Australasian Groundwater & Environmental Consultants Pty Ltd

REPORT on

DRAYTON SOUTH COAL PROJECT

GROUNDWATER IMPACT ASSESSMENT

Prepared for
ANGLO AMERICAN METALLURGICAL COAL PTY LTD

Project No. G1544
October 2012

ABN:64 080 238 642

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EXECUTIVE SUMMARY

Drayton Mine is managed by Anglo Coal (Drayton Management) Pty Ltd which is owned by Anglo American. Drayton Mine commenced production in 1983 and currently holds Project Approval 06_0202 (dated 1 February 2008) that expires in 2017, at which time the operation will have to close.

The Project will allow for the continuation of mining at Drayton Mine by the development of open cut and highwall mining operations within the Drayton South mining area while continuing to utilise the existing infrastructure and equipment from Drayton Mine.

The Project is located approximately 10 km north-west of the village of Jerrys Plains and approximately 13 km south of the township of Muswellbrook in the Upper Hunter Valley of New South Wales (NSW). The Project will extend the life of Drayton Mine by a further 27 years ensuring the continuity of employment for its workforce, the ongoing utilisation of its infrastructure, and the orderly rehabilitation of Drayton Mine's completed mining areas.

This groundwater impact assessment was prepared for the Environmental Assessment report to support the application for Project Approval under Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act).

The groundwater impact assessment included a review of previous studies undertaken for the Drayton South area and surrounding mine, conceptualisation of the groundwater regime, development of a finite difference groundwater flow model, and simulation of the impact of the Project on the groundwater regime.

Previous Studies

A number of previous studies have been undertaken at the Drayton South site and surrounding mines. Studies undertaken by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) and for which approvals were obtained included the Mt Arthur Coal South Pit Extension, Bengalla Mine, Wantana Extension and the Drayton Mine Extension. These projects involved development of groundwater flow models and impact simulation. The most recent studies of the Drayton South site were undertaken by Mackie Environmental Research in 1998, 2000, and 2001, being prepared for pre-feasibility assessments.

Aquifer Systems

A review of existing data and reports indicates that the hydrogeological regime of the study area and surrounds consists of:

- A Quaternary alluvial aquifer system associated with the Hunter River and tributary creeks and a smaller alluvial system associated with Saddlers Creek and minor tributaries;
- A thin veneer of weathered bedrock (regolith); and
- The coal seams of the Permian Wittingham Coal Measures.

The Hunter River alluvium is up to 18 m thick and contains a basal gravel layer that is exploited for irrigation and stock supplies in some locations where water quality is sufficiently good. The upper section of the alluvium is predominantly silt with minor portions of clay, while all of the Saddlers

Creek alluvium, which is relatively thin, has a clay dominated composition. The groundwater quality of the alluvial aquifers is variable with the poorest quality water in the basal sections due to discharge from the underlying coal seam aquifers.

The regolith comprising superficial soils and weathered bedrock is approximately 20 m thick and is a temporary groundwater store during sustained wet periods providing recharge to the underlying coal measures.

The Permian strata and coal seam aquifers outcrop in the elevated areas and subcrop beneath the alluvium. They are generally low yielding and contain poor quality water. The water table / potentiometric surface of the Permian aquifers form a subdued reflection of the topography with groundwater flow and discharge to the alluvial areas.

Hydraulic Properties

Numerous testing consisting of packer tests, falling head tests, and core permeability tests have been undertaken during past studies (and this assessment) within the study area to assess the hydraulic properties of the aquifers, overburden and interburden. This data has indicated a representative hydraulic conductivity for the Hunter River alluvium of about 8 m/day, and for the Saddlers Creek alluvium of about 0.8 m/day. The hydraulic conductivity values for the coal seams range from about 2.0×10^{-1} m/day near the surface to about 1.0×10^{-3} m/day at a depth of approximately 300 m. The hydraulic conductivity values for the interburden range from about 8.3×10^{-7} m/day and 3.4×10^{-3} m/day. Results confirm very low values of hydraulic conductivity and a potential for interburden to effectively hydraulically isolate flow between coal seams unless jointing within the unit is present.

Numerical Model

A finite difference numerical model was developed from the conceptualisation of the groundwater flow regime using the MODFLOW SURFACT software package. The model consisted of 18 layers, the upper layer representing the alluvium and weathered bedrock (regolith) and the bottom (base of model layer), representing the Maitland Group. The intermediate layers represent the Permian coal measures, these being individual coal seams separated by interburden. The hydraulic conductivity was reduced continuously with depth to account for the effect of increasing confining stress and the model was calibrated by adjusting the hydraulic conductivity.

Previous numerical modelling results obtained from surrounding mining projects were compared with the results from the Drayton South Project simulations to assess the potential cumulative impacts.

Predictive Simulations

Results of the predictive simulations are summarised below:

- During the 27 year mining period, the modelling indicates the cumulative seepage rate to the open cut voids will be on average 2.4 ML/day inflow. This will vary throughout the mining period with a predicted peak of 4.5 ML/day in Year 10.
- The modelling indicates the zone of depressurisation attributable to the Project will expand to the south, south-west and south-east of the open cut pits and highwall mines, but will be

restricted by outcropping coal measures located towards the east and north, and the Saddlers Creek alluvium towards the north.

- The modelling predicted that there would be a very limited reduction of the seepage flux from the Permian units into the Hunter River alluvium. The maximum reduction in flux to the Hunter River alluvium was predicted to be 0.01 ML/day. This small reduction in flux may not be measureable.
- The modelling also predicted that the seepage flux to the Saddlers Creek alluvium would be reduced by a maximum rate of about 0.2 ML/day. The impact of the Project on flows within Saddlers Creek is expected to be measurable as groundwater base flow to the creek is a measurable contribution to the creeks water balance. The model results indicate a reduction of net flux into the Saddlers Creek alluvium will occur, and when combined with flux impact estimates from neighbouring mines, suggest that flux to the alluvial unit may be reversed.
- Groundwater Dependent Ecosystems (GDEs) identified along the length of Saddlers Creek (east of Edderton Road) may be impacted by reduced availability to groundwater resulting from groundwater drawdown within the alluvial unit.
- Only two existing bores are anticipated to be encompassed within the zone of influence by the Project. These bores are located on land owned by Anglo American and are likely to be destroyed by mining.

Rejects and Tailings Emplacement

At the completion of coal mining operations at Drayton Mine, three voids will remain. It is proposed that water, coarse rejects, and tailings generated at the Coal Handling and Preparation Plant (CHPP) from the Drayton South operation will be deposited in these voids.

Coarse rejects will be trucked from the CHPP, whilst thickened tailings will be pumped via a pipeline and deposited within an allocated void. Decant water recovered in this process will be recycled within the site water management system.

Geochemical assessment of the rejects material indicate that the materials will have a very low risk of generating Acid and Metalliferous Drainage (AMD) and the risk of potential impact on the quality of surface and groundwater from the Project should be low for overburden and coal reject materials, although this finding should be confirmed by the ongoing water quality monitoring program for surface water and groundwater at the site.

Mitigation Options

The Drayton South Mine plan will not encroach within the 150 m buffer zone of the Hunter River alluvium, nor will the mine plan encroach within 40 m of the Saddlers Creek bed or bank, protecting the geomorphic integrity of the stream.

Mitigative measures for any identified negative impacts beyond those predicted, may include replacement in water supply or relinquishment of groundwater or surface water allocations as an offset to monitored leakage from the alluvial aquifers in excess of predictions.

Management of the tailings and rejects emplacement area should include a monitoring program to ensure that key water quality parameters remain within appropriate criteria. A closure strategy for the emplacement areas should also consider options for a cover (i.e. capping) system.

Groundwater Monitoring Program

A groundwater monitoring network has previously been established by Anglo American within the Study area, comprising paired and discrete bores located at 13 sites. All of these sites are regularly monitored for water levels, pH and electrical conductivity. Recently, the monitoring bore network was expanded to include bores located within the Hunter River alluvium and the Saddlers Creek alluvium. In addition, a network of five vibrating wire piezometers was also recently installed across the site to record the pore pressure within individual coal seams and interburden layers.

The expanded groundwater monitoring network consisted of paired bores, one in the alluvium and the second in the underlying Permian strata. The purpose of the bores is to monitor depressurisation and groundwater quality with the objective of quantifying leakage from the alluvial aquifers.

The Drayton Mine currently undertakes a groundwater monitoring program in accordance with their mining approval. This monitoring program will be continued and expanded with addition of the Drayton South groundwater monitoring program. Therefore, a common groundwater monitoring program will be undertaken for the entire complex.

For the areas near the tailings and rejects emplacements, the monitoring program should include the installation of monitoring bores in strategic locations which are capable of detecting the movement of seepage water away from the emplacement areas.

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REPORT ON

DRAYTON SOUTH COAL PROJECT
GROUNDWATER IMPACT ASSESSMENT

1. INTRODUCTION

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has been engaged by Hansen Bailey Environmental Consultants (Hansen Bailey) on behalf of Anglo American Metallurgical Coal Pty Ltd (Anglo American) to complete a groundwater impact assessment for the Drayton South Coal Project (the Project). The purpose of the assessment is to form part of an Environmental Assessment (EA) being prepared by Hansen Bailey to support an application for a contemporary Project Approval under Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to facilitate the continuation of mining at Drayton Mine by the development of an open cut and highwall coal mining operation and associated infrastructure within the Drayton South area.

In October 2011, Part 3A of the EP&A Act was repealed. However, the Project has been granted the benefit of transitional provisions, and as such, is a development to which Part 3A still applies.

The scope of work completed by AGE for the assessment included:

- Reviewing and identifying existing groundwater monitoring networks and resources;
- Designing a suitable drilling and monitoring bore construction program;
- Analysing historical and current groundwater monitoring data;
- Undertaking a detailed modelling and assessment of potential impacts of the Project, including cumulative impacts on groundwater;
- Assessing potential impacts of the Project on Groundwater Dependent Ecosystems (GDEs);
- Assessing the potential for contamination from tailings dam leachate/co-disposed materials to enter and impact on the local and regional groundwater system; and
- Provision of mitigation and management measures to avoid or minimise the impacts on groundwater.

1.1 Project Description

Drayton Mine is managed by Anglo Coal (Drayton Management) Pty Ltd which is owned by Anglo American. Drayton Mine commenced production in 1983 and currently holds Project Approval 06_0202 (dated 1 February 2008) which expires in 2017, at which time the operation will have to close. The Project will allow for the continuation of mining at Drayton Mine by the development of open cut and highwall mining operations within the Drayton South mining area while continuing to utilise the existing infrastructure and equipment from Drayton Mine.

The Project is located approximately 10 km north-west of the village of Jerrys Plains and approximately 13 km south of the township of Muswellbrook in the Upper Hunter Valley of New South Wales (NSW). The Project is predominately situated within the Muswellbrook Shire Local Government Area (LGA), with the south-west portion falling within the Singleton LGA. Drawing No. 1 illustrates the regional locality of the Project. The Project is located adjacent to two thoroughbred horse studs, two power stations and several existing coal mines.

The Project will extend the life of Drayton Mine by a further 27 years ensuring the continuity of employment for its workforce, the ongoing utilisation of its infrastructure and the orderly rehabilitation of Drayton Mine's completed mining areas. Anglo American is seeking Project Approval under Part 3A of the EP&A Act to facilitate the extraction of coal by both open cut and highwall mining methods within Exploration Licence (EL) 5460 for a period of 27 years. The Project Application Boundary (Project Boundary) is shown on Figure 1.

The Project generally comprises:

- The continuation of operations at Drayton Mine as presently approved with minor additional mining areas within the East, North and South Pits;
- The development of an open cut and highwall mining operation extracting up to 7 Mtpa of ROM coal over a period of 27 years;
- The utilisation of the existing Drayton Mine workforce and equipment fleet (with an addition of a highwall miner and coal haulage fleet);
- The Drayton Mine fleet consists of at least a dragline, excavators, fleet of haul trucks, dozers, graders, water carts and associated supporting equipment;
- The use of the Drayton Mine existing voids for rejects and tailings disposal and water storage to allow for the optimisation of the Drayton Mine final landform;
- The utilisation of the existing Drayton Mine infrastructure including the Coal Handling and Preparation Plant (CHPP), rail loop and associated loadout infrastructure, workshops, bath houses and administration offices;
- The construction of a transport corridor between Drayton South and Drayton Mine;
- The utilisation of the Antiene Rail Spur off the Main Northern Railway to transport product coal to the Port of Newcastle for export;
- The realignment of a section of Edderton Road; and
- The installation of water management and power reticulation infrastructure at Drayton South.

The conceptual layout of the Project is shown in Figure 1.

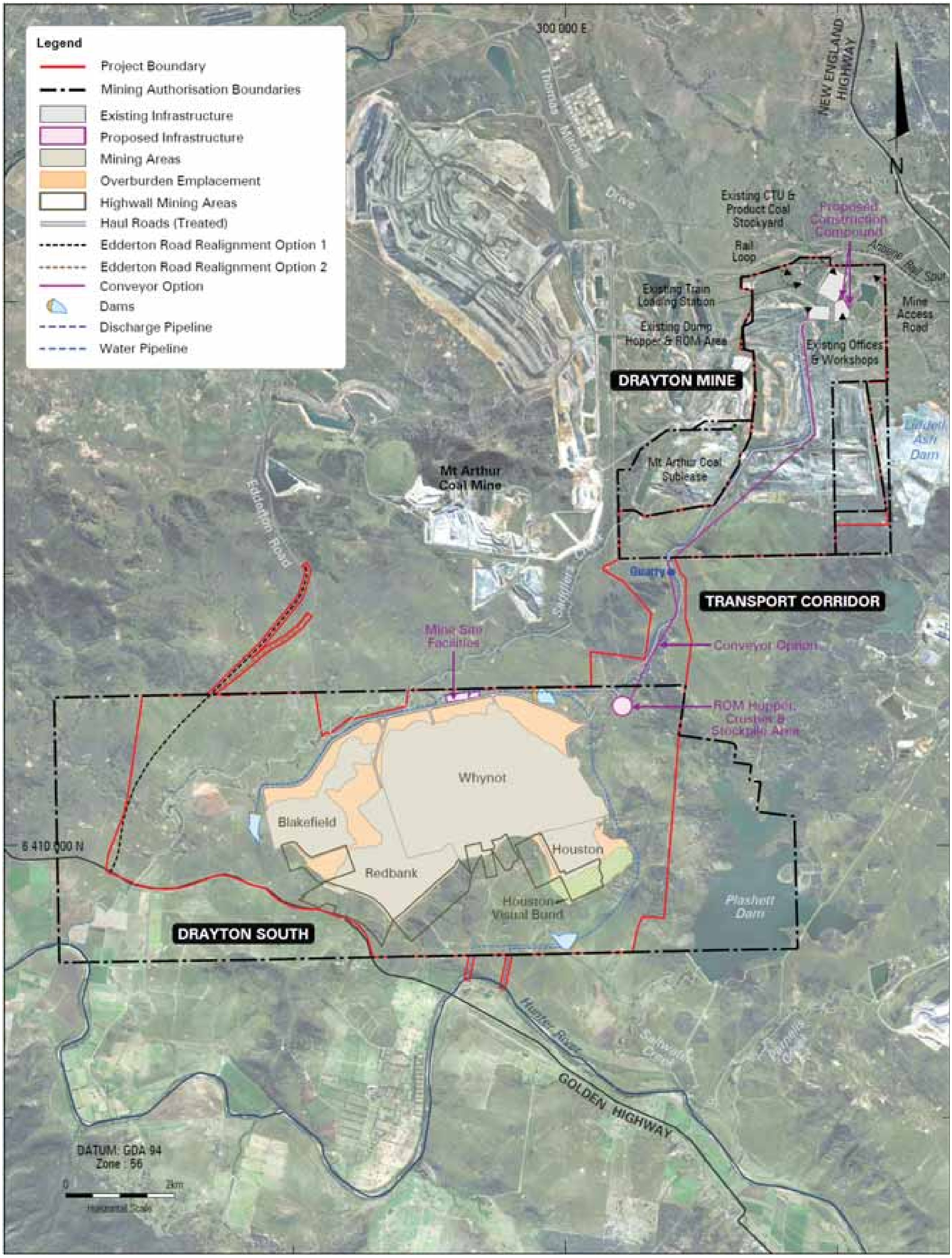

Figure 1: Conceptual Project Layout

Source: Hansen Bailey, 2011

1.2 Study Area

The Project Boundary comprises an overall area of approximately 6,092 ha (Figure 1) and includes the proposed Drayton South disturbance footprint, Drayton Mine and the transport corridor.

The study area, including the groundwater flow model upon which the impact assessment is based, extends beyond the Project Boundary and encapsulates an area commensurate with the regional groundwater flow regime (see Drawing No. 13).

1.3 Related Studies

The studies which are to be read in conjunction with this assessment include the following:

- The EA surface water impact assessment;
- The EA ecology impact assessment;
- The EA stygofauna impact assessment;
- The EA agricultural impact statement;
- The EA soil and land capability impact assessment; and
- The EA geochemistry impact assessment.

2. LEGISLATION, POLICY AND GUIDELINES

The following section outlines NSW State Government legislation, policy and guidelines with respect to groundwater that must be addressed in the assessment and operation of mining proposals.

2.1 Water Act 1912

The *Water Act 1912* (Water Act) governs the issue of water licences from water sources including rivers, lakes and groundwater aquifers in NSW. It also manages the trade of water licences and allocations.

The Water Act is progressively being replaced by the *Water Management Act 2000* (WM Act), but some provisions of the Water Act are still in force where water sharing plans are not in place. This is the case in the bedrock outcrop area where the Project is located.

Two water sharing plans have commenced for the Hunter River and associated alluvial aquifers, surface water, and other groundwater sources that surround the Project. Water access licences and approvals to take and use water are granted according to the WM Act.

2.2 Water Management Act 2000

The objectives of the WM Act include the sustainable and integrated management of the State's water for the benefit of both present and future generations. The WM Act provides clear arrangements for controlling land based activities that affect the quality and quantity of the State's water resources. It provides relevantly for three types of approvals:

- Management works approvals:
    - water supply work approval;
    - drainable work approval; and
    - flood work approval (Section 90 WM Act)
- *Water use approval – which authorises the use of water at a specified location for a particular purpose, for up to 10 years (Section 89 WM Act);*
- *Activity approvals comprising:*
    - controlled activity approval; and
    - aquifer interference activity approval – which authorises the holder to conduct *activities that affect an aquifer such as approval for activities that intersect groundwater, other than water supply bores and may be issued for up to 10 years (Section 91 WM Act).*

The WM Act requires that the activities avoid or minimise their impact on the water resource and land degradation, and where possible the land must be rehabilitated (see the "Water Management Principles" set out in Section 5 of the WM Act).

2.3 Water Sharing Plans

2.3.1. Hunter Regulated River Water Sharing Plan

The Hunter Regulated River Water Sharing Plan 2003 (HRRWSP) commenced on 1st July 2004 and applies for a period of 10 years to 30 June 2014. It is a legal document made under the WM Act.

The HRRWSP contains rules for how water is shared between the environment and water users and different categories of licences.

The Hunter River water source is located in the central eastern area of NSW and drains an area of some 17,500 km^2. The Hunter River rises in the Mount Royal Range north east of Scone and travels approximately 450 km to the sea at Newcastle. The river is regulated from Glenbawn Dam to Maitland, a distance of about 250 km. Glennies Creek is regulated by Glennies Creek Dam, which also provides water to the lower reaches of the Hunter River. The area to which the WSP applies is shown on Figure 2.

The HRRWSP applies to rivers (and associated alluvial sediments) regulated by Glenbawn and Glennies Creek Dams. The water source is divided into three management zones. These are:

- The Hunter River from Glenbawn Dam to its junction with Glennies Creek;
- The Hunter River downstream of its junction with Glennies Creek; and
- Glennies Creek downstream of Glennies Creek Dam.

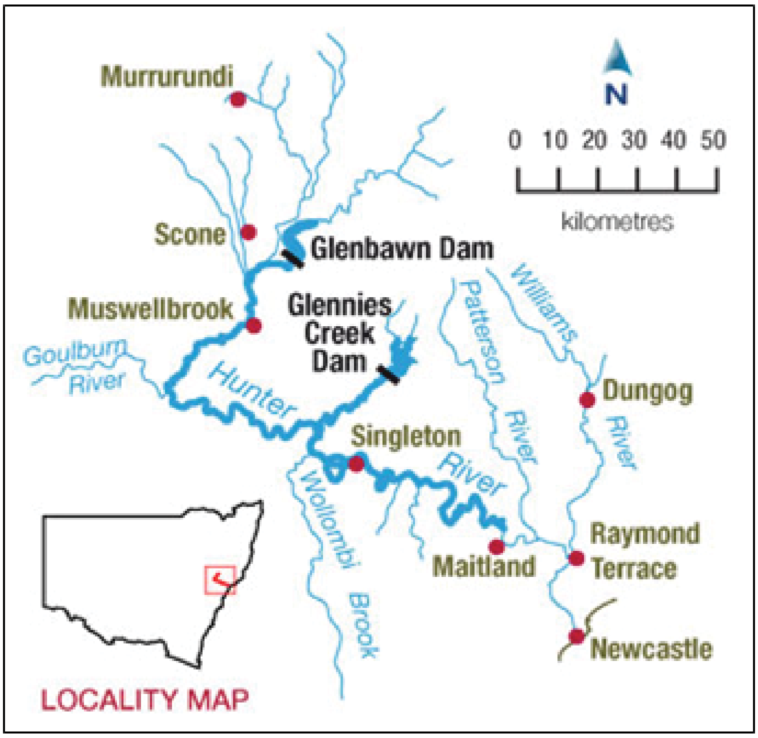

Figure 2: Locality Map for the Hunter Regulated River Water Sharing Plan

Source: NOW, 2011

The study area is located within the first Hunter River management zone listed above; this being the Hunter River from Glenbawn Dam to its junction with Glennies Creek.

The vision for the HRRWSP is to achieve a healthy diverse and productive water source and sustainable management for the community, environment, towns, agriculture and industry. The HRRWSP also recognises the significance of water to the Aboriginal community.

The WM Act requires that the sharing of water must protect the water source and its dependent ecosystems and that water sharing plans establish specific environmental water rules. The environmental water rules are designed to:

- *Reserve all water volume above a specified limit for the environment;*
- *Ensure that flows in the river do not drop below a prescribed minimum flow rate;*
- *Provide water in Glenbawn and Glennies Creek Dams that can be used for water quality and other environmental management purposes; and*
- *Preserve a portion of natural flows during periods when supplementary water access licences are permitted to extract water.*

The HRRWSP provides for domestic and stock rights and native title rights – both forms of basic landholder rights which allow some extraction of water from the river without an access licence. All water extraction, other than basic landholder rights extractions, must be authorised by an access licence.

2.3.2. Hunter Unregulated and Alluvial Water Sources Water Sharing Plan

The Hunter Unregulated and Alluvial Water Sources Water Sharing Plan (HUAWSP) commenced on 1 August 2009 and applies for a period of 10 years to 31 July 2019. It is a legal document made under the WM Act. The area to which the HUAWSP applies is shown on Figure 3.

Figure 3: Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources
Source: NOW, 2011

Water sharing plans for unregulated rivers and groundwater systems (such as the HUAWSP) have been completed using a "macro" or broader scale river catchment or aquifer system approach. Unregulated rivers are those which rely only on natural flow and are not regulated by releases from upstream dams.

The HUAWSP set rules for sharing water between the environment and water users and clearly defines shares in available water for licence holders, enabling better water trading opportunities. Water sharing plans support the long-term health of rivers and aquifers by making water available specifically for the environment.

With respect to groundwater, macro water sharing plans for unregulated rivers may include rules that recognise that some alluvial aquifers are highly connected to their parent streams and in these circumstances, the goal of water sharing rules is to manage the surface water and highly connected groundwater as one resource.

A long term average annual extraction limit referred to as the Extraction Management Unit (EMU) applies across an entire catchment area. The limit is a longer term management tool against which total extraction will be monitored and managed over the 10-year life of the plan. The rules in the plan that determine when licence holders can and cannot pump on a daily basis are more specific. Basic landholder rights (i.e. extraction of a "reasonable use" volume of surface or groundwater for stock or domestic supply) do not require a water access licence, however, water access licences are required for mining activities where these activities intercept an unregulated river or connected aquifer water.

The water source of Saddlers Creek and the alluvial aquifers associated with Saddlers Creek are regulated by the HUAWSP. They are contained within the Jerrys management zone.

2.4 State Groundwater Policy

The NSW State Government Groundwater Policy Framework Document (1997) was adopted in 1997 for the purpose of providing a framework for the management of the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three parts, namely the:

- NSW Government (1998a) Groundwater Quality Protection Policy, adopted in December 1998;
- NSW Government (2002) State Groundwater Dependent Ecosystems Policy, adopted in 2002; and
- NSW Government (undated) Groundwater Quantity Management Policy advice.

2.4.1. Groundwater Quality Protection Policy

The NSW Groundwater Quality Protection Policy (1998), states that the objectives of the policy will be achieved by applying the management principles listed below:

- *All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained.*
- *Town water supplies should be afforded special protection against contamination.*
- *Groundwater pollution should be prevented so that future remediation is not required.*
- *For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource.*
- *A groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwaters that are incompatible with soil, vegetation and receiving waters.*
- *Groundwater dependent ecosystems will be afforded protection.*
- *Groundwater quality protection should be integrated with the management of groundwater quality.*
- *The cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource.*
- *Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.*

2.4.2. Groundwater Dependent Ecosystems Policy

The NSW Groundwater Dependent Ecosystems Policy is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines GDEs as *"communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater"*.

