			180		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP2 (MC5024) page:4 of 5	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 21/03/2013 LOGGED BY: W.Han		DRILLING COMPANY: Eastern Drilling DRILLER: D.Huth DRILLING METHOD: Mud Rotary DRILL RIG: WDR09	
COMMENTS: Bore not surveyed		EASTING: 408639 mE NORTHING: 7594209 mN DATUM: GDA94Z55 RL: 404 mAHD TD: 306.45 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	VWP Construction
Belts Creek Beds (Permian)	SANDSTONE: Fine to medium grained, light, grey, lithic silty bands, low strength rock, medium bedded(200-600mm), minor siderite		-185 m
	SILTSTONE: Greyish, rare sideritic bands, low strength rock, medium bedded(200-600mm).		
A Seam	COAL: Dull, discrete layers of tuff and carbonaceous siltstone throughout. A seam		-210 m
B Seam	COAL: Dull, discrete layers of tuff and carbonaceous siltstone throughout. B seam		
C Seam	COAL: Black. C seam		
	SANDSTONE: Fine grained, light, grey, rare silty bands, near base of unit, low strength rock.		
	COAL: Black. C4 seam		



 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP3 (MC5027) page:1 of 6			
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 15/03/2013 LOGGED BY: B.Diaz		DRILLING COMPANY: Watson Drilling DRILLER: L.Hogan DRILLING METHOD: Mud Rotary DRILL RIG: WDR04			
COMMENTS: Bore not surveyed		EASTING: 407582 mE NORTHING: 7598318 mN DATUM: GDA94Z55 RL: 457 mAHD TD: 348.31 mBGL			
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	VWP Construction	VWP Description
Tertiary sediments	SOIL: Red.		460		
	SANDSTONE: Medium to coarse grained, red, extremely weathered, hard.		0	-0 m	
	IRON: Very fine grained, red, weathered.		450		
	CONGLOMERATE: Coarse grained, reddish, brown, weathered.		10		152 mm PCD from 0 to 87 m 125mm PVC to 87 m 101.6 mm PCD from 86 to 221.35 m
Rewan Formation (Triassic)	SILTSTONE: Light, yellowish, white, clayey silty, weathered, very soft.		440		
	SANDSTONE: Fine to medium grained, light, yellowish, white, silty in part, weathered.		20		96 mm HQ core from 221.35 m to 348.3 m
	CLAYSTONE: Medium, brownish, red, sandy in part, weathered.		430		
			30		
	SANDSTONE: Fine to medium grained, light, brownish, white, weathered.		420		SWL during construction (open hole): 33.36 mBGL on the 18th March 2013
	CLAYSTONE: Medium, brownish, red, weathered.		40		
	SANDSTONE: Fine to medium grained, light, yellowish, white, lithic, weathered.		410		
	CLAYSTONE: Medium, brownish, red, weathered.		50		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP3 (MC5027) page:2 of 6			
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 15/03/2013 LOGGED BY: B.Diaz		DRILLING COMPANY: Watson Drilling DRILLER: L.Hogan DRILLING METHOD: Mud Rotary DRILL RIG: WDR04			
COMMENTS: Bore not surveyed		EASTING: 407582 mE NORTHING: 7598318 mN DATUM: GDA94Z55 RL: 457 mAHD TD: 348.31 mBGL			
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	VWP Construction	VWP Description
Rewan Formation (Triassic)			400		
			60		
	SILTSTONE: Medium, brownish, red, clayey, in part.				
			390		
	SANDSTONE: Fine to medium grained, light, brownish, yellow, weathered.				
	SANDSTONE (50%) / CLAYSTONE (50%): Medium, brownish, red, weathered.		70		
	CLAYSTONE: Light to medium, brownish, red, silty in part. Base of tertiary				
	CLAYSTONE: Light to medium, brownish, red, weathered.		380		
	CLAYSTONE: Light, whitish, yellow, silty in part.		80		
			370		
			90		
			360		
	CLAYSTONE: Light to medium, blueish, brown, silty in part, weathered. Base of weathering.		100		
			350		
			110		


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Consultants Pty Ltd**

Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

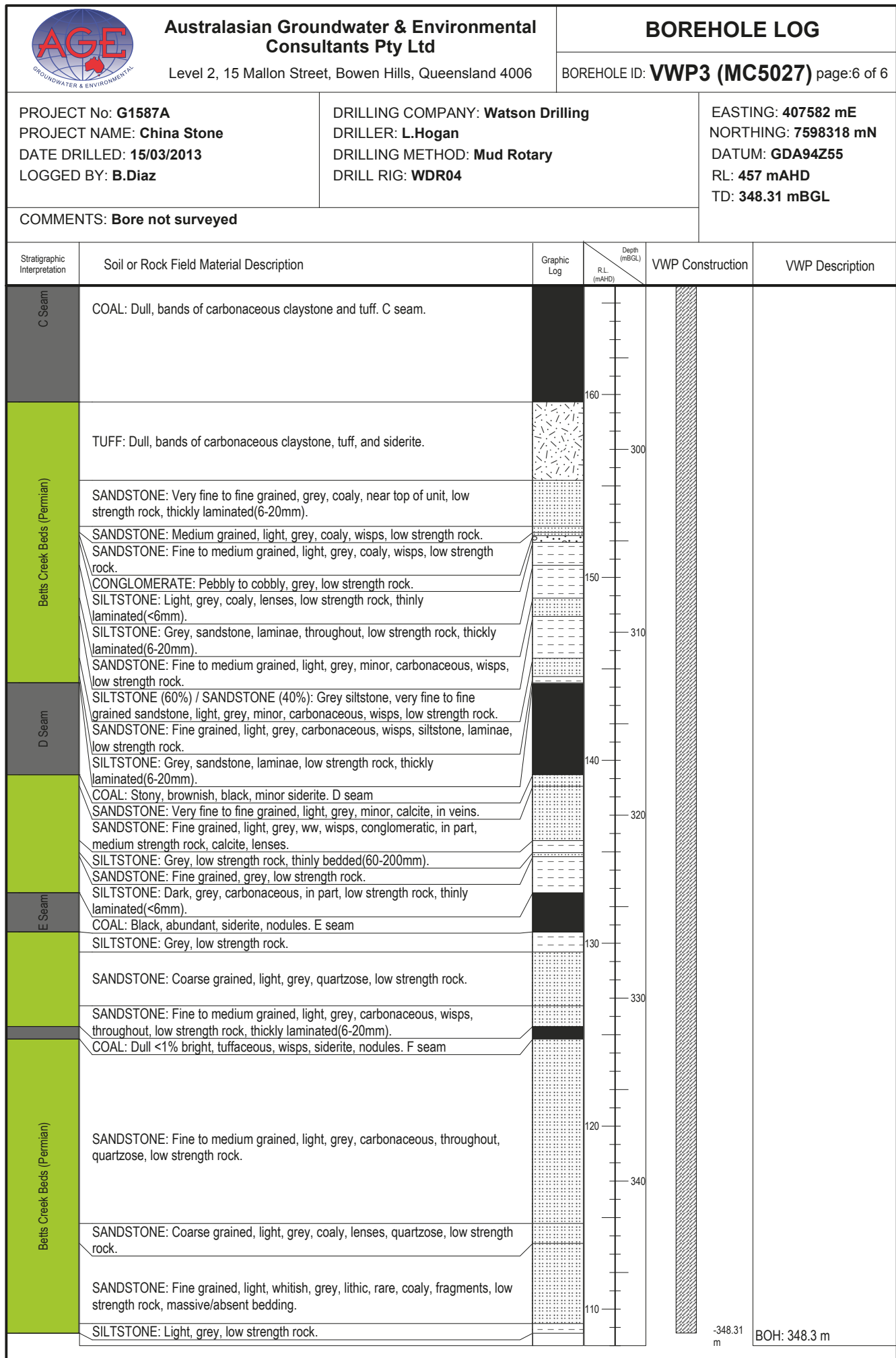
 BOREHOLE ID: **VWP3 (MC5027)** page:3 of 6

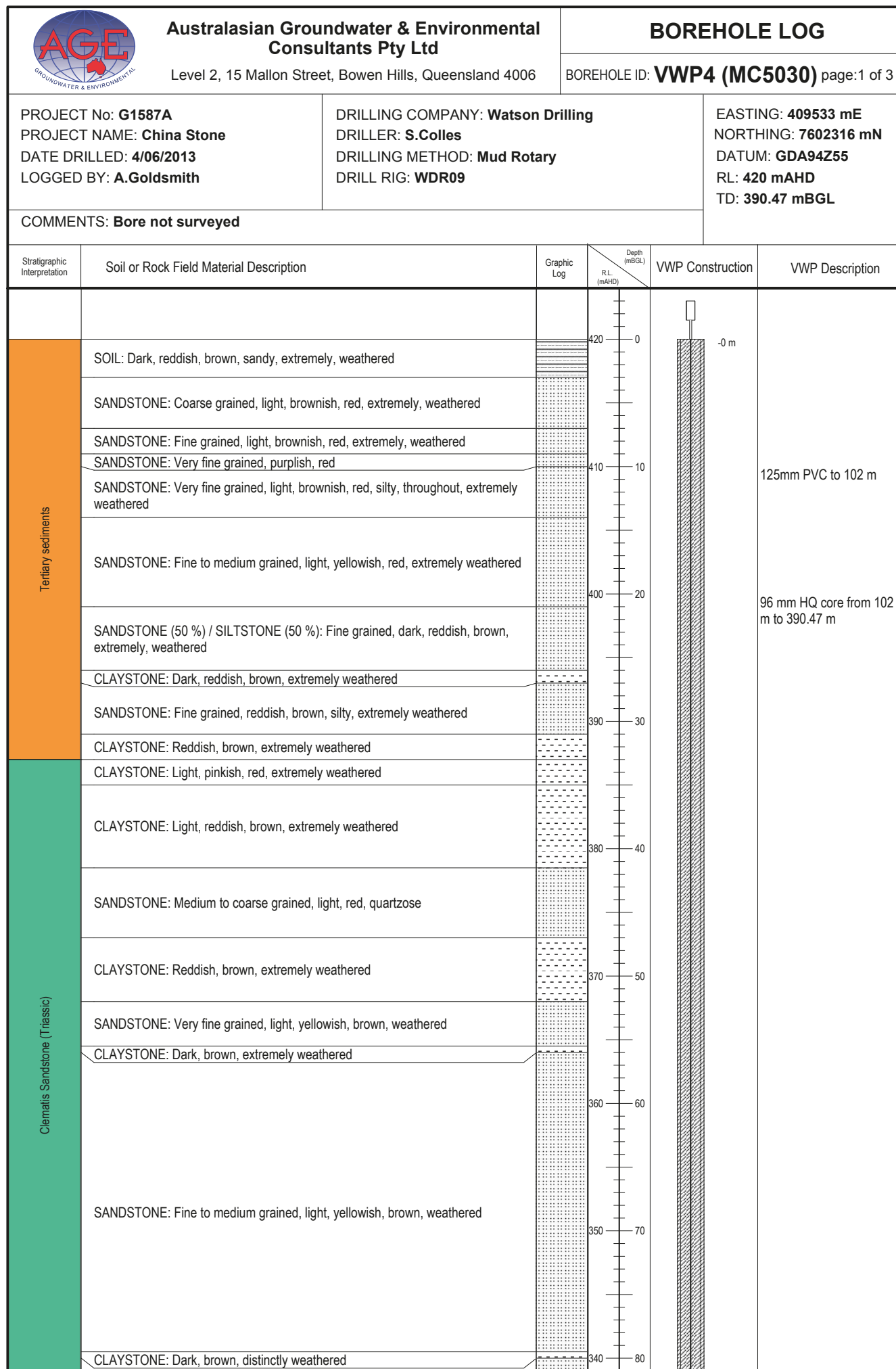
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 15/03/2013 LOGGED BY: B.Diaz	DRILLING COMPANY: Watson Drilling DRILLER: L.Hogan DRILLING METHOD: Mud Rotary DRILL RIG: WDR04	EASTING: 407582 mE NORTHING: 7598318 mN DATUM: GDA94Z55 RL: 457 mAHD TD: 348.31 mBGL
COMMENTS: Bore not surveyed		

Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD)	VWP Construction	VWP Description
Rewan Formation (Triassic)	SILTSTONE: Light, blueish, grey, fresh.		340 120		
	SANDSTONE: Very fine grained, light, blueish, grey, fresh.		330 130 320 140 310		
	SILTSTONE: Medium, blueish, grey.		300 160 290 170		

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: WVP3 (MC5027) page:4 of 6		
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 15/03/2013 LOGGED BY: B.Diaz		DRILLING COMPANY: Watson Drilling DRILLER: L.Hogan DRILLING METHOD: Mud Rotary DRILL RIG: WDR04		
COMMENTS: Bore not surveyed		EASTING: 407582 mE NORTHING: 7598318 mN DATUM: GDA94Z55 RL: 457 mAHD TD: 348.31 mBGL		
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	VWP Construction	VWP Description
Rewan Formation (Triassic)				
	SANDSTONE: Fine grained, light to medium, blueish, grey.			
	SILTSTONE: Medium, blueish, grey. Base of Rewan.			
Betts Creek Beds (Permian)	SANDSTONE: Fine to medium grained, light to medium, grey.			
	SANDSTONE: Fine to medium grained, light, grey, medium strength rock.			
	SANDSTONE: Fine to medium grained, light, grey, lithic, carbonaceous, wisps, conglomeratic near base of unit, medium strength rock.			
	SANDSTONE: Fine to medium grained, light, grey, lithic, carbonaceous, wisps, conglomeratic near base of unit, medium strength r			
	SANDSTONE: Light, grey, lithic, conglomeratic, near middle of unit, carbonaceous wisps, medium strength rock.			

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: VWP3 (MC5027) page:5 of 6	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 15/03/2013 LOGGED BY: B.Diaz		DRILLING COMPANY: Watson Drilling DRILLER: L.Hogan DRILLING METHOD: Mud Rotary DRILL RIG: WDR04	
COMMENTS: Bore not surveyed		EASTING: 407582 mE NORTHING: 7598318 mN DATUM: GDA94Z55 RL: 457 mAHD TD: 348.31 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD) VWP Construction VWP Description
Belts Creek Beds (Permian)	SILTSTONE: Medium to dark, grey, siltstone, in part, low strength rock, thickly laminated(6-20mm).		
	SILTSTONE (70%) / SANDSTONE (30%): Dark, grey siltstone, sideritic, bands, throughout interbedded with fine grained sandstone, brownish, grey, low strength rock, thinly bedded(60-200mm), sedimentary dykes.		
	SANDSTONE: Fine to medium grained, dark, brownish, grey, lithic, sideritic, in part, medium strength rock.		
	SILTSTONE: Dark, grey, low strength rock.		
	SILTSTONE (70%) / SANDSTONE (30%): 70% dark, grey siltstone interbedded with brownish, grey sandstone, lithic, low strength rock, sedimentary dykes.		
	SANDSTONE: Fine to medium grained, grey, lithic, low strength rock, thickly laminated(6-20mm).		
	SILTSTONE: Dark, grey, abundant, sandstone, bands, low strength rock, very thickly bedded(>2m).		
A Seam	SILTSTONE: Medium to dark, grey, low strength rock. Black.		
	CARBONACEOUS CLAYSTONE: Black.		
B Seam	COAL: Dull, bands of carbonaceous claystone, tuff, and siderite. A seam.		
	COAL: Dull, bands of carbonaceous claystone and tuff. B seam.		





Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE ID: **VWP4 (MC5030)** page:2 of 3

EASTING: 409533 mE
NORTHING: 7602316 mN
DATUM: GDA94Z55
RL: 420 mAHD
TD: 390.47 mBGL

Stratigraphic Interpretation

Graphical Log

VWP Description

Clematis Sandstone (Triassic)

SILTSTONE: Light, greenish, grey

Rewan Formation (Triassic)

-102 m

-160 m

SWL during construction
(open hole): 90.75 mBGL
on 30th May 2013

Sensor 1. Serial no.
12-8929. Depth 160
mbGL. Lithology Rewan
Formation.

 Australasian Groundwater & Environmental Consultants Pty Ltd Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006		BOREHOLE LOG BOREHOLE ID: WVP4 (MC5030) page:3 of 3	
PROJECT No: G1587A PROJECT NAME: China Stone DATE DRILLED: 4/06/2013 LOGGED BY: A.Goldsmith		DRILLING COMPANY: Watson Drilling DRILLER: S.Colles DRILLING METHOD: Mud Rotary DRILL RIG: WDR09	
COMMENTS: Bore not surveyed		EASTING: 409533 mE NORTHING: 7602316 mN DATUM: GDA94Z55 RL: 420 mAHD TD: 390.47 mBGL	
Stratigraphic Interpretation	Soil or Rock Field Material Description	Graphic Log	Depth (mBGL) R.L. (mAHD) VWP Construction VWP Description
Rewan Formation (Triassic)	SANDSTONE: Fine grained, greenish, grey, clayey, in part		250 170
			240 180
	SILTSTONE: Greenish, grey, sandy, in part, clayey, in part		230 190
			220 200
	SANDSTONE: Fine grained, light, greenish, grey		210 210
	SILTSTONE: Greenish, grey		200 220
	SANDSTONE: Fine to medium grained, light, greenish, grey.		190 230
			180 240
	SANDSTONE: Fine to medium grained, light, greyish		170 250

Sensor 2. Serial no. 12-8930. Depth 200 mbGL. Lithology siltstone overburden.

Sensor 3. Serial no. 12-8931. Depth 240 mbGL. Lithology sandstone overburden.

Appendix A-3
Groundwater quality data

**G1587 - China Stone Project****Groundwater Quality Results****Physical Parameters, Major Ions and Nutrients**

Page 1/9

Parameter	Units	LOR ^a	ANZECC GUIDELINES		NHMRC								
Sample Location			Irrigation Water	Stock Water	Drinking Water	MB03	MB03	MB06	MB06	MB07	MB07	MB08	MB08
Lab Number						EB1313987001	EB1408474007	EB1318364003	EB1408474004	ES1307244001	EB1408474013	ES1307244002	EB1408474012
Date Sampled						7/06/2013	2/04/2014	18/07/2013	2/04/2014	26/03/2013	3/04/2014	25/03/2013	3/04/2014
Lithology						A Seam	A Seam	A/B Seams	A/B Seams	Tertiary	Tertiary	Betts Creek	Betts Creek
Sampling Date													
Field pH	pH units		-	-	-	8.0	-	7.4	-	-	-	-	-
Field Electivcal Conductivity (EC)	µS/cm		-	-	-	1905	-	2137	-	-	-	-	-
Depth to Groundwater	m bTOC		-	-	-	59.35	-	71.71	-	-	-	-	-
Physical Parameters													
pH	pH Units	0.1	6.0 - 8.5	-	6.5 - 8.5 ^b	8.1	8.0	8.0	8.4	8.1	8.1	8.2	8.1
Electrical conductivity	µS/cm	1	-	-	-	1880	2040	2840	3180	830	565	1010	1090
Sodium Absorption Ration (SAR)	-	0.01	-	-	-	9.69	-	10.4	-	7.47	-	7.24	-
Total Dissolved Solids (grav) @180°C	mg/L	1.00	-	3000 - 13000*	600 ^b	1220	1330	1850	2070	540	367	656	708
Total Hardness as CaCO3	mg/L	1.00	-	-	200 ^b	192	200	339	414	63	116	96	114
Hydroxide Alkalinity as CaCO3	mg/L	1.00	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	-	-	-	<1	<1	<1	21	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1.00	-	-	-	72	85	290	274	65	120	109	125
Total Alkalinity as CaCO3	mg/L	1.00	-	-	-	72	85	290	295	65	120	109	125
Major Ions													
Sulfate as SO4 - Turbidimetric	mg/L	1	-	1000 - 2000	500 / 250 ^b	57	65	90	101	20	10	21	21
Chloride	mg/L	1	40	-	250 ^b	541	530	743	728	191	85	233	225
Fluoride	mg/L	0.1	1.0	2	1.5	0.3	0.3	0.6	0.6	0.6	0.6	0.4	0.4
Calcium	mg/L	1	-	1000	-	16	19	65	70	7	35	12	16
Magnesium	mg/L	1	-	-	-	37	37	43	58	11	7	16	18
Sodium	mg/L	1	-	-	180 ^b	309	318	440	494	136	60	163	162
Potassium	mg/L	1	-	-	-	8	8	13	14	5	3	10	8
Total Anions	meq/L	0.01	-	-	-	17.9	18	28.6	28.5	7.1	5	9.19	9.28
Total Cations	meq/L	0.01	-	-	-	17.5	18	26.2	30.1	7.3	5.01	9.26	9.53
Ionic Balance	%	0.01	-	-	-	1.14	0.06	4.34	2.68	1.33	0.06	0.38	1.3
Nutrients													
Ammonia as N	mg/L	0.01	-	-	0.5 ^b	0.11	0.13	0.74	0.35	-	0.07	-	0.05
Nitrite as N	mg/L	0.01	-	30	3	<0.01	<0.01	<0.01	<0.01	-	<0.01	-	<0.01
Nitrate as N	mg/L	0.01	-	-	50	<0.01	0.02	<0.01	0.04	-	0.08	-	0.04
Nitrite + Nitrate as N	mg/L	0.01	-	400	-	<0.01	0.02	<0.01	0.04	-	0.08	-	0.04
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	-	-	1	1.4	1.8	0.4	-	3.5	-	1.1
Total Nitrogen as N	mg/L	0.1	-	-	-	1	1.4	1.8	0.4	-	3.6	-	1.1
Total Phosphorus as P	mg/L	0.01	-	-	-	0.07	0.64	0.12	0.03	-	4.57	-	1.11
Reactive Phosphorus as P	mg/L	0.01	0.05	-	-	<0.01	<0.01	<0.01	<0.01	-	<0.01	-	0.29

Notes:

a. Limit of reporting

b. Aesthetic guidelines for Drinking Water

mbTOC metres below top of casing

0.7 Detected concentration above ANZECC (2000) Long Term Irrigation purposes

0.024 Detected concentration above ANZECC (2000) Stock purposes

0.024 Detected concentration above NHMRC (2011) Drinking Water Guidelines

* maximum concentration at which good condition might be expected, with 13,000 mg/L for sheep, 5,000 mg/L for beef cattle, 4,000 mg/L for dairy cattle, 6,000 mg/L for horses and 3,000 mg/L for pigs and poultry.