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. The principles are:

- *Groundwater Dependent Ecosystems can have important values. Threats should be identified and action taken to protect them;*
- *Groundwater extractions should be managed within the sustainable yield of aquifers;*
- *Priority should be given to Groundwater Dependent Ecosystems, such that sufficient groundwater is available at all times to meet their needs;*
- *Where scientific knowledge is lacking, the precautionary principle should be applied to protect Groundwater Dependent Ecosystems; and*
- *Planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater ecosystems where necessary.*

2.4.3. Groundwater Quantity Protection Policy

The objectives of managing groundwater quantity in NSW are:

- *To achieve the efficient, equitable and sustainable use of the State's groundwater;*
- *To prevent, halt and reverse degradation of the State's groundwater and their dependent ecosystems;*
- *To provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and*
- *To involve the community in the management of groundwater resources.*

2.4.4. NSW Aquifer Interference Policy

An *Aquifer Interference Policy* (AIP) has been developed by the NSW Government as a component of the Strategic Regional Land Use Policy. The aim of the policy is to create a balance between agricultural, mining and energy sectors, while ensuring the protection of high value conservation lands.

The AIP was on public exhibition from Thursday 8 March to Thursday 3 May 2012. Following consultation with the community, the policy was finalised and new regulations made. The final AIP has been applied state wide to clarify water licence and approval requirements for aquifer interference activities.

The WM Act defines an aquifer interference activity as that which involves any of the following:

- *The penetration of an aquifer;*
- *The interference with water in an aquifer;*
- *The obstruction of the flow of water in an aquifer;*
- *The taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and*
- *The disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.*

Examples of aquifer interference activities include mining, coal seam gas extraction, injection of water, and commercial, industrial, agricultural and residential activities that intercept the water table or interfere with aquifers.

According to the WM Act, an aquifer is defined as a geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water. This is at odds with the commonly used definition, which refers to an aquifer as a groundwater system that is sufficiently permeable to yield productive volumes of groundwater. The definition of an aquifer provided by the WM Act is more consistent with the term groundwater system, which refers to any type of saturated geological formation that can yield low to high volumes of water. The Policy states that "*all water taken by aquifer interference activities, regardless of quality, needs to be accounted for within the extraction limits defined by the water sharing plans. A water licence is required under the WM Act (unless an exemption applies or water is being taken under a basic landholder right) where any act by a person carrying out an aquifer interference activity causes:*

- *The removal of water from a water source; or*
- *The movement of water from one part of an aquifer to another part of an aquifer; or*
- *The movement of water from one water source to another water source, such as:*
    - *from an aquifer to an adjacent aquifer; or*
    - *from an aquifer to a river/lake; or*
    - *from a river/lake to an aquifer.*

The AIP requires assessment of the likely volume of water taken from a water source(s) as a result of an aquifer interference activity. These predictions need to occur prior to Project approval. After Project approval and during operations, these volumes need to be measured and reported in annual environmental management reports (AEMR). The water access licence must hold sufficient share component and water allocation to account for the take of water from the relevant water source at all times.

The Policy states that a water licence is required for the aquifer interference activity regardless of whether water is taken directly for consumptive use or incidentally. Activities may induce flow from adjacent groundwater sources or connected surface water. Flows induced from other water sources also constitute take of water. In all cases, separate access licences are required to account for the take from all individual water sources.

In water sources where water sharing plans do not yet apply, an aquifer interference activity that takes groundwater is required to hold a water licence under the Water Act 1912. It is possible for the Water Act 1912 to apply in a groundwater source and the WM Act to apply in a connected surface water source or vice versa. Where this occurs and the aquifer interference activity is taking water from both water sources, then licences will be required under each Act.

In addition to the volumetric water licensing considerations, the following information needs to be considered to enable assessment and approval of the activity:

- *establishment of baseline groundwater conditions including groundwater depth, quality and flow based on sampling of all existing bores in the area;*
- *a strategy for complying with any water access rules applying to relevant categories of water access licences, as specified in relevant water sharing plans;*
- *details of potential water level, quality or pressure drawdown impacts on nearby water users who are exercising their right to take water under a basic landholder right;*
- *details of potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources;*

- *details of potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems;*
- *details of potential for increased saline or contaminated water inflows to aquifers and highly connected river systems;*
- *details of the potential to cause or enhance hydraulic connection between aquifers;*
- *details of the potential for river bank instability, or high wall instability or failure to occur.*

In particular, the AIP describes minimal impact considerations for aquifer interference activities based upon whether the water source is “highly productive” or “less productive” and whether the water source is alluvial or porous / fractured rock in nature. In general, the policy applies a predicted 2 m drawdown maximum limit at existing groundwater users.

Highly productive groundwater is defined as a groundwater source that is declared in the Regulations and will be based on the following criteria:

a) *has total dissolved solids of less than 1,500 mg/L, and*

b) *contains water* supply works that can yield water at a rate greater than 5 L/sec.

Highly productive groundwater sources are further grouped by geology into alluvial, coastal sands, porous rock, and fractured rock. “Less productive” groundwater includes aquifers that cannot be defined as “highly productive” according the yield and water quality criteria.

The Hunter River alluvium adjacent to the project is considered to fit within the “highly productive” category, while the Saddlers Creek alluvium and the Permian coal measures fit within the “less productive” category. The aquifer interference policy defines the following Minimal Impact Considerations for “highly productive” and less productive groundwater. Table 1 summaries the Minimal Impact Considerations for the “highly productive” Hunter River alluvium, and the “less productive” Saddlers Creek alluvium and the Permian coal measures. If these considerations are not met, the Project needs to demonstrate to the Minister’s satisfaction that the impact will be sustainable, or that “make good agreements” are in place.

Table 1: SUMMARY MINIMAL IMPACT CONSIDERATIONS – AQUIFER INTERFERENCE POLICY

Category	**1. Water Table**	**Water Pressure**	**Water Quality**
Highly productive alluvium – Hunter River Alluvium	1. Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a 2 m decline cumulatively at any water supply work.	1. A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2 m decline, at any water supply work.	1. (a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity; and (b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected(3) surface water source that is defined as a "reliable water supply"(4) is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above. (c) No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply". (d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a "reliable water supply"
Less productive Saddlers Creek Alluvium and Permian Coal Measures		A cumulative pressure head decline of not more than a 2 m decline, at any water supply work.	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.

2.4.5. NSW Aquifer Interference Policy Assessment Framework

The NOWs assessment of impacts and subsequent advice and proposed conditions of approval for a project is based on an "*account for, mitigate, avoid/prevent, and remediate*" approach. NOW's methodology is based on "*a risk management approach to assessing the potential impacts of aquifer interference activities, where the level of detail required to be provided by the proponent is proportional to a combination of the likelihood of impacts occurring on water sources, users and dependent ecosystems and the potential consequences of these impacts*."

For Project approval, the following key issues would need to be addressed in order for NOW to grant an aquifer interference approval.

Water Licences

Demonstrate ability to obtain necessary licences in order to account for the take of water from relevant water sources. If "... *necessary licence entitlements cannot easily be obtained ... include mitigation or avoidance strategies in order to reduce the take of water to a point where it can be accounted for*" (page 11 of the AIP).

Prevent Take

Demonstrate that the Project has been "… *designed in such a way as to prevent the take of water"* if there is inability to meet the above requirement (see page 11 of AIP).

Prevent Any More than "*Minimal Harm"*

Demonstrate the Project has *"… adequate arrangements in place to ensure that the minimal impact considerations can be met".* The minimal impact considerations are listed above in Table 1.

Remedial Action

Demonstrate that the "… *proposed remedial actions for impacts greater than those that were predicted as part of the relevant approval. The requirement for remedial actions may occur where modelled predictions were inaccurate or where planned mitigation, prevention or avoidance strategies have failed. The assessment will include:*

a) consideration of the potential types and risks of unforeseen impacts that may occur during the operational phase or post-closure of the aquifer interference activity; and

b) whether the proposed mitigation, prevention or avoidance strategies will minimise these risks; and

c) whether the proposed remedial actions are adequate, should the proposed risk minimisation strategies in (b) fail; and

d) advice on what further mitigation, prevention, avoidance or remedial actions may be required; and

e) appropriate conditions that maintain any mitigation, prevention, avoidance or remediation actions until they are no longer required to keep the impacts at or below the predicted levels.

The AIP assessment criteria are addressed by this assessment in the sections outlined in Table 2.

Table 2: ASSESSMENT CRITERIA PROPOSED UNDER THE AQUIFER INTERFERENCE POLICY	
Assessment Criteria	**Section Reference**
1. Water Licenses	
Discussion of predicted groundwater inflow to mining areas	9.2
Discussion of predicted groundwater loss from alluvial aquifers	9.6
Description of required water licences and allocations	11.0
2. Prevent Take	
Description of mine plan and discussion of alluvial area avoidance	7.0
3. Prevent Any More than "*Minimal Harm*"	
(a) water level or pressure drawdown and impacts on nearby water users	9.3, 9.4, and 9.5
(b) water level drawdown and related impacts on surface and ground water dependent ecosystems	6.1.6, 9.6, 9.7 and the EA ecology and stygofauna impact assessment
(c) for acidity issues to arise	9.8 and 10.5
(d) for waterlogging or water table rise to occur	9.3 and 9.4
(e) the occurrence of significant levels of aquifer compaction and the extent to which this will result in permanent loss of groundwater storage and yield from the entire aquifer	Not applicable to the open cut mining scenario proposed for the Project
(f) deterioration of ambient water quality	9.8, 10.5, and 10.6
(g) river bank instability	2.6 and 7.0
(h) significant soil erosion	Refer to EA soil and land capability impact assessment
4. Remedial Action	
Details of proposed monitoring programs	12.0
Details of reporting procedures for monitoring programs	12.7
Assessment of aquifer sterilisation	9.11
Details of monitoring frequency and deriving trigger levels	12.3 and 12.4
Discussion of potential remedial measures	12.9

2.5 Aquifer Risk Categories

In mid-1997, the NSW Government announced a series of water reforms which included an assessment of the State's groundwater systems in terms of risk of over extraction and/or contamination. Aquifers at high risk were to have priority management attention with groundwater management plans started immediately. Those at medium risk were to have plans prepared over a five-year period. Those in the low risk category were to be regularly reviewed and steps taken to prevent them from becoming stressed.

The ultimate aim of the reforms was:

- To achieve clean and healthy groundwater systems (and rivers) and productive use of water by providing:
  - Better balance in sharing water between the environment and water users;
  - Better clarity of access and use rights for water; and
  - A water transfer market that will facilitate reallocation of water to its highest valued use.

The NSW Government Aquifer Risk Assessment Report (1998b)[1] used a number of criteria to classify risks to various significant groundwater resources across the State. It classified the regulated reaches of the Hunter Valley Alluvium as a 'High Risk Aquifer', the Hunter Miscellaneous Tributaries Alluvium as 'Medium Risk Aquifers', and the Hunter Coal-Associated Fractured Rocks as 'Low Risk Aquifers'.

The aquifer classification process was designed as a rapid desktop assessment of the (then) current and potential future stress of groundwater systems. The reported findings were designed to aid resource planning and prioritisation of action for aquifers across NSW.

2.6 Buffer Zone Guidelines

Guidelines were prepared for the Hunter Region in April 2005, by the Department of Infrastructure, Planning and Natural Resources (DIPNR 2005[2]) (now the Department of Planning and Infrastructure) to assist the coal mining industry in managing risks when mining close to streams using either longwall or open cut mining methods. The guidelines relate to the classification of the stream that may be impacted by mining.

The guidelines provide a range of assessment and management criteria for each stream classification. This range is developed on the basis of:

- *A checklist for minor stream systems (Schedule 1) with monitoring and remediation procedures to minimise the extent of damage which occurs to them;*
- *A notification system for significant stream systems (Schedule 2) to the department, so that an agreed monitoring and management regime can be developed for the stream system involved; and*
- *A precautionary stance for primary rivers (Schedule 3), subject to environmental assessment which can demonstrate that the impact on those rivers and associated alluvial groundwaters can be minimised.*

2.6.1. Hunter River System

Based on the management guidelines, the Hunter River system is classified as a Schedule 3 stream/river. The guideline document indicates that the NSW Office of Water (NOW) is adopting a precautionary approach to mining in the vicinity of Schedule 3 streams and associated alluvial groundwater, involving a buffer between the mining area and the stream. The guideline states that '*the buffer provides a front line protection for surface and groundwater quality and managing connectivity'*.

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[1] NSW Department of Land and Water Conservation, (April 1998), "*Aquifer Risk Assessment Report*", HO/16/98.

[2] Department of Infrastructure, Planning and Natural Resources, (April 2005), "*Management of Stream/Aquifer Systems in Coal Mining Developments, Hunter Region*". Guidelines Ver. 1.

The management guideline requires a buffer of 150 m between an open cut mining area and the stream and its related alluvium, as shown on Figure 4. The guideline states that '*this buffer should be used except where detailed assessment, developed to the department standard, indicates minimal likely impact on stream flow, stability or water quality in surface or groundwaters will occur*'.

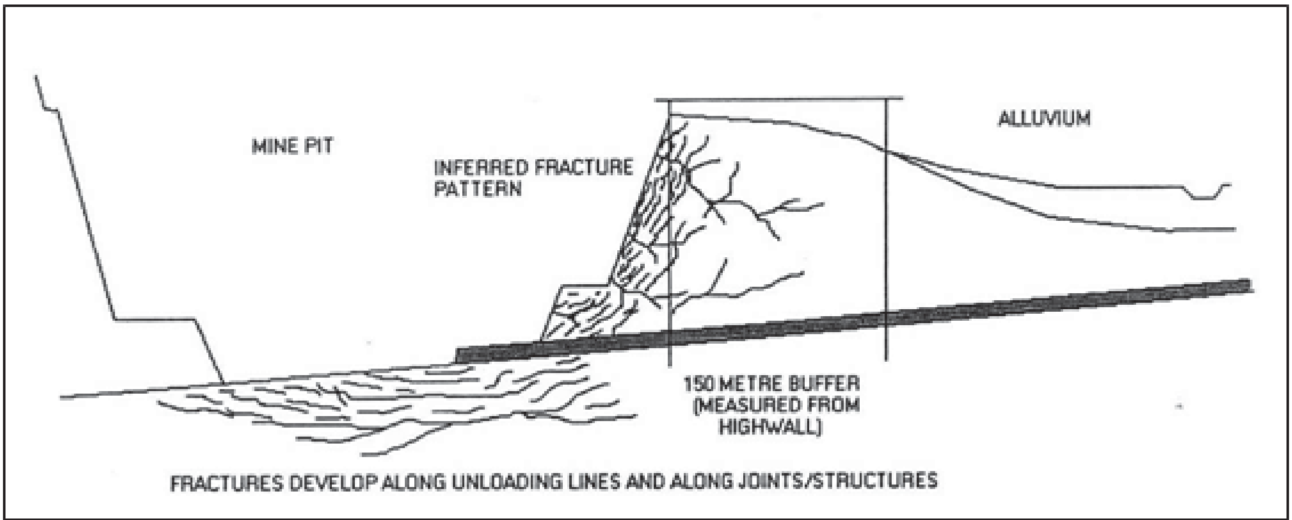

Figure 4: Buffer Zone Requirement for Open Cut Mining Operations Next to Rivers / Alluvium

Source: DIPNR Hunter Region, 2005

The management guidelines indicate that mining would not be allowed to impact the groundwater or surface waters of the Hunter River and that a buffer would be required between open cut mines and the alluvium.

Based on the April 2005 guideline[2] and Schedule 3 stream classification for the Hunter River, it is assessed that open cut mining will not be permitted within the Hunter River alluvial plain. Figure 1 illustrates that the Project will not encroach within 150 m of the Hunter River alluvial plain.

2.6.2. Saddlers Creek

Saddlers Creek drains a relatively small catchment in comparison to the Hunter River. The alluvial system associated with this creek system is much less extensive compared to the Hunter River alluvium.

It is assessed that Saddlers Creek (and associated alluvium) would be classified according to the guidelines as possibly a Schedule 2, or more likely, as it does not have a permanent flow, a Schedule 1 stream.

The guidelines state that for Schedule 2 streams:

- *Operators are responsible to develop open cut mine plans, which prevent damage or degradation to Schedule 2 stream systems; and*
- *A general outcome is sought by the department for any activity, which includes subsidence, fracture development, longitudinal gradient changes, bed or bank alterations or the construction of any works within 40 metres of a Schedule 2 stream. This outcome is that the geomorphic integrity of the stream will be maintained, the ecosystem habitat values of the stream will be protected, and no significant alteration of water quality will occur in the stream.*

The guidelines state that for Schedule 1 streams:

- *The general outcome to be expected of mining companies is that Schedule 1 streams will maintain their geomorphic integrity without degradation into the post-mining period.*

Figure 1 illustrates that the Project will not encroach within 40 m of the Saddlers Creek bed or bank. This protects the geomorphic integrity of the stream maintains the stability of the banks.

2.7 Director-General's Requirements

The Director-General of the Department of Planning and Infrastructure required the water component of the EA to assess the following:

1. *A detailed site water balance for the Drayton complex as proposed, including a description of site water demands (including access to any flows within the Hunter Regulated River source), water disposal methods, water supply infrastructure and water storage structures;*
2. *A detailed modelling and assessment of the potential impacts of the project on:*
    a. *The quantity and quality of existing surface and ground water resources;*
    b. *Affected licensed water users and basic landholder rights;*
    c. *The riparian, ecological, geomorphological and hydrological values of watercourses both on site and downstream of the project;*
    d. *Environmental flows;*
    e. *Flooding; and*
    f. *Agriculture.*
3. *A detailed description of the proposed water management system for the Drayton complex as proposed (including all infrastructure and storages);*
4. *A detailed description of measures to minimise all water discharges; and*
5. *A detailed description of measures to mitigate surface water and groundwater impacts (including a comprehensive rehabilitation plan for Saddlers Creek).*

The specific requirements of the Muswellbrook Shire Council were as follows:

- *The environmental assessment should include an assessment on the hydrology and water quality of this creek (Saddlers Creek). This shall include, but not limited to, identification of temporary, or permanent, changes to the catchment; assessment of the impacts thereof; and propose mitigation measures.*

The specific requirements of the NOW were as follows:

- *The EA must analyse the impacts of the proposal on connected surface and alluvial ground waters within the water source, and any measures required to ensure continuity of flow transmission along any rivers within the impact zone surrounding the application. This should concentrate on Saddlers Creek, which is a 5th order river within the application area.*
- *The EA must provide a detailed baseline analysis of matrix and fracture transmission properties of local geology between Saddlers Creek and the mining proposal area. This is to form a basis for a detailed risk analysis of potential connectivity between the mining operation and Saddlers Creek.'*

- *The assessment is required to identify groundwater issues and potential degradation to the groundwater source and provide the following:*

  Groundwater Source

  1. *Details on the groundwater sources which will be intersected during the mining operation;*
  2. *Details on the predicted highest groundwater table within the aquifers within the area of mine area and adjacent catchments;*
  3. *Details on connectivity of aquifers and extent of alluvium within the Saddlers Creek catchment;*
  4. *Details of any works likely to intersect or connect with or result in contamination sources into identified groundwater sources;*
  5. *Details of any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes;*
  6. *Details of the existing groundwater users in the area (including any environmental groundwater dependency) and include details of any potential impacts on these users;*
  7. *Detailed analysis of matrix and fracture flow of alluvial and porous rock groundwaters, and analysis of any potential changes in groundwater migration within the drawdown zone of the mining proposal , which should include a minimum 5 km assessment radius surrounding the mining proposal footprint;*
  8. *Baseline monitoring or data for a minimum of 2 years for groundwater quantity and quality for all aquifers within and adjacent to the mining operation area;*
  9. *Describe the range of flow direction and rates through the stratigraphic section to be mined to a 5 kilometre radius surrounding the proposal footprint, and the physical and chemical characteristics of the groundwater regime;*
  10. *Impact assessment of mining operations of potential affects to quality of groundwater both in the short and long term, extending to equilibration of the porous rock groundwater system;*
  11. *Impact assessment of salinity to adjacent catchments downstream of Saddlers Creek;*
  12. *Details on groundwater salinity, including salinity budgets for the operational and post-mining landform to equilibrium of the porous rock groundwater system;*
  13. *Detailed discussion on potential impacts of final landform, including analysis of final landform options on the groundwater regime;*
  14. *Details of the results of any models or predictive tools used to predict groundwater drawdown, inflows into the site and impacts on affected water sources within Saddlers Creek catchment and the Hunter River;*

15. *Determine critical thresholds for negligible impacts to groundwater sources, and any mitigation options for the life time of the project.*

Groundwater Dependent Ecosystems

1. *Identification of potential Groundwater Dependent Ecosystems within the study area, including but not limited to riparian vegetation communities and dependent fauna, and any groundwater fauna communities associated with Saddlers Creek and its alluvium;*
2. *Identification of groundwater extraction limits necessary to provide surface flow and/or alluvial groundwater saturation limits sufficient to sustain ecological processes and maintain biodiversity;*
3. *Discussion of any protective measures to minimise any impacts on Groundwater Dependent Ecosystems and any potential offset areas, including details on monitoring and protection and/or remediation criteria.*

Contingency Measures

1. *Details of any proposed monitoring programs, including water levels and quality data;*
2. *Reporting procedures for any monitoring program including mechanism for transfer of information to NOW;*
3. *An assessment of any groundwater source/aquifer that may be sterilised as a consequence of the proposal;*
4. *Identification of any nominal thresholds as to the level of impact beyond which remedial measures or contingency plans would be initiated (this may entail water level triggers or beneficial use category for each impacted water source);*
5. *Description of remedial measures or contingency plans proposed;*
6. *Any funding assurances covering the anticipated post development maintenance cost, for example groundwater monitoring for the nominated period.*

The objective of the groundwater study was to fully assess the impact of the proposed mining on the hydrogeological regime and address all of the Director-General's requirements for the EA. To achieve this objective, a scope of work was developed and is outlined in this report. The scope included a data review, field investigations, and numerical modelling sufficient to meet the applicable Director-General's requirements. Table 3 indicates where the Director-General's requirements are addressed in this report.

Table 3: DIRECTOR-GENERAL'S EARs AND SECTION REFERENCE	
Requirements	**Section Reference**
Department of Planning and Infrastructure	
1	Refer to the EA surface water impact assessment
2a	6.0 and 9.0
2b	4.4, 9.5 and refer to the EA surface water impact assessment
2c	6.0, 9.0 and refer to the EA surface water impact assessment, ecology impact assessment and stygofauna impact assessment
2d	6.0, 9.0 and refer to the EA surface water impact assessment
2e	9.6.2 and refer to the EA surface water impact assessment and agricultural impact statement
2f	Refer to the EA surface water impact assessment
3	Refer to the EA surface water impact assessment
4	Refer to the EA surface water impact assessment
5	12.0 and refer to the main volume of the EA, surface water impact assessment and ecology impact assessment
Muswellbrook Shire Council	
	6.1, 9.6, 9.8 and refer to the EA surface water impact assessment
NOW Requirements	
Groundwater Sources	
1	6.0
2	6.0
3	6.0
4	7.0, 9.2 and 9.8
5	7.0, 9.2 and 11
6	4.4 and 9.5
7	6.0, 9.3 and 9.4
8	5.0 and 6.0
9	6.0
10	9.8
11	9.8 and refer to the EA surface water impact assessment
12	6.0 (for salinity budget refer the EA surface water impact assessment)
13	9.4

Table 3: DIRECTOR-GENERAL'S EARs AND SECTION REFERENCE	
14	9.0
15	12.0
Groundwater Dependent Ecosystems	
1	6.1.6, 6.3.6 and the EA ecology impact assessment and stygofauna impact assessment
2	9.6 and 9.7 and the EA ecology impact assessment
3	12.9 and the EA ecology impact assessment and stygofauna impact assessment
Contingency Measures	
1	12.0
2	12.7
3	9.0
4	12.3, 12.4 and 12.5
5	12.9
6	Refer to the main volume of the EA

3. EXISTING ENVIRONMENT

The following section describes the existing environment of the study area and its surrounds.

3.1 Topography and Drainage

The topography within the study area consists of moderately to steeply undulating low hills controlled by the underlying geology that is comprised of sedimentary coal measures overlain by alluvial sediments in areas immediately adjacent to drainage features such as Saddlers Creek and the Hunter River as shown in Drawing No. 3. The orientation of eroded valleys and drainages is governed to a significant extent by regional joint weakness. The outcrop of the coal measures forms the undulating hills on which the Project is situated. Flat alluvial flood plains flank the Hunter River and to a lesser degree along Saddlers Creek.

The topographic elevation is approximately RL 150 m to 200 m (Australian Height Datum) along the northern boundary of the study area decreasing to RL 130 m where Saddlers Creek bisects the western portion of the study area. The land surface within the study area is primarily cleared, open paddock grazing land, with limited native remnant vegetation. To the south of the Hunter River, the landform steepens with rugged terrain in the Wollemi National Park peaking between RL 400 m and RL 600 m.

The undulating topography creates numerous small creeks which drain the area and feed into larger order creeks. Small creeks are ephemeral and only flow for short periods after rainfall. The main water courses in the area comprise the Hunter River and Saddlers Creek.

The Hunter River is located to the south of the Project Boundary and meanders from north-west to south-east. The river is constantly flowing (perennial) and provides water to the majority of the agricultural pursuits in the area. The Hunter River has a large catchment and has an elevation of about RL 75 m (above sea level) near the Project.

The central reaches of the Saddlers Creek catchment area is situated within the study area. The headwaters are generally to the north-east and include south flowing drainage from Mt Arthur at a height of RL 482 m. Saddlers Creek is ephemeral and only flows occasionally after significant rainfall. The creek flows in a south-westerly direction and discharges into the Hunter River near the south-western corner of the study area. The ground immediately adjacent to Saddlers Creek is flat; however, away from the creek bed the land is undulating to hilly with slopes between 20% and 30%. Saddlers Creek is known to have extended periods of low flow driven by groundwater discharge of poor quality[3].

Plashett Dam was built to provide water to the nearby Bayswater Power Station. It is situated on Saltwater Creek which only flows during times of dam discharge into the Hunter River.

3.2 Land Uses

The Upper Hunter region has long been subject to a variety of land use activities, predominantly grazing and coal mining. In recent years, dominant land uses within and adjacent to the study area include open cut coal mining, power generation, industrial activities, thoroughbred horse breeding, agricultural activities and allocation for rural and residential areas.

A large proportion of the prime agricultural land adjacent to the study area is situated on the floodplain of the Hunter River and its larger tributaries. The Hunter River also plays an important

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[3] MineCraft Consulting Pty Ltd, (2006), "*Saddlers Creek – Pre-feasibility Study of the Whynot Underground*", for Anglo Coal (Saddlers Creek) Pty Ltd – November 2006.

role in the operation of the region's mining and power generation industries and in irrigating two premier thoroughbred horse studs (Coolmore Stud and Woodlands Stud) which share a common boundary with the Project.

The land to the north of the study area is associated with coal mines including Mt Arthur Coal Mine and Drayton Mine. The Dellworth EL 6812 adjoins the study area to the immediate north-east and east and the Spur Hill EL 7429 adjoins the study area to the west. This is a strong indication of the prevalence of coal mining as a dominant land use in the surrounding area. Bayswater and Liddell Power Stations (both operated by Macquarie Generation) are located approximately 5 km and 7.5 km to the north-east of the study area, respectively.

3.3 Climate

The climate of the region is temperate and characterised by hot summers and mild dry winters. Climate monitoring data collected by the Bureau of Meteorology (BoM)[4] is available for Jerrys Plains (Station No. 061086) located about 9 km to the south-east of Project, and Scone (Station No. 061089) which is about 40 km north of the Project. Mean monthly temperatures and rainfall are available from the Jerrys Plains Station for the period 1884 to 2011. The closest weather station to the Project recording evaporation is located at the township of Scone.

Jerrys Plains has a temperate climate with mean maximum temperatures ranging from 31.7°C in January to 17.4°C in July. Mean minimum temperatures range from 17.1°C in January and February to 3.8°C in July. Heat waves can occur between October and March and frosts between May and August. The average annual rainfall at Jerrys Plains is 644.7 millimetres (mm), of which the majority falls in the warmer months of the year (November to February), with January being the wettest month (77 mm). Mean daily pan evaporation in the summer season reaches 7.1 mm in December and January, and 1.6 mm in June. Average daily evaporation of 4.4 mm/day (1606 mm/year) exceeds mean rainfall throughout the year, the highest moisture deficit occurring during summer.

In order to place recent rainfall years into a historical context the Cumulative Rainfall Departure (CRD), which is a summation of the monthly departures of rainfall from the long-term average monthly rainfall, was calculated as follows:

$$CRDn = CRDn\text{-}1 + (Rn - Rav)$$

Where:	*CRDn*	=	CRD for a given month
	CRDn-1	=	CRD for a preceding month
	Rav	=	long-term average rainfall for a given month
	Rn	=	actual rainfall for given month

The average monthly rainfall used to produce the CRD graph shown on Figure 5 was obtained from the BoM, Jerrys Plains Station.

[4] http://www.bom.gov.au/climate/data/weather-data.shtml

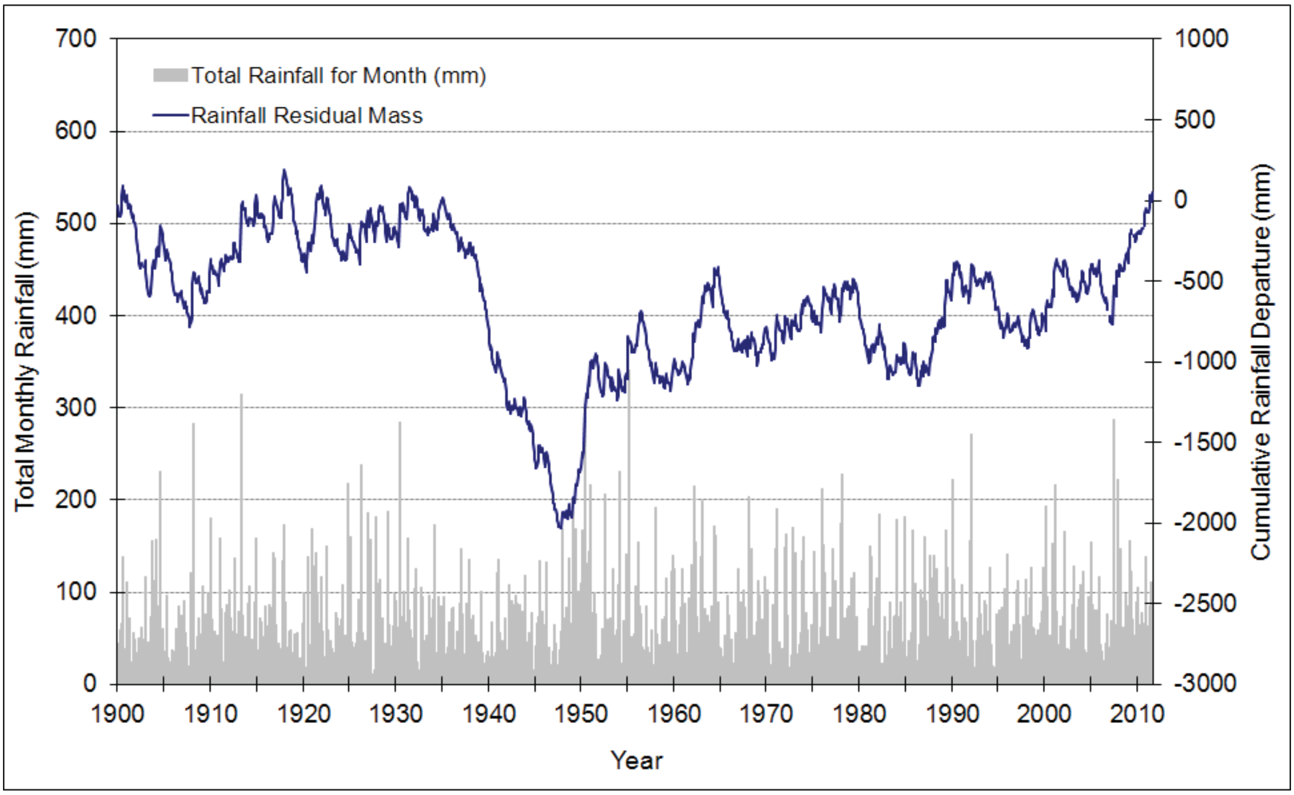

Figure 5: Cumulative Rainfall Departure – Jerrys Plains (Station No. 061086)

A positive slope in the CRD plot indicates periods of above average rainfall, whilst a negative slope indicates periods when rainfall is below average. The CRD indicates that the area has been generally experiencing above average rainfall since 2006.

3.4 Geology

According to the Singleton 1:250,000 geological sheet (Singleton 1:250,000 Geological Series Sheet SI 56-1) the underlying geology of the study area comprises two distinct formations: Quaternary alluvial deposits and Permian coal measures situated within the Singleton Supergroup (formerly known as the Singleton Coal Measures). The Singleton Supergroup incorporates several geological sub-groups including the Newcastle Coal Measures, Tomago Coal Measures, Watts Sandstone and the Wittingham Coal Measures.

The five main coal seams, Whybrow Seam, Redbank Creek Seam, Wambo Seam, Whynot Seam, and Blakefield Seam, targeted by the Project are located on the western side of the Muswellbrook Anticline within strata of the Jerrys Plains subgroup of the Late Permian Wittingham Coal Measures as shown in Drawing No. 4. These coal measures outcrop in the north of the study area and along the strike of the Muswellbrook Anticline (see Figure 6). In the southern part of the study area, the lowest coal seam targeted by the Project (Blakefield Seam) lies at around 200 m below ground level, which is an elevation of approximately RL-100 m. The coal measures include a sequence of coal seams, siltstones, sandstones and claystone and generally dip gently to the south-west.

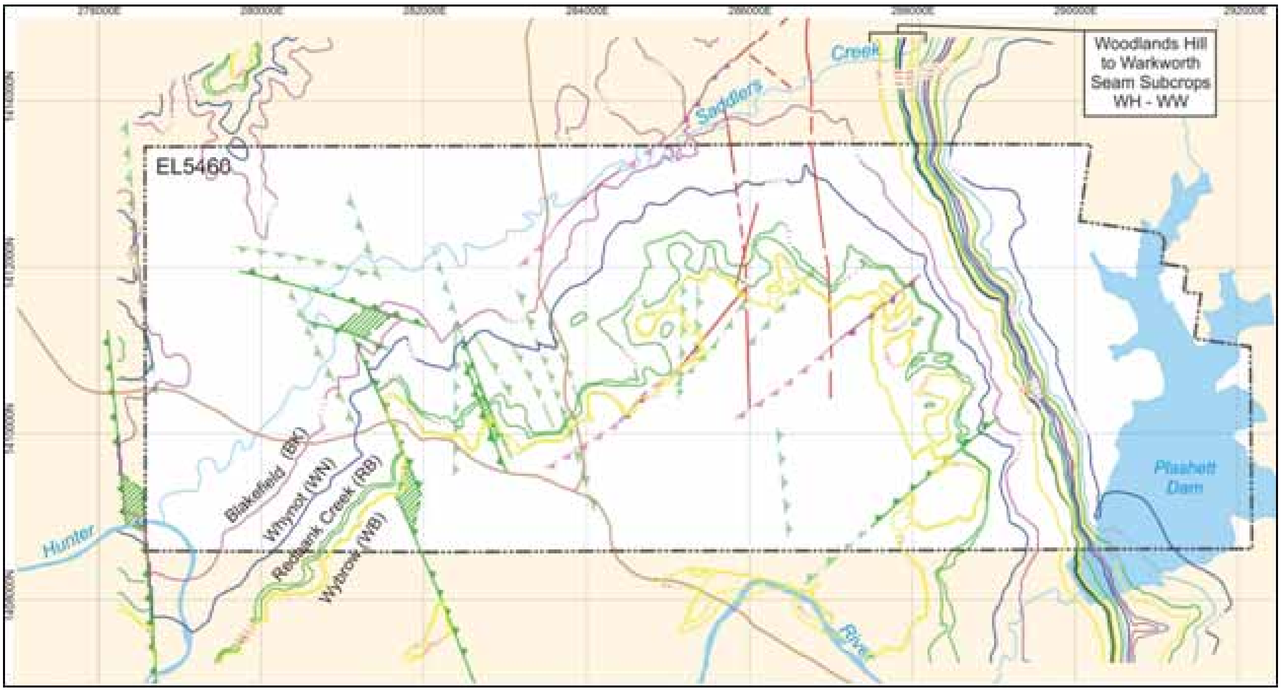

Figure 6: Coal Seam Subcrop within the Study Area

Source: MineCraft, 2006[3]

A summary of stratigraphic sequence is given in Table 4 and a typical stratigraphic column of the Jerrys Plains subgroup is shown in Figure 7.

Table 4: SUMMARY OF STRATIGRAPHIC SEQUENCE

Age	Group	Subgroup	Coal Seams	Lithology
Quaternary	--	--	--	Residual soils and colluvium units including all blanketing sandy, loamy and clay soils
Permian	Wittingham Coal Measures	Jerrys Plains Subgroup	Whybrow	Coal seams, claystone, tuff, siltstone, sandstone and conglomerate
			Redbank Creek	
			Wambo	
			Whynot	
			Blakefield	

Source: MineCraft, 2006

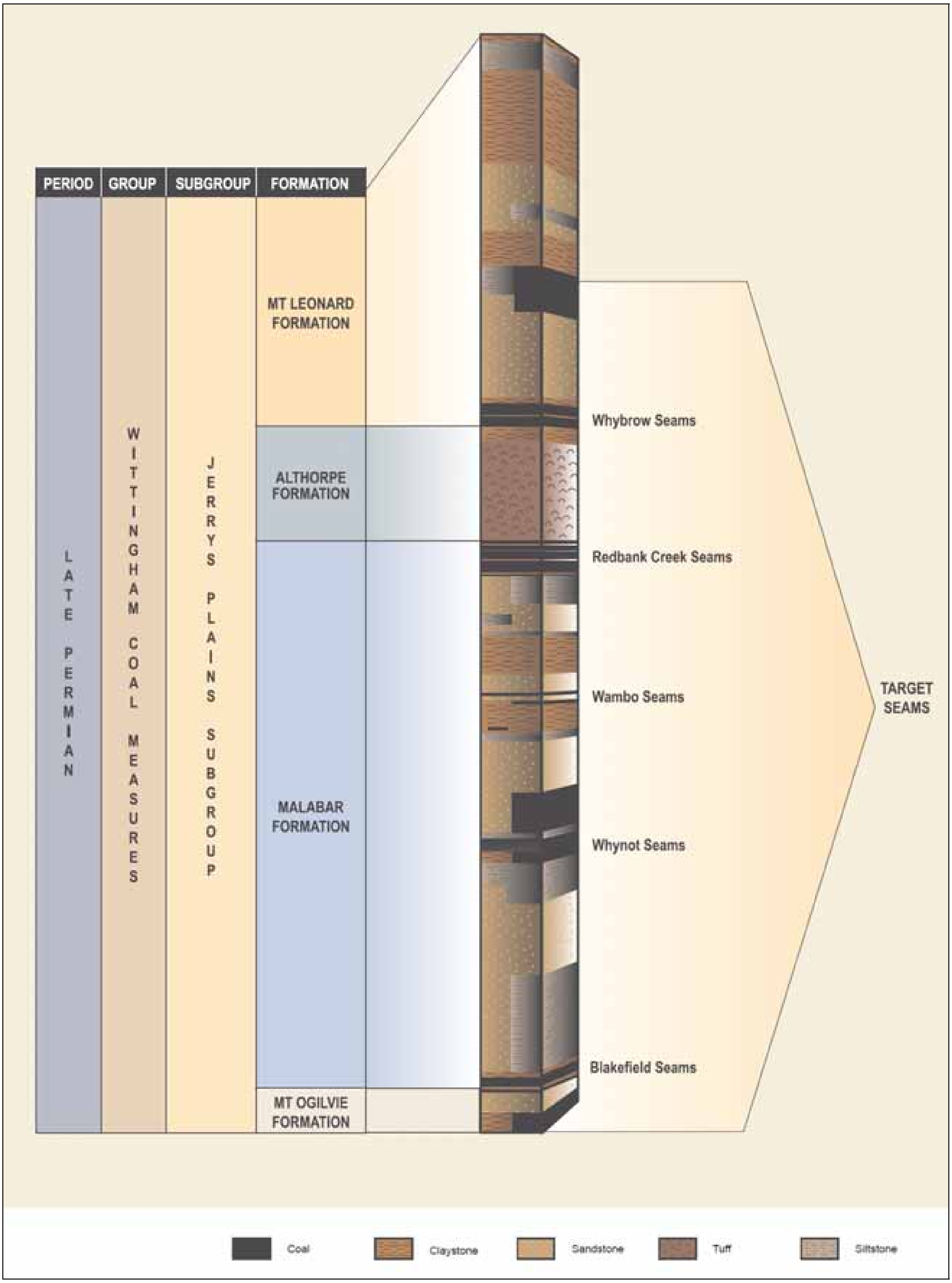

Figure 7: Typical Stratigraphic Column of Jerrys Plains Subgroup

Source: Anglo American, 2011

A summary of the thickness associated with targeted coal seams and the interburden/overburden within the study area is presented in Table 5.

Table 5: TYPICAL COAL SEAMS AND ASSOCIATED WASTE THICKNESS

Seam Name	Thickness (m)		Interburden/Overburden Thickness (m)
	Range	Average	Average
Whybrow	3.35 – 4.52	3.87	~50
Redbank Creek	3.59 – 4.94	4.23	~15 – 20
Wambo		1.25	~20
Whynot	1.2 – 2.4	1.8	~15
Blakefield		2.5	~20 – 30

Source: MineCraft, 2006[3] and RGS[5], 2012

The Permian coal measures within the study area are overlain by thin unconsolidated Quaternary age deposits along the alignments of Saddlers Creek and the Hunter River. The Quaternary deposits consist of unconsolidated silts, sand and minor fine gravels of mixed colluvial-alluvial origin. Drawing No. 4 shows the distribution of the Quaternary alluvium (Qa) across the study area.

There is limited public domain data available for the Quaternary unit associated with Saddlers Creek. However, recent drilling and monitoring bore installations have confirmed that this unit is thin, averaging less than 10 m thickness. Data held by NOW suggests that the alluvial deposits of the Hunter River to the immediate south of the study area are up to 13 m thick with basal gravel varying between about 2.5 m and 4 m in thickness. The material overlying the basal gravel consists predominantly of silt with minor clay. More information on the alluvial sequence is presented in Section 6.1.

3.4.1. Structural Geology

The geology within the study area has a moderate level of structural complexity. A number of major structures affect the area. The axis of the south-southeast plunging Muswellbrook Anticline shown on Drawing No. 4 is located near the eastern boundary of the study area where strata dip steeply (from approximately 20° to > 40°) to the west-southwest from the seam outcrop along the anticline's western limb (see Figure 6 and Drawing No. 4). Dip of the strata across the remainder of the study area flattens and is gentle at 3° to 5°, towards the south-west. A typical east-west cross section across the study area is shown in Figure 8.

[5] RGS Environmental Pty Ltd, (2012), "*Drayton South Coal Project – Geochemical Impact Assessment of Overburden and Coal Rejects Materials*", Prepared for Hansen Bailey Environmental Consultants, Project No. 091018

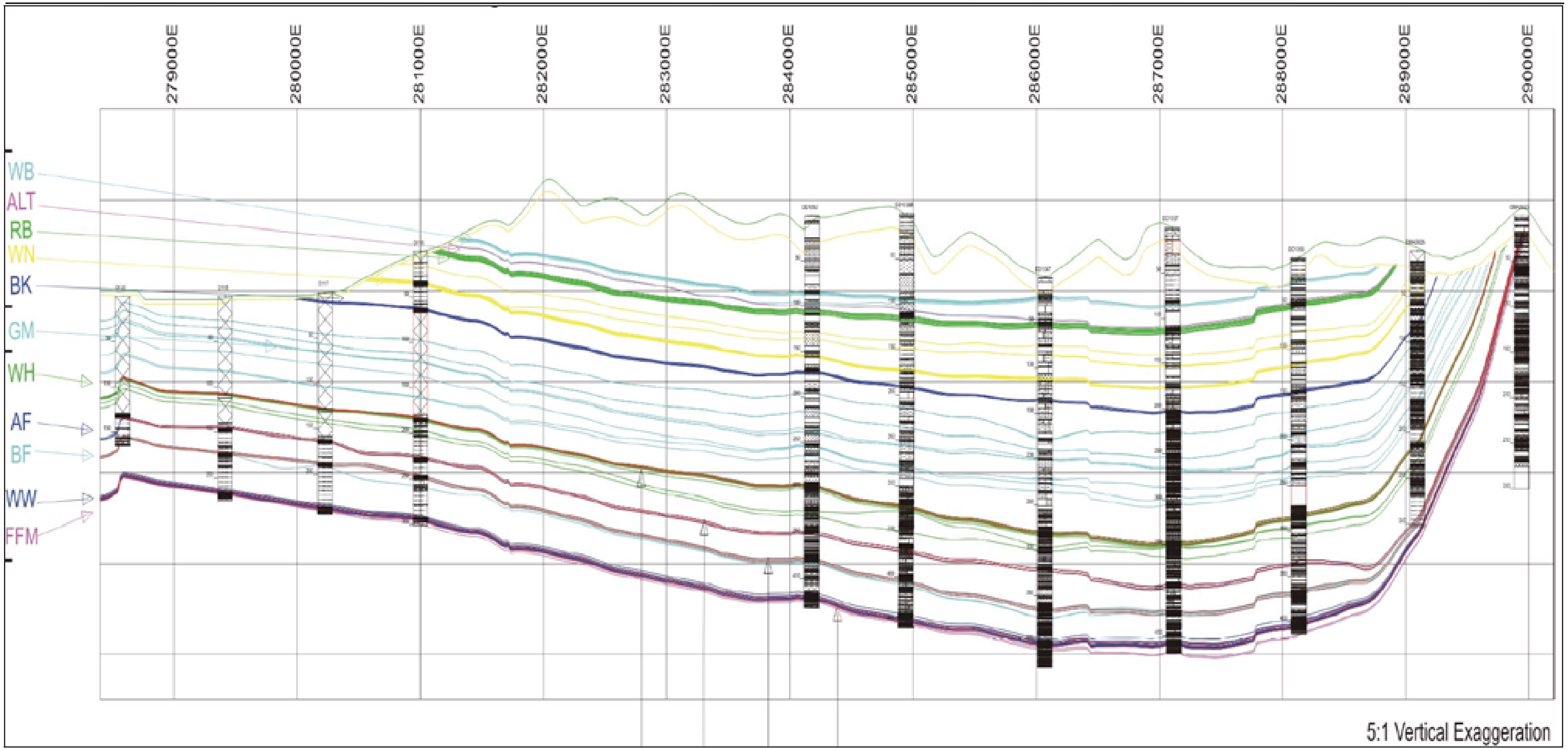

Figure 8: East-West Stratigraphic Cross-section

Source: Anglo American, 2006

3.4.2. Faulting

Major faulting within the study area is uncommon; however, several faults have been identified within the vicinity, including:

- The northerly trending Mount Ogilvie Fault that forms a structural boundary approximately 1 km to 2 km to the west of the study area (as shown on Drawing No. 4) with a regional displacement (down-throw to the west) of greater than 150 m;
- The Eastern Fault, located proximal to the western boundary of the study area (as shown in Figure 9) that has a down-throw to the west of greater than 50 m;
- A north-northwest trending graben structure (Randwick Park Fault) located in the western part of the study area that varies in width from 1100 m to 1300 m and has variable throws of up to 60 m. The northern and southern extents of the graben block are not well defined. Locations of smaller, localised faults interpreted by CSIRO[6] and Anglo American are shown in Figure 9. The CSIRO interpretation is broadly similar to the Anglo American model. The graben fault system contains short overlapping fault segments connected by more structurally complex zones.

3.4.3. Igneous Activity

Dykes

Since 2006, no dykes had been encountered by exploration drill holes; however, five minor dykes were interpreted from a high resolution ground magnetic survey[3]. Two of these dykes were trending north-south, two were trending north-north east, south-south west and one was trending northeast-southwest, which is also associated with a significant fault structure. The two north-south dykes have been confirmed by surface trenching. Interpretations suggest that all dykes are near-vertical and are between 0.5 m and 5 m in thickness. The surface trenches revealed highly weathered igneous material.

Approximate dyke locations, which are illustrated as basaltic units (with the symbol Jv), are shown on Drawing No. 4.

Plugs

A number of plugs have been tentatively interpreted from a high resolution ground magnetic survey. A group of high amplitude magnetic anomalies in the south-east of the study area was interpreted as being due to pipes or sub-volcanic complex. These pipes are classified as inferred only, as their interpretation is tentative and is not evidenced by any drill hole intersections or other geological data[3].

Sills

The strata (preferentially the coal seams) have been extensively and variably intruded by sills within the study area, with various coal seams intruded in different areas creating an overlapping sill sequence[3]. Some isolated sills are evident and are inferred to be associated with a dyke or dykes.

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[6] CSIRO Exploration and Mining, (2003), *"Fault Interpretation at Saddlers Creek EL5460 – Hunter Valley, NSW"*, Report No 1102C.

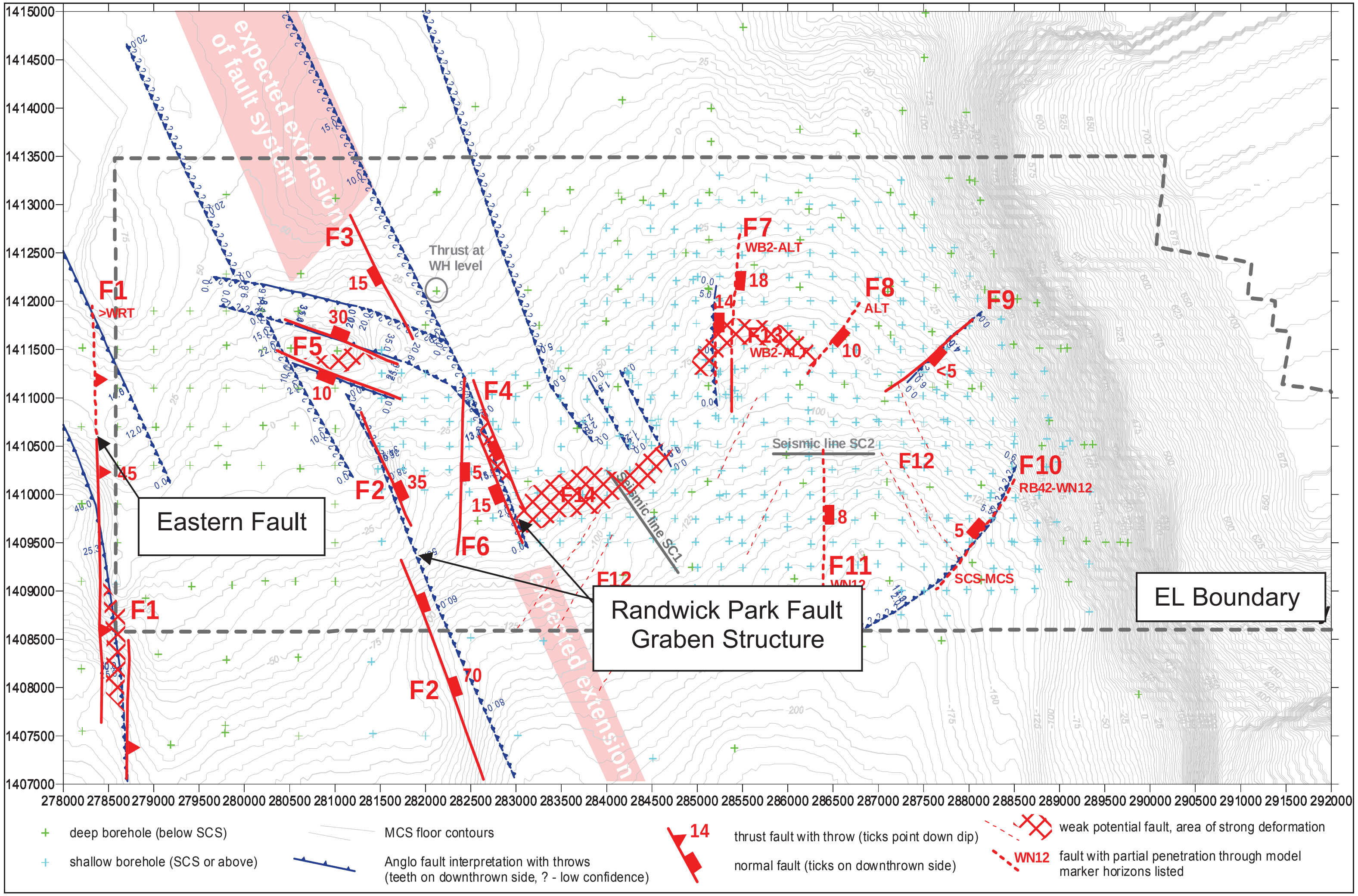

Figure 9: Locations of Interpreted Faults within the Study Area

Source: CSIRO, 2003

4. METHODOLOGY

A field investigation was undertaken as part of the coal resource exploration drilling program to gather additional hydrogeological information within the study area. The hydrogeological investigation program included:

- Construction and installation of nine groundwater monitoring bores, and five vibrating wire piezometers (VWPs), within different lithological units;
- Collection of groundwater samples for water quality analysis from the new monitoring bores;
- Collection of groundwater levels (and pore pressures) from the new monitoring bores and VWPs;
- Aquifer permeability testing within the new monitoring bores; and
- A census of bores within the study area.