- No value


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Groundwater Quality Results
Physical Parameters, Major Ions and Nutrients

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Parameter	Units	LOR ^a	ANZECC GUIDELINES		NHMRC								
Sample Location			Irrigation Water	Stock Water	Drinking Water	MB10	MB10	MB 11	MB11	MB13	MB13	MB14	MB14
Lab Number						EB1318364002	EB1408474008	EB1313987002	EB1408474010	ES1307244003	EB1408474001	EB1318364005	EB1408474019
Date Sampled						18/07/2013	2/04/2014	7/06/2013	2/04/2014	25/03/2013	2/04/2014	21/07/2013	2/04/2014
Lithology						Betts Creek	Betts Creek	A/B Seams	A/B Seams	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm
Sampling Date													
Field pH	pH units		-	-	-	6.5	-	7.5	-	-	-	9.4	-
Field Electivcal Conductivity (EC)	µS/cm		-	-	-	720	-	1035	-	-	-	1729	-
Depth to Groundwater	m bTOC		-	-	-	33.69	-	35	-	-	-	133.41	-
Physical Parameters													
pH	pH Units	0.1	6.0 - 8.5	-	6.5 - 8.5 ^b	6.7	7.9	7.8	7.9	8.0	8.1	9.48	10.1
Electrical conductivity	µS/cm	1	-	-	-	713	768	1020	1070	4920	5290	1950	1800
Sodium Absorption Ration (SAR)	-	0.01	-	-	-	4.84	-	6.3	-	9	-	23.4	-
Total Dissolved Solids (grav) @180°C	mg/L	1.00	-	3000 - 13000*	600 ^b	463	499	663	696	3200	3440	1270	1170
Total Hardness as CaCO3	mg/L	1.00	-	-	200 ^b	91	100	128	121	936	1060	47	117
Hydroxide Alkalinity as CaCO3	mg/L	1.00	-	-	-	<1	<1	<1	<1	<1	<1	<1	8
Carbonate Alkalinity as CaCO3	mg/L	1	-	-	-	<1	<1	<1	<1	<1	<1	81	62
Bicarbonate Alkalinity as CaCO3	mg/L	1.00	-	-	-	67	74	92	90	109	137	93	<1
Total Alkalinity as CaCO3	mg/L	1.00	-	-	-	67	74	92	90	109	137	174	69
Major Ions													
Sulfate as SO4 - Turbidimetric	mg/L	1	-	1000 - 2000	500 / 250 ^b	36	27	22	6	188	288	4	5
Chloride	mg/L	1	40	-	250 ^b	163	159	288	243	1340	1350	551	553
Fluoride	mg/L	0.1	1.0	2	1.5	0.2	0.2	0.3	0.3	0.1	0.2	0.4	0.3
Calcium	mg/L	1	-	1000	-	10	12	25	22	220	246	14	47
Magnesium	mg/L	1	-	-	-	16	17	16	16	94	109	3	<1
Sodium	mg/L	1	-	-	180 ^b	106	103	164	144	633	635	370	319
Potassium	mg/L	1	-	-	-	6	5	11	11	30	30	30	22
Total Anions	meq/L	0.01	-	-	-	6.69	6.53	10.4	8.78	43.9	46.8	19.1	17.1
Total Cations	meq/L	0.01	-	-	-	6.58	6.61	9.98	8.96	47	49.6	17.8	16.8
Ionic Balance	%	0.01	-	-	-	0.82	0.59	2.17	1.02	3.44	2.93	3.53	0.88
Nutrients													
Ammonia as N	mg/L	0.01	-	-	0.5 ^b	0.07	0.05	0.31	0.31	-	0.2	1.33	1.82
Nitrite as N	mg/L	0.01	-	30	3	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	-	-	50	0.01	0.02	0.02	0.02	-	0.01	0.02	0.07
Nitrite + Nitrate as N	mg/L	0.01	-	400	-	0.01	0.02	0.02	0.02	-	0.01	0.02	0.07
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	-	-	0.4	0.3	0.8	0.4	-	0.2	3.1	2.1
Total Nitrogen as N	mg/L	0.1	-	-	-	0.4	0.3	0.8	0.4	-	0.2	3.1	2.2
Total Phosphorus as P	mg/L	0.01	-	-	-	0.11	0.10	0.07	0.31	-	0.02	0.46	0.04
Reactive Phosphorus as P	mg/L	0.01	0.05	-	-	0.03	0.01	0.01	<0.01	-	<0.01	0.02	<0.01

Notes:

a. Limit of reporting

b. Aesthetic guidelines for Drinking Water

mbTOC metres below top of casing

0.7 Detected concentration above ANZECC (2000) Long Term Irrigation purposes

0.024 Detected concentration above ANZECC (2000) Stock purposes

0.024 Detected concentration above NHMRC (2011) Drinking Water Guidelines

* maximum concentration at which good condition might be expected, with 13,000 mg/L for sheep, 5,000 mg/L for beef cattle, 4,000 mg/L for dairy cattle, 6,000 mg/L for horses and 3,000 mg/L for pigs and poultry.

- No value

**G1587 - China Stone Project****Groundwater Quality Results****Physical Parameters, Major Ions and Nutrients**

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Parameter	Units	LOR ^a	ANZECC GUIDELINES		NHMRC								
Sample Location			Irrigation Water	Stock Water	Drinking Water	MB 15	MB15	MB 17	MB17	MB18	MB19	MB21	MB21
Lab Number						EB1313987003	EB1408474009	EB1313987004	EB1408474003	EB1408474016	ES1307244004	EB1401396001	EB1408474006
Date Sampled						6/06/2013	1/04/2014	8/06/2013	3/04/2014	3/04/2014	25/03/2013	17/01/2014	2/04/2014
Lithology						Rewan Fm	Rewan Fm	Tertiary	Tertiary	Tertiary	Rewan Fm	Clematis SS	Clematis SS
Sampling Date													
Field pH	pH units		-	-	-	8.2	-	7.8	-	-	-	-	-
Field Electivcal Conductivity (EC)	µS/cm		-	-	-	732	-	534	-	-	-	-	-
Depth to Groundwater	m bTOC		-	-	-	86	-	63.33	-	-	-	-	-
Physical Parameters													
pH	pH Units	0.1	6.0 - 8.5	-	6.5 - 8.5 ^b	8.5	9.31	8.0	7.9	8.5	8.5	12.4	12.2
Electrical conductivity	µS/cm	1	-	-	-	724	564	506	728	989	1000	6900	6810
Sodium Absorption Ration (SAR)	-	0.01	-	-	-	5.24	-	2.98	-	-	7.57	-	-
Total Dissolved Solids (grav) @180°C	mg/L	1.00	-	3000 - 13000*	600 ^b	471	367	329	473	643	650	4480	4430
Total Hardness as CaCO3	mg/L	1.00	-	-	200 ^b	96	48	82	105	96	98	1440	1340
Hydroxide Alkalinity as CaCO3	mg/L	1.00	-	-	-	<1	<1	<1	<1	<1	<1	1980	1460
Carbonate Alkalinity as CaCO3	mg/L	1	-	-	-	12	49	<1	<1	17	14	159	49
Bicarbonate Alkalinity as CaCO3	mg/L	1.00	-	-	-	196	103	63	58	209	187	<1	<1
Total Alkalinity as CaCO3	mg/L	1.00	-	-	-	208	152	63	58	226	201	2140	1510
Major Ions													
Sulfate as SO4 - Turbidimetric	mg/L	1	-	1000 - 2000	500 / 250 ^b	20	<1	12	11	47	48	7	<1
Chloride	mg/L	1	40	-	250 ^b	93	80	112	161	134	154	43	34
Fluoride	mg/L	0.1	1.0	2	1.5	0.4	0.5	0.3	0.2	0.3	0.4	0.3	0.3
Calcium	mg/L	1	-	1000	-	22	16	8	9	22	21	578	539
Magnesium	mg/L	1	-	-	-	10	2	15	20	10	11	<1	<1
Sodium	mg/L	1	-	-	180 ^b	118	91	62	85	159	172	271	143
Potassium	mg/L	1	-	-	-	9	11	7	8	17	22	97	49
Total Anions	meq/L	0.01	-	-	-	7.2	5.29	4.67	5.93	9.27	9.36	44.1	31.1
Total Cations	meq/L	0.01	-	-	-	7.28	5.2	4.51	6	9.27	10	43.1	34.4
Ionic Balance	%	0.01	-	-	-	0.58	0.89	1.74	0.55	0.04	3.27	1.13	4.98
Nutrients													
Ammonia as N	mg/L	0.01	-	-	0.5 ^b	0.09	0.24	0.1	0.05	0.06	-	13	8.11
Nitrite as N	mg/L	0.01	-	30	3	<0.01	<0.01	<0.01	<0.01	<0.01	-	0.07	0.04
Nitrate as N	mg/L	0.01	-	-	50	0.01	0.02	0.03	0.15	0.01	-	0.02	0.1
Nitrite + Nitrate as N	mg/L	0.01	-	400	-	0.01	0.02	0.03	0.15	0.01	-	0.09	0.14
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	-	-	0.8	0.6	0.9	0.2	2.2	-	15.7	14.4
Total Nitrogen as N	mg/L	0.1	-	-	-	0.8	0.6	0.9	0.4	2.2	-	15.8	14.5
Total Phosphorus as P	mg/L	0.01	-	-	-	0.37	0.25	0.28	0.05	2.65	-	0.20	0.54
Reactive Phosphorus as P	mg/L	0.01	0.05	-	-	0.06	0.04	<0.01	<0.01	<0.01	-	0.01	<0.01

Notes:

a. Limit of reporting

b. Aesthetic guidelines for Drinking Water

mbTOC metres below top of casing

0.7 Detected concentration above ANZECC (2000) Long Term Irrigation purposes

0.024 Detected concentration above ANZECC (2000) Stock purposes

0.024 Detected concentration above NHMRC (2011) Drinking Water Guidelines

* maximum concentration at which good condition might be expected, with 13,000 mg/L for sheep, 5,000 mg/L for beef cattle, 4,000 mg/L for dairy cattle, 6,000 mg/L for horses and 3,000 mg/L for pigs and poultry.

- No value


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Groundwater Quality Results
Physical Parameters, Major Ions and Nutrients

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Parameter	Units	LOR ^a	ANZECC GUIDELINES		NHMRC									
Sample Location			Irrigation Water	Stock Water	Drinking Water	MB22	MB22	MB24	MB24	MB25	MB26	MB26	MB27	MB27
Lab Number						EB1401396002	EB1408474014	EB1401396003	EB1408474018	EB1318364004	EB1401396004	EB1408474015	EB1401396005	EB1408474005
Date Sampled						17/01/2014	2/04/2014	19/01/2014	1/04/2014	28/07/2013	16/01/2014	1/04/2014	18/01/2014	1/04/2014
Lithology						Clematis SS	Clematis SS	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm
Sampling Date														
Field pH	pH units		-	-	-	-	-	-	-	7.3	-	-	-	-
Field Electivcal Conductivity (EC)	µS/cm		-	-	-	-	-	-	-	776	-	-	-	-
Depth to Groundwater	m bTOC		-	-	-	-	-	-	-	99.61	-	-	-	-
Physical Parameters														
pH	pH Units	0.1	6.0 - 8.5	-	6.5 - 8.5 ^b	8.5	7.3	9.66	9.3	7.6	8.5	8.5	8.57	8.4
Electrical conductivity	µS/cm	1	-	-	-	2030	422	889	295	891	2000	1900	1310	1190
Sodium Absorption Ration (SAR)	-	0.01	-	-	-	-	-	-	-	6.84	-	-	-	-
Total Dissolved Solids (grav) @180°C	mg/L	1.00	-	3000 - 13000*	600 ^b	1320	274	578	192	579	1300	1240	852	774
Total Hardness as CaCO3	mg/L	1.00	-	-	200 ^b	301	51	5	15	91	301	264	122	93
Hydroxide Alkalinity as CaCO3	mg/L	1.00	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	-	-	-	19	<1	50	16	<1	20	18	25	11
Bicarbonate Alkalinity as CaCO3	mg/L	1.00	-	-	-	158	29	35	29	323	162	169	180	121
Total Alkalinity as CaCO3	mg/L	1.00	-	-	-	177	29	85	45	323	182	187	206	132
Major Ions														
Sulfate as SO4 - Turbidimetric	mg/L	1	-	1000 - 2000	500 / 250 ^b	6	16	19	26	2	8	7	25	30
Chloride	mg/L	1	40	-	250 ^b	540	96	212	35	75	540	477	246	270
Fluoride	mg/L	0.1	1.0	2	1.5	0.2	0.3	0.5	0.7	0.5	0.3	0.2	0.8	0.9
Calcium	mg/L	1	-	1000	-	48	4	2	6	15	48	43	21	19
Magnesium	mg/L	1	-	-	-	44	10	<1	<1	13	44	38	17	11
Sodium	mg/L	1	-	-	180 ^b	275	53	172	49	150	275	266	214	190
Potassium	mg/L	1	-	-	-	13	8	18	6	7	13	12	10	10
Total Anions	meq/L	0.01	-	-	-	18.9	3.62	8.07	2.43	8.61	19	17.3	11.6	10.9
Total Cations	meq/L	0.01	-	-	-	18.3	3.53	8.04	2.58	8.52	18.3	17.2	12	10.4
Ionic Balance	%	0.01	-	-	-	1.58	1.24	0.22	-	0.56	1.95	0.55	1.82	2.39
Nutrients														
Ammonia as N	mg/L	0.01	-	-	0.5 ^b	0.05	0.06	0.07	0.17	0.32	0.07	0.03	<0.01	0.13
Nitrite as N	mg/L	0.01	-	30	3	<0.01	<0.01	0.06	0.14	<0.01	<0.01	<0.01	<0.01	0.02
Nitrate as N	mg/L	0.01	-	-	50	<0.01	0.6	0.31	0.17	0.02	<0.01	0.05	<0.01	0.09
Nitrite + Nitrate as N	mg/L	0.01	-	400	-	<0.01	0.6	0.37	0.31	0.02	<0.01	0.05	<0.01	0.11
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	-	-	1.1	7	0.5	0.6	1.6	0.8	0.2	0.3	0.3
Total Nitrogen as N	mg/L	0.1	-	-	-	1.1	7.6	0.9	0.9	1.6	0.8	0.2	0.3	0.4
Total Phosphorus as P	mg/L	0.01	-	-	-	0.02	9.92	0.10	0.07	0.40	0.56	0.02	0.02	0.27
Reactive Phosphorus as P	mg/L	0.01	0.05	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Notes:

- a. Limit of reporting
- b. Aesthetic guidelines for Drinking Water
- mbTOC metres below top of casing
- 0.7 Detected concentration above ANZECC (2000) Long Term Irrigation purposes
- 0.024 Detected concentration above ANZECC (2000) Stock purposes
- 0.024 Detected concentration above NHMRC (2011) Drinking Water Guidelines
- * maximum concentration at which good condition might be expected, with 13,000 mg/L for sheep, 5,000 mg/L for beef cattle, 4,000 mg/L for dairy cattle, 6,000 mg/L for horses and 3,000 mg/L for pigs and poultry.
- No value

**G1587 - China Stone Project****Groundwater Quality Results****Physical Parameters, Major Ions and Nutrients**

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Parameter	Units	LOR ^a	ANZECC GUIDELINES		NHMRC					
Sample Location			Irrigation Water	Stock Water	Drinking Water	MB28	MB28	MB33	MB33	WILD BORE
Lab Number						EB1318364006	EB1408474002	EB1318364001	EB1408474017	EB1313987005
Date Sampled						24/07/2013	1/04/2014	23/07/2013	1/04/2014	8/06/2013
Lithology						Rewan Fm	Rewan Fm	Clematis SS / Rewan Fm	Clematis SS / Rewan Fm	Clematis Sandstone?
Sampling Date										
Field pH	pH units		-	-	-	7.6	-	10.6	-	5.2
Field Electivcal Conductivity (EC)	µS/cm		-	-	-	1803	-	912	-	414
Depth to Groundwater	m bTOC		-	-	-	113.36	-	102.01	-	-
Physical Parameters										
pH	pH Units	0.1	6.0 - 8.5	-	6.5 - 8.5 ^b	8.0	8.5	9.02	9.36	5.77
Electrical conductivity	µS/cm	1	-	-	-	1860	1650	904	332	387
Sodium Absorption Ration (SAR)	-	0.01	-	-	-	8.47	-	6.13	-	3.96
Total Dissolved Solids (grav) @180°C	mg/L	1.00	-	3000 - 13000*	600 ^b	1210	1070	588	216	252
Total Hardness as CaCO3	mg/L	1.00	-	-	200 ^b	222	209	113	21	38
Hydroxide Alkalinity as CaCO3	mg/L	1.00	-	-	-	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1	-	-	-	<1	12	79	27	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1.00	-	-	-	242	104	188	44	12
Total Alkalinity as CaCO3	mg/L	1.00	-	-	-	242	117	267	71	12
Major Ions										
Sulfate as SO4 - Turbidimetric	mg/L	1	-	1000 - 2000	500 / 250 ^b	12	10	19	6	11
Chloride	mg/L	1	40	-	250 ^b	485	430	124	46	105
Fluoride	mg/L	0.1	1.0	2	1.5	0.5	0.3	0.6	0.6	0.1
Calcium	mg/L	1	-	1000	-	41	44	24	5	2
Magnesium	mg/L	1	-	-	-	29	24	13	2	8
Sodium	mg/L	1	-	-	180 ^b	290	220	150	56	56
Potassium	mg/L	1	-	-	-	14	15	10	5	6
Total Anions	meq/L	0.01	-	-	-	18.8	14.7	9.23	2.84	3.43
Total Cations	meq/L	0.01	-	-	-	17.4	14.1	9.05	2.98	3.35
Ionic Balance	%	0.01	-	-	-	3.78	1.92	1.02	-	1.24
Nutrients										
Ammonia as N	mg/L	0.01	-	-	0.5 ^b	0.23	0.16	0.27	0.17	0.02
Nitrite as N	mg/L	0.01	-	30	3	<0.01	0.04	<0.01	0.02	<0.01
Nitrate as N	mg/L	0.01	-	-	50	0.02	0.14	0.04	0.12	0.69
Nitrite + Nitrate as N	mg/L	0.01	-	400	-	0.02	0.18	0.04	0.14	0.69
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	-	-	0.9	1.9	1.1	0.5	0.6
Total Nitrogen as N	mg/L	0.1	-	-	-	0.9	2.1	1.1	0.6	1.3
Total Phosphorus as P	mg/L	0.01	-	-	-	0.62	0.06	0.09	0.03	0.45
Reactive Phosphorus as P	mg/L	0.01	0.05	-	-	<0.01	<0.01	0.03	<0.01	<0.01

Notes:

a. Limit of reporting

b. Aesthetic guidelines for Drinking Water

mbTOC metres below top of casing

0.7 Detected concentration above ANZECC (2000) Long Term Irrigation purposes

0.024 Detected concentration above ANZECC (2000) Stock purposes

0.024 Detected concentration above NHMRC (2011) Drinking Water Guidelines

* maximum concentration at which good condition might be expected, with 13,000 mg/L for sheep, 5,000 mg/L for beef cattle, 4,000 mg/L for dairy cattle, 6,000 mg/L for horses and 3,000 mg/L for pigs and poultry.

- No value

[illegible]

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Groundwater Quality Results															
Metals															
Parameter	Units	LOD ^a	ANZECC GUIDELINES		NHMRC	MB17	MB17	MB18	MB19	MB21	MB21	MB22	MB22	MB24	MB24
Sample Location			Irrigation Water	Stock Water	Drinking Water	MB17	MB17	MB18	MB19	MB21	MB21	MB22	MB22	MB24	MB24
Lab Number						EB1313987004	EB1408474003	EB1408474016	ES1307244004	EB1401396001	EB1408474006	EB1401396002	EB1408474014	EB1401396003	EB1408474018
Date Sampled						8/06/2013	3/04/2014	3/04/2014	25/03/2013	17/01/2014	2/04/2014	17/01/2014	2/04/2014	19/01/2014	1/04/2014
Lithology						Tertiary	Tertiary	Tertiary	Rewan Fm	Clematis SS	Clematis SS	Clematis SS	Clematis SS	Rewan Fm	Rewan Fm
Dissolved Metals															
Aluminium	mg/L	0.01	-	-	0.2 ^b	0.01	<0.01	<0.01	<0.01	0.57	0.59	0.03	<0.01	<0.01	1.06
Antimony	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Arsenic	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.012	<0.001	<0.001	0.005
Barium	mg/L	0.001	-	-	-	0.316	0.442	0.085	0.121	1.03	1.11	0.87	0.206	0.105	0.082
Beryllium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.05	-	-	-	0.26	0.2	0.28	0.32	<0.05	<0.05	0.28	0.12	0.24	<0.05
Cadmium	mg/L	0.0001	-	-	-	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Caesium	mg/L	0.001	-	-	-	<0.001	0.001	<0.001	<0.001	0.014	0.011	<0.001	<0.001	<0.001	<0.001
Cerium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	0.005	0.007	<0.001	<0.001	0.003	0.003
Cobalt	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	0.002	0.002	<0.001	0.001	<0.001	<0.001
Copper	mg/L	0.001	-	-	-	0.001	0.004	<0.001	<0.001	0.05	0.03	0.002	<0.001	0.001	0.012
Dysprosium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Europium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Gadolinium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Gallium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	0.004	<0.001	<0.001	0.002
Hafnium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Holmium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Indium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.05
Lanthanum	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	0.003	0.402	<0.001	<0.001	<0.001	0.003
Lithium	mg/L	0.001	-	-	-	0.004	0.004	0.01	0.01	0.376	0.313	0.018	0.005	0.02	0.006
Lutetium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	-	-	-	0.182	0.3	0.041	0.054	<0.001	<0.001	0.2	0.078	0.002	<0.001
Molybdenum	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	0.05	0.03	0.003	<0.001	0.01	0.01
Neodymium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/L	0.001	-	-	-	0.006	0.004	<0.001	<0.001	0.013	0.007	0.008	0.006	0.002	0.001
Praseodymium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Rubidium	mg/L	0.001	-	-	-	0.028	0.032	0.033	0.042	0.222	0.157	0.027	0.032	0.033	0.019
Samarium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	mg/L	0.001	-	-	-	0.111	0.146	0.655	0.704	3.44	3.85	0.86	0.052	0.308	0.31
Tellurium	mg/L	0.005	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Terbium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thulium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tin	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Titanium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ytterbium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.005	-	-	-	<0.005	0.027	<0.005	<0.005	0.047	0.038	0.077	0.015	<0.005	0.006
Zirconium	mg/L	0.005	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Metals															
Aluminium	mg/L	0.01	5	5	-	2.84	0.55	16	0.24	-	15	-	40	-	2.75
Antimony	mg/L	0.001	-	-	0.003	<0.001	<0.001	<0.001	<0.001	-	0.005	-	<0.001	-	0.001
Arsenic	mg/L	0.001	0.1	0.5	0.01	0.003	<0.001	0.009	0.001	-	0.016	-	0.016	-	0.004
Barium	mg/L	0.001	-	-	2	0.394	0.495	0.306	0.126	-	1.35	-	1.37	-	0.132
Beryllium	mg/L	0.001	0.1	-	0.06	<0.001	<0.001	0.004	<0.001	-	<0.001	-	0.003	-	<0.001
Bismuth	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	-	<0.001	-	<0.005	-	<0.001
Boron	mg/L	0.05	0.5	5.0	4	0.27	0.26	0.27	0.31	-	<0.05	-	<0.05	-	<0.05
Cadmium	mg/L	0.0001	0.01	0.01	0.002	0.0003	0.0002	0.0005	<0.0001	-	0.0007	-	0.0003	-	0.0002
Caesium	mg/L	0.001	-	-	-	0.003	0.002	0.03	<0.001	-	0.016	-	0.343	-	<0.001
Cerium	mg/L	0.001	-	-	-	0.047	0.005	0.243	0.001	-	0.04	-	3.44	-	0.009
Chromium	mg/L	0.001	0.1	1.0	0.05	0.006	0.002	0.031	<0.001	-	0.042	-	0.067	-	0.013
Cobalt	mg/L	0.001	0.05	1.0	-	0.001	0.001	0.011	<0.001	-	0.025				

G1587 - China Stone Project Groundwater Quality Results Metals															Page 9/9
Parameter	Units	LOD ^a	ANZECC GUIDELINES		NHMRC	MB25	MB26	MB26	MB27	MB27	MB28	MB28	MB33	MB33	WILD BORE
Sample Location			Irrigation Water	Stock Water	Drinking Water	EB1318364004 28/07/2013	EB1401396004 16/01/2014	EB1408474015 1/04/2014	EB1401396005 18/01/2014	EB1408474005 1/04/2014	EB1318364006 24/07/2013	EB1408474002 1/04/2014	EB1318364001 23/07/2013	EB1408474017 1/04/2014	EB1318367005 8/06/2013
Lithology						Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm	Rewan Fm	atis SS / Rewa	atis SS / Rewa	atis Sandstor
Dissolved Metals															
Aluminium	mg/L	0.01	-	-	0.2 ^b	0.03	<0.01	<0.01	<0.01	0.14	0.06	0.02	0.03	0.06	<0.01
Antimony	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Arsenic	mg/L	0.001	-	-	-	0.002	0.013	0.011	0.001	0.002	0.001	0.001	0.001	0.002	<0.001
Barium	mg/L	0.001	-	-	-	0.601	0.897	0.791	0.508	0.454	0.761	0.327	0.15	0.098	0.267
Beryllium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bismuth	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.05	-	-	-	0.29	0.27	0.27	0.35	0.41	0.37	0.43	0.09	<0.05	0.08
Cadmium	mg/L	0.0001	-	-	-	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Caesium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Cerium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.001	0.001	0.002	<0.001
Cobalt	mg/L	0.001	-	-	-	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Copper	mg/L	0.001	-	-	-	<0.001	<0.001	0.002	<0.001	0.008	<0.001	0.012	<0.001	0.007	<0.001
Dysprosium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Erbium	mg/L	0.001	-	-	-	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Europium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Gadolinium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Gallium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hafnium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Holmium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Indium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05	-	-	-	1.8	<0.05	<0.05	<0.05	0.2	<0.05	<0.05	<0.05	<0.05	1.1
Lanthanum	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	mg/L	0.001	-	-	-	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
Lithium	mg/L	0.001	-	-	-	0.008	0.015	0.011	0.033	0.022	0.013	0.022	0.015	0.011	0.004
Lutetium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	-	-	-	0.4	0.2	0.2	<0.001	0.087	0.4	0.052	0.008	<0.001	0.019
Molybdenum	mg/L	0.001	-	-	-	0.03	0.002	0.002	0.009	0.005	0.009	0.007	0.01	0.01	<0.001
Neodymium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	mg/L	0.001	-	-	-	0.007	0.006	0.003	<0.001	0.006	0.002	0.016	0.002	0.002	0.006
Praseodymium	mg/L	0.001	-	-	-	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Rubidium	mg/L	0.001	-	-	-	0.014	0.025	0.023	0.017	0.019	0.019	0.026	0.018	0.012	0.028
Samarium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	mg/L	0.001	-	-	-	0.726	0.855	0.817	0.385	0.414	1.49	0.873	0.271	0.286	0.048
Tellurium	mg/L	0.005	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Terbium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thallium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thulium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tin	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	mg/L	0.001	-	-	-	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.002	<0.001	<0.001
Vanadium	mg/L	0.01	-	-	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ytterbium	mg/L	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Yttrium	mg/L	0.001	-	-	-	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.005	-	-	-	0.02	0.014	0.125	<0.005	0.034	0.128	0.06	0.008	<0.005	0.024
Zirconium	mg/L	0.005	-	-	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Metals															
Aluminium	mg/L	0.01	5	5	-	16	-	0.28	-	9	37	1.82	35	0.38	<0.01
Antimony	mg/L	0.001	-	-	0.003	<0.001	-	0.001	-	<0.001	<0.001	0.002	<0.001	<0.001	<0.001
Arsenic	mg/L	0.001	0.1	0.5	0.01	0.004	-	0.016	-	0.002	0.004	<0.001	0.005	0.002	<0.001
Barium	mg/L	0.001	-	-	2	0.878	-	0.846	-	0.631	1.21	0.276	1.12	0.087	0.281
Beryllium	mg/L	0.001	0.1	-	0.06	<0.001	-	<0.001	-	<0.001	0.002	<0.001	0.002	<0.001	<0.001
Bismuth	mg/L	0.001	-	-	-	<0.001	-	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	mg/L	0.05	0.5	5.0	4	0.25	-	0.26	-	0.47	0.39	0.47	0.11	<0.05	0.09
Cadmium	mg/L	0.0001	0.01	0.01	0.002	<0.0001	-	0.0002	-	0.0002	0.0002	0.0002	0.0002	<0.0001	<0.0001
Caesium	mg/L	0.001	-	-	-	0.007	-	<0.001	-	0.005	0.012	0.001	0.014	<0.001	0.001
Cerium	mg/L	0.001	-	-	-	0.054	-	0.001	-	0.033	0.102	0.006	0.125	<0.001	<0.001
Chromium	mg/L	0.001	0.1	1.0	0.05	0.019	-	0.002	-	0.026	0.069	0.014	0.097	0.004	0.002
Cobalt	mg/L	0.001	0.05	1.0	-	0.014	-	<0.001	-	0.009	0.025	0.002	0.026	<0.001	0.003
Copper	mg/L	0.001	0.2	0.5	1 ^b / 2	0.023	-	0.003	-	0.019	0.092	0.013	0.08</		

Appendix B

Numerical modelling report

B1. Groundwater modelling

B1.1 Overview of groundwater modelling

Predictive numerical modelling was undertaken to assess the impact of the project on the groundwater regime. The objectives of the predictive modelling were to:

- assess the groundwater inflow to the open cut and longwall areas over the life of mine;
- simulate and predict the area of influence of dewatering and the level and rate of drawdown at specific locations;
- identify areas of potential risk where groundwater impact mitigation/control measures may be necessary;
- simulate mitigation/control strategies if adverse impacts are identified; and
- predict the impact of mine dewatering on the groundwater regime.

The key to the modelling exercise is the adequate conceptualisation of the groundwater regime. The conceptual model is a demonstration of how the groundwater system operates given the available data, and is an idealised representation of the natural system.

The conceptual groundwater model of the project site and surrounding area was developed based on geological and topographical maps, geological information from coal exploration bores drilled across the project site, a geological model developed by the proponent, installation of monitoring bores, results from previous hydrogeological investigations and relevant data from the DNRM groundwater database, as previously described in Section 7 of the main report.

B1.2 Model construction and development

B1.2.1 Model code

The modelling code was selected to meet the model objectives. Numerical simulation of groundwater flow for the project was undertaken using the MODFLOW-SURFACT code (referred to as SURFACT for the remainder of the report). SURFACT is a commercial derivative of the standard MODFLOW code, distributed by HGL and has some distinct advantages over MODFLOW that are critical for the simulation of groundwater flow for the project.

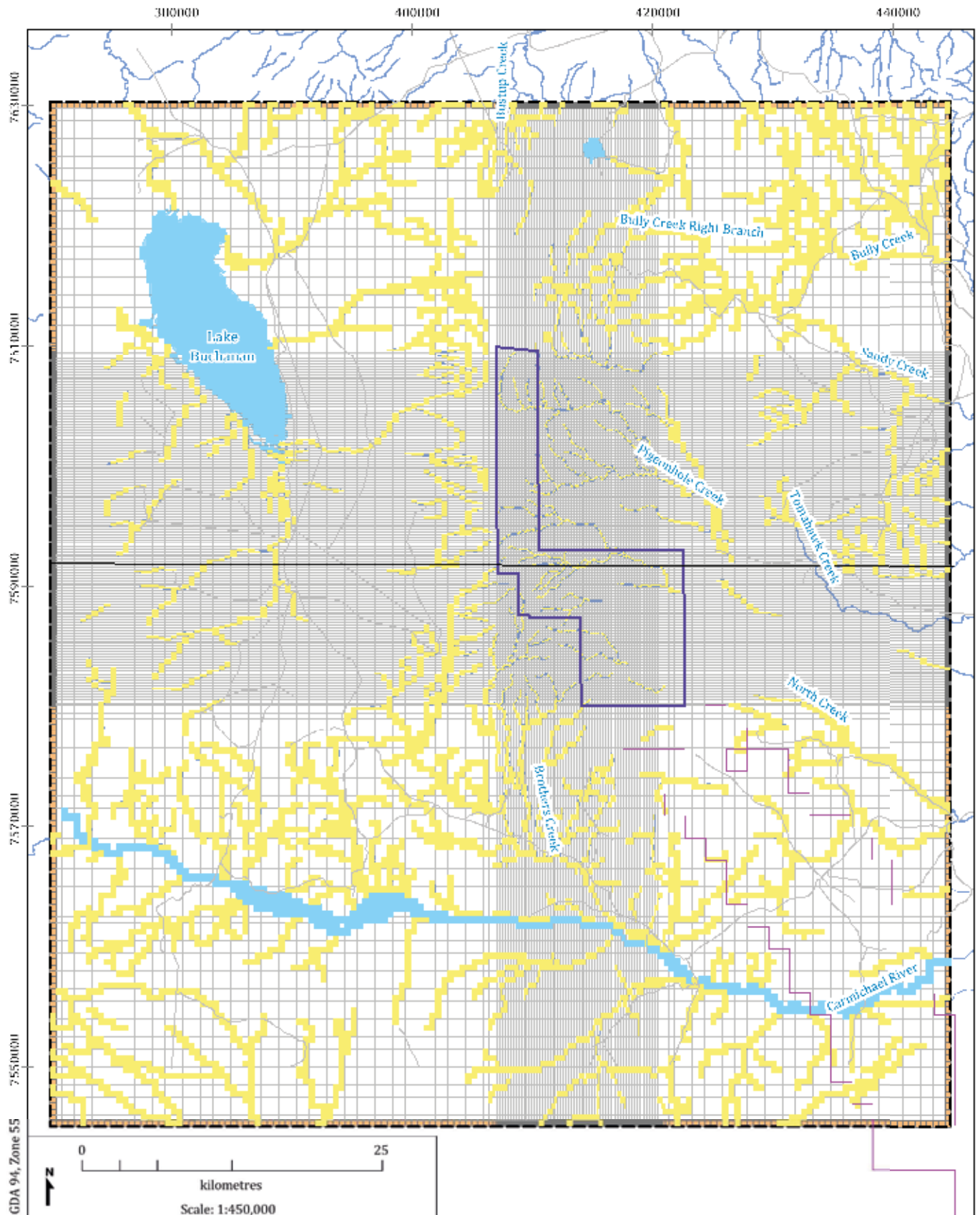
The MODFLOW code (on which SURFACT is based) is the most widely used code for groundwater modelling and is presently considered an industry standard. Use of the SURFACT modelling package is widespread, particularly in mining applications where groundwater dewatering and recovery are simulated.

SURFACT is capable of simulating unsaturated conditions. This is critical for the requirements of the project, where coal seams will be progressively dewatered during active mine operations, and re-wet following the cessation of mining. SURFACT is also supplied with more robust numerical solution schemes to handle the more complex numerical problem resulting from the unsaturated flow formulation. Added to the more robust numerical solution schemes is an adaptive time-stepping function that aides the progression of the solution past difficult and complex numerical situations such as oscillations.

The input files for the SURFACT model were created using Fortran code and a SURFACT edition of the Groundwater Data Utilities (Watermark Numerical Computing, 2012). These were used to allow for the additional capabilities of SURFACT.

B1.2.2 Model geometry

The model domain is discretised into rectangular cells arranged into 18 layers comprising 507 columns and 307 rows. There are 155,649 active cells in each layer with the dimensions of the cells varying from 75 m by 75 m within the mining area up to 500 m by 500 m at the extremities of the model size. The model boundary extends 75 km from west to east, and 85 km from north to south. These dimensions provide a model domain of sufficient size to capture the full extent of any potential impacts on the groundwater system. The extent of the model was chosen to encompass the Proposed Carmichael Coal Mine Project, Carmichael River and Lake Buchanan. The active model cells cover an area of 572 km². Figure B 1 shows the model grid, which represents an East – West cross section through the model domain.



LEGEND:

- Model boundary
- Model grid
- Boundary conditions
- Drain cell
- River cell
- Project site
- Carmichael Coal Mine Project
- Road
- Drainage
- Cross-section for figure B-2

Project China Stone (G1587)

Model Grid & Boundary Conditions

DATE:
24/6/2015FIGURE No:
B-1

B1.2.3 Model layers

MBGS (2013) developed a regional geological model of the major stratigraphic units for use in the groundwater model. They used detailed data collected from the project exploration program at the site and adjacent sites, along with data from deep wells in the region outside the proposed mining area.

The numerical model represented the following key units:

- Quaternary sediments;
- Tertiary sediments;
- Weathered rock;
- Ronlow Beds;
- Triassic sediments (Moolayember Formation, Clematis Sandstone, Dunda Beds, Rewan Formation); and
- Permian Betts Creek Beds and Joe Joe Group.

Table B 1 summaries the hydrostratigraphic layers represented in the model.

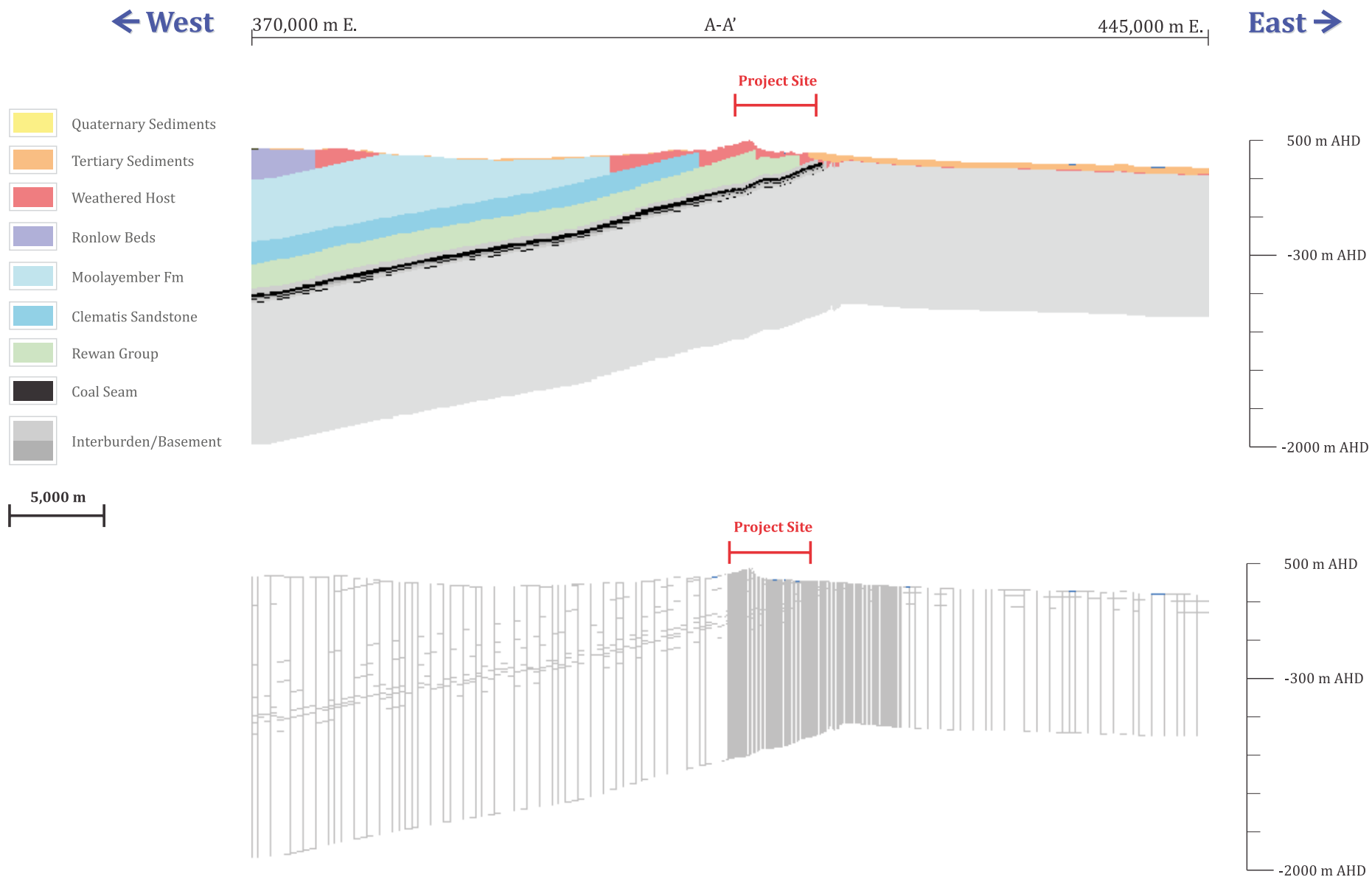
Table B 1 Model layers

Geological age	Stratigraphic unit		Model layer
Quaternary	Quaternary sediments (if present) and weathered zone		1
Tertiary	Tertiary sediments		2
Jurassic	Ronlow Beds		3
Triassic	Moolayember Formation		4
	Clematis Sandstone		5
	Dunda Beds		6
	Rewan Formation		7
Permian	Betts Creek Beds	<i>Interburden</i>	8
		A Seam	9
		<i>Interburden</i>	10
		B Seam	11
		<i>Interburden</i>	12
		C Seam	13
		<i>Interburden</i>	14
		D Seam	15
		<i>Interburden</i>	16
		E Seam	17
		<i>Interburden</i>	
		F Seam	
		<i>Interburden</i>	
		G Seam	
		<i>Interburden</i>	
	Joe Joe Group		18

The Quaternary and the Tertiary sediments are represented in the model as zones within the top two model layers. The extent of Quaternary sediments defined on the regional geology maps was used in the model. The extent of the Tertiary sediments was also based on surface geology maps and site exploration data was used to define a representative thickness. Where the Quaternary and Tertiary sediments were not present, a regolith layer was included in the model.

Two model layers accounted for the full thickness of the Rewan Formation to provide better representation of the behaviour of this key geological unit and its hydraulic conductivity. The model represented the A, B, C and D coal seams of the Betts Creek Beds as individual layers, separated by low permeability interburden.

The model represented all target coal seams with discrete layers to provide high resolution representation of the mining sequence. Figure B 2 shows a cross section through the model.



Model Grid - Cross Section - West - East

Figure B-2

Model boundaries

The model boundaries were set at a sufficient distance from the proposed mining so that the zone of depressurisation was contained well within the model.

The northern and southern boundaries were set parallel to interpreted groundwater flow directions. General head boundaries (GHBs) were conservatively adopted for all lateral model domain boundaries to allow for the transfer of groundwater to and from the model domain. This allowed for flow of water out of the model towards the west further into the GAB, if hydraulic gradients necessitated this. The hydraulic conductance for each boundary cell was assigned according to the calibrated horizontal hydraulic conductivity, multiplied by the surface area of the cell wall.

The northern and southern boundaries were set parallel to interpreted groundwater flow directions. General head boundaries (GHB) were conservatively adopted for all lateral model domain boundaries to allow for the transfer of groundwater to and from the model domain. This allowed for flow of water out of the model towards the west further into the GAB, if hydraulic gradients necessitated this. The hydraulic conductance for each boundary cell was assigned according to the calibrated horizontal hydraulic conductivity, multiplied by the surface area of the cell wall. Groundwater levels assigned to the GHB cells were based on interpolated regional groundwater levels sourced from the DNRM groundwater database.

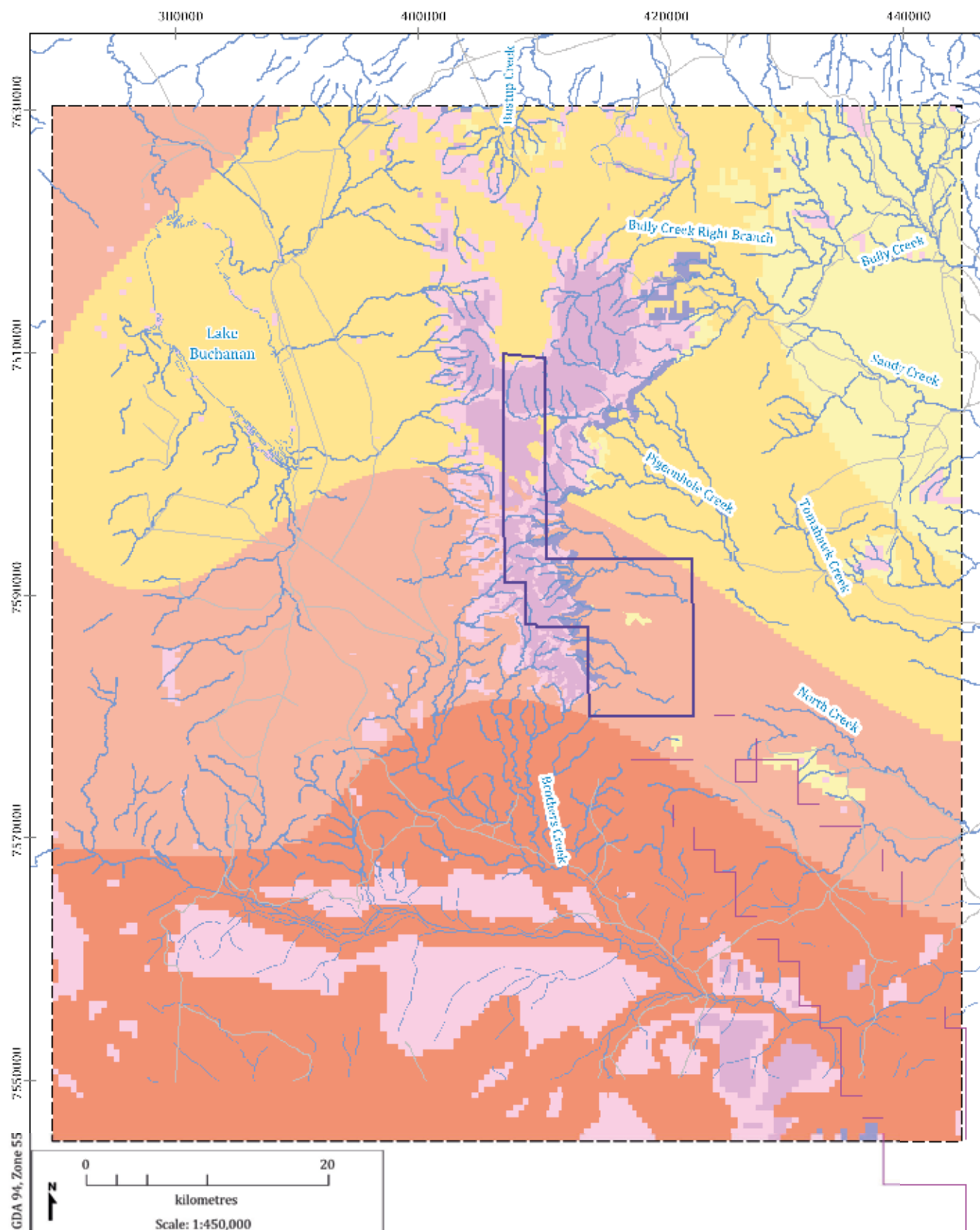
The base of the model was set as a no-flow boundary. This selection has no significant bearing on the model outcomes.

Recharge and evapotranspiration

SURFACT simulates diffuse rainfall recharge using the recharge package (RCH), and evapotranspiration from shallow water tables with the EVT package.

The model applied diffuse rainfall recharge to Layer 1. The rate of recharge was estimated during the calibration process, and set as a percentage of annual average rainfall for each geological unit. Within each geological unit, the model included a separate zone representing the break of slope at the foot of Darkies Range. This zone represented the area where runoff from the slopes collects and enhances recharge to the groundwater system. Figure B 3 shows the recharge zones.

The model represented evapotranspiration in Layer 1 with an extinction depth of 2 m. The rate of evapotranspiration was taken from the Bureau of Meteorology (BOM) evapotranspiration map of Australia, which is approximately 1,600 mm/year over the model domain.



LEGEND:

- Model boundary
- Model grid
- Project site
- Carmichael Coal Mine Project
- Road
- Drainage

Modelled recharge rates (mm/yr)

	0.01	to 0.1
	0.001	to 0.005
	0.0001	to 0.001
	0.000058	to 0.0001
	0.000057	to 0.000058
	0.000056	to 0.000057
	0.00001	to 0.000056

Project China Stone (G1587)

Modelled Recharge Rates

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B-3

Table B-2 presents the calibrated rate of recharge for each geological unit, and the break of slope zone within each unit. The volume of diffuse recharge (ML/day) presented in the table is based on the area of outcrop for each unit in the numerical model.

Table B 2 Modelled recharge rates

Unit	Diffuse recharge (%)	Diffuse recharge (ML/day)	Break of slope recharge (ML/day)	Break of slope recharge (%)
Quaternary sediments	0.01	0.12		
Tertiary Sediments	0.01	0.62		
Jurassic Units	0.03	0.18	0.08	0.01
Clematis Sandstone	0.30	1.13	0.13	0.05
Rewan Formation	0.12	0.08	1.92	3.19
Betts Creek Beds / Joe Joe Group	0.15	0.08	0.03	0.01
Total	0.62	2.21	2.17	3.26

Table B 2 shows that the unit with the highest rate of diffuse recharge in the model was the Clematis Sandstone, with a rate of approximately 0.3% of annual rainfall (1.8 mm/year).

Evapotranspiration occurred predominantly from Lake Buchanan where the water table is considered to occur close to the ground surface.