The key components of the field investigation program are described in more detail below.

4.1 Monitoring Bore and Vibrating Wire Piezometer Installations

A review of the adequacy of the existing groundwater monitoring network was undertaken for the assessment. This indicated that there were no Anglo American groundwater monitoring bores located in the alluvium of Saddlers Creek and the alluvial aquifer of the Hunter River. Three drilling sites were selected for new bores along Saddlers Creek, with two sites within the Hunter River alluvial flood plain. In the short term, the new bores were designed to provide information on the alluvium and the hydraulic connectivity between the alluvium and the underlying bedrock, needed for numerical modelling. Those bores located outside the Drayton South footprint will allow impacts of the operations on groundwater levels and quality to be monitored over the life of the Project.

New monitoring bores were installed between 4 July and 2 August 2011. At each site, separate bores were constructed in the alluvial sediments and underlying coal measures. A total of nine new monitoring bores were installed at four sites situated between the Drayton South footprint, Saddlers Creek to the north and north-west, and the Hunter River in the south and south-east. Monitoring bores were originally anticipated to be installed at five sites, however, no alluvium was intersected at the fifth site, and subsequently, a monitoring bore was not installed at this site.

The shallow alluvial bores were identified with the suffix ‘alluvial’, the deeper bores constructed in weathered Permian with ‘regolith’, and bores constructed in coal seams with either ‘Whybrow or Redbank’. The positioning of these bores will ensure that any potential drawdown is detected before it propagates out to these water systems. The location of new and existing monitoring bores is shown in Drawing No. 5.

Lucas Drilling Contractors undertook the drilling, installation and construction of the monitoring bores with supervision provided by geologists from the Moultrie Group. AGE provided initial training to the geologists and ongoing remote supervision during the drilling program. The boreholes were drilled using the rotary air method, with drilling foam used to stabilise the alluvium where necessary.

At each site, the deeper bedrock monitoring bore was drilled first to determine the nature and thickness of the alluvial sediments. The alluvial sediments were then sealed off with casing, and a 150 mm diameter hole drilled in the underlying rock until a flow of water was encountered. Rock chip samples were collected at 1 m intervals and logged onsite. The boreholes were cased with Class 18, 50 mm diameter, lead free, uPVC casing. Machine slotted uPVC screens were placed at the base of the hole with blank PVC casing completing the hole to the surface. A clean, 3 mm to 6mm gravel filter was placed by gravity around the screens and a bentonite seal (1/2” bentonite pellets) was placed above the gravel pack. A cement/bentonite grout plug was used to seal the hole to the surface. Lockable steel covers protruding about 1 m at the surface were placed at each site. Table 6 summarises the construction of the monitoring bores, with more detailed borehole logs included in Appendix 1.

After construction, the monitoring bores were developed using the airlift method, until all drilling foam was removed and clear sediment free water was being produced.

Table 6: MONITORING BORE CONSTRUCTION DATA

Bore ID	Target Aquifer	Coordinates		Ground Level (mRL)	Depth Drilled (m)	Screen Zone (m)
		Easting (m)	Northing (m)			
MB1-Alluvial	Alluvium	297933	6407459	81.01	11	8-11
MB1-Whybrow	Coal	297928	6407448	80.84	30	25-28
MB1-Redbank	Coal	297930	6407453	80.89	60	51-57
MB2-Alluvial	Alluvium	294998	6411669	115.34	7	5-7
MB2-Regolith	Permian	295004	6411675	115.43	30	20-29
MB3-Alluvial	Alluvium	297269	6412850	132.72	16	8.5-14.5
MB3-Regolith	Permian	297328	6412729	137.34	30	27-30
MB4-Alluvial	Alluvium	300302	6406234	81.43	20	10-18
MB4-Coal	Coal	300307	6406231	81.34	60	42-47
MB5	Alluvium	292608	6409855	97.82	Abandoned – alluvium not present at site	

Notes: mbGL – metres below Ground Level
Coordinate Projection - MGA94, Zone 56

In addition to the monitoring bores, a network of VWPs was installed to measure the pressure within coal seams and interburden. A summary of VWP construction details is provided in Table 7.

Table 7: VWP CONSTRUCTION SUMMARY

VWP Name	Easting (m)	Northing (m)	Collar RL (mAHD)	Total Depth (mbgl)	Sensor Positions (mbgl)	Date Installed
BLK6R12 (RD1220)	293653.1	6409558	186.25	135	Whybrow Seam – 25mbgl Redbank Seam – 40.5mbgl Whynot Seam – 86.5mbgl Blakefield Seam – 113.7mbgl	August 2011
VWP1 (RDW006A)	297925.7	6407444	80.96	155	Interburden – 21mbgl Interburden – 40mbgl Interburden – 73mbgl Whybrow Seam – 87mbgl Whynot Seam – 109.2mbgl Blakefield Seam – 138mbgl	August 2011

Table 7: VWP CONSTRUCTION SUMMARY						
VWP Name	**Easting (m)**	**Northing (m)**	**Collar RL (mAHD)**	**Total Depth (mbgl)**	**Sensor Positions (mbgl)**	**Date Installed**
RBD1 (VWP)	295178.4	6409246	169.55	111.29	Whybrow Seam – 24.65mbgl Redbank Seam – 33.55mbgl Whynot Seam – 79.5mbgl Blakefield Seam – 103.3mbgl	April 2011
WND16 (VWP)	298121.5	6408842	130.58	126.16	Wambo Seam – 33.75mbgl Whynot Seam – 59.25mbgl Blakefield Seam – 90.15mbgl Blakefield Seam – 110.5mbgl	May 2011
WND26 (VWP)	299486.6	6409044	163.71	152	Whybrow Seam – 77.3mbgl Redbank Seam – 84.6mbgl Wambo Seam – 123.45mbgl Whynot Seam – 144.25mbgl	May 2011

Coordinate System: MGA1994, zone 56

4.2 Water Sample Collection and Analysis

Groundwater samples were collected from the new monitoring bores in August 2011. The groundwater samples were analysed by Australian Laboratory Services for:

- pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS);
- Major anions: Carbonate (CO_3), Bicarbonate (HCO_3), Chloride (Cl), Sulphate (SO_4);
- Major cations: Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K);
- Metals: Aluminium (Al), Arsenic (As), Beryllium (Be), Barium (Ba), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Lead (Pb), Lithium (Li), Manganese (Mn), Nickel (Ni), Selenium (Se), Strontium (Sr), Zinc (Zn), Boron (B), Iron (Fe), and Mercury (Hg);
- Nutrients (total phosphorous); and
- Organics (total organic carbon).

The results of the laboratory testing are presented and discussed in Sections 6.1, 6.2, and 6.3.

4.3 Permeability Tests

Permeability tests were conducted in the new monitoring bores using the falling and rising head methods. The tests were designed to evaluate the hydraulic conductivity of aquifer material surrounding the bore screen. A falling head test requires a “slug” of water being poured into the bore and the rate of decline in water level being monitored. A rising head test requires the water level within the bore to be lowered, followed by monitoring the rate of water level recovery. In this case, the water level was lowered by inserting a slug of compressed air into the bore.

Testing with both methods was not always possible due to either the bore construction, or because of artesian conditions. Falling head tests were not undertaken within MB2-Regolith due to artesian (i.e. flowing bore) conditions. Rising head tests were not possible within the alluvial bores because the water level within each bore was either within, or only slightly above, the screened casing (refer Section 6.2.3), and compressed air would leak into the aquifer.

The estimated hydraulic conductivity for each monitoring bore is included in Appendix 2. The data were analysed by the Hvorslev Method and the Bouwer-Rice Method using *Aquifer Test Version 2.5* software. The results of the analyses are discussed in more detail in Sections 6.1.3, 6.2.3 and 6.3.2.

4.4 Bore Census

A site inspection undertaken in 2011 identified four registered bores/wells are located within the study area, and another registered well is located to the south of the study area on land owned by Anglo American. The locations of the five bores/wells are shown on Drawing No. 6. The Shearers Bore/Well and the Bowfield Wells are currently utilised for stock and domestic purposes; however, the Plashett Well is abandoned and appears to be destroyed.

The closest registered water bore located outside of the study area and not on land owned by Anglo American is GW049223. This bore is screened within the Permian Coal measures and is located approximately 1.3 km north of the Project (see Drawing No. 6).

The second closest bores/excavations are located about 1.4 km to 1.5 km to the south of the Project. The registered bore (GW271031) and the registered excavation (GW047305) access the Hunter River alluvium (see Drawing No. 6). The registered bore (GW271031) is a NOW monitoring bore, while the excavation (GW47305) is a water extraction facility.

All other registered bores are located no closer than 3 km from the Project. The details of registered bores located within 4km of the Project are provided in Table 8.

Table 8: REGISTERED BORES WITHIN 4 KM OF PROPOSED MINE PLAN

Bore Works No.	Bore Name	Bore Type	Owner	Date Installed	Depth (m)	Aquifer Type	Distance from Drayton South Mine Plan (km)
-	Shearer's Well	Well	Anglo American	-	-	Regolith	na
-	Shearer's Well Bore	Bore	Anglo American	-	-	Permian	na
-	Bowfield Well	Well	Anglo American	-	-	Alluvial	1.9
-	Bowfield House Well	Well	Anglo American	-	-	Alluvial	1.9
-	Plashett Well	Well	Anglo American	-	-	Alluvial	2.8
GW049223	-	Bore	Private	1/1/1979	67.1	Permian	1.3
GW271031	-	Bore	NOW	28/3/2008	12	Alluvial	1.4
GW047305	-	Excavation	Private	-	11	Alluvial	1.5
GW043365		Well	Private	1/7/1974	6.4	Alluvial	3.2
GW019786	-	Well	Private	1/11/1961	12.8	Alluvial	3.4
GW053348	-	Well	Private	-	13	Alluvial	3.5
GW078709	-	Bore	-	-	50	Permian	4.1
GW029655	-	Bore	Private	1/01/1936	25.5	Permian	4.1

4.5 Previous Hydrogeological Studies

A number of previous groundwater studies have been undertaken within the study area and immediate surrounds.

The earliest study conducted within the immediate area was undertaken to the north of the study area at the adjacent Mount Arthur North Coal Project (MAN). The groundwater studies of MAN were initiated during the late 1970s and continued until recently (2009).

The groundwater studies conducted on the adjacent MAN lease consisted of various components of field investigations and groundwater flow modelling. The objective of most of these studies were to obtain data on the hydraulic characteristics of the stratigraphic profile in order to provide an assessment of groundwater inflow to mining operations, water supply sources, dewatering requirements and potential impact of dewatering on the Hunter River alluvium.

The coal seams of interest for the MAN groundwater studies were Woodlands Hill, Piercefield, Vaux, Bayswater, Edinglassie and Ramrod Creek. These coal seams are located stratigraphically beneath the priority seams for the Drayton South Project.

Groundwater and surface water management studies were conducted over the Drayton South Project EL5460 by Mackie Environmental Research (MER) in October 1998[7]. The MER 1998 study was conducted as part of a Pre-feasibility study to assess implications for mine plan development within EL5460. The report provided results of preliminary field measurements within EL5460 and addressed likely water management issues for a conceptual opencut and underground mine plan. The study included regional data gathering, installation of eight piezometers into coal measures, core inspections and laboratory testing, formation hydraulic testing and monitoring of coal measures water levels. The studies identified moderately saline, low permeability aquifers within coal measures, and moderate to high permeability aquifers within alluvium/colluvium along Saddlers Creek and adjacent to the Hunter River.

Computer based groundwater flow modelling conducted by MER in 1998, was undertaken to simulate both underground and opencut mining scenarios. Based on the mine plans at the time, the MER groundwater flow modelling indicated that opencut mining would not induce leakage from the Hunter River. However, groundwater flow simulations of the underground mine plan indicated that potential leakage from the river to the longwall operations was possible. The computer based simulations also indicated that impact of mine development on surrounding areas to be low, suggesting that the viticultural activities within the Arrowfield Winery Estate holding would not be affected by opencut mining operations.

MER (2000)[8] was also commissioned to undertake a review of water management aspects of the Drayton South Project based on alternative mine plans. These plans provided for simultaneous opencut and shallow underground operations and analysis of a conjunctive Saddlers Creek-Drayton Mine water management system, where a coal washing plant would be constructed. Pre-feasibility studies were completed in respect of likely groundwater seepage rates to both opencut and underground operations. Mine water management systems were assessed in detail in order to determine the likely surpluses or deficits for a wide range of climatic conditions. Findings indicated that opencut operations would not induce significant rates of seepage since planned extraction had only limited penetration of the water table. Shallow underground operations would however induce seepage at an increasing rate to about 0.7 ML/day towards the end of a 21 years mining period.

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[7] Mackie Environmental Research (1998) "*Saddlers Creek Coal: Pre-feasibility Water Management Studies in the Edderton Resource Block – October 1998*".

[8] Mackie Environmental Research, (July 2000), "Saddlers Creek Coal: Groundwater Management Pre-feasibility Study".

In 2001[9], MER was again commissioned to consolidate hydrogeological data arising from the 2001 exploration drilling program targeting the deeper Woodlands Hill, Arrowfield, Bowfield and Warkworth coal seams. During this program, hydrogeological information continued to be gathered in order to more fully appreciate the regional hydrogeology and the potential impacts of groundwater seepage on future opencut or underground mine operations. In particular, airlift yield measurements were conducted in exploration bores, water sampling was undertaken to further characterise groundwater qualities, three piezometers were installed and monitoring of the existing monitoring bore network continued. The report provided factual data and analysis including:

- an updated regional potentiometric surface based on measurement of water levels at all piezometers;
- permeability analyses based on airlift testing;
- water quality analyses including basic parameters pH and EC, and laboratory analyses for ionic speciation and rare elements; and
- hydrogeological overview of implications for future mine development.

AGE have also undertaken impact assessment studies involving finite element modelling in obtaining approvals for nearby mines; MAN (AGE 2006[10], AGE 2007[11] and AGE 2009[12]), the Drayton Mine Extension (AGE, 2006[13]) and the Bengalla Mine Wantana Extension (AGE, 2007[14]).

Data from all of the above studies have been used in undertaking the current assessment.

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[9] Mackie Environmental Research, (September 2001), *"Saddlers Creek Coal Project: 2001 Groundwater Data Collection".*

[10] Australasian Groundwater and Environmental Consultants Pty Ltd, (March 2006), *"Report on Mt Arthur North Opencut Coal Mine – Groundwater Impact Assessment",* Project No. G1301/A.

[11] Australasian Groundwater and Environmental Consultants Pty Ltd, (July 2006), *"Report on Groundwater Impact Assessment, Mt Arthur Coal South Pit Extension Project",* Project No. G1329.

[12] Australasian Groundwater and Environmental Consultants Pty Ltd, (June 2009), "*Report on Mt Arthur Coal Consolidation Project – Groundwater Impact Assessment",* Project No. G1446.

[13] Australasian Groundwater and Environmental Consultants Pty Ltd, (October 2006), *"Report on Drayton Mine Extension – Groundwater Impact Assessment",* Project No. G1341.

[14] Australasian Groundwater and Environmental Consultants Pty Ltd, (April 2007), *"Report on Bengalla Mine Wantana Extension – Groundwater Impact Assessment",* Project No. G1372.

5. HISTORICAL GROUNDWATER MONITORING

Groundwater levels and quality have historically been monitored within the study area and this monitoring continues to the present. Both groundwater levels and groundwater chemistry have been monitored and specific information relating to this monitoring is detailed below.

5.1 Groundwater Level Data

The WM Act allows for exploration holes to be converted to monitoring bores under the premise they comply with the construction standards required for all other water bores and that a water licence to drill the bore has been obtained. These construction standards are presented within the document *Minimum Construction Requirements for Water Bores in Australia*, 2nd Edition, September 2003[15]. Correctly installed monitoring bores are designed / constructed to gather representative data specific to a target aquifer.

Eight groundwater monitoring bores were installed in 1998 and reported by Mackie Environmental Research (MER)[7] (see Table 9 and Drawing No. 5). The bores were installed in existing exploration holes drilled in the coal measures for the purposes of obtaining groundwater level data. Geological (text) logs are available for the exploration drill holes; however, no records of monitoring bore construction or screen intervals are available.

A further seven bores were installed between 2000 and 2003 following scheduled exploration activities. Of these, three bores (DD1043, DD1057 and DD1052) targeted groundwater levels specifically in the Blakefield and Whynot coal seams. At the time, bore construction details were limited to installations undertaken in 2002 and 2003 as presented in Table 9 and Drawing No. 5 and Drawing No. 6. During the program, no monitoring bores were installed in alluvial aquifers or the regolith unit.

Table 9: HISTORICAL MONITORING BORE CONSTRUCTION SUMMARY

Bore Name	Easting (m)	Northing (m)	Collar RL (mAHD)	Total Depth (mbgl)	Monitoring Bore Screen Interval (mbgl)	Data Range
DD1004	299798	6410922	217.38	105.74	-	Oct 1998 – ongoing
DD1005	298799	6410901	225.02	138.55	-	Oct 1998 – ongoing
DD1014	296799	6410864	183.4	90.48	-	Sep 1998 – ongoing
DD1015	298815	6409900	162.5	162.5	-	Oct 1998 – ongoing
DD1016	297801	6410882	126.4	126.4	-	Oct 1998 – ongoing
DD1017	-	-	198.6	-	-	Sep 1998 – 2005 (Destroyed)
DD1018	-	-	-	-	-	Oct 1998 – Mar 1999 (Destroyed)
DD1025	298764	6411901	169.81	44.62	-	Aug 1998 – ongoing

[15] Land and Water Biodiversity Committee, (2003), *"Minimum Construction Requirements for Water Bores in Australia"*, 2nd edition, September 2003.

Table 9: HISTORICAL MONITORING BORE CONSTRUCTION SUMMARY						
Bore Name	**Easting (m)**	**Northing (m)**	**Collar RL (mAHD)**	**Total Depth (mbgl)**	**Monitoring Bore Screen Interval (mbgl)**	**Data Range**
DD1027			235.82	252.75	-	July 2000 – ongoing (Water level only)
DD1030	301754	6408961	160.08	282.48	-	July 2000 – ongoing
DD1032	297143	6412495	140.25	276.46	-	July 2001 – ongoing
DD1041	296202	6409476	187.32	387.32	-	July 2001 – ongoing
DD1043	295200	6409458	173.78	203	182 – 203	Apr 2003 – ongoing
DD1052	296274	6408513	183.12	127	105 – 127	Apr 2003 – ongoing
DD1057	295181	6410458	146.93	188	164 – 188	Apr 2003 – ongoing

Coordinate System: MGA1994, zone 56

Two VWPs were installed in 2010. A summary of VWP construction details is provided in Table 10.

Table 10: HISTORICAL VWP CONSTRUCTION SUMMARY						
VWP Name	**Easting (m)**	**Northing (m)**	**Collar RL (mAHD)**	**Total Depth (mbgl)**	**Sensor Positions (mbgl)**	**Date Installed**
RD1189 (SD1_DD001)	299896.4	6412419	208.63	322	Woodlands Hill Seam – 78.9mbgl ZZBF Seam – 145.5mbgl Warkworth Seam – 186.2mbgl Mt Arthur Seam – 230mbgl Piercefield Seam – 255.5mbgl Bayswater Seam – 315mbgl Wynn Seam – 322mbgl	2010
RD1192 (RBR2)	296091.8	6409038	177.06	148.5	Wambo Seam – 61.2mbgl Redbank Seam – 80mbgl Blakefield Seam – 148.5mbgl	2010

Coordinate System: MGA1994, zone 56

5.2 Groundwater Quality Data

Monitoring of pH and EC has been undertaken from all monitoring bores on a regular basis. The monitoring of these in-situ physico-chemical parameters occurred on about a twice yearly basis from 2000 until 2008, and then quarterly from 2009 until present.

An initial laboratory assessment of ionic speciation was undertaken by MER[9] in 2001 from four monitoring bores (DD1014, DD1015, DD1025, and DD1041), as part of a study into a potential underground mine at the site.

Laboratory analysis of ionic speciation has been continued since 2009 on a twice yearly basis, with the entire monitoring network sampled by AECOM, and the samples analysed by ALS. The samples have been collected by disposable bailers, filtered in the field, and acidified to pH<2 for preservation.

Specifically, groundwater samples have been collected from 13 monitoring bores (i.e. all bores listed in 5.1, with exception to DD1017, DD1018 and DD1027). The following water quality parameters have been monitored:

- pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Turbidity and Total Alkalinity as $CaCO_3$;
- Major cations: Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg);
- Major anions: Chloride (Cl) and Sulphate (SO_4);
- Metals: Aluminium (Al), arsenic (As), Barium (Ba), Beryllium (Be), Boron (B), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Lithium (Li), Manganese (Mn), Mercury (Hg), Nickel (Ni), Selenium (Se), Strontium (Sr), Sulphur (S), and Zinc (Zn); and
- Other parameters: silicon and total phosphorus.

The groundwater quality is discussed in Sections 6.1.4, 6.2.4 and 6.3.4. Groundwater chemistry of the Permian coal measures, the regolith, and the alluvial aquifers has been classified using a technique proposed by Piper (1944)[16] as described in Hem (1970)[17].

[16] Piper M.M., (1944), *"A Graphical Procedure in the Geochemical Interpretation of Water Analyses"*. Trans American Geophysical Union, Vol 25, pp914-923.

[17] Hem J.D., (1970), "*Study and Interpretation of the Chemical Characteristics of Natural Water",* 2nd ed. Us Geol. Surv. Water Supply Paper 1473, US Dept of the Interior, Washington DC.

6. HYDROGEOLOGICAL REGIME

Alluvial deposits present along the Hunter River and Saddlers Creek, especially near the confluence with the Hunter River, are known aquifers. Conversely, the Permian Wittingham Coal Measures in the study area is not considered to be a significant aquifer. While some coal seams may show an elevated hydraulic conductivity, the dominant interburden sections are of very low hydraulic conductivity. Occurrence and flow of groundwater is governed by the presence of micro faults, joints, fractures and bedding planes, which are often locally discontinuous. Only the weathered Permian bedrock (regolith) directly below the ground surface may have a higher hydraulic conductivity owing to weathering effects. Therefore, from a conceptual groundwater model perspective, the groundwater system in the study area is considered to consist of three aquifer systems, including:

- Alluvium along the Hunter River and Saddlers Creek;
- Weathered bedrock (regolith); and
- The coal seams of the Permian Wittingham Coal Measures.

Recharge to the aquifers is assumed to occur over the entire study area. The rate of recharge over the alluvial deposits and areas of coal seam sub-crops is considered to be higher than over areas covered by the Permian sandstone/siltstone bedrock basement.

The following section characterises different aquifer systems and discusses the underlying data.

6.1 Alluvial Aquifers

6.1.1. Distribution

Drainage channels have eroded the Permian strata over geologic time. These channels host Quaternary to recent unconsolidated alluvial materials. The floodplain that generally marks the extent of the Hunter River alluvial aquifer varies from about 500 m in width, to a maximum width of about 1.5 km. The alluvial aquifer and associated flood plain typically extends a short distance up the associated tributaries due to steep topography that prevents deposition of alluvial sediment. The extent of the aquifer has been mapped at 1:100,000 scale and is shown on Drawing No. 4.

The alluvial deposits of the Hunter River located to the immediate south of the Project are a significant storage for groundwater. Data held by NOW for stock and irrigation bores indicate that groundwater within the alluvial lands of the Hunter River occurs within the basal gravel sequence and overlying sands. The recent drilling program has validated this data. The Hunter River alluvium varies in thickness with MB1-Alluvial at 11 m, MB4-Alluvial at 18 m and basal gravel up to about 8 m as illustrated in the bore logs in Appendix 1. The material overlying the basal gravel is less permeable and consists predominantly of silt with minor clay.