Surface drainage

Groundwater discharge to surface drainage was modelled using the SURFACT river package (RIV). The surface drainage elevation was taken from the digital elevation model (DEM) and was adjusted to represent the creek bed elevation at each surface water feature. The river bed conductance was calculated from river width, a riverbed thickness, and a vertical hydraulic conductivity of the riverbed material. Carmichael River, and surface water features (e.g. Lake Buchanan) were set to allow water transfer to and from the aquifer system. Table B 3 summarises the parameters representing the drainage lines and creeks.

Table B 3 Modelled river bed parameters

Kz (m/day)	Width (m)	Depth (m)	Stage height (m)	Bed thickness (m)	ID	Zone
1.0×10^{-1}	2	1	0	1	Surface Drains	1
9.6	10	10	0.1	1	Carmichael River	2
6.8×10^{-1}	10	5	0	1	Bully Creek	3
7.5×10^{-1}	5	5	0	1	Dylingo Creek	4
1.5	5	2	0	1	Sandy Creek	5
3.2	5	2	0	1	North Creek	6
8.7×10^{-1}	2	2	0	1	Tomahawk Creek	7
9.8×10^{-3}	75	3	3	1	Minor Surface Water Feature	8
3.8×10^{-3}	500	5	5	1	Lake Buchanan	9

B1.3 Model calibration

B1.3.1 Calibration targets

All available groundwater level data was used to calibrate the model, including monitoring data installed at the project site and for the adjacent Proposed Carmichael Coal Mine Project. The model calibrated to steady state groundwater levels by adjusting the hydraulic conductivity and recharge to the uppermost layers. The median groundwater level from all available measurements was adopted as the steady state water level.

A total of 127 water level data points were used for calibration. This substantial calibration dataset was selected to provide a strong calibration result.

The calibration process weighted the water level data from each bore according to the quality of the observation target. Where a bore was known to be dry groundwater levels in the layers below the base of each calibration bore were examined to ensure unsaturated conditions occurred at each dry bore.

Water levels measured in the groundwater monitoring bores at the project site remained relatively static over the EIS monitoring period. Over this time rainfall was well below average with the area experiencing drought conditions. The groundwater monitoring therefore did not record any significant changes in groundwater level from hydraulic stresses, such as diffuse rainfall, surface water runoff, and landholder pumping. Consequently, a transient calibration to a static groundwater system was not considered beneficial. However a transient verification of the flat lining water levels was undertaken to confirm the model replicated the observations. If the verification had showed significant groundwater level variation, a transient calibration would have been considered, but this was not required.

B1.3.2 Calibration results

Table B 4 summaries the bores used in the calibration process, the measured and model predicted water levels, and the difference between levels.

Table B 4 Bore calibration targets

Bore ID	Easting GDA94 (m)	Northing GDA94 (m)	Observed water level (mAHD)	Calculated water level (mAHD)
MB04	413863	7590355		
MB05	413874	7590356	294.7	289.9
MB06	413874	7590369	294.8	289.2
MB07	415547	7590584	286.6	285.7
MB08	415553	7590570	282.9	285.7
MB09	414434	7592831		
MB10	414439	7592830	308.3	288.9
MB11	414442	7592837	308.1	288.7
MB12	410626	7590113	314.7	303.2
MB13	408638	7594223	322.3	312.4
MB14	407589	7598323	313.5	313.6
MB15	409522	7602328	323.8	321.1
MB16	417115	7585134		
MB17	417118	7585137	266.3	271.8
MB18	414442	7583778		
MB19	414446	7583780	289.8	277.5

Bore ID	Easting GDA94 (m)	Northing GDA94 (m)	Observed water level (mAHD)	Calculated water level (mAHD)
MB20	420926	7589917		
MB21	407809	7592771		
MB22	409254	7588046		
MB23	410019	7595392		
MB24	408081	7596736	352.7	313.2
MB25	407410	7596980	313.7	311.8
MB26	407115	7601043	314.8	315.3
MB27	407959	7600572		
MB28	409796	7599783	319.5	318.2
MB29	407367	7608867		
MB30	409939	7609491		
MB31	406705	7613342		
MB32	420524	7590538		
MB33	407079	7604221	320.8	317.4
VWP1_1	410643	7590108	319.0	303.2
VWP1_2	410643	7590108	315.8	300.3
VWP1_3	410643	7590108	312.4	297.8
VWP2_1	408642	7594211	305.5	309.2
VWP2_2	408642	7594211	299.7	306.5
VWP2_3	408642	7594211	297.6	306.4
VWP3_1	407578	7598319	304.9	313.6
VWP3_2	407578	7598319	296.2	312.5
VWP3_3	407578	7598319	296.6	312.5
VWP4_1	409533	7602316	328.0	321.9
VWP4_2	409533	7602316	307.2	321.7
VWP4_3	409533	7602316	297.1	321.1
5965	381254	7550613	272.0	291.3
16371	370461	7574850	315.4	316.2
16895	410061	7561628	224.5	247.7
16896	406868	7558257	245.0	253.6
17980	426849	7565142	260.4	233.6
17981	423527	7576054	265.3	248.3
17982	433592	7565399	211.3	220.8
32980	376195	7595709	356.6	305.4
39801	401187	7569715	256.8	270.6
39802	393849	7571397	258.7	281.5
47637	431780	7594906	268.3	249.6
47638	430935	7597284	269.9	252.3
47639	425622	7615420	295.2	280.8
62623	442969	7545554	235.0	214.7
90256	423671	7580878		
90257	442360	7576313	204.3	209.1
90258	426775	7565785	242.6	234.1
90259	423688	7577246	254.0	249.2
90260	436157	7551360	230.0	222.2

Bore ID	Easting GDA94 (m)	Northing GDA94 (m)	Observed water level (mAHD)	Calculated water level (mAHD)
103878	426591	7614110	271.4	275.3
BIG_BORE	394499	7591314	276.6	296.2
CAMP_BORE	416315	7592174	286.0	283.6
MOON_BORE	402814	7584618	270.0	287.9
ROO_BORE	415439	7588709	292.1	285.0
SWAMP_BORE	389547	7626125	296.0	296.5
LANE_BORE	374411	7603855	303.8	295.2
TUTOR_BORE	390274	7617086	285.9	295.7
C006P1	435726	7560833	211.3	218.6
C006P3R	435734	7560826	213.2	218.5
C007P2	434726	7559865	212.5	219.8
C007P3	434728	7559862	217.0	219.9
C008P1	433710	7558830	211.8	221.8
C008P2	433708	7558827	213.5	221.9
C011P1	428843	7569953	230.9	231.5
C011P3	428846	7569955	227.2	232.5
C012P1	430888	7569874	221.4	227.6
C012P2	430887	7569877	221.5	227.6
C014P2	430731	7563976	208.8	224.9
C016P2	422017	7574974	249.0	248.9
C018P1	423982	7574850	245.1	246.6
C018P2	423988	7574849	242.5	246.2
C018P3	423978	7574853	242.4	246.2
C020P2	427846	7566932	220.8	231.7
C022P1	426813	7565962	246.9	234.4
C024P3	428909	7571761	228.8	233.7
C025P2	438010	7555845	217.5	220.0
C027P1	433643	7554818	223.0	224.4
C027P2	433648	7554819	226.4	224.4
C029P1	437691	7555082	214.9	220.4
C029P2	437688	7555081	219.9	220.4
C034P1	442386	7547816	230.9	207.7
C034P3	442389	7547814	230.9	206.1
C035P1	441404	7546824	231.9	212.1
C035P2	441402	7546828	232.9	210.1
C056C_1	424920	7569970		
C056C_2	424920	7569970	232.2	240.3
C056C_3	424920	7569970	239.5	241.7
C180112SP	437715	7558820	219.3	217.8
C180114SP	438687	7557649	223.2	218.8
C553P_1	420993	7573965	219.1	250.2
C553P_2	420993	7573965	227.2	250.2
C555P_2	432450	7557881	219.1	223.7
C555P_3	432450	7557881	229.9	223.2
C555P1	432450	7557881	243.9	223.2

Bore ID	Easting GDA94 (m)	Northing GDA94 (m)	Observed water level (mAHD)	Calculated water level (mAHD)
C556P1	436524	7549882	249.2	222.4
C558P_1	430312	7566903	207.6	227.1
C558P_2	430312	7566903	219.7	226.9
C558P_3	430312	7566903	231.0	227.1
C558P1	430312	7566903	235.0	227.4
C823SP	433605	7562875	212.2	220.5
C825SP	434868	7561960	213.8	219.2
C827SP	436101	7560334	214.6	218.5
C829SP	436463	7559356	216.7	218.6
C832SP	439570	7554788	205.5	217.0
C833SP	439559	7554779	211.0	217.2
C834SP	439577	7554764	212.6	215.9
C840SP	439546	7552839	214.2	213.9
C844SP	441392	7546840	223.3	210.1
C9553P1R	421010	7573975	253.0	250.2
C9556PR_2	436543	7549885	223.2	220.6
C9556PR_3	436543	7549885	228.2	222.3
C9838SPR	439558	7552813	231.3	214.2
C9839SPR	439567	7552797	229.8	213.8
HD02	423823	7557008	219.1	231.9
HD03B	427559	7556119	227.2	228.1

Figure B 4 presents the observed and simulated groundwater levels graphically as a scattergram.

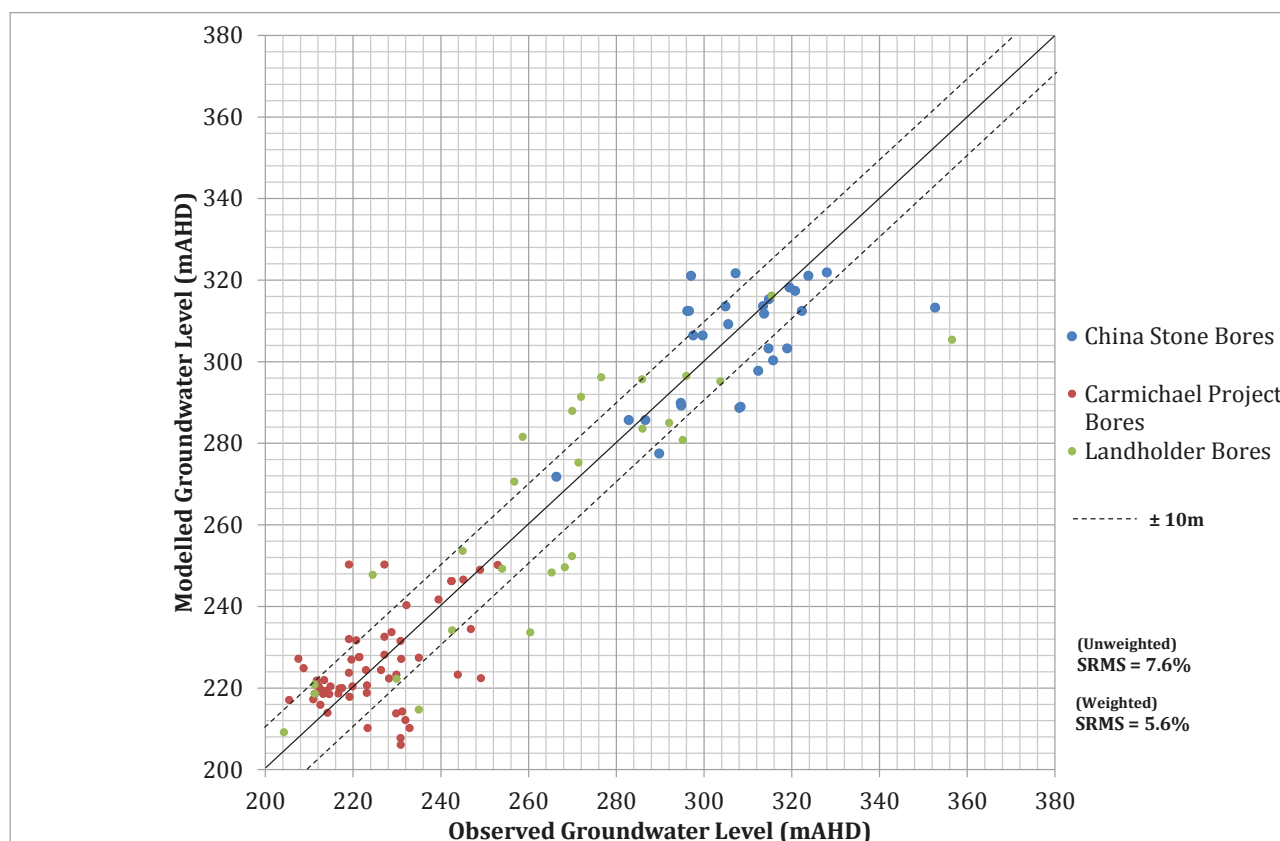


Figure B 4 Steady state calibration – modelled vs observed groundwater levels

The industry standard method to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. This is done by assessing the error between the modelled and observed (measured) water levels in terms of the root mean square (RMS). A root mean square (RMS) expressed as:

$$RMS = \left[1/n \sum (h_o - h_m)_i^2 \right]^{0.5}$$

where:

n	=	number of measurements
h_o	=	observed water level
h_m	=	simulated water level

RMS is considered to be the best measure of error, if errors are normally distributed. The RMS error calculated for the calibrated model is 16.4 m.

The acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head change in the system is small, the errors are only a small part of the overall model response. The total measured head change across the model domain is 215 m; therefore, the ratio of RMS to the total head loss (SMRS) is 7.6%. Incorporating the weighted residuals into the calibration statistics reduces the RMS error to 12.1 m, with an SRMS of 5.6%. This indicates a good calibration and is within the Australian guidelines of 10% Scaled RMS (Barnett *et al*, 2012).

The model was calibrated to vibrating wire piezometers to ensure the observed vertical groundwater gradients are replicated. Figure B 5 shows the location of the pressure sensors versus groundwater pressure.

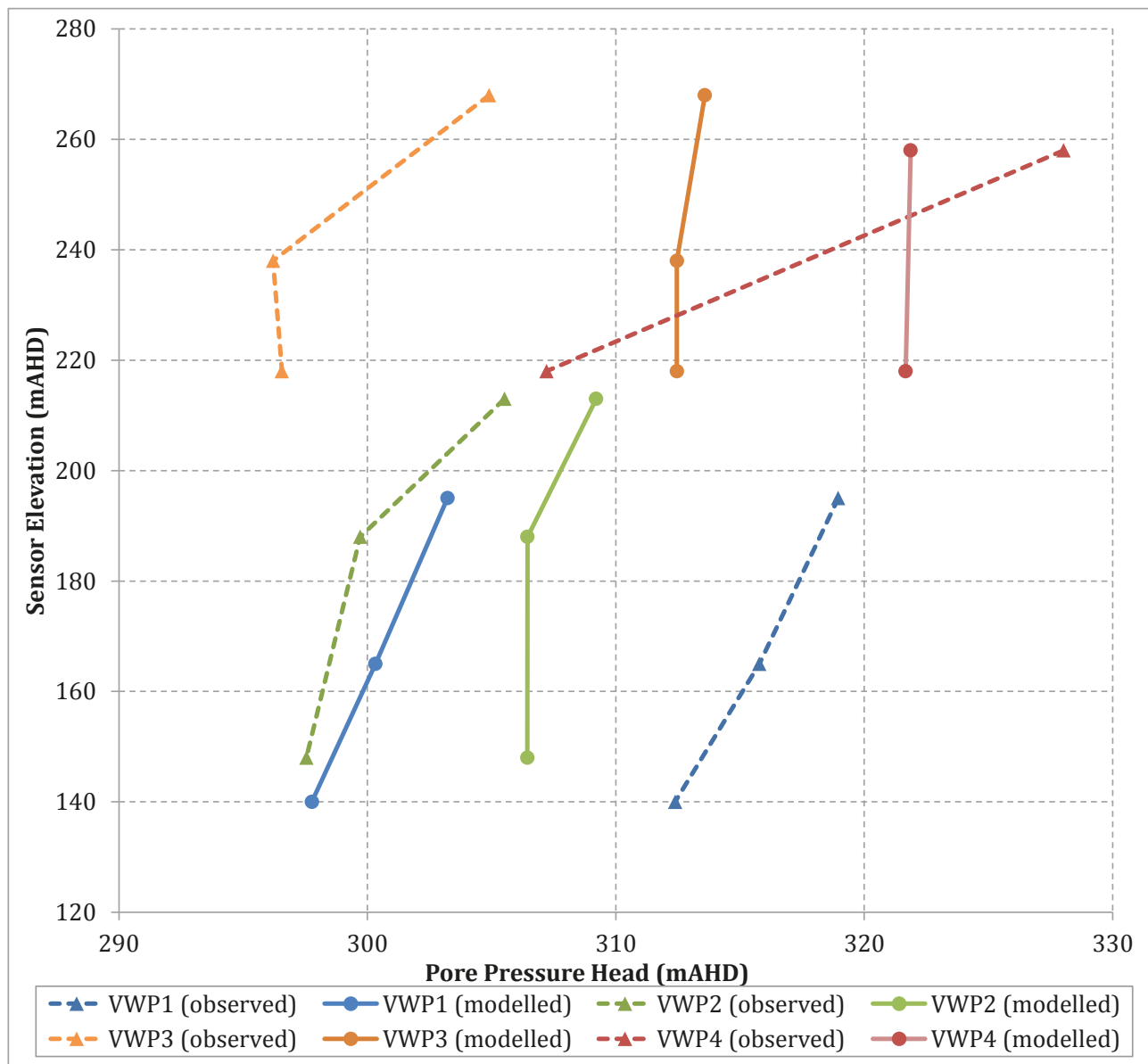


Figure B 5 Pressure head changes with depth

Whilst the model does not perfectly replicate the vertical gradients, it does simulate a downward gradient, which occurs along the Darkies Range and is typical of recharge areas.

B1.3.3 Calibration heads

Figure B 6 shows the calibrated heads:

- Layer 2 - Tertiary sediments; and
- Layer 4 - Moolayember Formation.

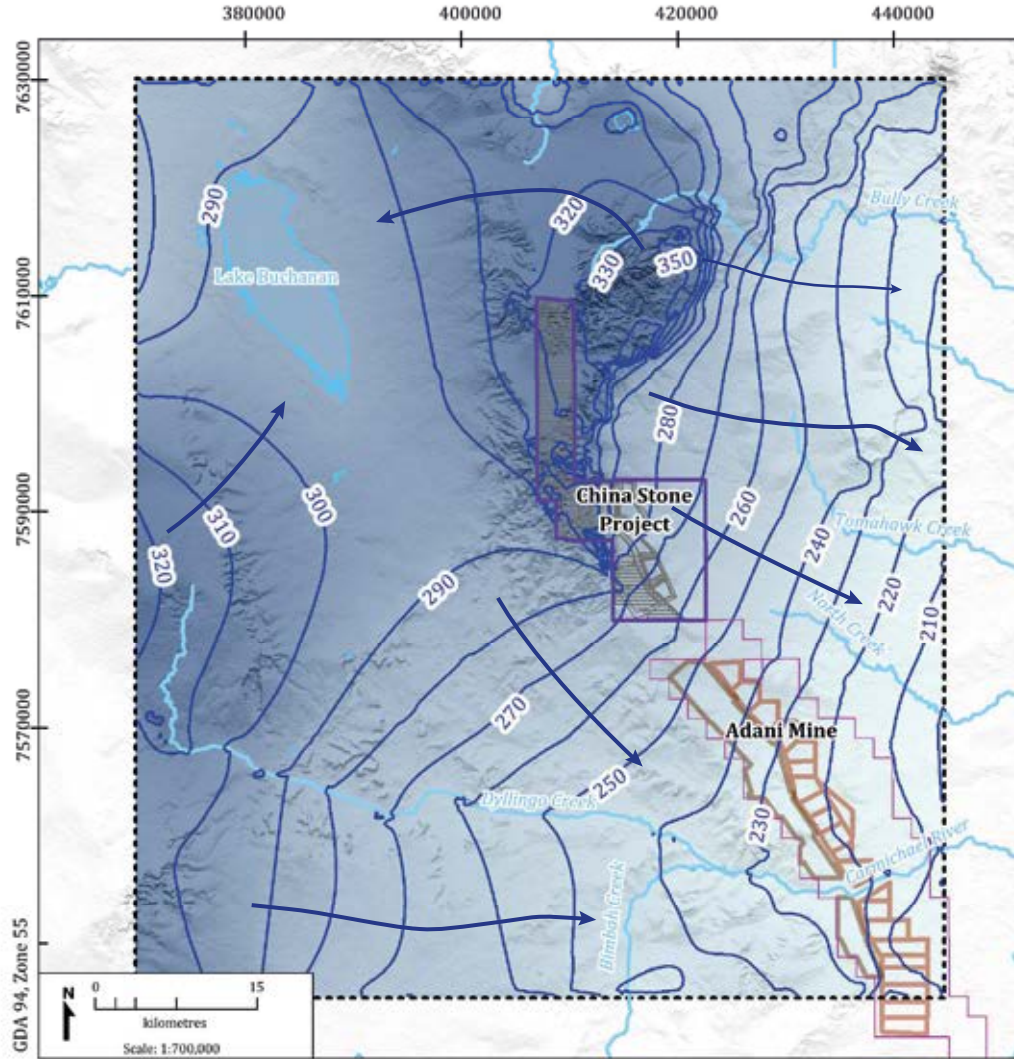
Figure B 7 shows calibrated heads for:

- Layer 5 - Clematis Sandstone; and
- Layer 8 – Rewan Formation.

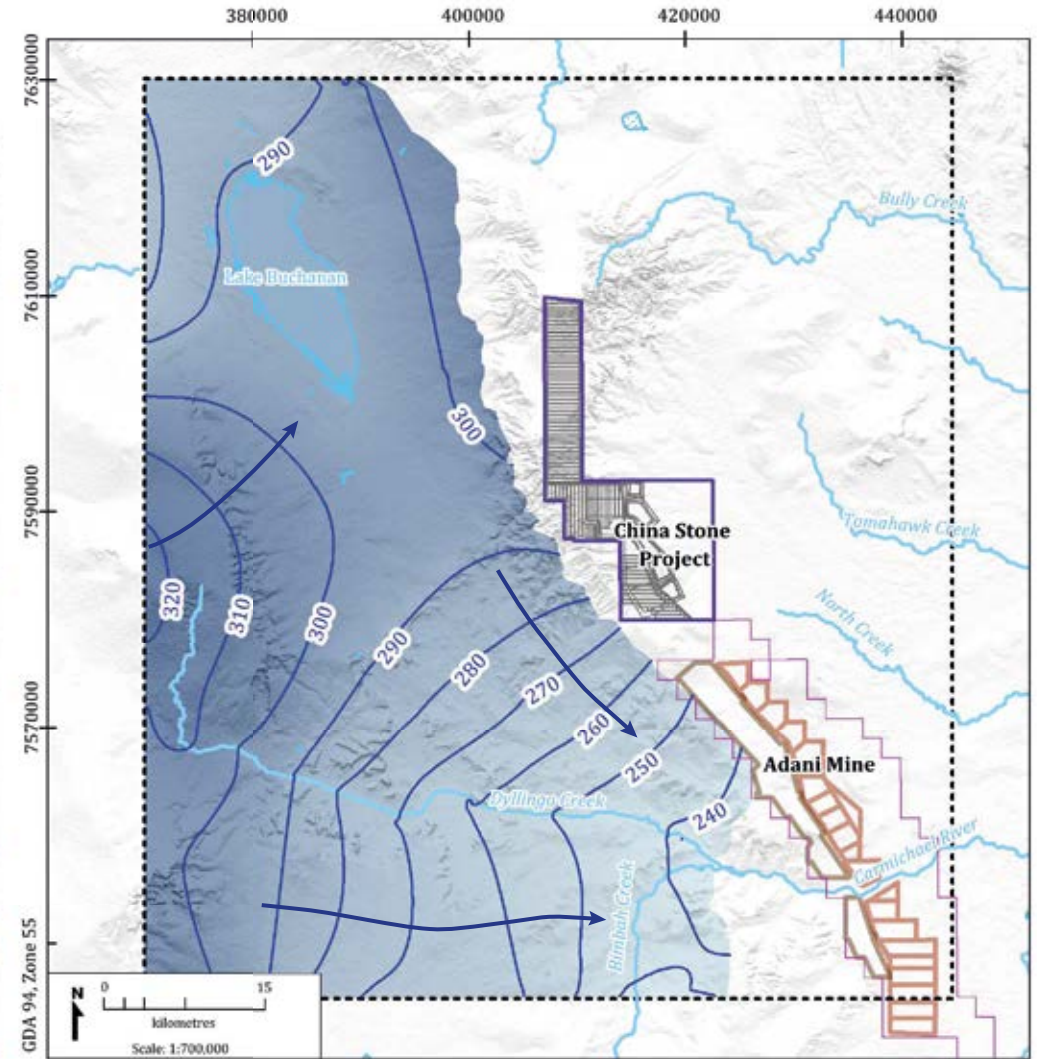
Figure B 8 shows calibrated heads for:

- Layer 10 - A coal seam; and
- Layer 10 – Joe Joe Group.

Modelled Steady State Heads - Tertiary (Layer 2)



Modelled Steady State Heads - Moolayember Formation (Layer 4)



LEGEND:

- Steady state groundwater contour (mAH)
- Major Drainage
- Model extent
- Project site
- Proposed China Stone mine
- ➔ Groundwater flow direction



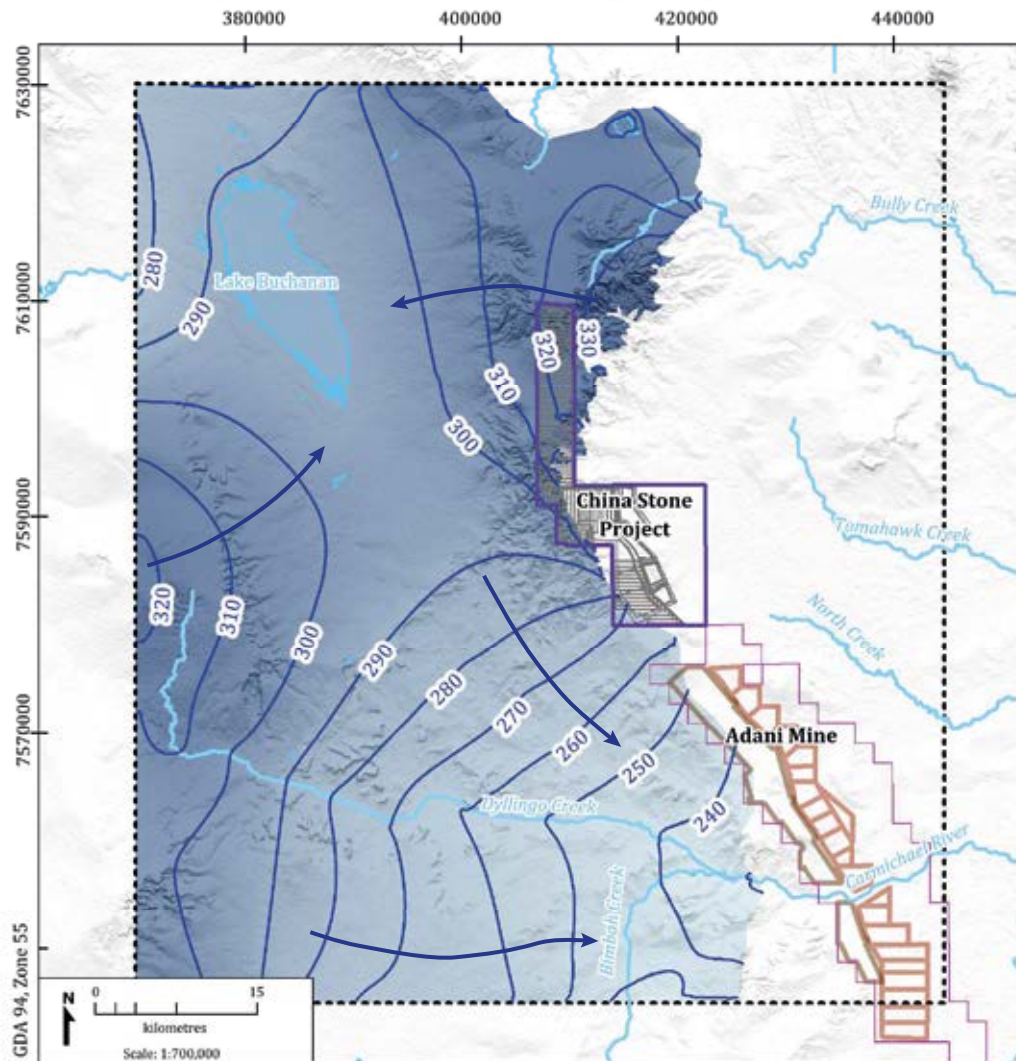
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Steady State Heads
Layer 2 and Layer 4

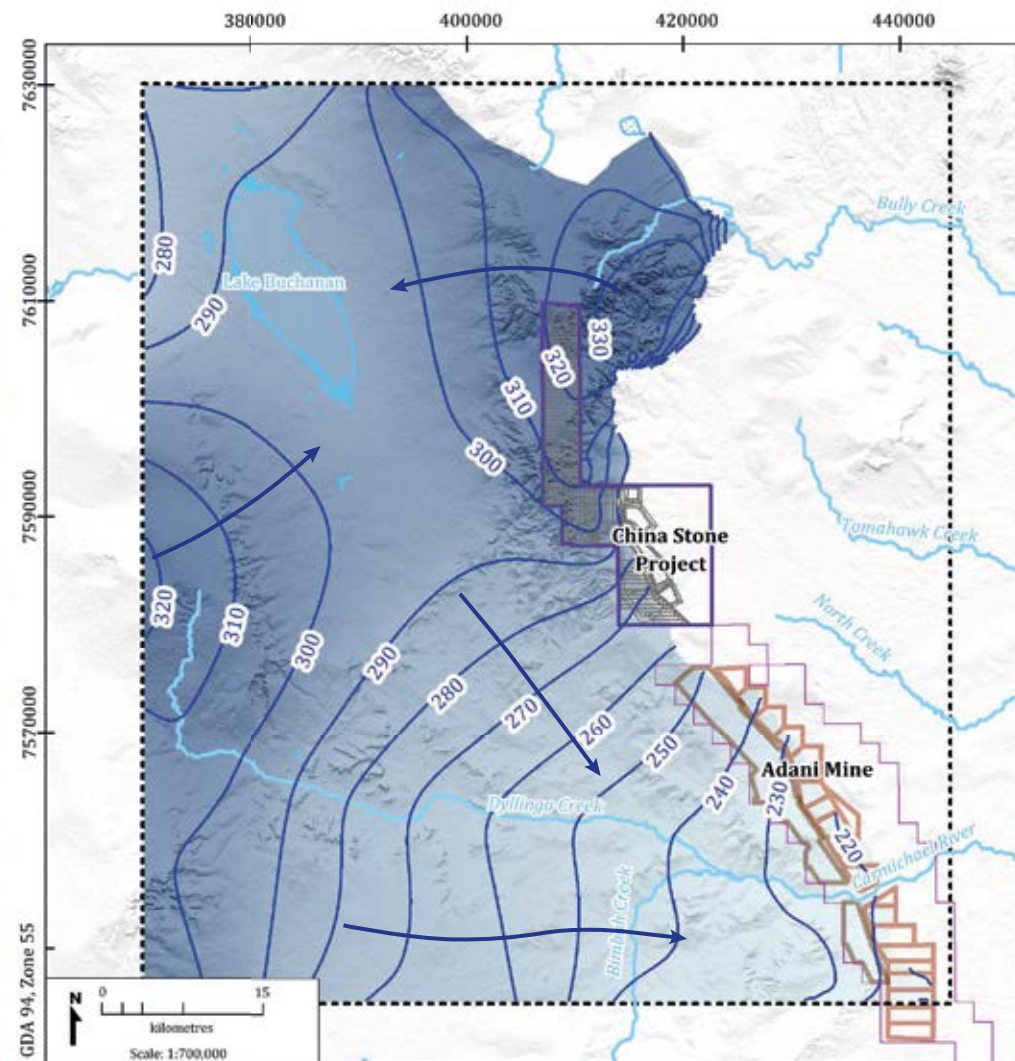
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FIGURE NO:
B-6

Modelled Steady State Heads - Clematis Sandstone (Layer 5)



Modelled Steady State Heads - Rewan Formation (Layer 8)



LEGEND:

- Steady state groundwater contour (mAH)
- Major Drainage
- Model extent
- Project site
- Proposed China Stone mine
- Groundwater flow direction



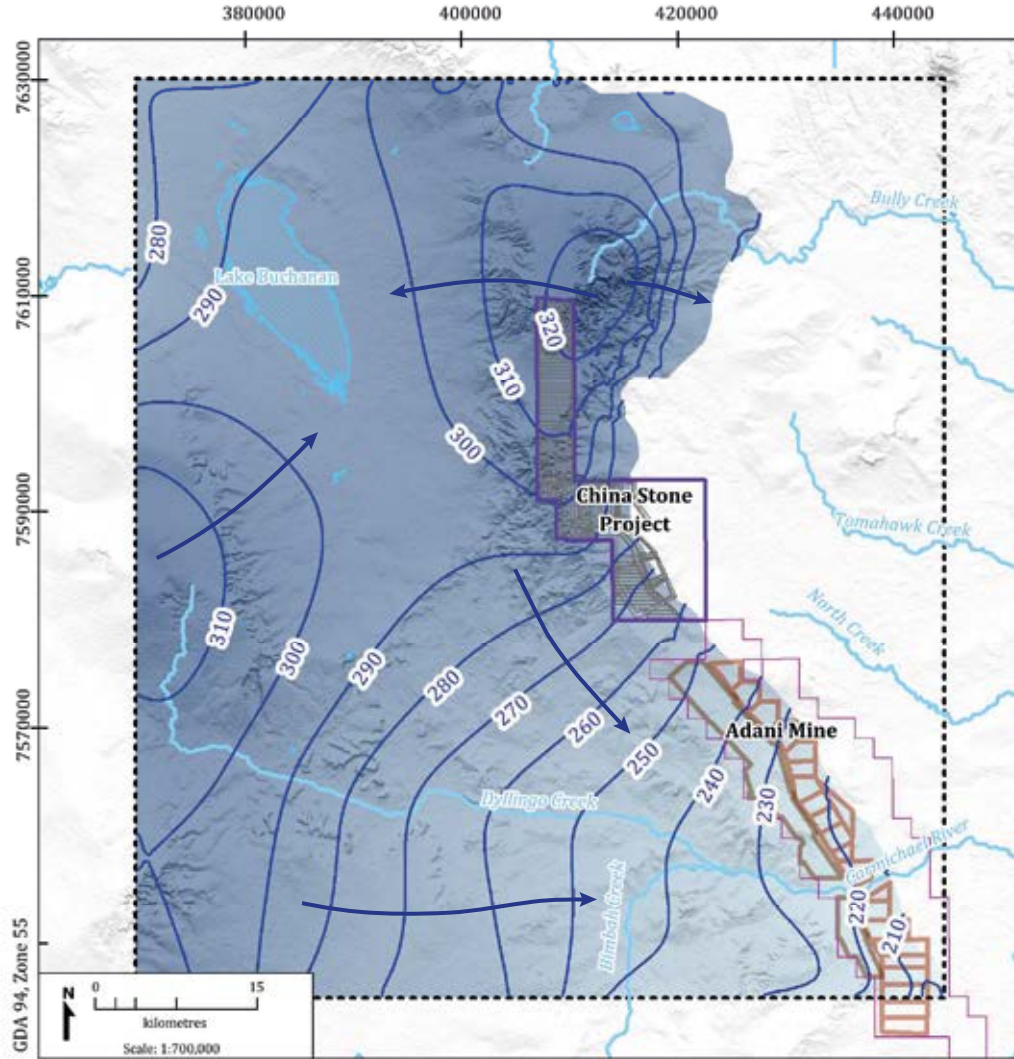
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**Steady State Heads
Layer 5 and Layer 8**

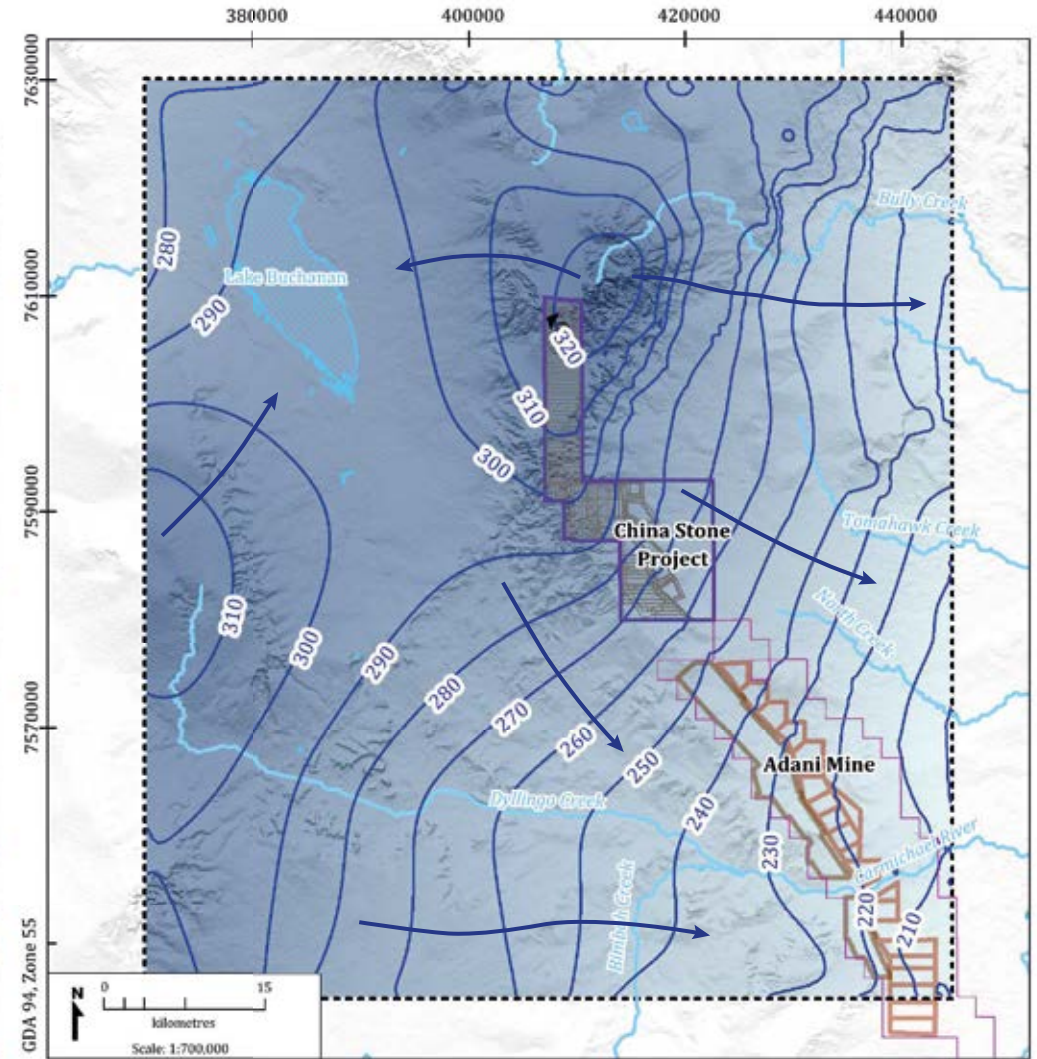
DATE:
24/6/2015

FIGURE NO:
B-7

Modelled Steady State Heads - AU Seam (Layer 10)



Modelled Steady State Heads - Joe Joe Group (Layer 17)



LEGEND:

- Major Drainage
- Model extent
- Project site
- Proposed China Stone mine

➔ Groundwater flow direction



Project China Stone (G1587)
Appendix D - Modelling

**Steady State Heads
Layer 10 and Layer 17**

DATE:
25/6/2015

FIGURE NO:
B-8

The heads reflect the groundwater flow regime prior to commencement of any mining within the model domain. The figures show a groundwater mound under Darkies Range with influence of the break of slope recharge is also evident in the heads. The mound under Darkies Range divides groundwater flow into easterly and westerly directions. Consistent with the conceptual model groundwater flows towards the east similar to the topography, and towards the west to Lake Buchanan.

B1.3.4 Hydraulic parameters

Table B-5 summarises the calibrated hydraulic conductivity of the hydrostratigraphic units in the model domain.

Table B 5 Model layer hydraulic parameters

Model layer	Lithology	Horizontal hydraulic conductivity (K _{xy}) (m/day)	Vertical hydraulic conductivity (K _z) (m/day)
1	Quaternary sediments	$1.50 \times 10^{+1}$	6.50
1 - 16	Weathered host rock	$1.28 \times 10^{-4} - 3.20 \times 10^{-1}$	$5.42 \times 10^{-6} - 4.00 \times 10^{-1}$
2	Tertiary sediments	1.25×10^{-1}	6.24×10^{-2}
3	Ronlow Beds	1.00×10^{-1}	2.42×10^{-2}
4	Moolayember Formation	6.50×10^{-2}	3.25×10^{-2}
5	Clematis Sandstone	5.00×10^{-2}	1.26×10^{-2}
6	Dunda Beds	1.08×10^{-3}	2.16×10^{-5}
7/8	Rewan Formation	2.79×10^{-3}	6.01×10^{-5}
9	Betts Creek Beds interburden	1.12×10^{-4}	1.12×10^{-6}
10	Betts Creek Beds A Seam	$4.20 \times 10^{-4} - 4.21 \times 10^{-2}$	$4.20 \times 10^{-4} - 4.21 \times 10^{-2}$
11	Betts Creek Beds interburden	5.00×10^{-4}	6.93×10^{-5}
12	Betts Creek Beds B Seams	$2.70 \times 10^{-4} - 2.27 \times 10^{-2}$	$2.38 \times 10^{-4} - 2.00 \times 10^{-2}$
13	Betts Creek Beds interburden	1.48×10^{-3}	5.20×10^{-4}
14	Betts Creek Beds C Seam	$5.00 \times 10^{-5} - 1.31 \times 10^{-2}$	$5.00 \times 10^{-6} - 1.31 \times 10^{-3}$
15	Betts Creek Beds interburden	4.67×10^{-4}	6.85×10^{-6}
16	Betts Creek Beds D Seam	$7.00 \times 10^{-5} - 8.71 \times 10^{-3}$	$7.00 \times 10^{-6} - 8.71 \times 10^{-4}$
17	Betts Creek Beds underburden	5.00×10^{-5}	2.50×10^{-5}
18	Joe Joe Group	5.00×10^{-5}	2.50×10^{-5}

Figure B 9 compares the distribution of the hydraulic conductivity (horizontal) field measurements against the geometric mean in the model. It shows graphically the match between the field data and the model developed for the project and by GHD (2013) for the Carmichael Coal Mine Project.

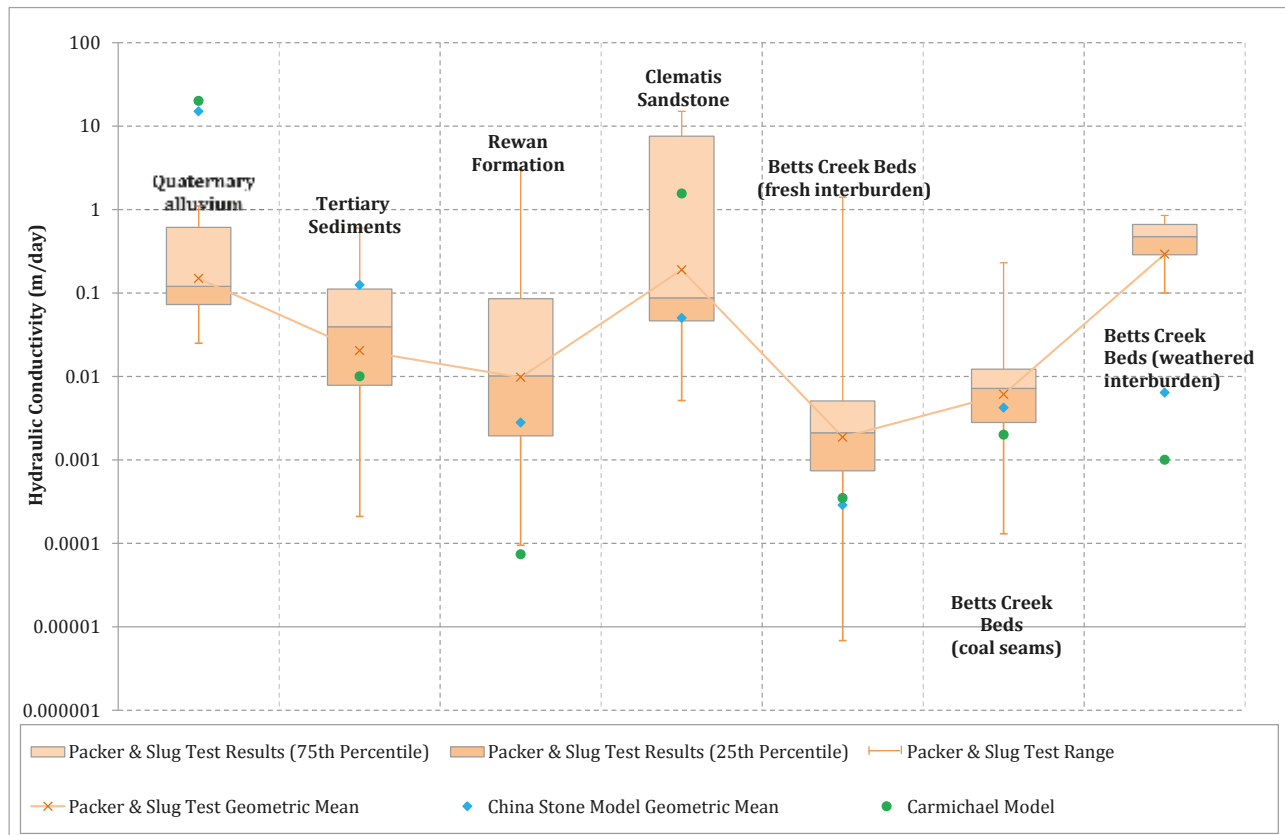


Figure B 9 Distribution of horizontal hydraulic conductivity - modelled and observed

Figure B 9 highlights the natural variability in hydraulic conductivity within fractured porous rocks, which vary across orders of magnitude. The calibrated hydraulic conductivity for each unit generally falls within the range of the field measurements. The exception is the modelled hydraulic conductivity for the Quaternary sediments and the weathered rock regolith that falls outside of the range of available field data, in both the project and Carmichael models. There is limited field data for both units; however, as these layers are generally unsaturated at the project site, the calibrated value is not considered to significantly influence the predictions.

All values for the Tertiary, Triassic and Permian units falls within the range of field data results. There is no available field data for the Moolayember Formation, therefore it was assumed to be 0.07 m/day, which is considered conservative given the properties of the unit. Similarly, no field data was available for bores screened in the Ronlow Formation, which primarily acts as an aquifer. Therefore a hydraulic conductivity of 0.1 m/day is reasonable. This unit is some 27 km from the proposed mining areas and therefore, the impacts from the project are not expected to be sensitive to uncertainties in the hydraulic properties at this distance.

B1.3.5 Water budget

The mass balance error, that is, the difference between calculated model inflows and outflows at the completion of the steady state calibration was 0.02%. This value indicates that the model is stable and achieves an accurate numerical solution. Table B-6 summarises the water budget for the steady state model.

Table B 6 Model budgets

Parameter	In (ML/day)	Out (ML/day)	In - Out (ML/day)
Rainfall recharge	4.38	0	4.38
River	79.44	17.30	62.14
General head	95.10	109.85	-14.76
Evapotranspiration	0	51.72	-51.72
Total	178.91	178.87	0.04
Error (%)			0.02

The water budget indicates that recharge to the groundwater system within the model averages 84 ML/day with approximately 17 ML/day being discharged via surface drainage, and 52 ML/day is lost to evapotranspiration in areas where the water table is within 2 m of the land surface.