In contrast, the alluvium associated with Saddlers Creek is dominated by clay and silt, interspersed with thin lenses of sandy material. The finer grained sediments of the Saddlers Creek alluvium and its thin nature means it transmits less water than the Hunter River alluvial deposits. Bore logs from recent drilling indicates that these lenses are typically only a few metres thick as shown in Appendix 1.

Deposits of mixed colluvial-alluvial origin occur in the valley of Saddlers Creek within the study area. The Saddlers Creek alluvium is thin and of limited areal extent due to a steep bed grade that prevents alluvial sediment being deposited. Often the distinction between alluvial-colluvial materials and the underlying regolith proves difficult to identify.

Groundwater within the Saddlers Creek alluvium is limited and is restricted to thin sandy lenses. Recent drilling at MB5, MB3-Alluvial, and MB2-Alluvial confirmed that the alluvium associated with Saddlers Creek has a poor capacity to store and transmit water and does not form a single, well-connected aquifer. Rather, the Saddlers Creek alluvium contains poorly connected, isolated sandy lenses where groundwater is able to accumulate after infiltration from surface water runoff following periods of heavy rainfall. The alluvium is expected to drain quickly and discharge/baseflow to the creeks is short lived. The extent of the alluvium associated with Saddlers Creek is shown on Drawing No. 4.

Similarly, the alluvium associated with Saltwater Creek (and particularly its tributaries) is thin and of limited areal extent due to a steep bed grade that prevents alluvial sediment being deposited. Very limited occurrence of groundwater is likely to occur within the Saltwater Creek alluvium.

6.1.2. Yield and Usage

Yield from the Hunter River alluvium and the Saddlers Creek alluvium varies widely. The highest yielding bores typically interest areas of significant saturated thickness mostly associated with areas of thick Hunter River alluvium. Yields are generally low in areas where thin saturated profiles exist. Data provided by NOW for stock and irrigation bores located immediately south and south west of the study area, indicates bore yields vary from 0 L/s to 21 L/s, with higher yielding bores being close to the Hunter River. The NOW registered stock and irrigation bore locations and their yields are shown on Drawing No. 7.

Recent drilling undertaken for the Project confirmed low yields are available from the alluvial sand and gravel sediments where a thin saturated thickness is present in the Saddlers Creek alluvium. Similarly, yield from the recently installed monitoring bores within the Hunter River alluvium were estimated to be about 0.01 L/s. This yield is much lower than nearby high extraction facilities (e.g. GW271031) and this yield is consistent with bores that are located away from the river channel. The majority of bores located within the Hunter River alluvium located near the study area have low yields, up to 0.1 L/s as shown on Drawing No. 7. This is a result of the level to which the bore intercepted the saturated sand and gravel of the alluvium.

The NOW 2009 Report Card for the Jerrys Plains Water Source does not report any groundwater entitlements.

6.1.3. Hydraulic Parameters

Falling head tests were undertaken in monitoring bores MB1-Alluvial (Hunter River), and MB2-Alluvial (Saddlers Creek) and MB3-Alluvial (Saddlers Creek) to assess the hydraulic conductivity of these sediments. A falling head test was not undertaken in MB4-Alluvial because the water level within this bore was located within the screened section, a configuration which precludes meaningful test results when using the falling head method. The testing indicated moderate hydraulic conductivity values between 0.08 m/day and 0.47 m/day. It should be noted that the falling head method, tests a zone of sediment in the immediate vicinity of the borehole only, and the hydraulic conductivity will vary over a larger scale. The results of these tests are summarised in Table 11.

Elsewhere in the Hunter Valley the alluvium is known to have a highly variable hydraulic conductivity, dependent on the grain size of the sediment. This can potentially lead to more productive sands and gravels having a hydraulic conductivity of between 1 m/day and 100 m/day.

Table 11: HYDRAULIC PERMEABILITY TEST RESULTS - ALLUVIUM							
Bore ID	**Hydraulic Conductivity (K) (m/day)**						
	Falling Head Test		**Rising Head Test**		**Min.**	**Max.**	**Avg.**
	Bouwer-Rice	**Hvorslev**	**Bouwer-Rice**	**Hvorslev**			
Alluvium							
MB1-Alluvial	0.26	0.13	--	--	0.13	0.26	0.20
MB2-Alluvial	0.46	0.47	--	--	0.46	0.47	0.46
MB3-Alluvial	0.08	0.09	--	--	0.08	0.09	0.08

Notes: Bouwer-Rice (1976)[18] method of analysis
Hvorslev (1951)[19] method of analysis

6.1.4. Water Quality

Groundwater quality of the Hunter River alluvium and Saddlers Creek alluvium has not previously been monitored within the vicinity of the study area. The NOW database holds groundwater chemistry data for 14 registered bores located within the Hunter River alluvial aquifer.

The NOW data indicates that the water quality within the Hunter River alluvial aquifer, as reflected by the Electrical Conductivity (EC), is quite variable, ranging between 644 µS/cm (~412 mg/L Total Dissolved Solids [TDS]) and 6,700 µS/cm (~4288 mg/L TDS). The EC range across the bores possibly reflects the dominant recharge source at the time, that is, recharge from the underlying coal measures, which results in very poor quality water. Recharge from rainfall or the river itself has the potential to slightly improve water quality conditions. The pH ranges from 6.9 to about 8.4, that is, from slightly acid to slightly alkaline.

The salinity of the water samples can be categorised based on Total Dissolved Salts (TDS) concentrations as follows:

Fresh water	<500 mg/L
Slightly Brackish	500 to 1000 mg/L
Brackish	1000 to 3000 mg/L
Moderately saline	3000 to 7000 mg/L
Saline	7000 to 14000 mg/L
Highly saline	14000 to 35000 mg/L
Brine	>35000 mg/L

The water quality analyses indicate that the samples collected from the Hunter River and Saddlers Creek alluvial aquifers are categorised as brackish (1000 mg/L to 3000 mg/L) and moderately saline (3000 mg/L to 7000 mg/L), respectively (Table 12). The samples collected from the Saddlers Creek alluvium are too saline for stock watering, whereas the water samples collected

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[18] Bouwer H, Rice, RC (1976), "*A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells*", water Resources Research 12(3)423-428.

[19] Hvorslev M.J., (1951), "*Time Lag and Soil Permeability in Ground Water Observations*", U.S. Army Corps of Engineers Waterway Experimentation Station, Bulletin 36.

from the Hunter River alluvium are mostly suitable for stock and some irrigation in limited areas. The water from both systems is too saline for human consumption.

Table 12 summaries the results of the analyses for samples collected from the new bores constructed in the Saddlers Creek and the Hunter River alluvium.

Table 12: SUMMARY OF WATER QUALITY ANALYSES – ALLUVIAL AQUIFERS

Parameter	Drinking Water (ADWG)	Irrigation (ANZECC)	Stock Water (ANZECC)	Aquatic Ecosystems ANZECC Freshwater 95%	Monitoring Data			
					MB1-Alluvial (Hunter)	MB2-Alluvial (Saddlers)	MB3-Alluvial (Saddlers)	MB4-Alluvial (Hunter)
Sample Date					10/08/11	5/08/11	5/08/11	5/08/11
Electrical Conductivity (µS/cm)	-	**1250**	-	-	**3180**	**9180**	**8530**	**1661**
pH	**6.5 – 8.5**	-	-	-	7.2	7.2	7.4	7.3
Total Dissolved Solids (mg/L) (ECX 0.67)	**500**	Highly dependent on crop type and soils	4000 (beef) 2500 (dairy) 5000 (sheep)	-	**2130**	**6150**	**5715**	**1112**
Bicarbonate Alkalinity as $CaCO_3$	-	-	-	-	532	823	719	331
Total Alkalinity as $CaCO_3$ (mg/L)	-	-	-	-	532	823	719	331
Major Cations / Anions (mg/L)								
Chloride	**250**	**175** (sensitive crops) to >700 (tolerant crops)	-	-	**756**	**2780**	**2620**	**343**
Calcium	-	-	1000	-	118	130	75	95
Magnesium	-	-	2000	-	93	322	330	69
Potassium	-	-	1000	-	5	7	4	4
Sodium	-	**115** (sensitive crops) to >460 (tolerant crops)	-	-	**474**	**1490**	**1400**	**148**
Sulphate	**250**	-	-	-	100	**412**	**360**	46
Trace Elements (mg/L)								
Aluminium	0.2	5	5	0.055	<0.01	<0.01	<0.01	<0.01
Arsenic	0.007	0.1	0.5	0.037	<0.001	<0.001	<0.001	<0.001
Boron	**0.3**	0.5	5	**0.3**	0.08	0.24	**0.33**	<0.05
Chromium	**0.05**	0.1	1	**0.001**	**0.002**	**<0.005**	**0.001**	<0.001
Copper	1	0.2	0.4 – 5	**0.0014**	**0.01**	**0.002**	**0.002**	**0.003**
Iron	**0.3**	**0.2**	-	ID	**1.02**	<0.05	<0.05	<0.05
Lead	0.01	2	0.1	0.0034	<0.001	<0.001	<0.001	<0.001

Table 12: SUMMARY OF WATER QUALITY ANALYSES – ALLUVIAL AQUIFERS								
Parameter	Drinking Water (ADWG)	Irrigation (ANZECC)	Stock Water (ANZECC)	Aquatic Ecosystems ANZECC Freshwater 95%	Monitoring Data			
					MB1-Alluvial (Hunter)	MB2-Alluvial (Saddlers)	MB3-Alluvial (Saddlers)	MB4-Alluvial (Hunter)
Nickel	0.02	0.2	1	**0.011**	**0.019**	0.005	0.008	**0.026**
Zinc	3	2	20	**0.008**	**0.014**	0.007	0.008	<0.005

Notes:
1. aquatic ecosystems – ANZECC 2000 95% level of protection for freshwater ecosystems
2. stockwater – ANZECC 2000 - beef cattle trigger level used where values are species dependent
3. bold values exceed trigger levels

An assessment was made of the groundwater quality in accordance with the Australian and New Zealand Environment and Conservation Council (ANZECC) criteria and environmental value. The ANZECC (2000)[20] guideline refers to "environmental value", in terms of the following environmental values for water:

- Aquatic ecosystems;
- Primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods);
- Recreation and aesthetics;
- Drinking water;
- Industrial water; and
- Cultural and spiritual values.

ANZECC states:

> *Where two or more agreed environmental values are defined for a water body, the more conservative of the associated guidelines should prevail and become the water quality objective.*

Groundwater within the alluvial aquifers exhibits a higher quality compared with groundwater sourced from coal measures. Potable water quality is not common, and was not present in the monitoring bores constructed for the Project. Discharge of saline water under pressure from the coal measures to the basal sections of alluvium and colluvium along drainages can result in pockets of variably saline quality water in the alluvium, especially in areas distant from the Hunter River.

Given that groundwater in the alluvial aquifer is unsuitable for human consumption in most locations due to salinity in that it exceeds 500 mg/L TDS, the environmental value has been classified as "primary industry", with the main use being for irrigation and stock watering. The Saddlers Creek alluvium is too saline for primary industries and does not contribute significant baseflow to aquatic ecosystems.

6.1.5. Groundwater Levels and Recharge

There has been no historical monitoring of groundwater levels by Anglo American in either the Saddlers Creek alluvium or the Hunter River alluvium. Monitoring bores were installed at four sites

[20] Australian and New Zealand Environment and Conservation Council, (2000), "*Australia and New Zealand Guidelines for Fresh and Marine Water Quality*".

(two in Saddlers Creek alluvium and two in the Hunter River alluvium) as part of the current investigation. These have now been added to Anglo American's existing groundwater monitoring program.

Water levels in the alluvial bores were measured daily for the first two weeks after construction, and then on a weekly basis. Figure 10 presents groundwater levels measured in the alluvial monitoring bores. The hydrograph shown on Figure 10 illustrates a head difference of about 40 m to 60 m between the Saddlers Creek alluvium and the Hunter River alluvium.

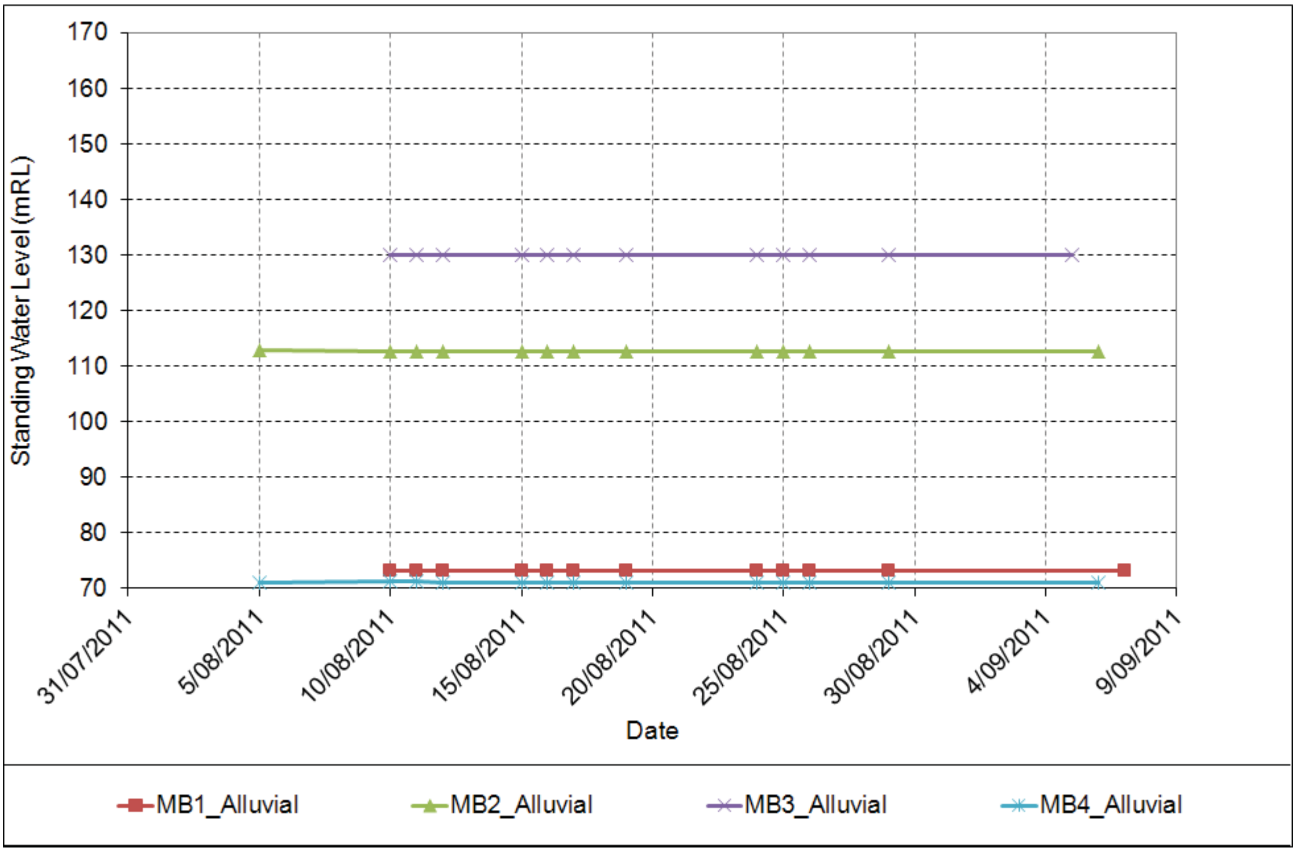

Figure 10: Alluvium Hydrographs

Recharge to the alluvium occurs through infiltrating rainfall and through runoff from adjacent bedrock areas. During very dry periods, the alluvium along the Hunter River is recharged from flow in the Hunter River which is maintained through the release of water from Glenbawn Dam upstream. However, during periods of above average rainfall the alluvial aquifers will provide water to the Hunter River as baseflow. Upward leakage from the underlying coal measures also recharges the Hunter River alluvium and Saddlers Creek alluvium.

Groundwater occurring within the thin, limited alluvial deposits associated with Saddlers Creek is perched above the main water table, and is short lived, draining relatively rapidly into the creeks and gullies.

There are no stream gauging stations located in close proximity to the study area to assess the hydraulic gradient between alluvial aquifers and Saddlers Creek / Hunter River. Notwithstanding this, groundwater levels within the Hunter River alluvium (Figure 10) have a similar elevation to the elevation of the base of the Hunter River (about RL 75 m), implying good hydraulic connectivity.

An analysis of water level data by MER[8] and recent data from the latest investigations indicated that groundwater levels in the alluvium have a shallow hydraulic gradient towards the Hunter River, consistent with the regional hydraulic gradient. That is, the hydraulic gradient from the edge of the alluvium appears to be consistent with that of the coal seams and the overall gradient in the study area. There is also an alluvial water table hydraulic gradient following the alluvium and the Hunter River downstream. The Hunter River acts as a regional sink to the entire system.

No field based studies of groundwater recharge into the Hunter River alluvium have been undertaken within the vicinity of the study area. Despite the lack of site data, recharge for the Hunter River alluvium is expected to fall between 5% and 15% of annual rainfall based on previous groundwater assessments and groundwater flow model calibrations throughout the Hunter Valley area.[8, 32, 35]

6.1.6. Groundwater Dependent Ecosystems

The Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources (2009) identifies several GDEs within the Hunter catchment area; however, none of these ecosystems are located within the Jerrys Water Source area, in which the Project is located.

Cumberland Ecology[21] undertook an ecology impact assessment (Appendix J of the EA) to determine the potential for GDEs to exist proximal to the study area. The identification of GDEs in the study area was determined on the basis of the presence of species such as *Eucalyptus camaldulensis* (River Red Gum) and *Casuarina cunninghamiana* (River Oak). These species are likely to have some root access to deep water tables and thus comprise a GDE. The majority of the native vegetation that once covered the study area has been cleared primarily for grazing; however, there are still a number of areas of remnant vegetation that occur.

Cumberland Ecology[21] noted:

> *One individual Eucalyptus camaldulensis (River Red Gum) was recorded along Saddlers Creek to the west of Edderton Road; occasional occurrences of Casuarina cunninghamiana (River Oak) were also found along the length of Saddlers Creek in this community. On the basis of the latter two occurrences, this community is considered to be a GDE. The community is restricted to the creek banks and is rarely found on the alluvial flats*.

Cumberland Ecology[21] also stated:

> *It is difficult to ascertain the degree of dependence of terrestrial ecosystems on groundwater. In the Hunter region where watercourses are typically ephemeral and historically have been degraded due to surrounding land use and water extraction, it is likely that communities characterised by Eucalyptus camaldulensis (River Red Gum) and Casuarina cunninghamiana (River Oak) trees have a moderate reliance, but not a complete dependence, on groundwater.*

Eco Logical[22] completed a stygofauna impact assessment (Appendix O of the EA) to determine the potential for stygofauna to exist proximal to the study area. This assessment included sampling within the alluvial units associated with Saddlers Creek and the Hunter River.

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[21] Cumberland Ecology, (2012), "*Drayton South Coal Project: Ecology Impact Assessment*", Prepared for Hansen Bailey Pty Ltd, 2012.

[22] Eco Logical Australia, (2012), "*Drayton South Coal Project: Stygofauna Impact Assessment",* Prepared for Hansen Bailey Pty Ltd, December 2012.

Two rounds of stygofauna sampling were undertaken from a combination of monitoring bores. Only two occurrences of stygofauna taxa were collected from one monitoring bore during the first sampling round. Eco Logical[22] reported:

> *Two taxa collected from the Saddlers Creek alluvial aquifer are unlikely to be endemic to the aquifer; however, their presence here indicates that there may be a larger stygofauna community present*.

Although no stygofauna taxa were collected from the Hunter River alluvium near the Project during the sampling program, Eco Logical[22] indicate that other studies undertaken throughout the region have identified stygofauna colonies within this alluvial system.

6.2 Shallow Bedrock (Regolith) Aquifer

6.2.1. Distribution

The regolith or shallow weathered Permian aquifer comprises surficial soils and weathered rock. The depth of the unit is variable and depends on the depth of weathering and frequency of fracturing. Available data indicates that the depth of weathering recorded in drill holes varies widely with abrupt changes between adjacent drill holes. However, the weathered Permian regolith unit generally extends to a depth of about 30 m below ground surface.

Perched aquifers are generally limited within the weathered Permian rock. However, some perched groundwater has recently been noted at the adjacent Mt Arthur Coal Mine operation, located to the immediate north of the Project. Perched aquifers typically occur at the interface between soils and coherent rock, and zones of locally increased permeability caused by weathering.

Recent drilling and installation of two monitoring bores (MB2-Regolith and MB3-Regolith) confirmed that groundwater, in small volumes, is stored within the regolith unit. The regolith is likely to act as a temporary water storage during sustained wet periods and provides a source for recharge to the underlying coal measures. The volume of recharge to the underlying coal measures is limited given the very low hydraulic conductivity of deeper strata and the fact that the deep monitoring bores throughout the region do not fluctuate rapidly in response to rainfall. This contrasting permeability between the regolith and underlying coal measures can sometimes result in the presence of shallow springs and/or artesian conditions near changes of topographical slope. Artesian conditions were present within MB2-Regolith following installation of the monitoring bore.

Drilling of monitoring bores through the bedrock underlying the Hunter River alluvial aquifer intersected fresh rock indicating the weathered zone was not present in this area. In elevated areas of the site the regolith is largely dry, and only becomes saturated in the lower lying flood plain areas near Saddlers Creek.

6.2.2. Yield and Usage

Variable yields, ranging between 0.2 L/s to 1 L/s, were recorded during drilling of the two recently installed regolith monitoring bores near Saddlers Creek. The use of groundwater held within the weathered Permian regolith aquifer is limited as indicated by the limited number of registered bores located within the immediate vicinity of the study area. The yield from the regolith unit is not well documented within the NOW registered bore database, reflecting the limited use of the unit as a source of water. Notwithstanding this, it is likely that the regolith unit can provide low yields of groundwater where sufficiently fractured material is present.

6.2.3. Hydraulic Parameters

Measurements of hydraulic properties in the weathered Permian regolith unit within the study area are limited to tests undertaken within the recently constructed monitoring bores. Falling head tests were undertaken in monitoring bores MB2-Regolith and MB3-Regolith, both located near Saddlers Creek, to assess the hydraulic conductivity of this unit. The results of these tests are summarised in Table 13.

Table 13: HYDRAULIC PERMEABILITY TEST RESULTS – REGOLITH

Bore ID	Hydraulic Conductivity (K) (m/day)						
	Falling Head Test		Rising Head Test		Min.	Max.	Avg.
	Bouwer-Rice	Hvorslev	Bouwer-Rice	Hvorslev			
MB2-Regolith	--	--	0.10	0.09	0.09	0.10	0.10
MB3-Regolith	1.61	1.28	0.87	0.90	0.87	1.61	1.16

Notes: Bouwer-Rice (1976)[18] method of analysis
Hvorslev (1951)[19] method of analysis

The testing indicated moderate hydraulic conductivity values between 0.1 m/day and 1.2 m/day. The order of magnitude difference between the hydraulic conductivity measured within the two bores highlights the variability in the weathering, fracture networks and groundwater occurrence in this unit.

It is important to note that the falling head tests measure the hydraulic conductivity of the zone immediately around the bore only. The representative average hydraulic conductivity of the regolith is likely to be much lower than the tested values due to the presence of poorly interconnected fracture networks that are not identified with the falling head test method.

6.2.4. Water Quality

The results of the analyses undertaken on samples collected from the weathered Permian regolith monitoring bores are summarised in Table 14. The salinity of the water samples was categorised based on TDS concentrations outlined in Section 6.1.4. The water quality analysis indicated that the samples collected from the weathered Permian regolith falls in the moderately saline (3000 mg/L to 7000 mg/L) range. Similar to the Saddlers Creek alluvial groundwater chemistry, the quality of regolith groundwater is only suitable for stock watering. In general, the data indicates saline groundwater is hosted within the regolith and alluvial units, this being attributed to upwards leakage of saline coal measures groundwater without significant rainfall or river water flushing. Notwithstanding this, occasional exceptions may exist where the shallow regolith hosts relatively fresh water, but these events are likely to be infrequent.

The concentrations of trace metals within the regolith were low in all samples and below trigger levels in accordance with ANZECC (2000) for stock water. Concentrations of metals are also below the ANZECC (2000) trigger levels for freshwater aquatic ecosystems. Future aluminium analyses will require a lower level of reporting to compare data with the ANZECC (2000) trigger levels. The environmental value of the groundwater in the regolith zone is for primary industries with the main use being for stock watering.