B1.3.6 Composite model sensitivities

Sensitivity analysis evaluates the effect of changing individual model parameters on model results and indicates the uncertainty in the estimates of model parameters. The sensitivity of simulated heads to parameters was assessed to aid model calibration. The relative composite sensitivity (RCS) was calculated as outlined by Doherty (2010):

$$s_i = (J^t Q J)^{0.5} b_i / m$$

- where:
- J = Jacobian matrix, derivatives of simulated heads at observations with respect to the i^{th} parameter in vector b.
 - Q = cofactor matrix, a diagonal matrix with the elements being the squared observation weights.
 - b_i = i^{th} parameter value in vector b.
 - m = number of observations that have non-zero weights.

The composite sensitivity values were calculated during the PEST calibration process for the steady-state model and were converted to RCS as shown in Figure B 10.

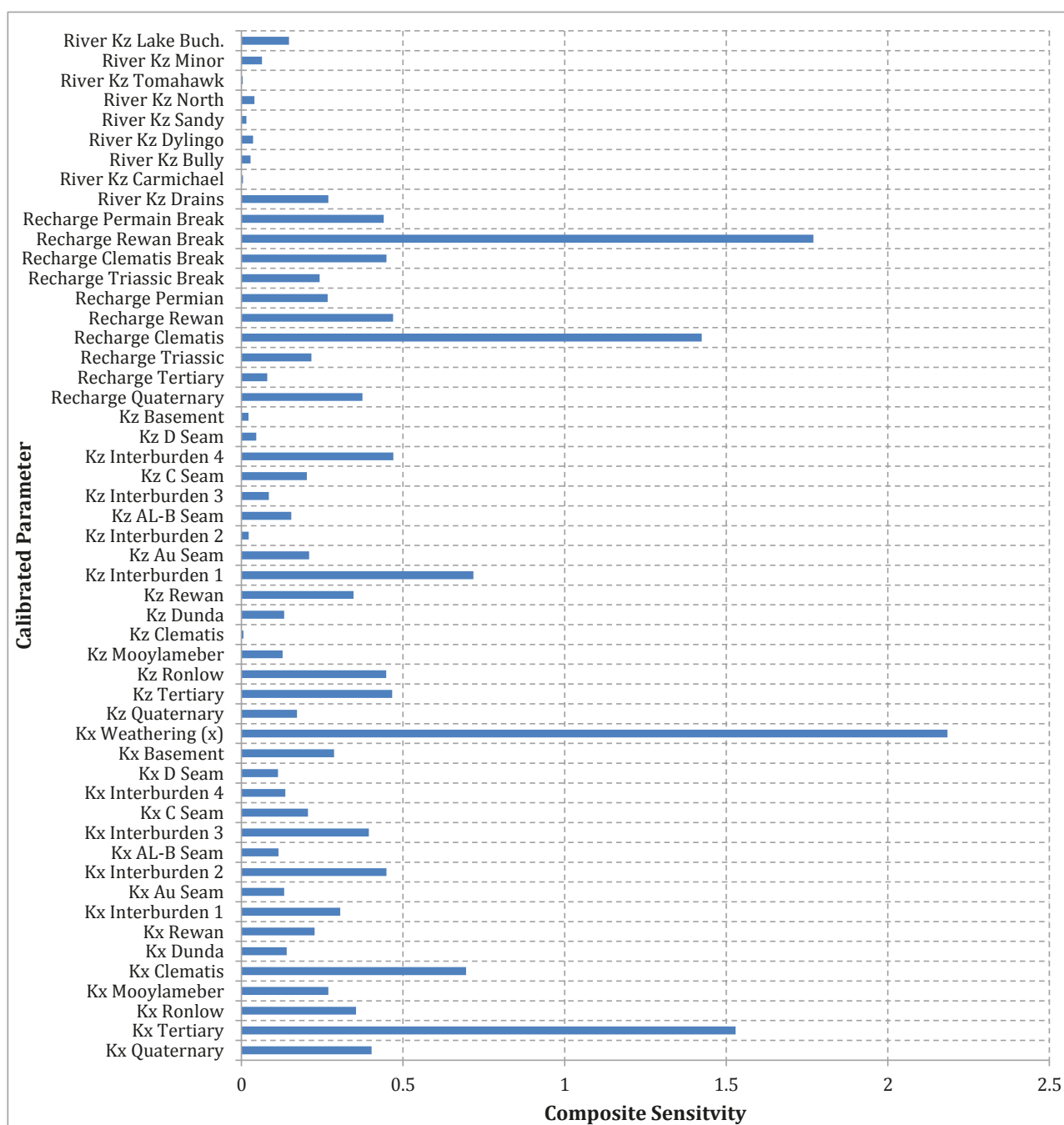


Figure B 10 Model composite sensitivity

The reason for scaling the sensitivity data is that sensitivities are typically presented in the units of the simulated value divided by the units of the parameter (Hill and Tiedeman, 2007). For example, the parameter units may consequently be in m^3/day , m/day or mm/yr and the method of scaling (composite sensitivity) provides sensitivity measures with the same units and a method for comparison. RCS is therefore a dimensionless statistic and is a measure of the composite changes in model outputs that are incurred by a change in the value of the parameter. That is, whether the model calibration is sensitive to an input parameter such as hydraulic conductivity or recharge. This statistic can be used to assess the relative sensitivity of model parameters given the set of observations used in the model.

RCS can reflect the total amount of information provided by the observations for the estimation of each parameter (Hill and Tiedeman, 2007). Generally, if the RCS of a parameter is greater than one, the model is sensitive to this parameter and the model observations have provided enough information to estimate the parameter with greater certainty. Figure B 9 shows that parameters with a RCS greater than 1 are:

- recharge to the Rewan Formation at the break of slope;
- recharge to the Clematis Sandstone;
- factor applied to the hydraulic conductivity to represent weathering of host rock; and
- hydraulic conductivity of the Quaternary / Tertiary sediments.

Where parameters have a low RCS, the model calibration is less sensitive to these, yet there is greater uncertainty associated with them and they are likely to contribute more to the uncertainty of the model predictions. In this case, the predictive uncertainty has been guided by this sensitivity analysis within the constraints of the model calibration statistics.

B1.3.7 Transient verification

The model was not calibrated to transient water level data as monitoring was undertaken during a drought period with limited significant recharge events occurring during the baseline period for the EIS. Instead, the transient water level records were used to verify the model could replicate water levels measured in the monitoring bore network installed for the project. The model ran with fortnightly stress periods for the period of available water level data from November 2011 to February 2014. Recharge was applied to the groundwater model according to averages from BOM station 36010.

Appendix D-1 contains hydrographs showing the measured and simulated water levels for 26 of the site-based bores and vibrating wire sensors used for the verification. The hydrographs show that the model generally simulates the muted response to recharge events recorded in the monitoring bores.

B1.3.8 Model confidence level classification

Barnett *et al* (2012) developed a system to classify the confidence-level for groundwater models. Models are classified as either Class 1, Class 2 or Class 3 in order of increasing confidence (i.e. Class 3 has the highest level of confidence). Several factors are considered in determining the model confidence level:

- available data;
- calibration procedures;
- consistency between calibration and predictive analysis; and
- level of stresses.

The model has achieved and generally exceeded the criteria considered for a Class 1 model, and in some respects it has met a number of the criteria for a Class 2 confidence level classification. The following aspects are where the modelling approach does not achieve the Class 2 level:

- a transient calibration has not been undertaken;
- transient predictions are made when calibration is in steady state only; and
- the model has not been reviewed.

While the guidelines indicate that the model is a Class 1 the other aspects that have been satisfied for Class 1 also satisfy the Class 2 key indicators, meaning that the model is very close to being a Class 2. Because of this, the model is considered to be fit-for-purpose as an impact assessment model.

One reason the model remains a Class 1 model is the lack of transient calibration, and hence the prediction period is greater than 10 times the calibration period. From the limited transient data available it is apparent that there is little seasonal pattern to the groundwater behaviour, especially with the water table deeper than 60 m below ground level in some areas. It could be argued that the steady state calibration has addressed the long term groundwater behaviour. While this means that storage characteristics of the aquifer have not been calibrated, this limitation has been addressed in the sensitivity analysis undertaken.

B2. Predictive simulations

B2.1 Time slices

A simplified iterative approach was applied involving running the model in short time frames (time “slices” of six months) to represent the mining process and changes in hydraulic conductivity. The 50 years of mining was subdivided into 100 stages, each six months in length. At the end of each stage, the model was stopped and the last predicted groundwater levels for the simulation were used as starting points for the next simulation stage. At this point in time, changes in aquifer parameters resulting from the effects of the subsidence of material into the mined panel and the formation of a goaf above the panel, were applied. The vertical hydraulic conductivity was increased using the log-linear ramp function. A Fortran computer program was written to undertake the “stop-start” nature of the staged simulation. This program defined the active cell drains on a biannual basis and applied pre-defined rules for the changes in aquifer parameters and finally generated each of the time slices. This approach has been used successfully for a large number of impact assessment flow models.

B2.2 Mine drainage

During the transient run, drain cells were used to simulate the effect of the proposed mine and other mines in the area. A nominally high drain conductance of 100 m²/day was applied to the drain cells and the elevation of the mined seam floor was used as the drain level. For the open cut mines, the drain cells were set in all layers from the mined seam to the surface. For the underground mines, the drain cells were only set in the mined layer.

The model represented mining using the drain (DRN) package. This required setting a reference elevation and a conductance term. Groundwater levels in the model are compared to the reference elevation in each cell, and when the groundwater level is above the reference level, water is removed from the model domain at a rate determined by the head difference and the conductance term. In the case of the project, the drain cells used to simulate mining were set to a reference level at the base of each mined coal seam (i.e. base of AU, B, C and D coal seams). A nominally high drain conductance rate (approximately 100 m²/day) was used to facilitate free drainage conditions from the strata and ensure the groundwater level was lowered to the reference level, hence dewatering the coal seam.

B2.1 Storage properties

Table B-7 summarises the values of specific storage and specific yield adopted in the model.

Table B 7 Model layer hydraulic parameters

Model layer	Lithology	Specific yield Sy (%)	Specific storage Ss (m ⁻¹)
1	Quaternary sediments	10	1 x 10 ⁻³
1 - 16	Weathered host rock	1	2 x 10 ⁻⁴
2	Tertiary sediments	5	2 x 10 ⁻⁴
3	Ronlow Beds	1	2 x 10 ⁻⁵
4	Moolayember Formation	1	2 x 10 ⁻⁵
5	Clematis Sandstone	1	2 x 10 ⁻⁵
6	Dunda Beds	1	2 x 10 ⁻⁵
7/8	Rewan Formation	1	2 x 10 ⁻⁵
9	Betts Creek Beds - interburden	1	2 x 10 ⁻⁵
10	Betts Creek Beds - A Seam	1	2 x 10 ⁻⁵
11	Betts Creek Beds – interburden	1	2 x 10 ⁻⁵
12	Betts Creek Beds - B Seam	1	2 x 10 ⁻⁵
13	Betts Creek Beds – interburden	1	2 x 10 ⁻⁵
14	Betts Creek Beds - C Seam	1	2 x 10 ⁻⁵
15	Betts Creek Beds – interburden	1	2 x 10 ⁻⁵
16	Betts Creek Beds - D Seam	1	2 x 10 ⁻⁵
17	Betts Creek Beds – interburden	1	2 x 10 ⁻⁵
18	Joe Joe Group	1	2 x 10 ⁻⁵

Note: Parameters used in the model are conservative estimates using a combination of limited field data, hydrogeological expertise and knowledge of the region.

B2.2 Underground mining

The proposed underground mining schedule extends over 45 years and comprises the Northern and Southern Undergrounds mining the A and D seams, and C seams respectively. Longwall mining progresses from south to north. Mining commences in the D and C seams, while mining of the overlying A seam commences three years later, slightly offsetting the mining areas at any time.

The EIS Subsidence Report assessed the potential height of continuous cracking induced above the subsiding longwall panels. The EIS Subsidence Report concluded that:

- an upper bound height of 120 m for continuous fracturing associated with single seam extraction; and
- a conservative continuous fracturing height of 180 m above the upper seam extracted in dual seam mining areas.

The majority of the Northern Underground involves dual seam mining (A and D Seams). This area is overlain by the Clematis Sandstone. The interburden thickness between the A Seam and the base of the Clematis Sandstone is variable with a minimum thickness of 115 m to 120 m on the western side of the fault, and 140 m to 160 m on the downthrown eastern side. The height of connective cracking would therefore intersect the overlying Clematis Sandstone.

The model represented the continuous cracking above the longwall panels by increasing the vertical hydraulic conductivity (Kz) of each overlying layer intersected by cracking. The vertical hydraulic conductivity was calculated for each layer by increasing the base value by a factor ranging from 10 to 1000 times. Table B 8 details the factor used to calculate the vertical conductivity of each affected layer. Increases to Kz were based upon a log-linear factor ramp function, with, upper and lower limits applied to ensure a hydraulic connectivity was maintained throughout the cracking zone.

In addition, where the cracking height is predicted to intersect the base or part of a geological unit (e.g. the Clematis Sandstone above the Northern Underground), the entire geological unit has been assumed to be continuously cracked. That is to say, that each intersected geological unit has been modelled as cracked across its entire vertical profile, by applying the factored increase in vertical conductivity across the full thickness of the equivalent model layers.

Table B 8 Hydraulic conductivity of fractured zone

Layer	Geology	Value Kz (m/day) (base value)	D Seam mining factor (x)	D Seam mining value Kz (m/day)	A Seam mining factor (x)	A Seam mining value Kz (m/day)
5	Clematis Sandstone	1.26×10^{-2}	1	1.3×10^{-2}	10	1.3×10^{-1}
6-7	Rewan Formation	6.01×10^{-5}	1	6.0×10^{-5}	20	1.2×10^{-3}
8	Rewan Formation	6.01×10^{-5}	10	6.0×10^{-4}	50	3.0×10^{-3}
9	Betts Creek Beds interburden	1.12×10^{-6}	1000	1.1×10^{-3}	5000	5.6×10^{-3}
10	Betts Creek Beds A Seam	5.00×10^{-5}	50	2.5×10^{-3}	500	2.5×10^{-2}
11	Betts Creek Beds interburden	6.93×10^{-5}	100	6.9×10^{-3}		
12	Betts Creek Beds B Seams	8.72×10^{-5}	100	8.7×10^{-3}		
13	Betts Creek Beds interburden	5.20×10^{-4}	100	5.2×10^{-2}		
14	Betts Creek Beds C Seam	1.00×10^{-5}	500	5.0×10^{-3}		
15	Betts Creek Beds interburden	6.85×10^{-6}	1000	6.9×10^{-3}		
16	Betts Creek Beds D Seam	1.00×10^{-5}	1000	1.0×10^{-2}		

Figure B 11 shows the relationship between the change in Kz and height above D and C Seam, and above A Seam.

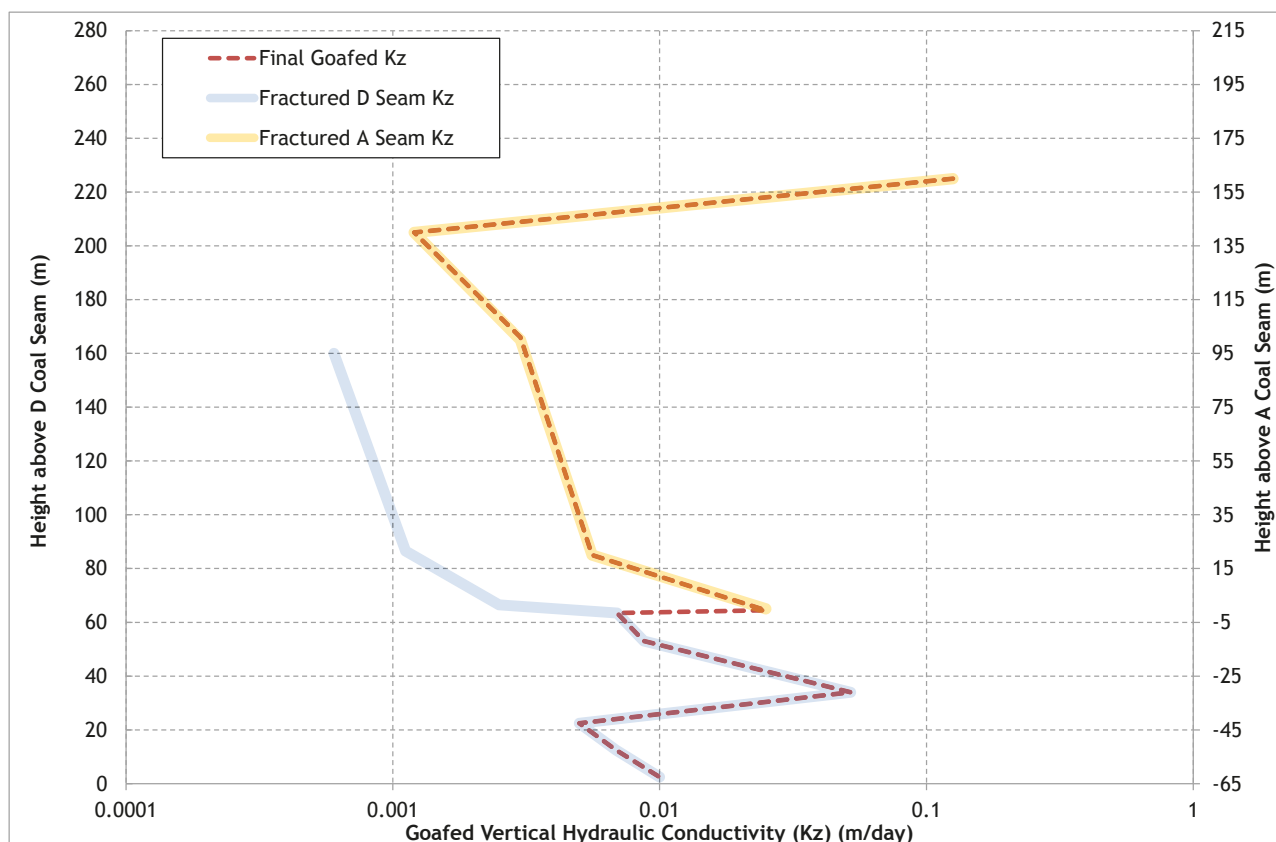


Figure B 11 Fractured vertical hydraulic conductivity by height above coal

The hydraulic conductivity of the fractured zone above the D and C Seams was adjusted in the model to follow the trend shown in black, with units overlying the A seam adjusted according to the trend shown in yellow. The combined values after both seams are mined are shown in green.

B2.3 Opencut mining

The project includes 30 years of truck and shovel mining from the surface to the base of the B coal seam. Within the open cut areas, the model changed the hydraulic properties and recharge rates to represent development of the spoil piles on a two yearly basis.

B3. Sensitivity analysis

A sensitivity analysis was carried out to assess the response of the model to varying input parameters. The objective of the sensitivity analysis was to rank the input parameters in terms of their influence on the predicted results. The model parameters were adjusted to encompass the range of likely uncertainty in key parameters.

The following perturbations were assessed in the sensitivity analysis:

- ± 1 order of magnitude change in horizontal and vertical hydraulic conductivity (K) of all units;
- $\pm 50\%$ change in horizontal and vertical hydraulic conductivity (K) of overburden;
- $\pm 100\%$ change in the specific yield (S) of all units in the model;
- $\pm 50\%$ change in specific yield (S) of overburden;
- ± 1 order of magnitude change in the specific storage (S) of all units in the model;
- $\pm 100\%$ change in the specific storage (S) of overburden;
- ± 1 order of magnitude change in the rainfall recharge (Rch) rate across the model domain; and
- $\pm 50\%$ change in the rainfall recharge rate (Rch) on the overburden.

In addition, a specific sensitivity analysis was undertaken to test the influence of the geological fault on the predicted results. The perturbations investigated in this analysis comprised:

- a low permeability fault plane running through the underground mining area, represented with the Horizontal Flow Barrier Package (HFB) set with a conductance term of $1 \times 10^{-7} \text{ m}^2/\text{day}$; and
- a highly permeable fault plane represented by a zone of cells $75\text{m} \times 75\text{m}$ cells set to the same hydraulic conductivity and storage as the Clematis Sandstone (K/S).

These perturbations represent extremes in the potential behaviour of the fault (i.e. groundwater conduit or groundwater flow barrier).

The following sections present the results of these sensitivity analyses in terms of their influence on groundwater inflow (seepage) predictions, groundwater level changes (zone of drawdown/depressurisation).

B3.1 Mining area seepage

Figure B 12 to Figure B 14 show the sensitivity of the predicted seepage rate to changing the parameters in the model.

The predicted seepage was most sensitive to changes in the storage parameters of the host hydrostratigraphic units during the open cut mining phase. Increasing the storage by one order of magnitude more than doubled the maximum predicted seepage peaks from 15 ML/day to 40 ML/day. Conversely reducing the storage by one order of magnitude effectively halved the maximum predicted seepage peak.

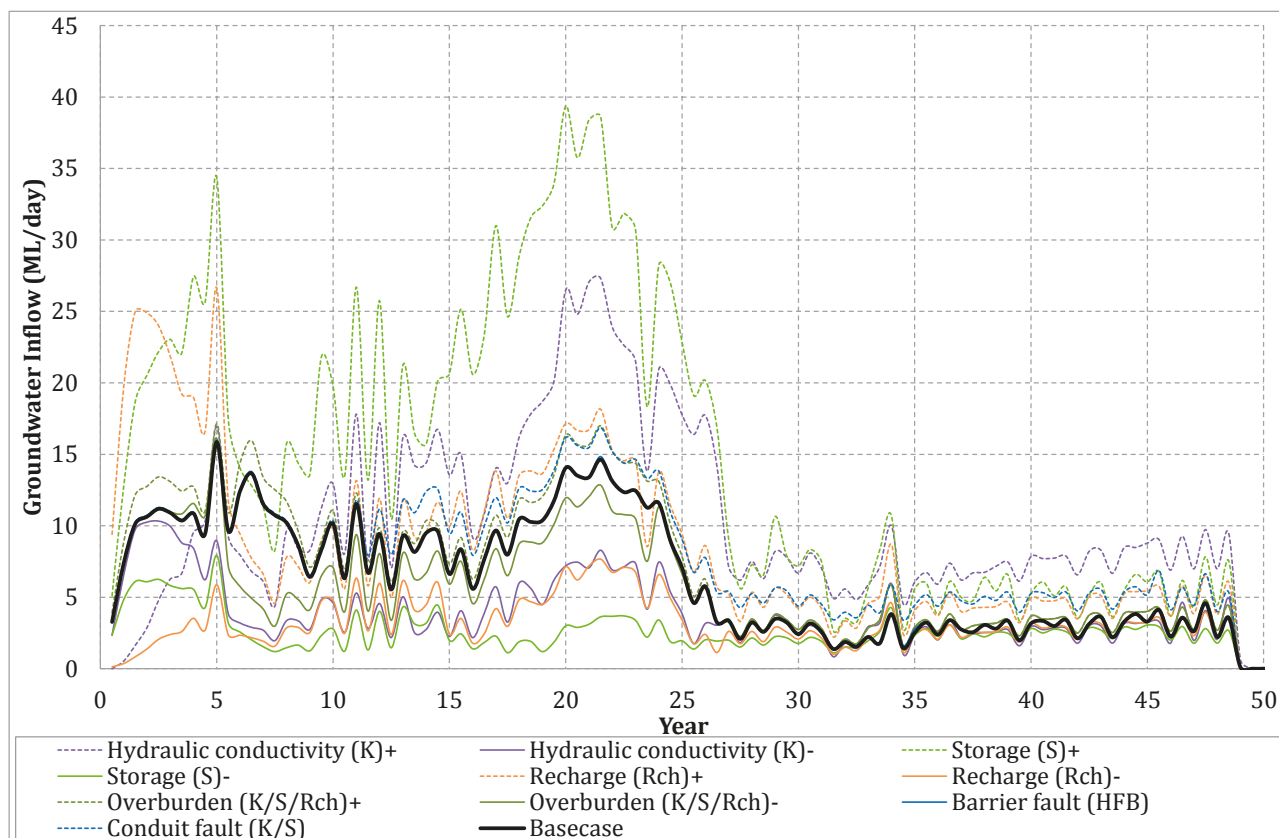


Figure B 12 Sensitivity of total mine inflows

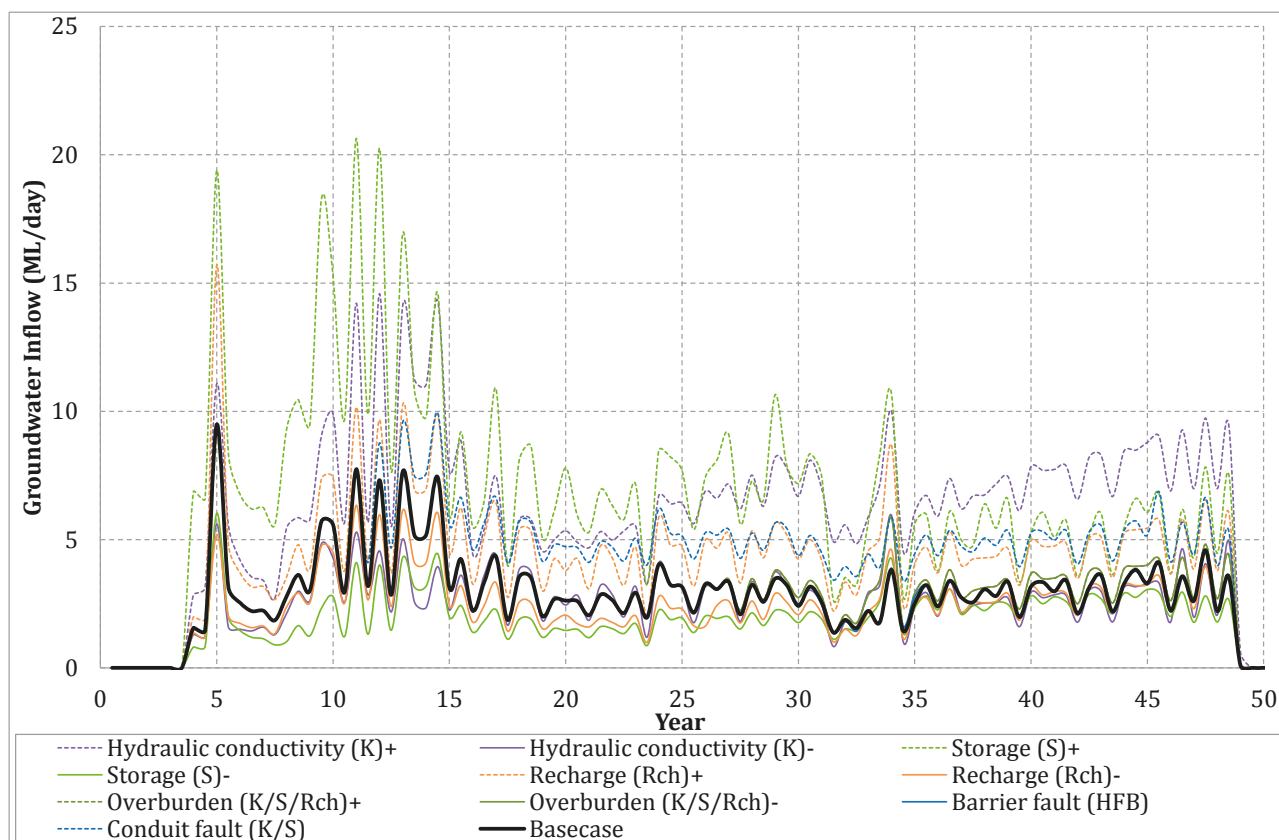


Figure B 13 Sensitivity of underground longwall mine inflows

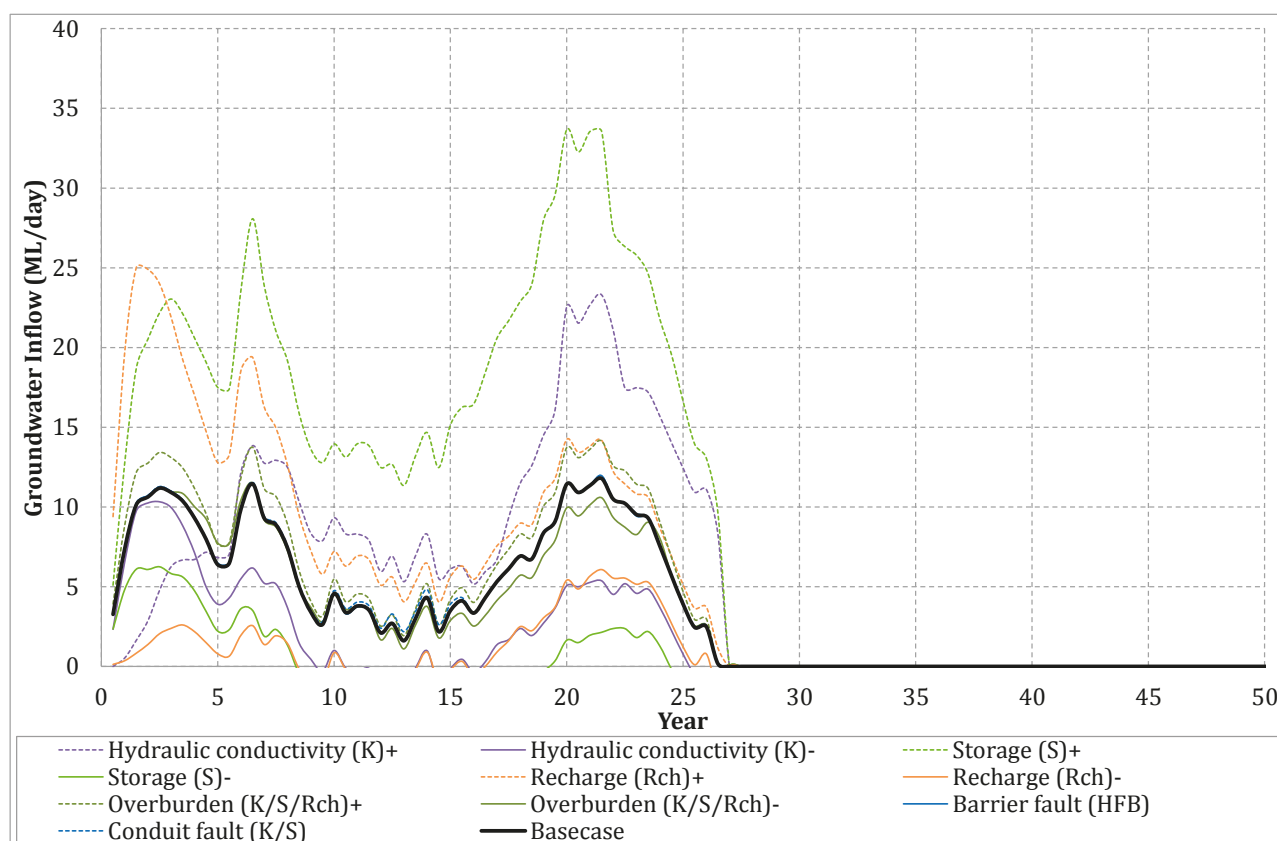


Figure B 14 Sensitivity of open cut mine inflows

Introducing a permeable fault plane of 75m width increased the inflow to the underground mine by approximately 2 ML/day. A similar increase in the inflow to the underground mine occurred when the recharge rate increased by an order of magnitude. Decreasing the permeability of the fault plane resulted in no discernible increase in the predicted inflow to the underground mine above the base case. When interpreting the scenario used to represent a permeable fault it is important to understand it is considered completely improbable because the model represented the faults as being a single cell wide, which is 75 m, with a hydraulic conductivity equivalent to porous sandstone. In our experience faults in Australian coal mining regions do not generate expansive zones of fractured rock either side of the slippage plane, and the zone where hydraulic properties are changed is typically only a few metres wide, thus a 75 m width is likely to be a gross over-representation of the fault plane.

Reducing hydraulic conductivity, storage and recharge had only a marginal impact, reducing the inflow to the underground mine by 0.5 ML/day or less.

Table B 9 shows how changing the model parameters influences the overall model error (as represented by the SRMS and the mine seepage). It shows that the magnitude of the changes to the hydraulic conductivity and recharge made during the sensitivity analysis reduced the ability of the model to match measured water levels and degraded the calibration statistics. This highlights the changes made during the sensitivity analysis are likely to represent conservative extremes for these parameters.

The exception was the changes made to represent the fault as a barrier or conduit to groundwater flow. These changes did not significantly affect the calibration statistics.

Table B 9 Summary results of sensitivity analysis

Parameter	Steady state SRMS (%)	Maximum mine seepage (MLpa)
Basecase	7.7	5,072
Hydraulic conductivity (K)+	12.4	9,471
Hydraulic conductivity (K)-	15.8	3,705
Storage (S)+	-	13,548
Storage (S)-	-	2,227
Recharge (Rch)+	16.6	9,118
Recharge (Rch)-	12.0	2,631
Overburden (K/S/Rch)+	-	5,886
Overburden (K/S/Rch)-	-	4,895
Conduit fault (K/S)	7.8	5860
Barrier fault (HFB)	7.8	5118

B3.2 Zone of depressurisation

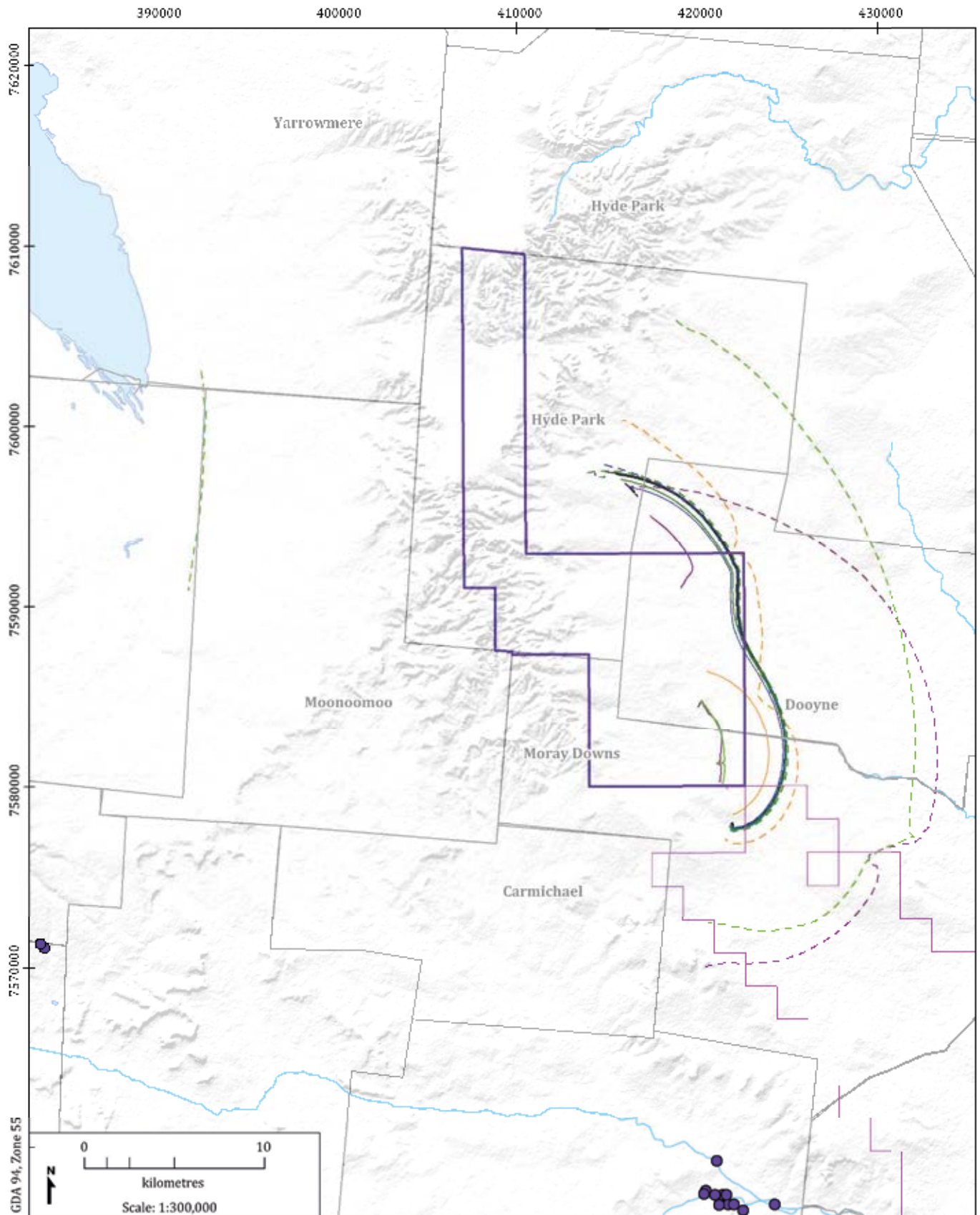
The sensitivity analysis assessed the changes to the zone of depressurisation in the Tertiary sediments and Clematis Sandstone during the operations and post mining phases.

Figure B 15 and Figure B 16 show the maximum groundwater depressurisation throughout the mine life, and Figure B 17 and Figure B 18 show groundwater depressurisation post mining.

The results show that groundwater depressurisation is most sensitive to changes in storage and hydraulic conductivity during the mining phase and post mining.

The properties of the fault have less influence than storage and hydraulic conductivity on the depressurisation during the mining and post mining phases.

Figure B 15 to Figure B 18 show that maximum drawdown extents do not extend to any springs located to the south or south-west of the project and therefore we can conclude with high confidence that the project will not affect these features.



LEGEND:

- Project site
- Carmichael Coal Mine Project
- Major drainage
- Springs
- Cadastre
- Lake

Sensitivity - 1m contour

- Basecase
- Hydraulic conductivity (K) +
- Hydraulic conductivity (K) -
- Conduit fault (K/S)
- Barrier fault (HFB)
- Recharge (Rch) -
- Recharge (Rch) +
- Storage (S) +
- Storage (S) -
- Overburden (K/S/Rch) +
- Overburden (K/S/Rch) -

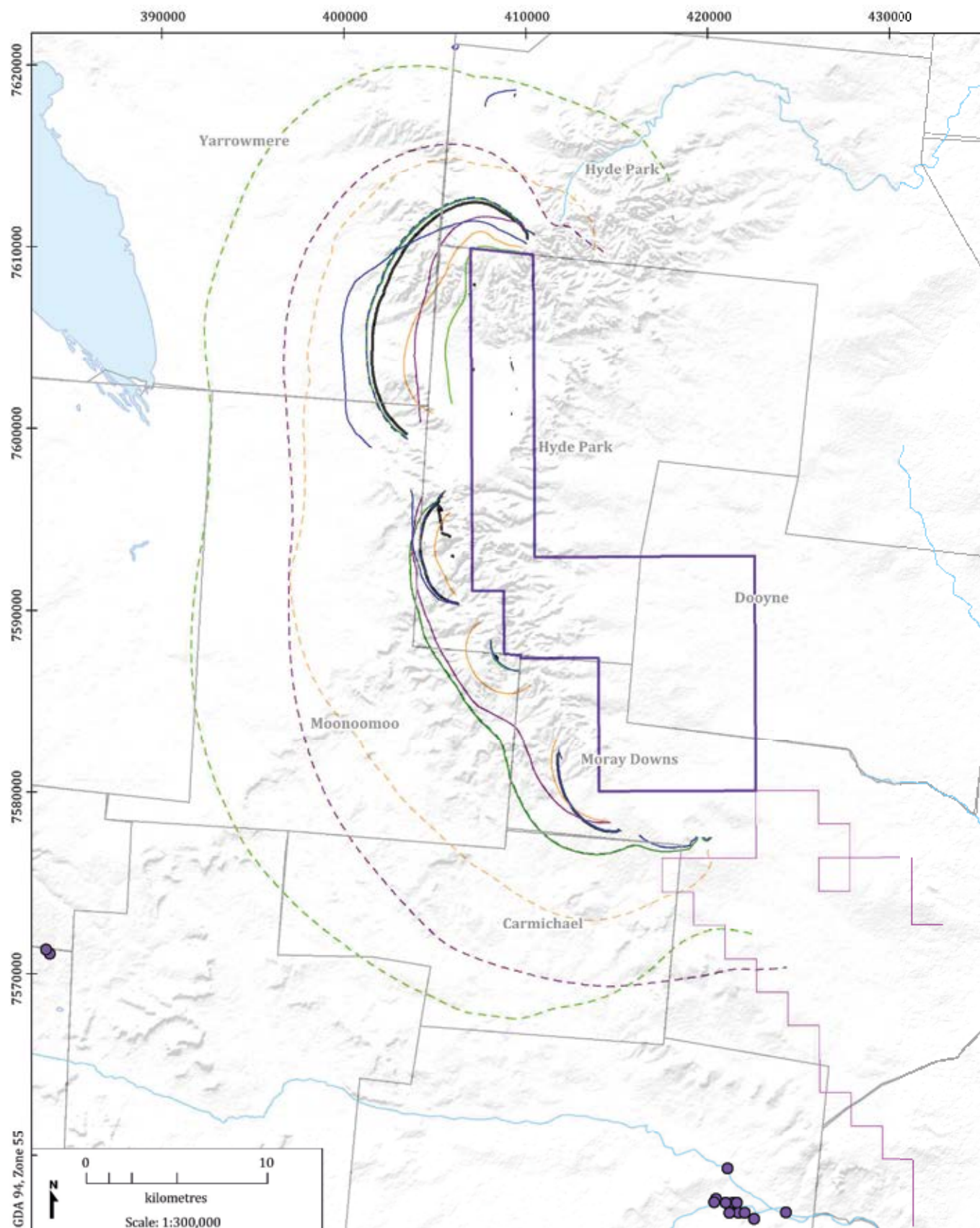
Project China Stone (G1587)

Sensitivity of maximum zone of depressurisation during mining - Tertiary sediments



DATE:
24/6/2015

FIGURE No
B-15



LEGEND:

- Project site
- Carmichael Coal Mine Project
- Major drainage
- Springs
- Cadastre
- Lake

Sensitivity - 1m contour

Basecase

- Hydraulic conductivity (K) +
- Hydraulic conductivity (K) -
- Conduit fault (K/S)
- Barrier fault (HFB)
- Recharge (Rch) -
- Recharge (Rch) +

Storage (S) -

Storage (S) +

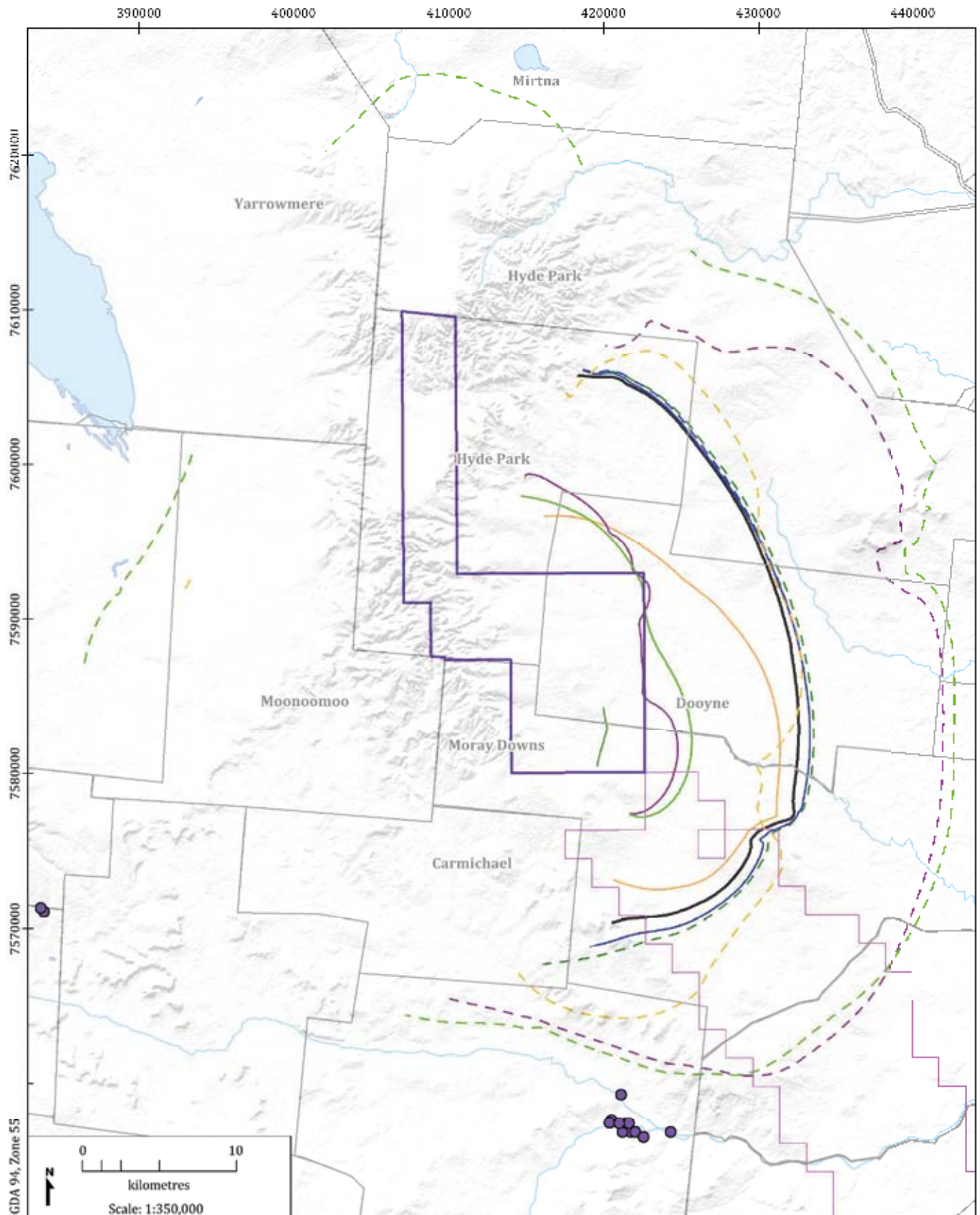
Overburden (K/S/Rch) +

Overburden (K/S/Rch) -

Project China Stone (G1587)

Sensitivity of maximum zone of depressurisation during mining - Clematis Sandstone

DATE:
24/6/2015FIGURE No:
B-16



LEGEND:

- Project site
- Carmichael Coal Mine Project
- Major drainage
- Springs
- Cadastre
- Lake