Table 14: SUMMARY OF WATER QUALITY ANALYSES – REGOLITH						
Parameter	**Drinking Water (ADWG)**	**Irrigation (ANZECC)**	**Stock Water (ANZECC)**	**Aquatic Ecosystems ANZECC Freshwater 95%**	**Monitoring Data**	
					MB2-Regolith	**MB3-Regolith**
Sample Date					5 Aug 2011	5 Aug 2011
Electrical Conductivity (µS/cm)	-	**1250**	-	-	**6200**	**5260**
pH	**6.5 – 8.5**	-	-	-	7.5	7.0
Total Suspended Solids (mg/L)	-	-	-	-	37	8
Total Dissolved Solids (mg/L)	**500**	Highly dependent on crop type and soils	4000 (beef) 2500 (dairy) 5000 (sheep) 4000 (horses) 4000 (pigs) 2000 (poultry)	-	**3970**	**3370**
Total Alkalinity as $CaCO_3$ (mg/L)	-	-	-	-	1090	699
Major Cations / Anions (mg/L)						
Chloride	**250**	**175** (sensitive crops) to >700 (tolerant crops)	-	-	1400	1280
Calcium	-	-	1000	-	37	127
Magnesium	-	-	2000	-	50	256
Potassium	-	-	1000	-	10	6
Sodium	-	**115** (sensitive crops) to >460 (tolerant crops)	-	-	**1320**	**694**
Sulphate	**250**	-	-	-	<1	**291**
Trace Elements (mg/L)						
Aluminium	0.2	5	5	0.055	<0.01	<0.01
Arsenic	0.007	0.1	0.5	0.037	0.001	0.01
Boron	0.3	0.5	5	0.3	-	-
Chromium	0.05	0.1	1	0.001	<0.005	<0.001
Copper	1	0.2	0.4 – 5	0.0014	<0.001	<0.001
Iron	0.3	0.2	-	ID	<0.05	0.14
Lead	0.01	2	0.1	0.0034	<0.001	<0.001
Nickel	0.02	0.2	1	0.011	0.001	0.007
Zinc	3	2	20	0.008	<0.005	<0.005

Notes:
aquatic ecosystems – ANZECC 2000 95% level of protection for freshwater ecosystems
stockwater – ANZECC 2000 - beef cattle trigger level used where values are species dependent
bold values exceed trigger levels

6.2.5. Groundwater Levels and Recharge

There has been no historical monitoring of groundwater levels by Anglo American in the regolith unit. As explained previously, monitoring bores were installed at two sites (MB2-Regolith and MB3-Regolith) as part of the current investigation. These have now been added to Anglo American's groundwater monitoring program. Water levels for the bores in the regolith aquifers were monitored daily for the first 2 weeks after construction and have since been monitored on a weekly basis. Figure 11 shows the groundwater levels in the Saddlers Creek regolith bores. The monitoring bores show a relatively stable groundwater level, which is expected given there were no significant rainfall events over the monitoring period.

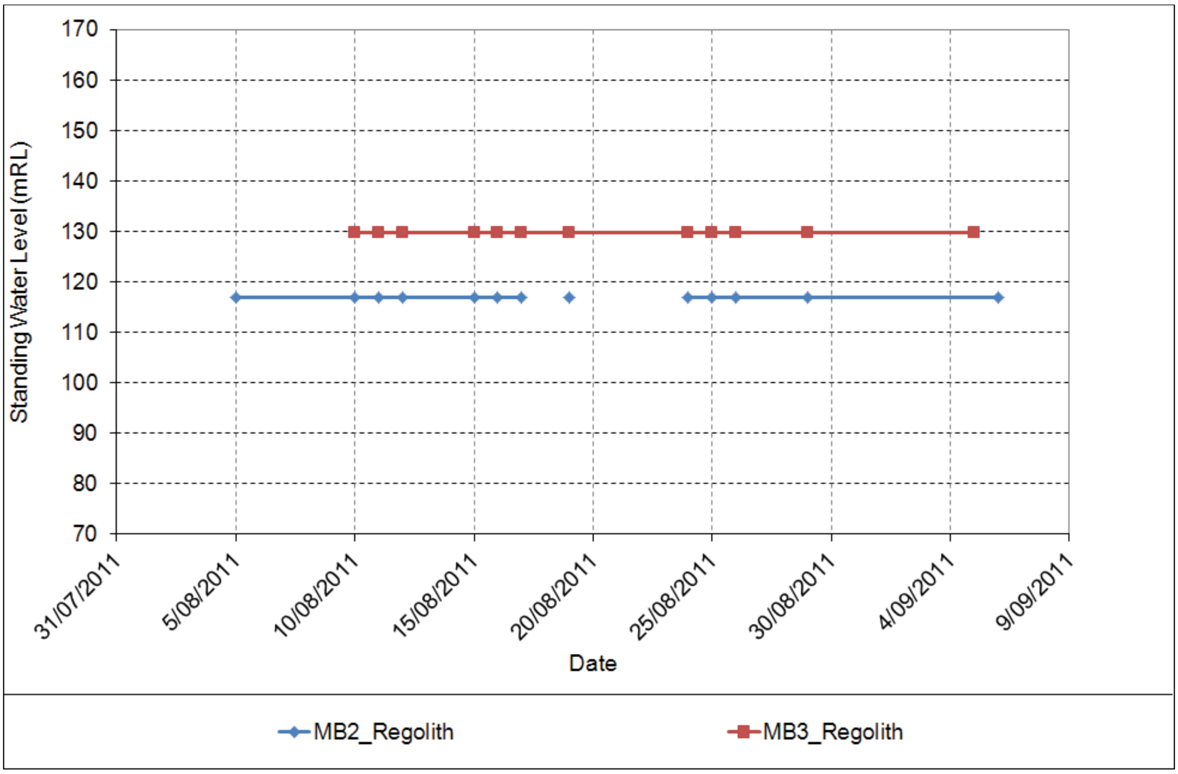

Figure 11: Permian Regolith Unit Hydrographs

6.3 Permian Coal Measure Aquifers

6.3.1. Distribution

The Permian coal seams subcrop on the eastern and northern areas of the study area and occur across the remainder of the study area as a regular layered sedimentary sequence.

The fresh unweathered Permian strata may be categorised into the following hydrogeological units:

- Hydrogeologically "tight" and hence very low yielding to essentially dry sandstone and lesser siltstone that comprise the majority of the Permian interburden/overburden; and
- Low to moderately permeable coal seams, typical ranging in thickness from 1 m to 5 m, which are the prime water bearing strata within the Permian sequence.

Groundwater has been noted to seep into open cut coal mines in neighbouring areas. Although groundwater seepage is often difficult to observe on the mining area walls due to low seepage rates and high evaporative losses, the joints are known to act as the main groundwater transmission mechanism. Seepage tends to be most evident in shallower high wall areas after extended rain periods when vertical infiltration through regolith generates weeps.

The interpolated seam surface contours for the floor of each of the seam groups are shown in a series of maps from Drawing No. 8 to Drawing No. 12. On a regional scale the coal seams surfaces dip gently to the south west. Towards the subcrop/outcrop area in the north and east, the seams are more steeply dipping.

Within the study area, the structure of the coal seams being mined has been mapped on relatively close drill spacing by the exploration program.

6.3.2. Hydraulic Parameters

The primary permeability of the interburden and overburden is known to be extremely low and typically does not yield significant quantities of water. The occurrence and flow of groundwater within the coal seams is governed by the presence of micro faults, joints, fractures and bedding planes which are often locally discontinuous. Areas devoid of secondary structural features tend to have poor groundwater transmission characteristics and confinement within different strata. Areas with enhanced jointing, such as near the sub-crop or the steeply dipping strata near the Muswellbrook Anticline, are likely to provide localised conduits for flow and the potential for more active recharge or discharge.

A number of hydraulic tests have previously been undertaken within study area. Aquifer testing provides a means of estimating the bulk groundwater transmission and storage characteristics of a geological formation. Various procedures can be employed depending upon the saturated aquifer thickness, regional extent, yields, and bore completeness. MER[7] undertook a number of tests using various assessment methods. These tests included:

- Airlift yield tests of coal measures;
- Injection (falling head) tests of coal measures; and
- Laboratory core tests of interburden (i.e. sandstone/siltstone).

The falling head tests undertaken by MER[7] involved the injection of water into eight monitoring bores. The response of the water level (a function of the aquifer hydraulic parameters) was measured over time to calculate the hydraulic conductivity of the coal measure. The results of the falling head tests are shown in Table 15.

Similarly, the results of the falling head tests undertaken with the coal seams as part of the current study are summarised in Table 16. The results shown in Table 15 are generally lower by multiple orders of magnitude compared to the results shown in Table 16. The lower values of hydraulic conductivity measured from the historical monitoring bores is most likely attributable to the bore constructions. The older bores are assumed to intersect multiple coal seams, and presumably the interburden between them. The interburden is expected to influence the results by lowering the 'averaged' hydraulic conductivity for the particular hole.

Table 15: HYDRAULIC CONDUCTIVITY FROM INJECTION (FALLING HEAD) TESTS		
Bore	**Depth (m)**	**Hydraulic Conductivity (m/day)**
DD1004	105.75	6.1×10^{-3}
DD1005	138.55	8.5×10^{-3}
DD1014	90.48	1.5×10^{-2}
DD1015	162.50	6.7×10^{-4}
DD1016	126.4	$7.6. \times 10^{-4}$
DD1017	--	9.9×10^{-3}
DD1018	--	6.2×10^{-4}
DD1025	44.62	2.1×10^{-3}

Table 16: HYDRAULIC PERMEABILITY TEST RESULTS – PERMIAN							
Bore ID	**Hydraulic Conductivity (K) (m/day)**						
	Falling Head Test		**Rising Head Test**		**Min.**	**Max.**	**Avg.**
	Bouwer-Rice	**Hvorslev**	**Bouwer-Rice**	**Hvorslev**			
MB1 Redbank	1.28	0.98	0.10	0.08	0.08	1.28	0.61
MB1 Whybrow	0.18	0.13	0.36	0.26	0.13	0.36	0.23
MB4-Coal	1.34	0.91	1.21	0.91	0.91	1.34	1.09

Notes: Bouwer-Rice (1976)[18] method of analysis
Hvorslev (1951)[19] method of analysis

Airlift yield measurements taken from exploration drill holes were reported by MER[7]. The flow rates were measured by the exploration drilling crew using a V-notch weir. MER[7] reported that many holes had no yield and 24 sites offered low but measurable yield for periods of up to 20 minutes. Estimates of hydraulic conductivity were generated by MER[7] at these exploration sites assuming the airlift yield represented a stabilised flow.

Table 17 provides a summary of calculated hydraulic conductivity derived from exploration drill hole airlift yield. Where zeros are indicated, no airlift yield was observed and the hydraulic conductivity is assumed to be lower than 1.0×10^{-5} m/day. Analyses of airlift yields were completed using the Logan method, as described by Kruseman & DeRidder[23], for steady state conditions to derive an estimate of hydraulic conductivity.

Airlift yields have also been recorded during subsequent exploration programs conducted in 2001, 2002/2003, 2004, 2005 and 2006. In approximately 104 exploration holes, groundwater airlift yield was not recorded (or no water present). Approximately 84 exploration holes produced low but measurable yield. The maximum recorded airlift yield from these exploration programs was 2.8 L/s and the median was 0.45 L/s. The median airlift yield for these later exploration programs is the same as that recorded during the 1998 program.

[23] Kruseman G.P. and DeRidder N.A., (2000), "*Analysis and Evaluation of Pumping Test Data*", Second Edition, International Institute for Land Reclamation and Improvement, The Netherlands.

Table 17: HYDRAULIC CONDUCTIVITY ESTIMATES FROM AIRLIFT YIELDS							
Bore	**Depth (mbgl)**	**Airlift (L/s)**	**Hydraulic Conductivity (m/day)**	**Bore**	**Depth (mbgl)**	**Airlift (L/s)**	**Hydraulic Conductivity (m/day)**
RD1000	127	0	--	RD1034	241	3.42	1.0×10^{-2}
RD1001	109	0	--	RD1036	139	0.45	4.7×10^{-3}
RD1002	103	0	--	RD1036	235	1.24	3.4×10^{-3}
RD1003	97	0	--	RD1037	114	0.139	1.5×10^{-3}
RD1004	127	0	--	RD1038	219	0.42	1.4×10^{-3}
RD1005	145	0	--	RD1040	-	-	-
RD1006	43	0.0899	5.6×10^{-2}	RD1041	169	0.219	1.8×10^{-3}
RD1007	121	0	--	RD1042	239	0.008	1.8×10^{-5}
RD1008	115	0	--	RD1043	145	0.788	6.0×10^{-3}
RD1009	118	0	--	RD1044	120	1.24	1.3×10^{-1}
RD1010	73	0	--	RD1044	187	1.24	1.3×10^{-2}
RD1011	97	0	--	RD1045	198	0.219	1.6×10^{-3}
RD1013	163	0	--	RD1046	-	-	-
RD1014	151	0	--	RD1047	312	0.788	1.2×10^{-3}
RD1015	139	0	--	RD1048	60	0.788	1.3×10^{-1}
RD1018	127	0	--	RD1048	127	1.82	2.2×10^{-2}
RD1017	121	0	--	RD1049	120	2.96	5.4×10^{-2}
RD1018	151	0	--	RD1050	145	1.24	3.0×10^{-2}
RD1022	78	0.322	2.8×10^{-2}	RD1051	80	0.45	3.8×10^{-2}
RD1026	145	0	--	RD1052	187	0.79	5.4×10^{-3}
RD1027	109	0.32	2.0×10^{-2}	RD1055	139	0.786	1.3×10^{-2}
RD1027	193	1.82	1.2×10^{-2}	RD1055	229	1.82	6.5×10^{-3}
RD1027	307	1.51	2.8×10^{-3}	RD1055	289	2.55	5.0×10^{-3}
RD1028	175	0	--	RD1023	70	0.766	3.3×10^{-2}
RD1029	271	0.45	1.5×10^{-3}	RD1023	127	0.508	4.7×10^{-3}
RD1030	157	0.08	6.4×10^{-4}	RD1024	84	0.168	4.4×10^{-3}
RD1032	121	0	--	RD1024	128	0.219	2.0×10^{-3}
RD1033	130	0	--	RD1026	110	0.422	9.1×10^{-3}
RD1034	91	1.24	8.1×10^{-2}	--	--	--	--

Hydraulic testing of exploration bores and geotechnical holes by MER[7] indicate low hydraulic conductivities prevailing within the coal measures with a median value less than 4.0×10^{-3} m/day calculated from falling head tests. Airlift yields measured during drilling have also been used to establish a median estimate of conductivity of 6.0×10^{-3} m/day for the coal measures. These estimates are lower than estimates derived at other adjacent mine sites.[32]

A summary of the results of aquifer testing undertaken by MER[7] is presented in Table 18.

Table 18: SUMMARY HYDRAULIC CONDUCTIVITY ESTIMATES				
Source of Data	**Minimum (m/day)**	**Maximum (m/day)**	**Average (m/day)**	**Median (m/day)**
Falling head tests of coal measures	6.2×10^{-4}	1.4×10^{-2}	5.4×10^{-3}	4.1×10^{-3}
Airlift yield tests of coal measures	1.9×10^{-5}	1.3×10^{-1}	2.2×10^{-3}	6.3×10^{-3}
Core tests of interburden	8.3×10^{-7}	3.3×10^{-3}	2.5×10^{-4}	3.5×10^{-6}

The relationship between hydraulic conductivity determined from the tests undertaken by MER[7] and depth below ground level is illustrated in Figure 12. An exponential relationship is observed within the hydraulic conductivity of the coal measures decreasing with depth below ground surface. The decline of coal seam hydraulic conductivity with depth has previously been documented for the Jerrys Plains subgroup for sites located within the Hunter Valley by AGC[24] in 1984. The data obtained via the MER[7] aquifer testing indicates a good correlation with the hydraulic conductivity values obtained by AGC[24].

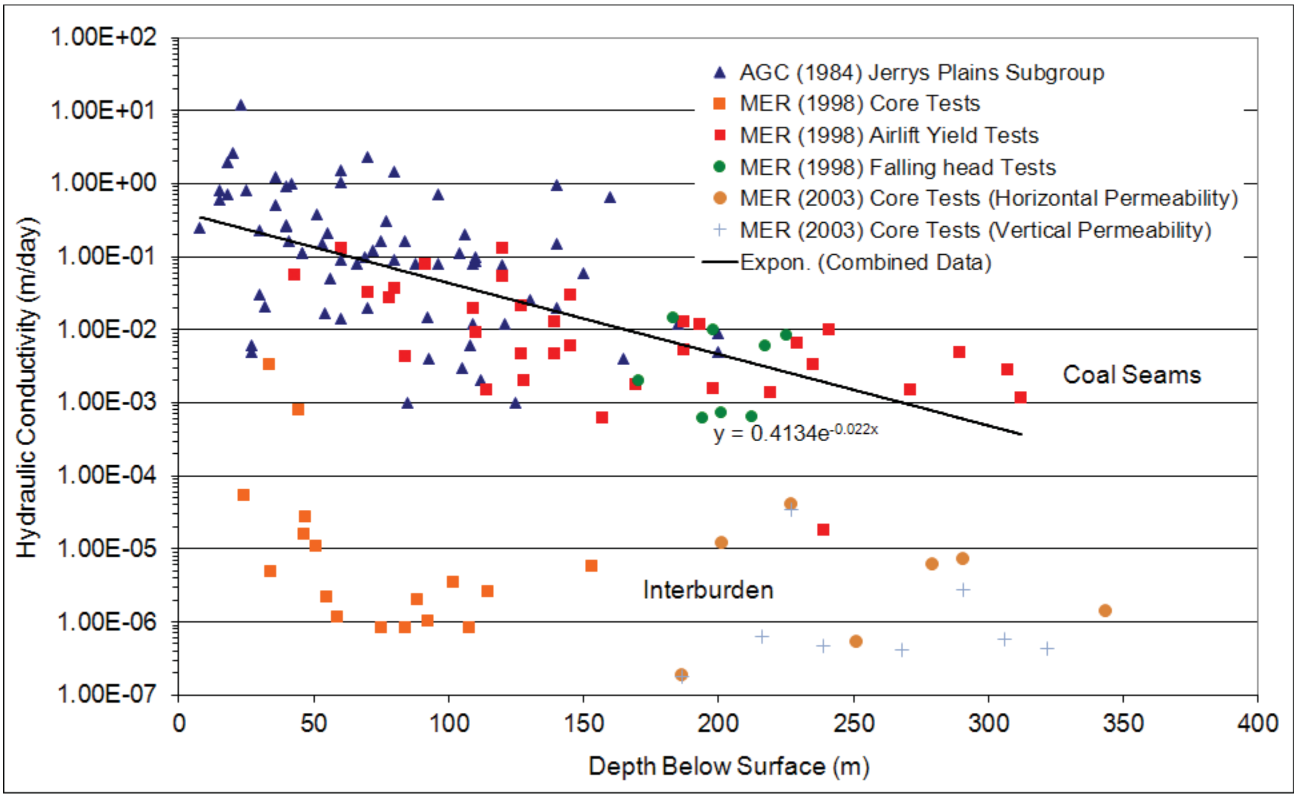

Figure 12: Hydraulic Conductivity versus Depth for Jerrys Plains Subgroup

Figure 12 indicates a general decline in coal seam permeability with increasing depth of about two orders of magnitude, from about 2.0 x 10^{-1} m/day near the surface to about 1.0 x 10^{-3} m/day at a depth of approximately 300 m. Figure 13 shows the data presented as a histogram and suggests the median hydraulic conductivity for the coal seams lies between 0.001 m/day and 0.01 m/day.

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[24] Australian Groundwater Consultants Pty Ltd, (June 1984), *"Effects of Coal Mining on Groundwater Resources in the Upper Hunter Valley"*, Volume 1.

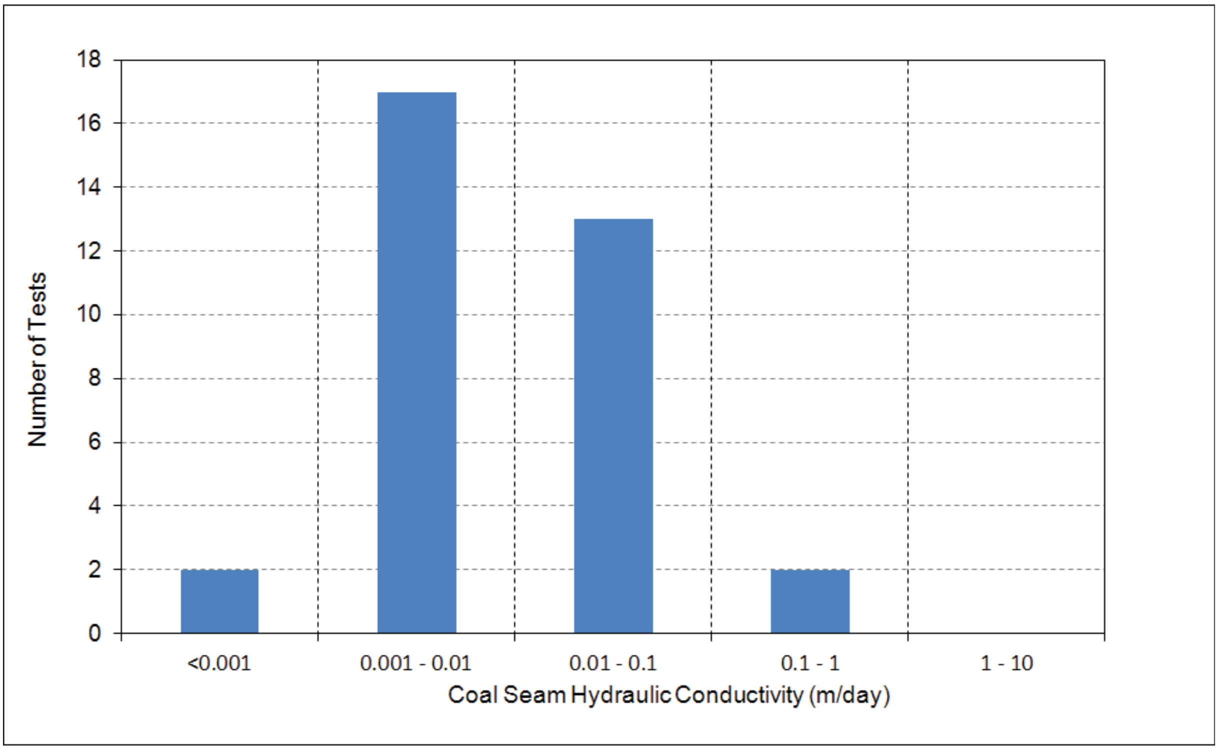

Figure 13: Coal Seam Hydraulic Conductivity

In addition to in situ hydraulic testing, laboratory tests for rock mass intergranular hydraulic conductivity were conducted by MER[7] and MER[25] on selected cores obtained from geotechnical bores. Tests were undertaken mainly on interburden exhibiting potential for intergranular storage and comprising sandstones and siltstones. Table 19 provides a summary of calculated hydraulic conductivity derived from laboratory tests of core samples.

[25] Mackie Environmental Research, (2003), "*Saddlers Creek Coal Project – 2003 Groundwater*", May 2003.

Table 19: INTERBURDEN HYDRAULIC CONDUCTIVITY ESTIMATES			
Bore	Depth (m)	Lithology	Vertical Hydraulic Conductivity (m/day)
DD1004	44.1	Sandstone – Medium Grained	7.9×10^{-4}
DD1004	50.7	Claystone	1.1×10^{-5}
DD1005	24.3	Sandstone – Medium Grained	5.5×10^{-5}
DD1005	47	Sandstone – Fine Grained	2.8×10^{-5}
DD1005	58.4	Sandstone – Fine Grained	1.2×10^{-6}
DD1014	74.7	Sandstone – Fine Grained	8.3×10^{-7}
DD1015	92	Claystone	1.1×10^{-6}
DD1015	107.4	Sandstone – Fine Grained	8.3×10^{-7}
DD1015	153	Sandstone – Fine Grained	5.8×10^{-6}
DD1016	46.5	Sandstone – Fine Grained	1.6×10^{-5}
DD1016	114.3	Siltstone	2.7×10^{-6}
DD1017	83.7	Claystone	8.3×10^{-7}
DD1017	101.5	Sandstone – Fine Grained	3.5×10^{-6}
DD1018	33.4	Conglomerate	3.4×10^{-3}
DD1018	54.8	Claystone-Siltstone	2.2×10^{-6}
DD1018	88.1	Sandstone – Fine Grained	2.1×10^{-6}
DD1025	33.8	Sandstone – Medium Grained	5.0×10^{-6}

The laboratory permeability tests on core samples yielded a vertical hydraulic conductivity range for the interburden between 8.3×10^{-7} m/day and 3.4×10^{-3} m/day. Results confirm very low values of vertical hydraulic conductivity and a potential for interburden to effectively hydraulically isolate flow between coal seams unless jointing within the unit is present. The vertical hydraulic conductivity values derived from laboratory core testing are presented in Figure 12. These results compare favourably with other groundwater assessments undertaken throughout the Hunter Valley which have indicated that the interburden has very low values of hydraulic conductivity.[35]

It should be noted that the laboratory results cannot take into account the impact of fracturing of the interburden and therefore does not show the rock mass hydraulic conductivity but only the hydraulic conductivity of an undisturbed sample. Based on experience with similar geologic settings, it is expected that the vertical horizontal hydraulic conductivity is 10 to 100 times lower than the horizontal hydraulic conductivity.

6.3.3. Yield and Usage

Three shallow monitoring bores drilled into the Permian strata underlying the alluvial aquifer as part of the current investigation returned moderate to low yields. The highest yielding bores were MB1-Redbank which recorded 1.19 L/s and MB1-Whybrow which recorded 1.8 L/s during drilling. The lowest yielding monitoring bore was MB4-Coal which recorded 0.16 L/s and intersected very low permeability siltstone and a thin intersection of coal.

Usage of groundwater from the Permian strata via bores is limited in the vicinity of the study area. Only one registered bore (GW049223) is located to the north of the Project, near the operations of Mt Arthur Coal Mine to the north, and two registered bores (GW078709 and GW029655) are located in the far west of the lease (Drawing No. 7). Information on these bores is relatively limited and yield information is not available. However, the yield is anticipated to be low based on yields measured during nearby exploration drilling.

Regionally, groundwater usage from the Permian strata is limited by the generally brackish to saline nature of the groundwater and the variable and low yields.

6.3.4. Water Quality

Groundwater within the Permian coal measures is known to be brackish to saline. The poor quality of this water is typical of coal seam water aquifers. The salinity of the groundwater means it cannot be classified as suitable for freshwater aquatic ecosystems or drinking water.

Table 20 provides pre-mining water quality data from boreholes intersecting coal seams. The groundwater contained within the Permian coal measures exhibit typical characteristics of coal seam water, with maximum values for TDS and chloride that exceed the Australian Drinking Water Guideline (ADWG) values (Table 20). In addition, maximum values for a range of metals (e.g. aluminium, boron, iron and lead) exceed the ADWG values. Elevated concentrations of aluminium, boron and lead are not uncommon in groundwater and are likely to be naturally occurring.

Table 20 indicates that the TDS content ranges from about 300 mg/L to 9470 mg/L and the pH is generally near neutral with a median of 7.1.

The generally low yield and poor quality of the groundwater in the coal seams indicates the environmental value can be classified as "primary industry" with the main potential use being for stock watering. Groundwater from the Permian coal measures is suitable for salt tolerant stock, that is, sheep and beef cattle. The Permian coal measures groundwater typically has a TDS concentration too high for irrigation, but as stated, in any case the yields are too low for irrigation. In some areas the Permian groundwater is too saline for any agricultural usage.

The concentrations of trace metals were low in all samples with Permian aquifers and below trigger levels in accordance with the ANZECC (2000) guideline for stock water. Median concentrations of chromium, copper and zinc slightly exceed ANZECC (2000) trigger levels for freshwater aquatic ecosystems in selected samples. However, as there is no industrial land use in the vicinity of the monitoring bore sites, the concentrations of dissolved trace elements are expected to be associated with minerals in the aquifer and as such, are naturally occurring.

Groundwater chemistry of the Permian coal measures, the regolith, and the alluvial aquifers has been classified using a technique proposed by Piper (1944)[16] as described in Hem (1970)[17]. The technique uses the ratios of major cations and anions to produce a single point for each water sample that represents the major ion water chemistry. Different plotting positions represent different ratios and hence different water types. The results for each of the monitoring bores sampled from the Drayton South monitoring bores are presented in Figure 14, a diagram that is commonly called a "Piper Plot".

Table 20: PRE-MINING GROUNDWATER QUALITY – PERMIAN AQUIFERS

Parameter	Drinking Water (ADWG)	Irrigation (ANZECC)	Stock Water (ANZECC)	Aquatic Ecosystems ANZECC Freshwater 95%	Monitoring Data			
					No.	Min.	Median	Max.
Electrical Conductivity (µS/cm)	-	**1250**	-	-	334	214	**4570**	**14140**
pH	**6.5 – 8.5**	-	-	-	328	6.2	7.1	**12.1**

Table 20: PRE-MINING GROUNDWATER QUALITY – PERMIAN AQUIFERS								
Parameter	**Drinking Water (ADWG)**	**Irrigation (ANZECC)**	**Stock Water (ANZECC)**	**Aquatic Ecosystems ANZECC Freshwater 95%**	**Monitoring Data**			
					No.	**Min.**	**Median**	**Max.**
Total Dissolved Solids (mg/L)	**500**	Highly dependent on crop type and soils	4000 (beef) 2500 (dairy) 5000 (sheep) 4000 (horses) 4000 (pigs) 2000 (poultry)	-	71	300	3520	**9470**
Bicarbonate Alkalinity as $CaCO_3$ (mg/L)	-	-	-	-	82	130	806	2220
Carbonate Alkalinity as $CaCO_3$ (mg/L)	-	-	-	-	28	10	110	722
Total Alkalinity as $CaCO_3$ (mg/L)	-	-	-	-	82	144	890	2525
Major Cation / Anions (mg/L)								
Chloride	**250**	**175** (sensitive crops) to >700 (tolerant crops)	-	-	82	58	**1235**	**5360**
Calcium	-	-	1000	-	82	3	26	215
Magnesium	-	-	2000	-	72	1	50	517
Potassium	-	-	1000	-	82	2	15	27
Sodium	-	**115** (sensitive crops) to >460 (tolerant crops)	-	-	82	81	**990**	**2640**
Sulphate	**250**	-	-	-	74	0.2	96	**520**
Trace Elements (mg/L)								
Aluminium	**0.2**	5	5	0.055	22	0.01	0.045	**16.2**
Arsenic	0.007	0.1	0.5	0.037	23	0.001	0.002	0.024
Boron	**0.3**	0.5	5	**0.3**	31	0.08	0.18	**0.43**
Chromium	0.05	0.1	1	**0.001**	12	0.001	**0.002**	0.016
Copper	1	0.2	0.4 – 5	**0.0014**	20	0.001	**0.002**	0.099
Iron	**0.3**	**0.2**	-	ID	36	0.22	**1**	**16**
Lead	**0.01**	2	**0.1**	**0.0034**	22	0.001	0.003	**0.154**
Nickel	0.02	0.2	1	**0.011**	23	0.001	0.003	0.027
Zinc	3	2	20	0.008	33	0.005	**0.014**	0.285

Notes:

1. aquatic ecosystems – ANZECC 2000 95% level of protection for freshwater ecosystems
2. stockwater – ANZECC 2000 - beef cattle trigger level used where values are species dependent
3. bold values exceed trigger levels

An overview of the grouping of data shows groundwater is dominated by a sodium chloride-bicarbonate type water with variable concentrations of magnesium. This water type is typical of regional groundwaters contained within the Wittingham Coal Measures. The similarity of plot positions indicates a similar ionic composition and therefore suggests a hydraulic connection between the alluvial and underlying regolith and Permian units.

The spread of the Permian coal measure water chemistry results presented on Figure 14, suggests water-rock interaction processes are taking place as groundwater migrates through the system. Van Voast[26] has identified high HCO_3 concentrations as the main cause for low Ca and Mg concentrations in coal seam waters. This is because the solubility of Ca and Mg decreases with high bicarbonate concentrations, which causes precipitation of calcite ($CaCO_3$) and dolomite ($CaMg[CO_3]_2$) in the aquifer. Another source of calcium and magnesium depletion is given by the process of ion exchange. In coal aquifers, groundwater may encounter clays or shales in adjoining units or in lenses or pockets as it flows through the coal seam. As a result, an ion exchange process takes place between these minerals and the water. In this process, Ca and Mg are held more tightly than Na in clays. Therefore, the outcome of this exchange is a soft groundwater (low Ca and Mg) with an enhanced Na concentration. This process is often more pronounced with increasing depth and away from sources of recharge. Therefore, as aquifer water flows into deeper parts of the basin, calcium and magnesium concentrations gradually decrease due to the exchange of ions with clays. The same inversely holds true for sodium concentrations which would increase further with increasing aquifer depth.

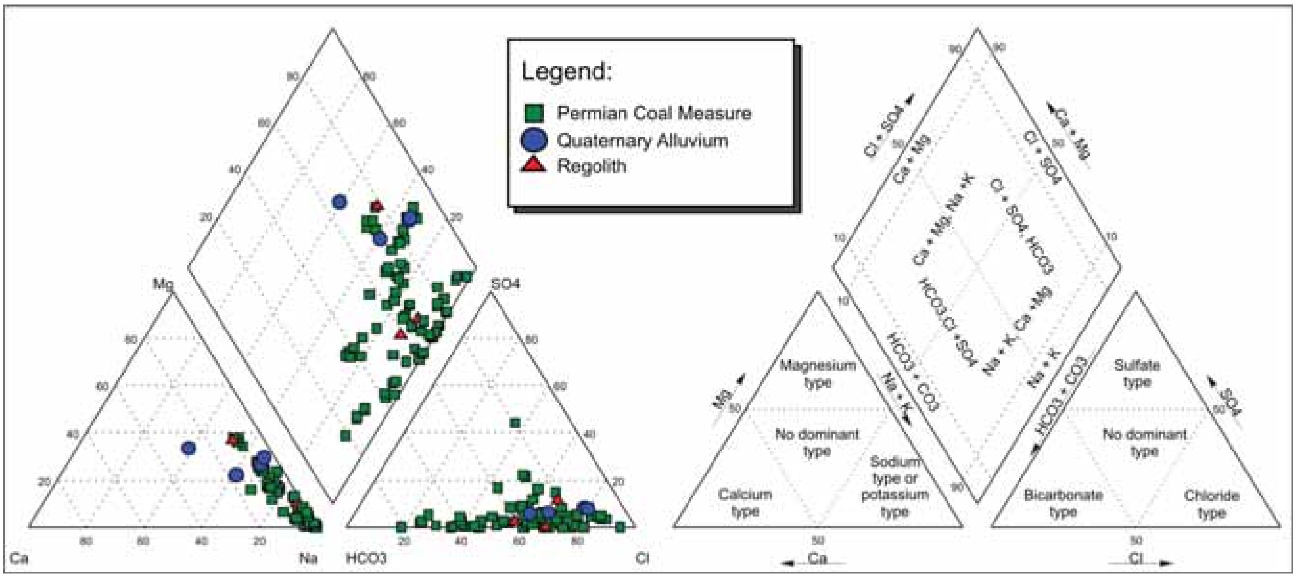

Figure 14: Groundwater Major Ion Chemical Composition – Trilinear (Piper) Diagram

6.3.5. Groundwater Levels and Recharge

The groundwater monitoring bores commissioned in 1998 are regularly monitored for water level and periodically for water quality as previously discussed. A hydrograph of the groundwater potentiometric head levels over the monitoring period are shown in Figure 15. The potentiometric head elevations have been reduced to the Australian Height Datum (RL m). The water levels within the bores reflect the regional potentiometric surface and illustrate the regional hydraulic gradient towards the Hunter River. More detailed hydrographs of the same data are presented in

[26] Van Voast, W.A., (2003), "*Geochemical signature of formation waters associated with coalbed methane*". AAPG Bulletin, 87(4): 667-676.

Figure 16 (RL 110 m to RL 130 m), Figure 17 (RL 130 m to RL 150 m), and Figure 18 (RL 150 m to RL 170 m).

The hydrograph of the bores monitoring the Jerrys Plains Subgroup Coal Measures illustrates little temporal variability in the potentiometric surface over time. This limited response to rainfall suggests recharge to the groundwater system is limited and slow. A CRD curve is also included on Figure 15 to Figure 18 to demonstrate the response of the coal measures to climatic events. The CRD curve is explained in the glossary of terms and Section 3.3. Drought conditions typically result in a decrease in aquifer recharge with a subsequent decline in groundwater levels, because water held in the aquifer is not being replenished. Conversely, increased aquifer recharge resulting from rainfall events subsequently raise groundwater levels. The hydrograph of potentiometric heads for most bores show a slow uniform decline during the period 2006 to 2007 coinciding with a decline in the CRD curve. Since 2007, a slight increase in the potentiometric surface has occurred as a result of above average rainfall conditions in most monitoring bores, while three monitoring bores have displayed a continuing decline, these being DD1005, DD1015, and DD1016. However, these results are anomalous to the surrounding bores of DD1004 and DD1014 where groundwater levels have remained relatively static since 2007.

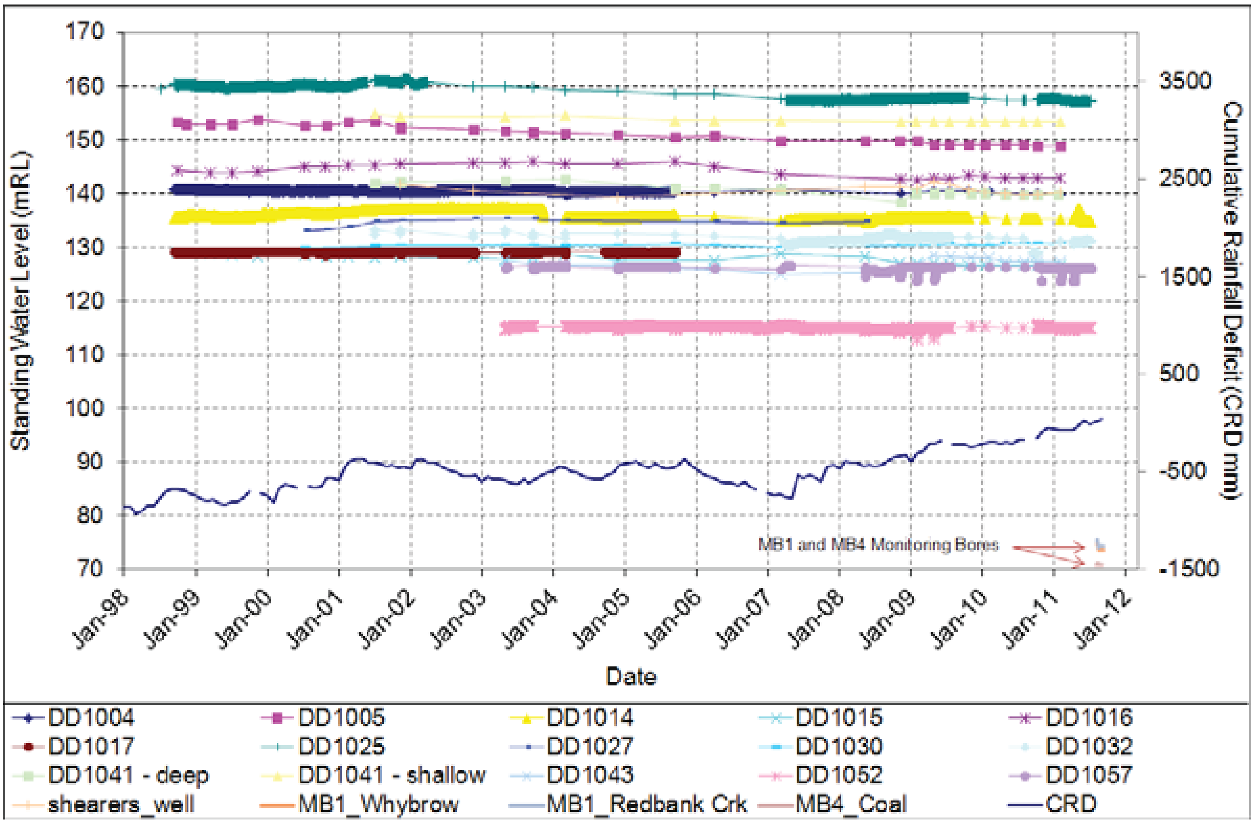

Figure 15: Hydrograph of Permian Coal Measures Potentiometric Head

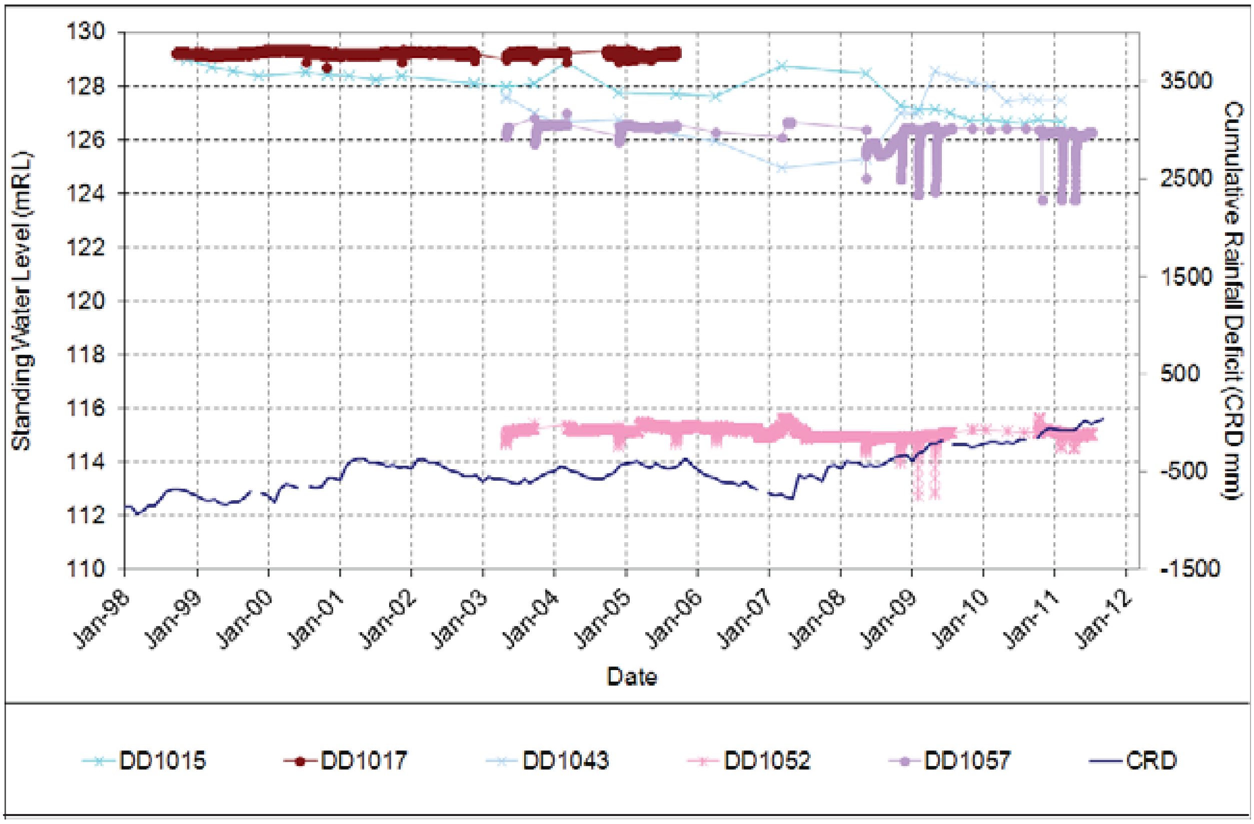

Figure 16: Hydrograph of Permian Coal Measures Potentiometric Head (RL 110 m – RL 130 m)

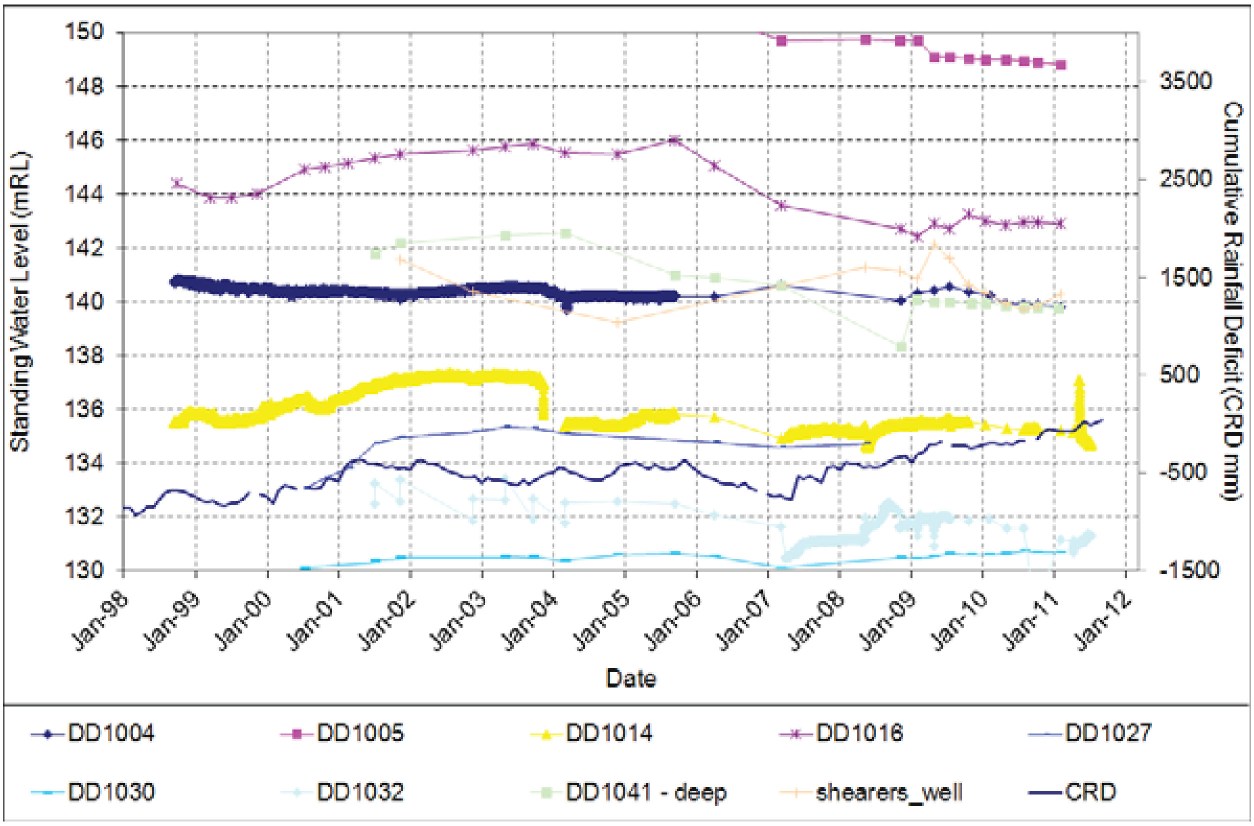

Figure 17: Hydrograph of Permian Coal Measures Potentiometric Head (RL 130m – RL 150m)

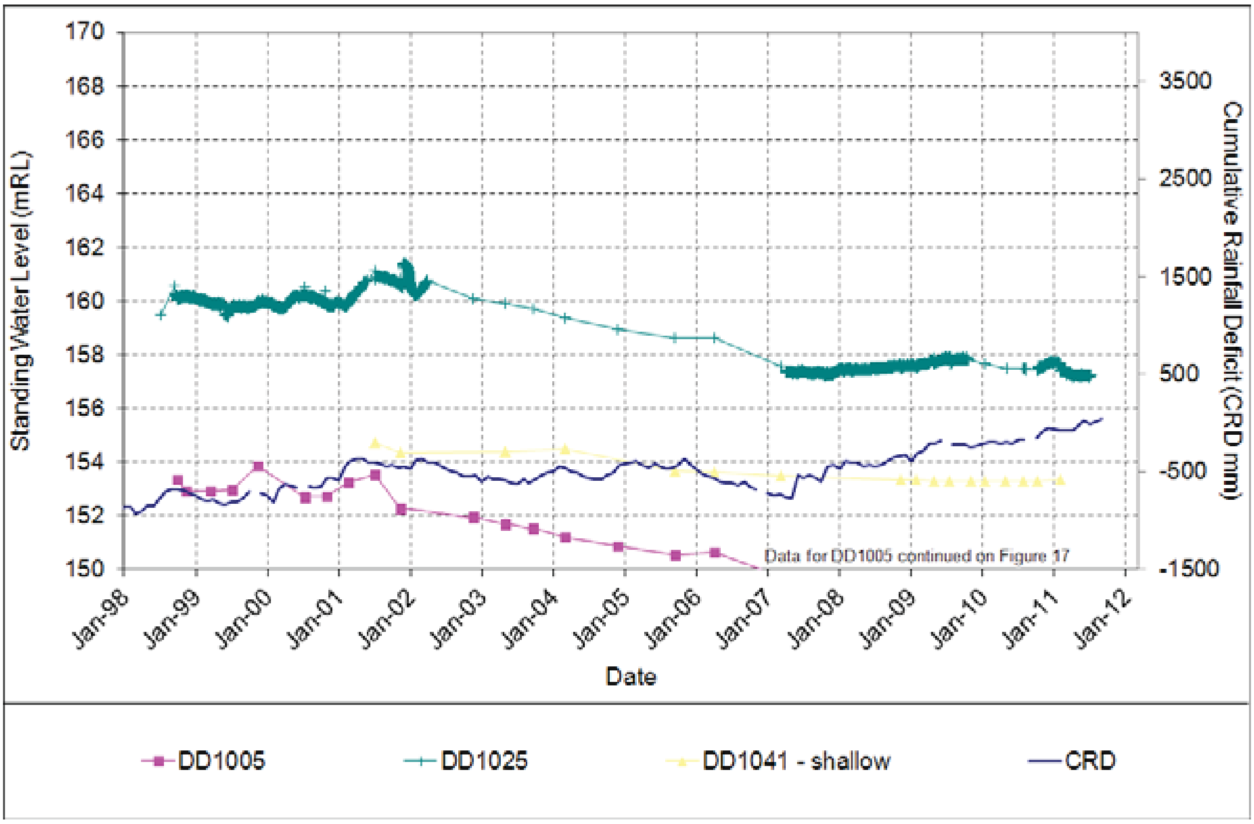

Figure 18: Hydrograph of Permian Coal Measures Potentiometric Head (RL 150 m – RL 170 m)

As indicated above, the potentiometric surface is the result of interactions between rainfall recharge over a very long period of time, and the influence of topography and geology. Groundwater recharge is by rainfall infiltration at seam subcrop areas, via the regolith (weathered Permian), and groundwater flows towards the lower lying areas where discharge occurs into the alluvial valleys and creeks/rivers. The Hunter River alluvium acts as a regional 'sink' to the entire system.

A groundwater level (potentiometric) surface contour plan was interpolated from water level measurements taken from open exploration holes and from monitoring bores. The contours shown on Drawing No. 13 indicate the potentiometric surface is a subdued reflection of the topography, with a groundwater mound beneath the topographically elevated areas of the ridgeline located in the east of the study area, and a hydraulic gradient towards the Hunter River.

Continuous pressure/water level monitoring at four piezometer sites exhibits low frequency movements relating to seasonal change, and higher frequency movement attributed to atmospheric pressure change. It is considered that these water level oscillations indicate low storativity in the coal measures[7].

The potentiometric surface grades from approximately RL 160 m in the north-east to RL 70 m in the south near the Hunter River. The new coal seam bores located near the Hunter River (MB1) confirm that a slight upward hydraulic gradient exists from the coal measures up into the base of the alluvial aquifer. A separate graph shown in Figure 19 illustrates that the groundwater heads within the two uppermost coal seams (the Whybrow and the Redbank Seams) are slightly higher than the head within the alluvial aquifer at the MB1 location confirming an upward hydraulic gradient. However, the head gradient at MB4 is marginally higher in the alluvium compared to the head within the underlying coal seam.