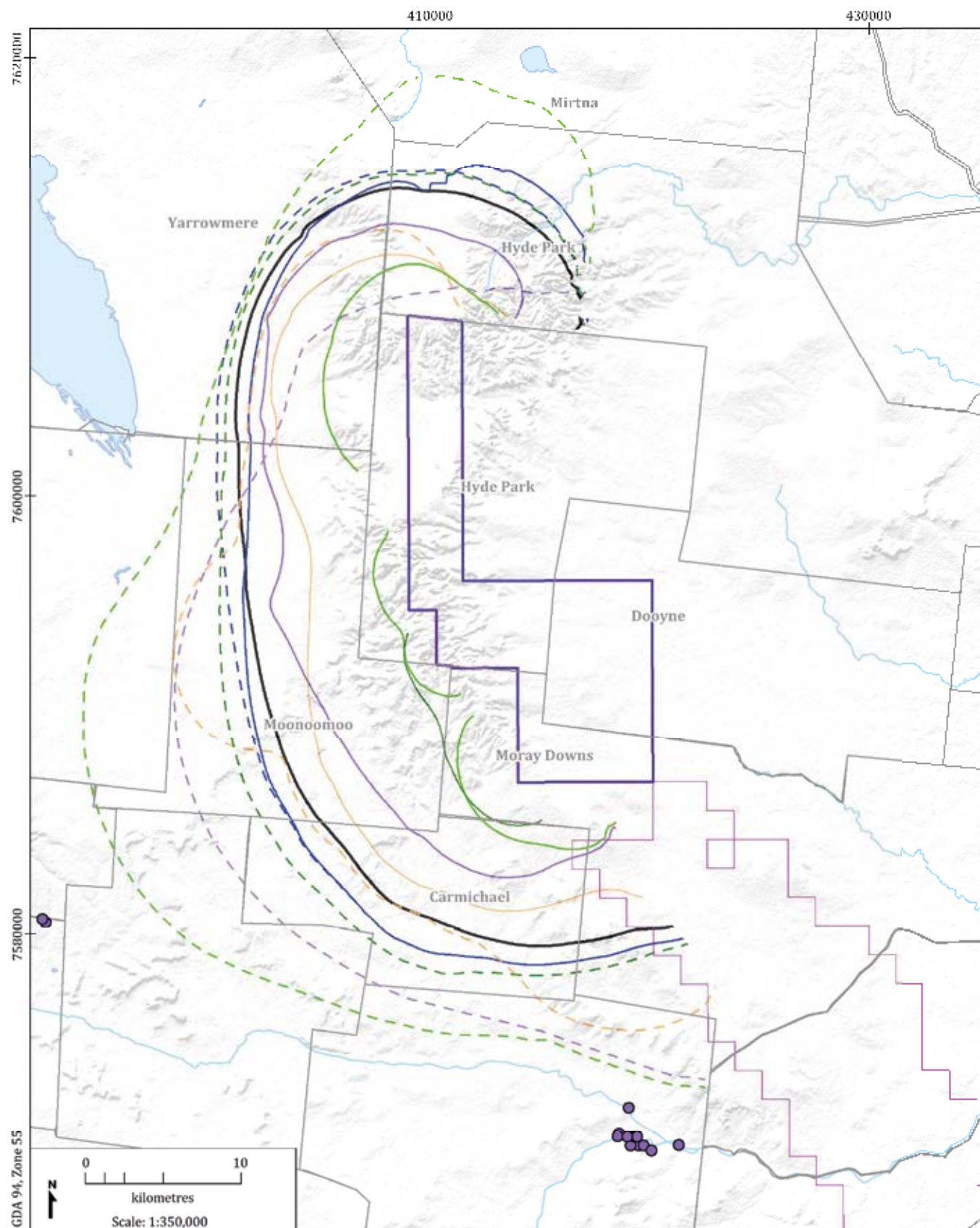
Sensitivity - 1m contour

- Basecase
- Hydraulic conductivity (K)+
- Hydraulic conductivity (K)-
- Conduit fault (K/S)
- Barrier fault (HFB)
- Recharge (Rch) -
- Recharge (Rch) +
- Storage (S) +
- Storage (S) -
- Overburden (K/S/Rch) -
- Overburden (K/S/Rch) +

Project China Stone (G1587)

Sensitivity of maximum zone of depressurisation post mining - Tertiary sediments

DATE:
24/6/2015FIGURE No:
B-17



LEGEND:

- Project site
- Carmichael Coal Mine Project
- Major drainage
- Springs
- Cadastre
- Lake

Sensitivity - 1m contour

- Basecase
- Hydraulic conductivity (K) +
- Hydraulic conductivity (K) -
- Conduit fault (K/S)
- Barrier fault (HFB)
- Recharge (Rch) +
- Recharge (Rch) -

- Storage (S) +
- Storage (S) -
- Overburden (K/S/Rch) +
- Overburden (K/S/Rch) -

Project China Stone (G1587)

Sensitivity of maximum zone of depressurisation post mining - Clematis Sandstone



DATE:
24/6/2015

FIGURE No:
B-18

B3.3 Sensitivity classification

The Murray Darling Basin Modelling Guidelines (Middlemis, 2000) recommends classifying parameter sensitivity by the resultant changes to the model calibration and predictions. The four sensitivity types are as follows:

- Type I: Insignificant changes to calibration and predictions;
- Type II: Significant changes to calibration – insignificant changes to predictions;
- Type III: Significant changes to calibration – significant changes to predictions; and
- Type IV: Insignificant changes to calibration – significant changes to predictions.

Types I and II are of no concern as these sensitivities either have an insignificant impact on model predictions. Type III is only of concern for un-calibrated models. Types I to III are of no concern for the current assessment, as the model developed for the project is a well calibrated, high complexity model.

Type IV is classed as ‘a cause for concern’ as non-uniqueness in a model input might allow a range of valid calibrations but the choice of value impacts significantly on a prediction (Middlemis, 2000).

There are no Type IV parameters in the model which provides confidence in the range of predictions.

B4. References

Barnett *et al*, (2012) *“Australian Groundwater Modelling Guidelines”*

Doherty, J. (2010) *“PEST: Model-Independent Parameter Estimation, User Manual”*: 5th Edition, Watermark Numerical Computing.

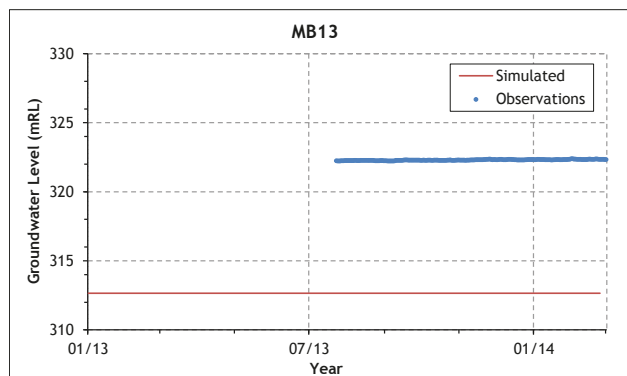
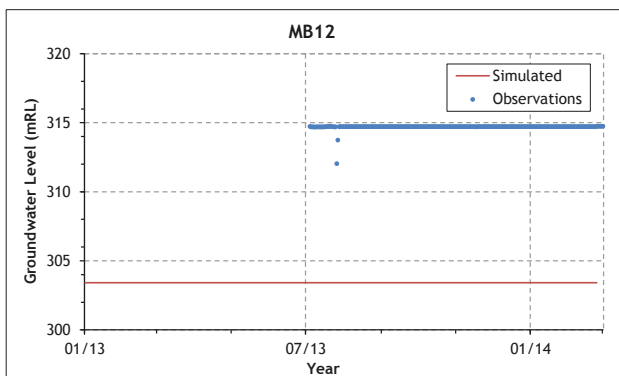
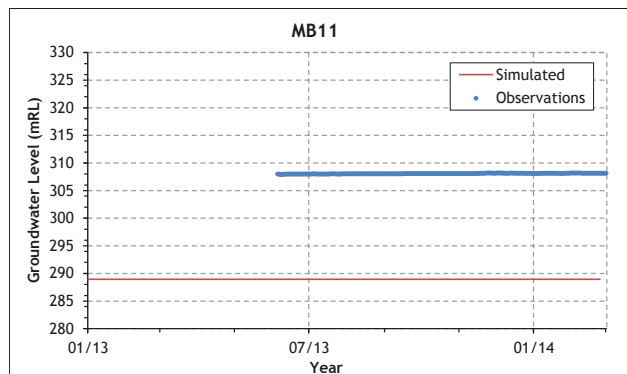
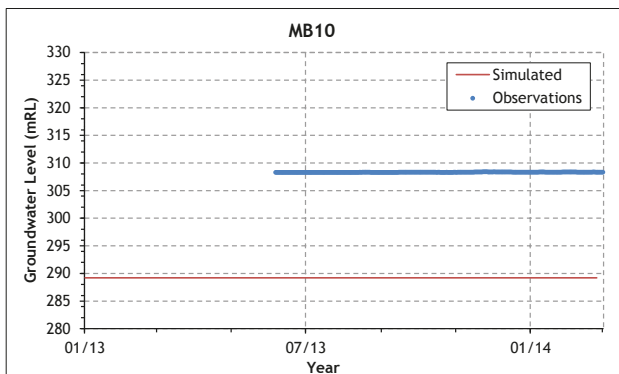
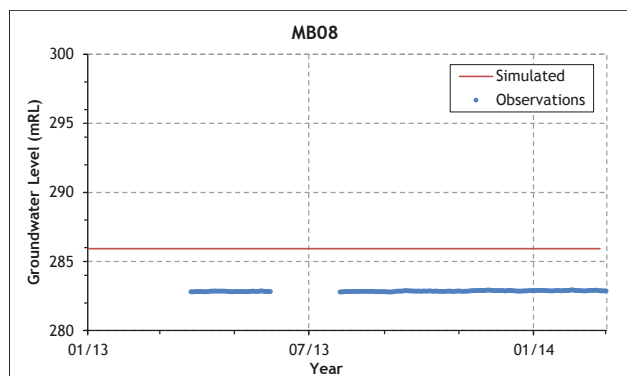
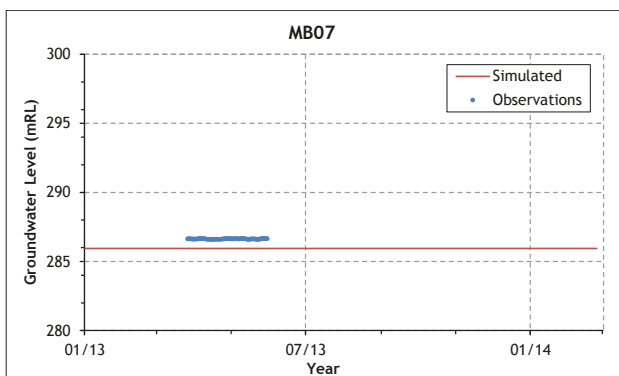
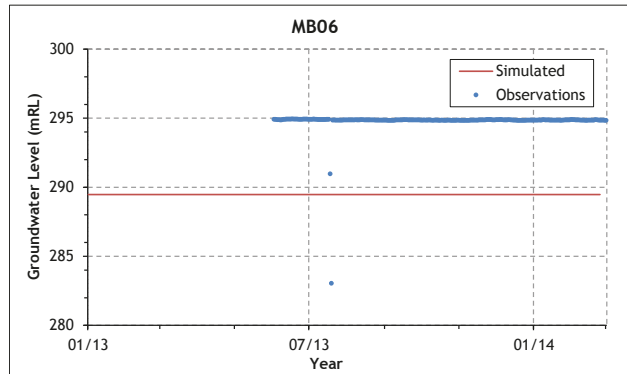
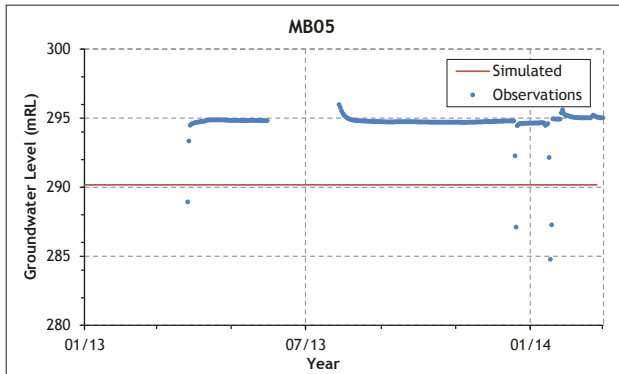
Hill and Tiedeman (2007) *“Effective Groundwater Model Calibration, with Analysis of Data, Sensitivities, Predictions, and Uncertainty”* By Mary C. Hill and Claire R. Tiedeman Published by John Wiley and Sons, New York, in 2007.

Middlemis H. (2000) *“Groundwater Flow Modelling Guideline”* Murray-Darling Basin Commission.

Appendix B-1
Model verification hydrographs

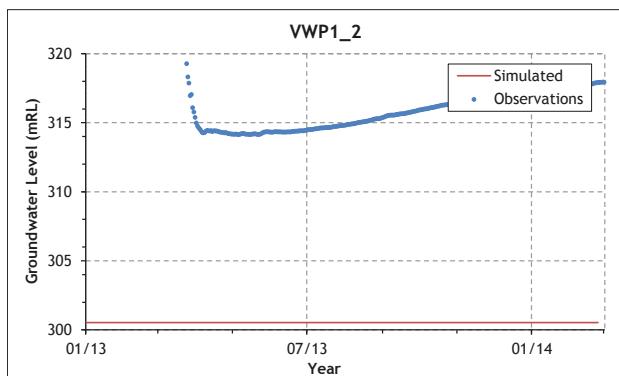
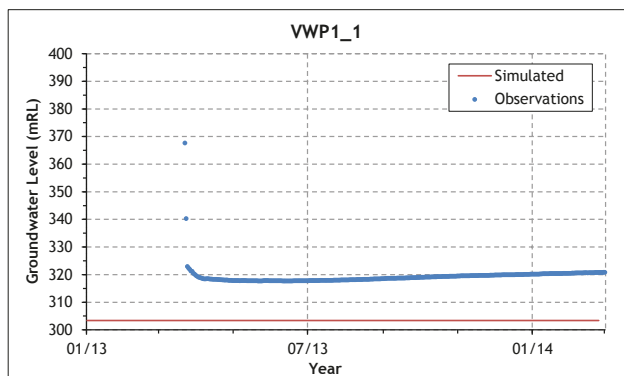
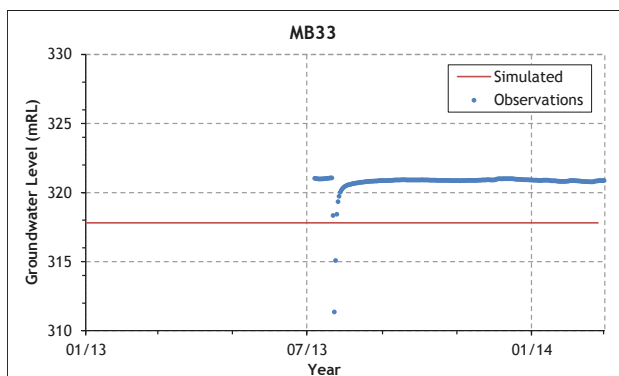
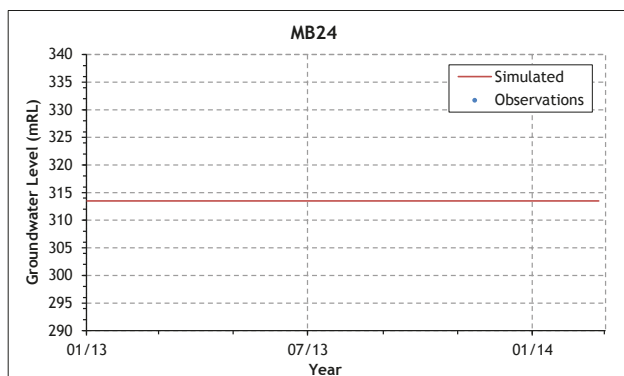
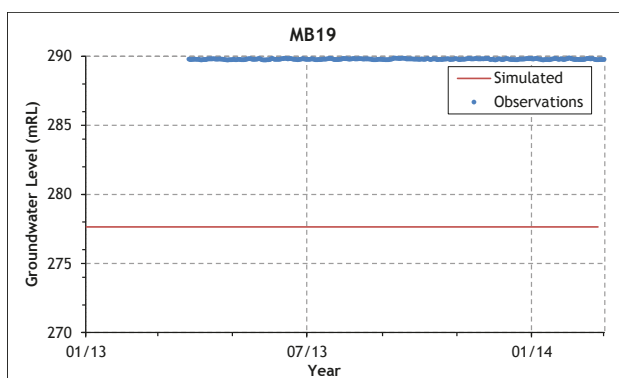
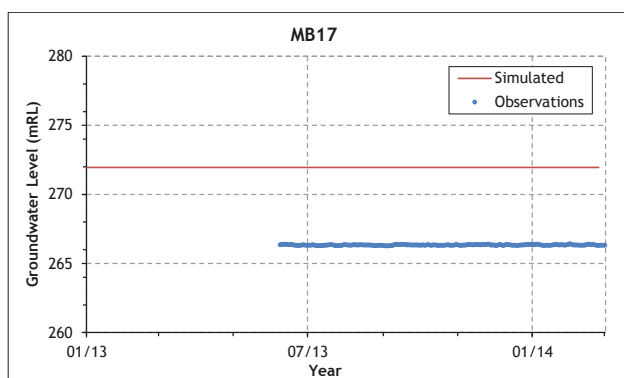
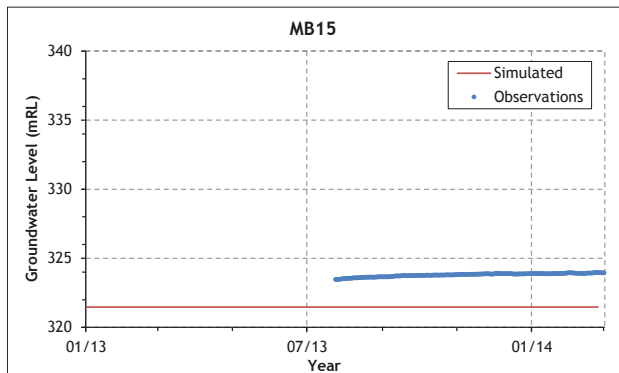
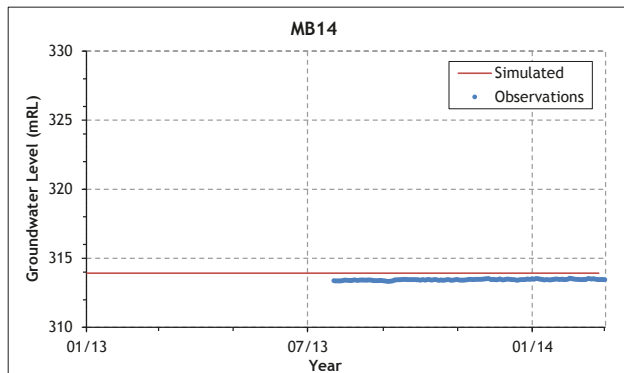


Verification Hydrographs



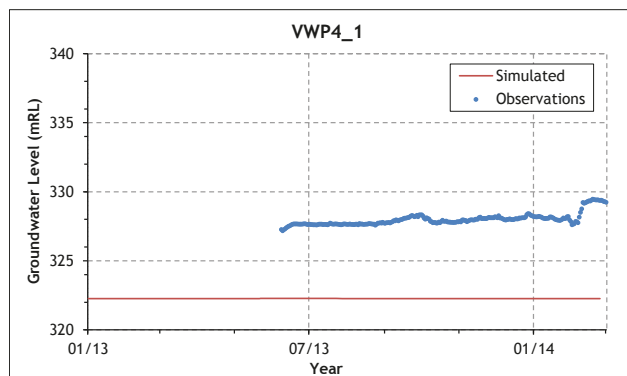
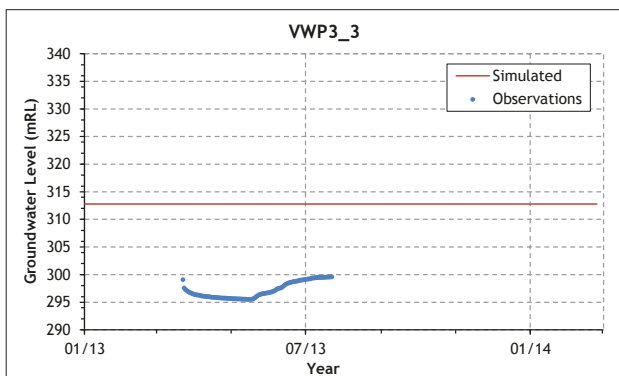
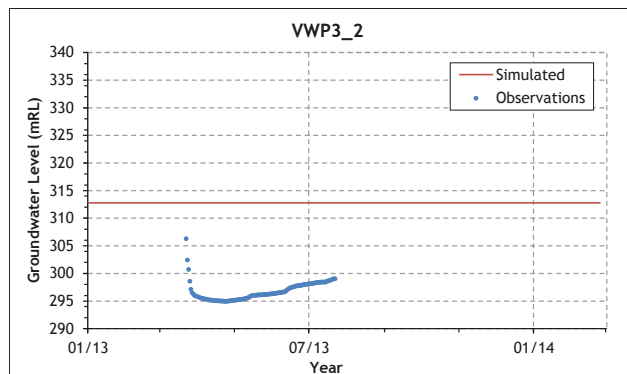
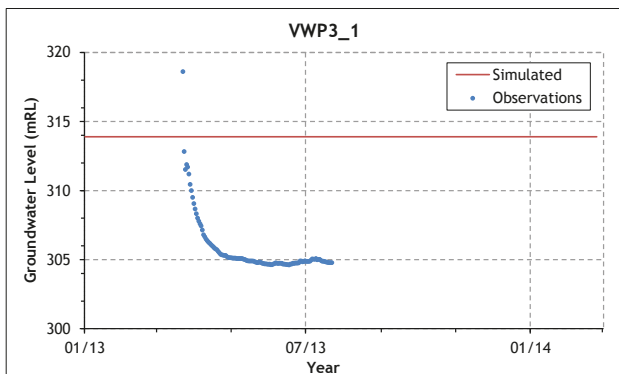
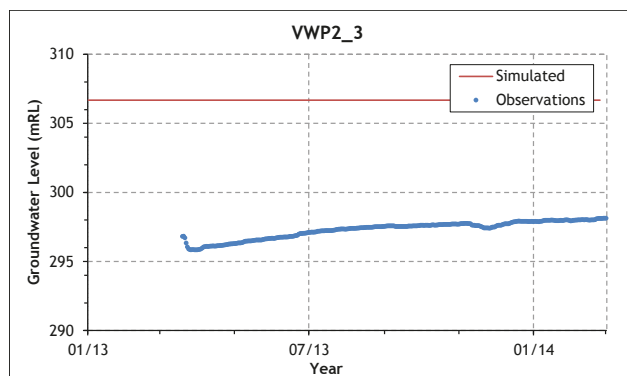
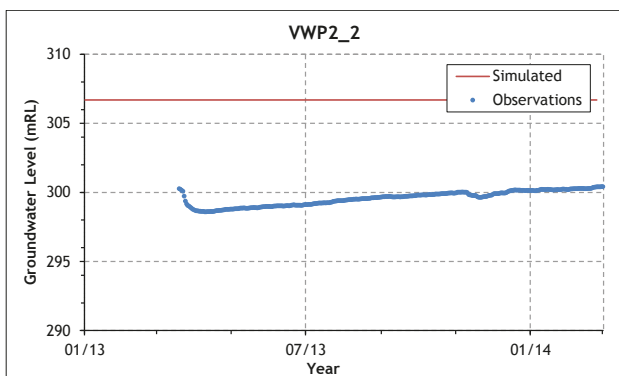
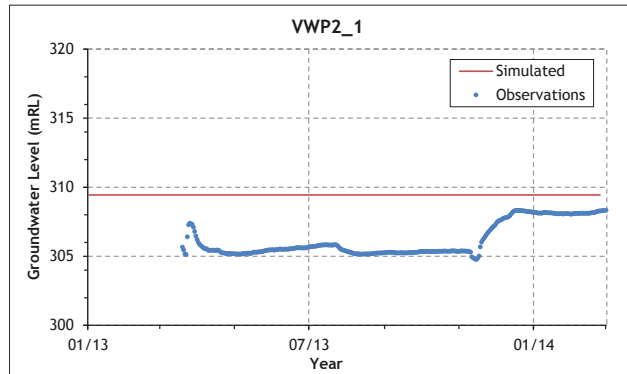
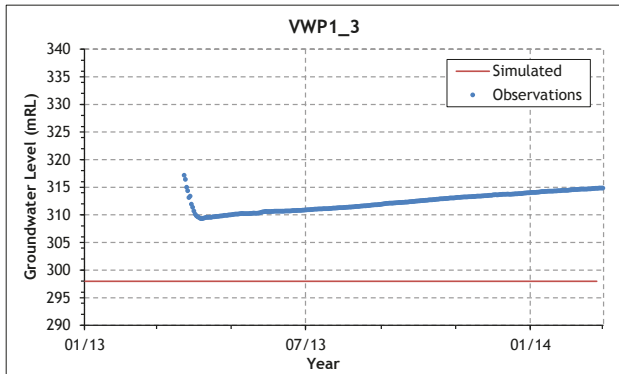


Verification Hydrographs





Verification Hydrographs





Verification Hydrographs