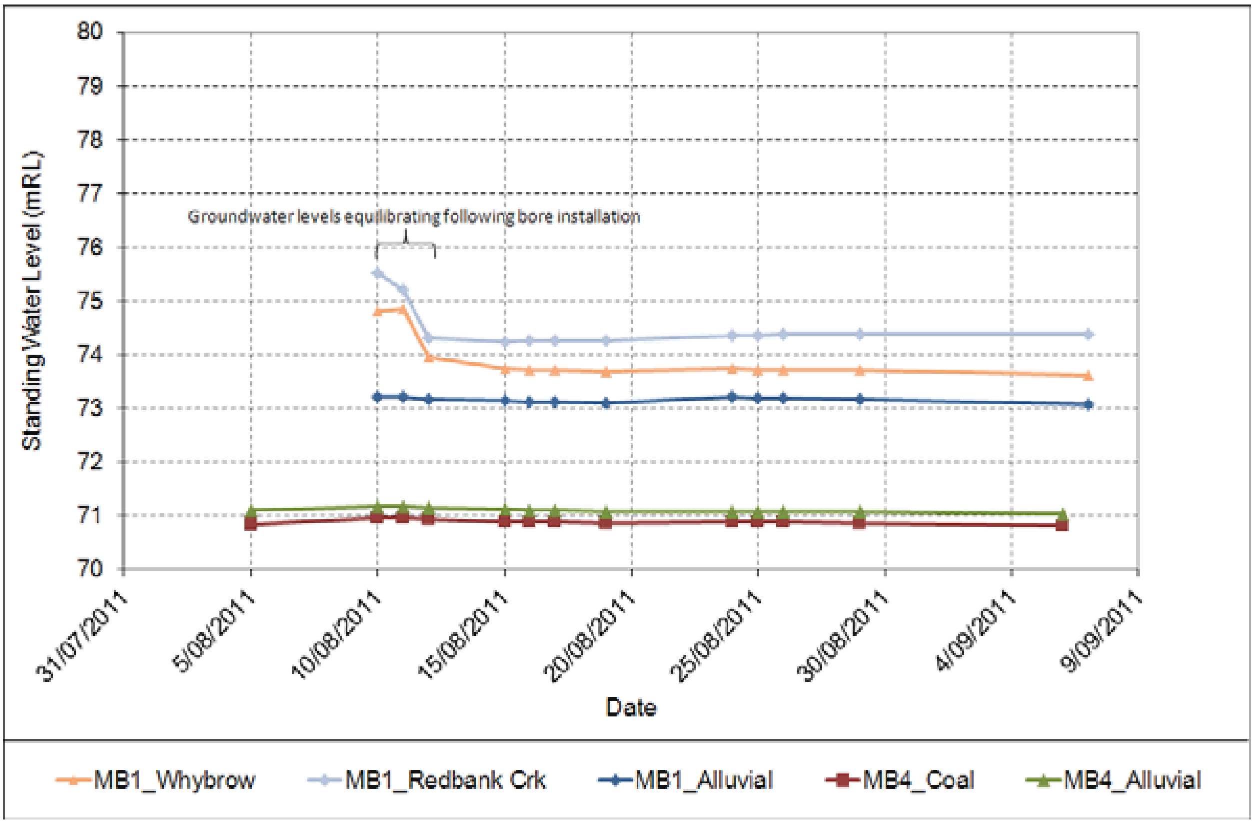

Figure 19: Hydrograph of Groundwater Levels within Monitoring Bores Located near the Hunter River

A vibrating wire piezometer was also installed near the monitoring bore MB1. The pressure sensors within VWP1 were installed within the following units:

- Interburden located immediately beneath the Hunter River alluvium (~21 mbgl);
- Interburden located between the Whybrow and Redbank Creek coal seams (~40 mbgl);
- Interburden located beneath the Redbank Seam (~73 mbgl);
- The Whybrow Seam (~87 mbgl); and
- The Whynot Seam (~109.2 mbgl).

The hydrograph of VWP MB1 is shown in Figure 20. The hydrograph illustrates that the interburden at a depth of about 21 mbgl (i.e. beneath the Hunter River) has a pore pressure of about RL 73 m. This pore pressure is comparable with the standing water levels measured within the MB1_Alluvial monitoring bore. This result further confirms an upward hydraulic gradient exists between the alluvium and the underlying units that exist immediately below.

Interestingly, the VWP MB1 sensors located within the deeper coal seams (Whybrow and Whynot coal seams) and interburden have a higher pore pressure at about RL100m. It is suggested that these pore pressures are a result of very low vertical hydraulic conductivity within the deeper coal measures which does not allow the heads to equilibrate with the overlying units. It is therefore anticipated that only the upper most coal seams and regolith are likely to have any significant hydraulic connection with the Hunter River alluvium. The higher potentiometric levels are consistent with the levels recorded in other VWPs located to the immediate north. Hydrographs of other VWPs located throughout the lease area are shown in Figure 21 to Figure 26 and their locations are shown on Drawing No. 5.

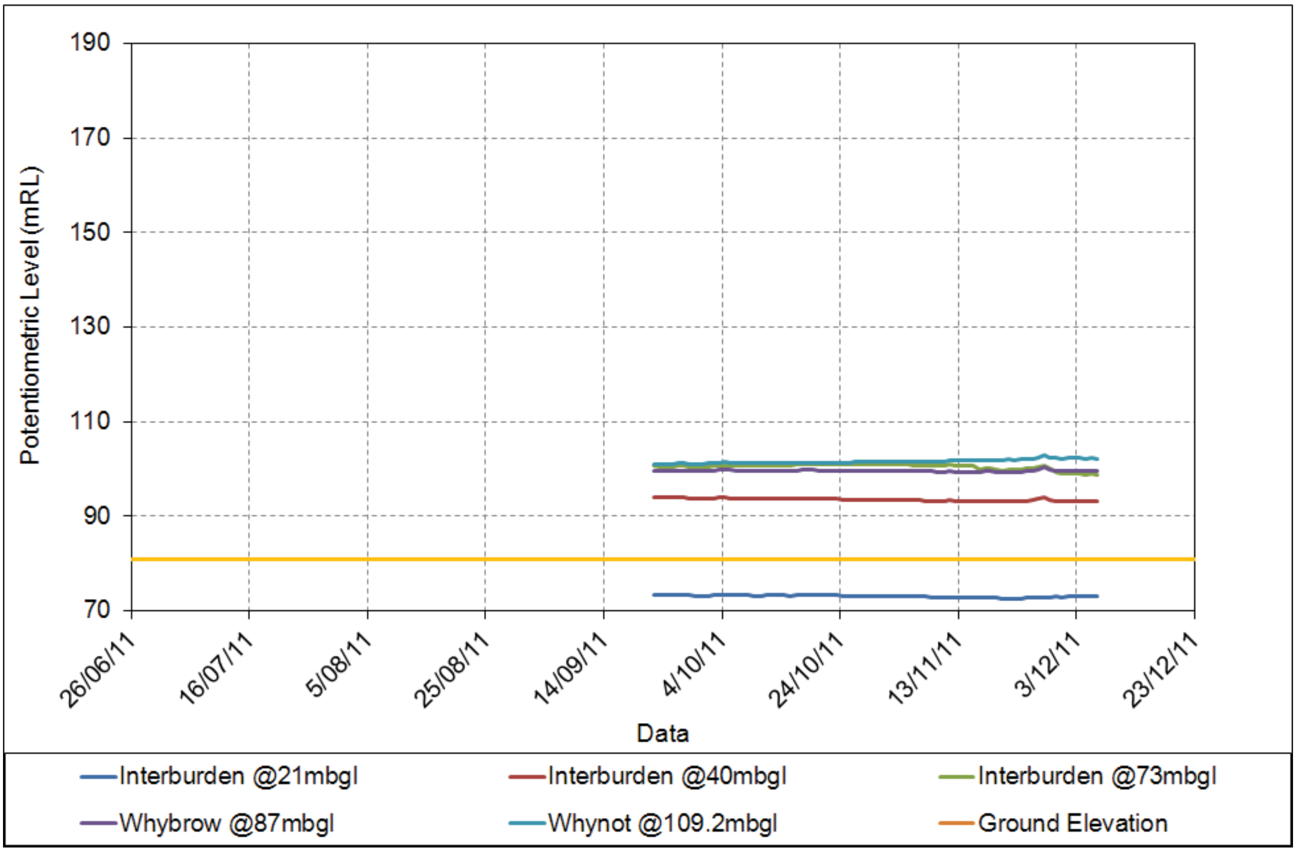

Figure 20: Hydrograph of VWP MB1 (RDW006a)

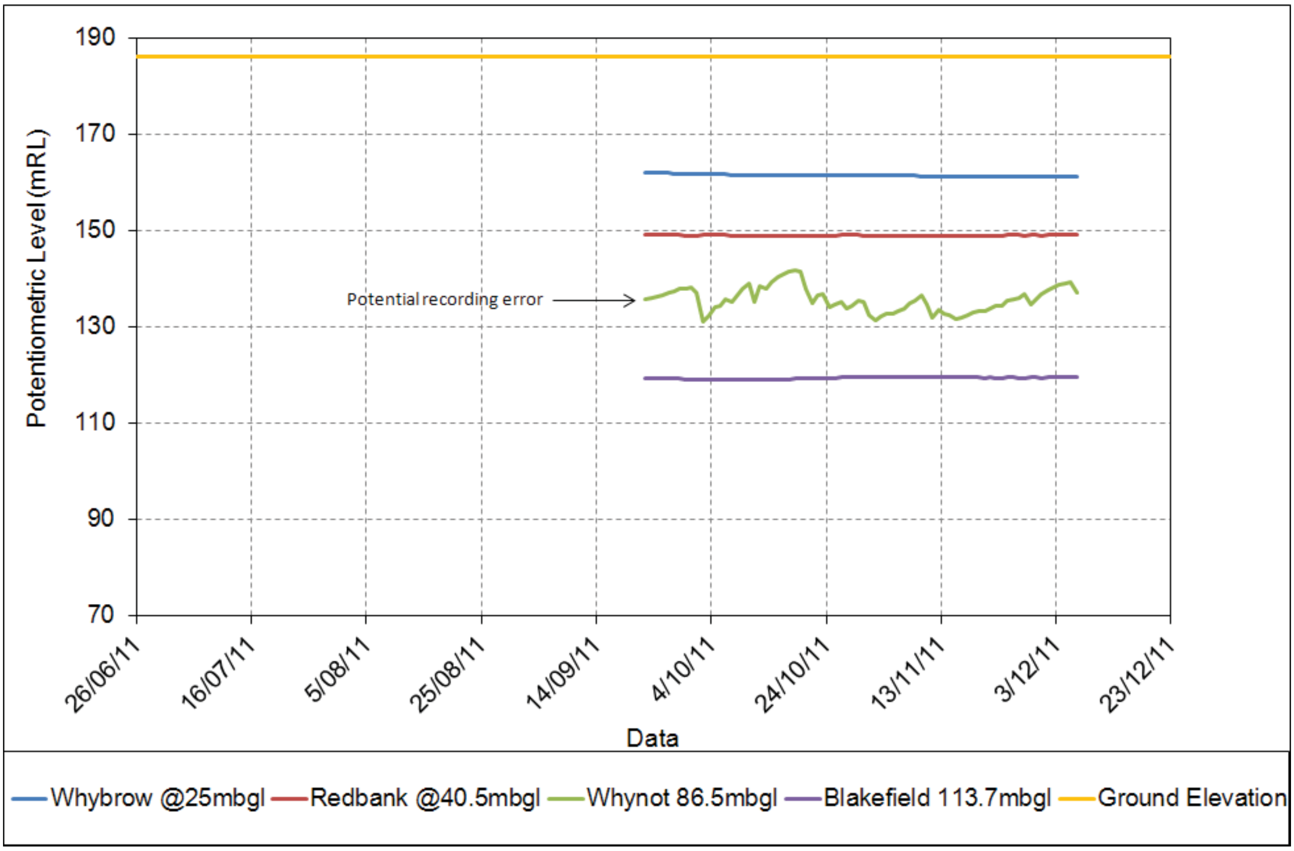

Figure 21: Hydrograph of VWP BLK6R12 (RD1220)

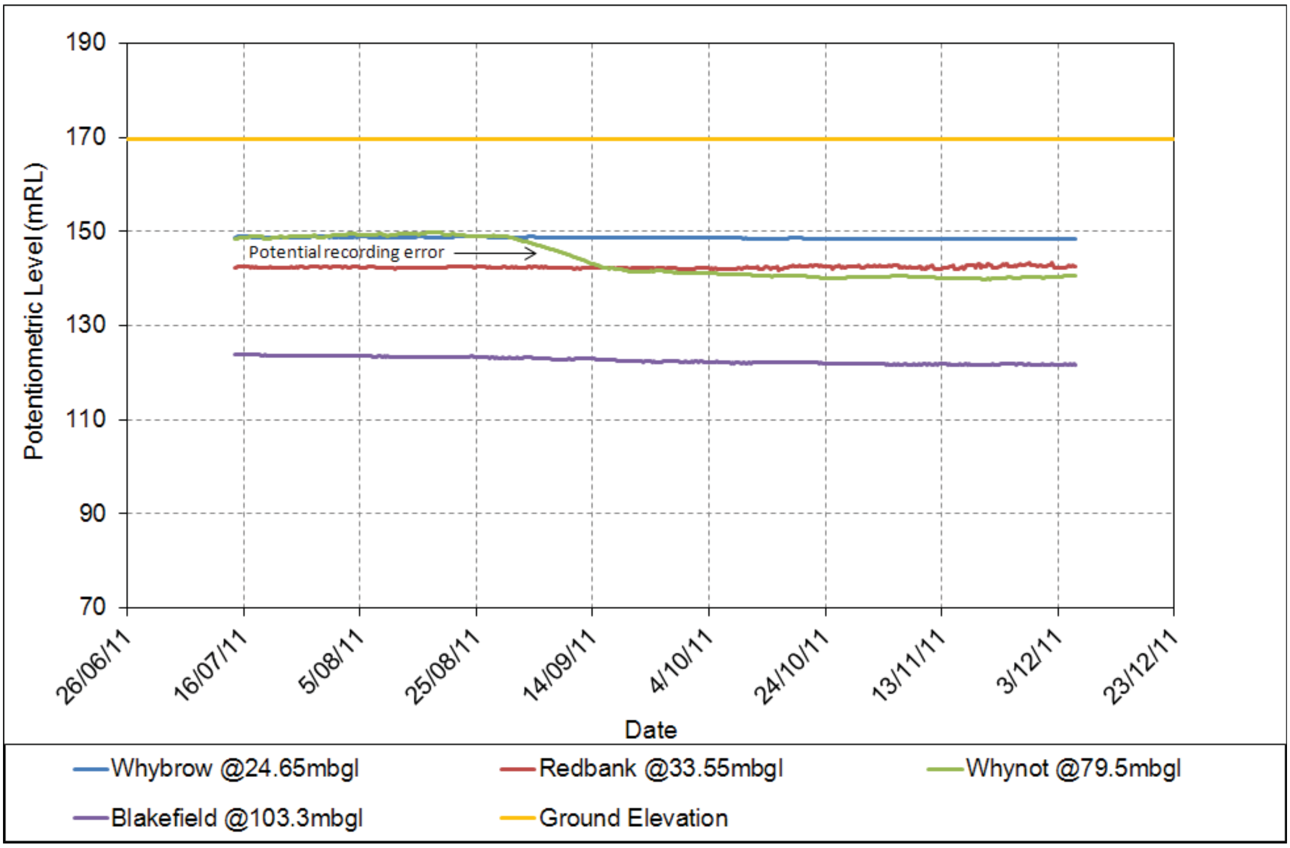

Figure 22: Hydrograph of VWP RBD1 (DD1170)

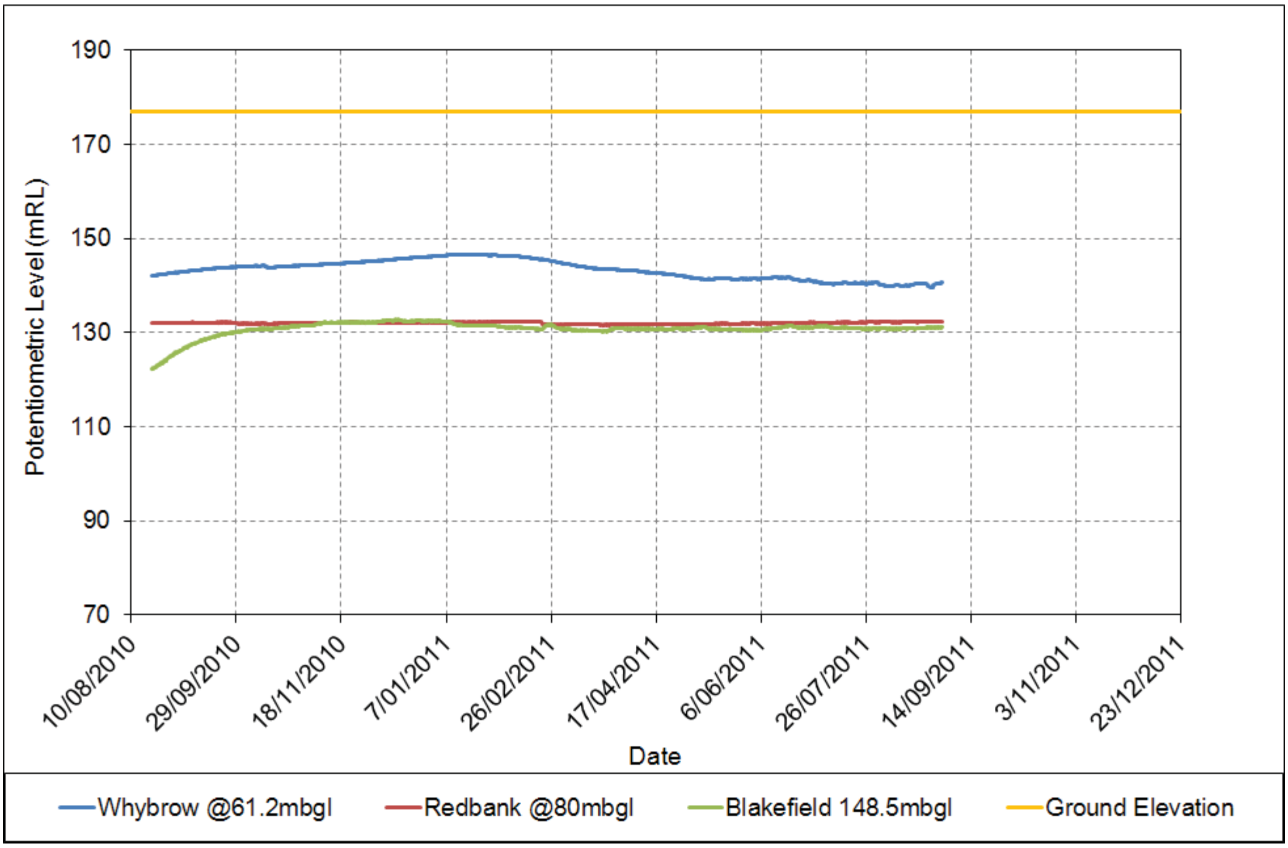

Figure 23: Hydrograph of VWP RBR2 (RD1192)

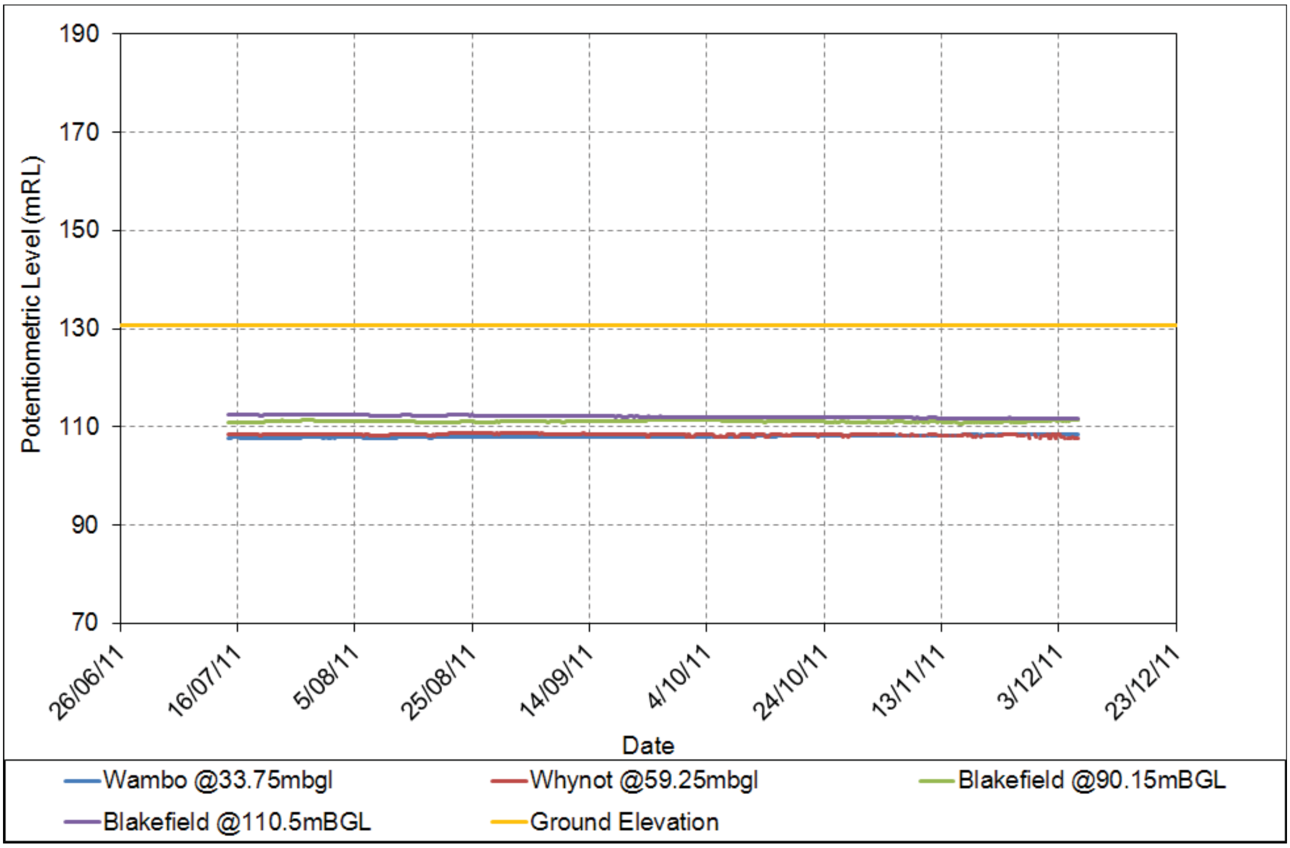

Figure 24: Hydrograph of VWP WND16 (DD1188)

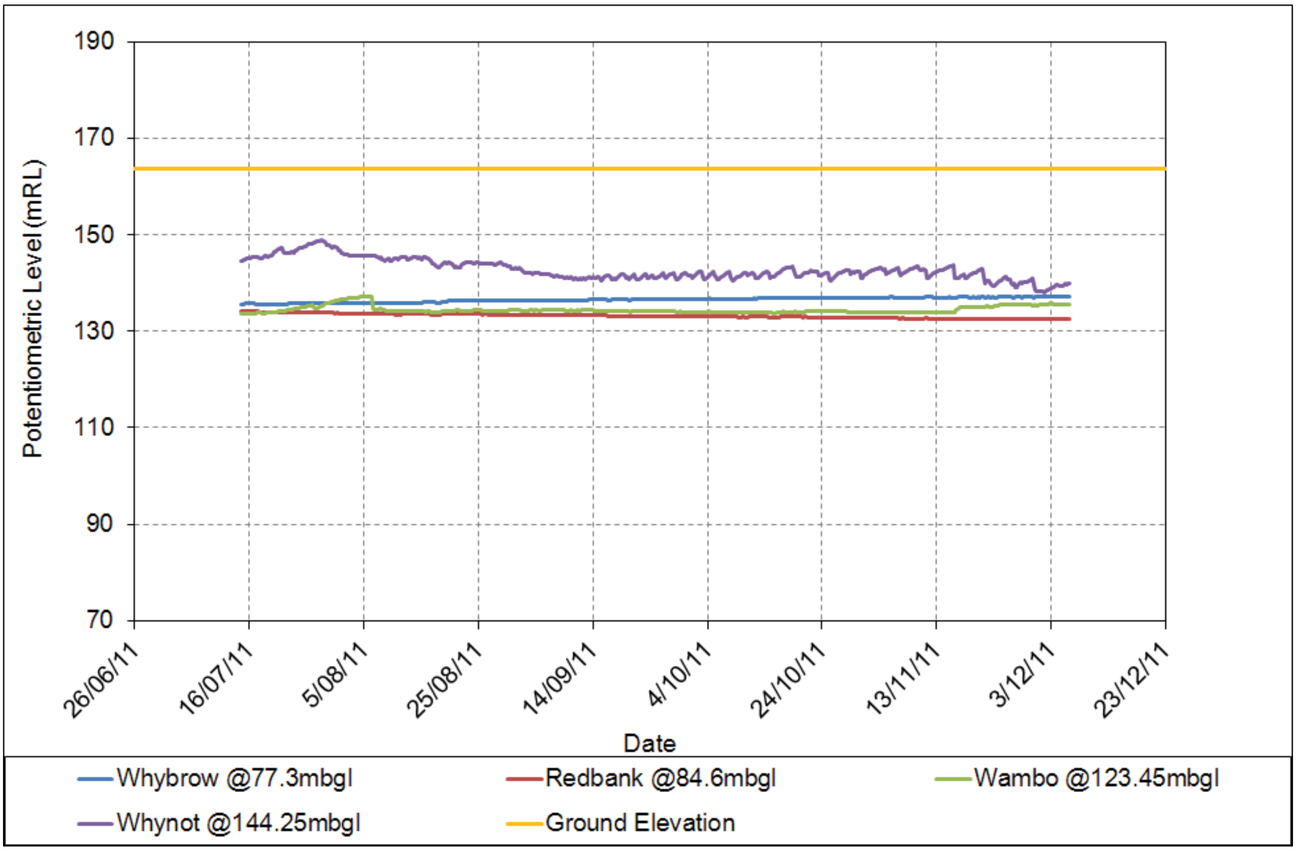

Figure 25: Hydrograph of VWP WND26 (DD1187)

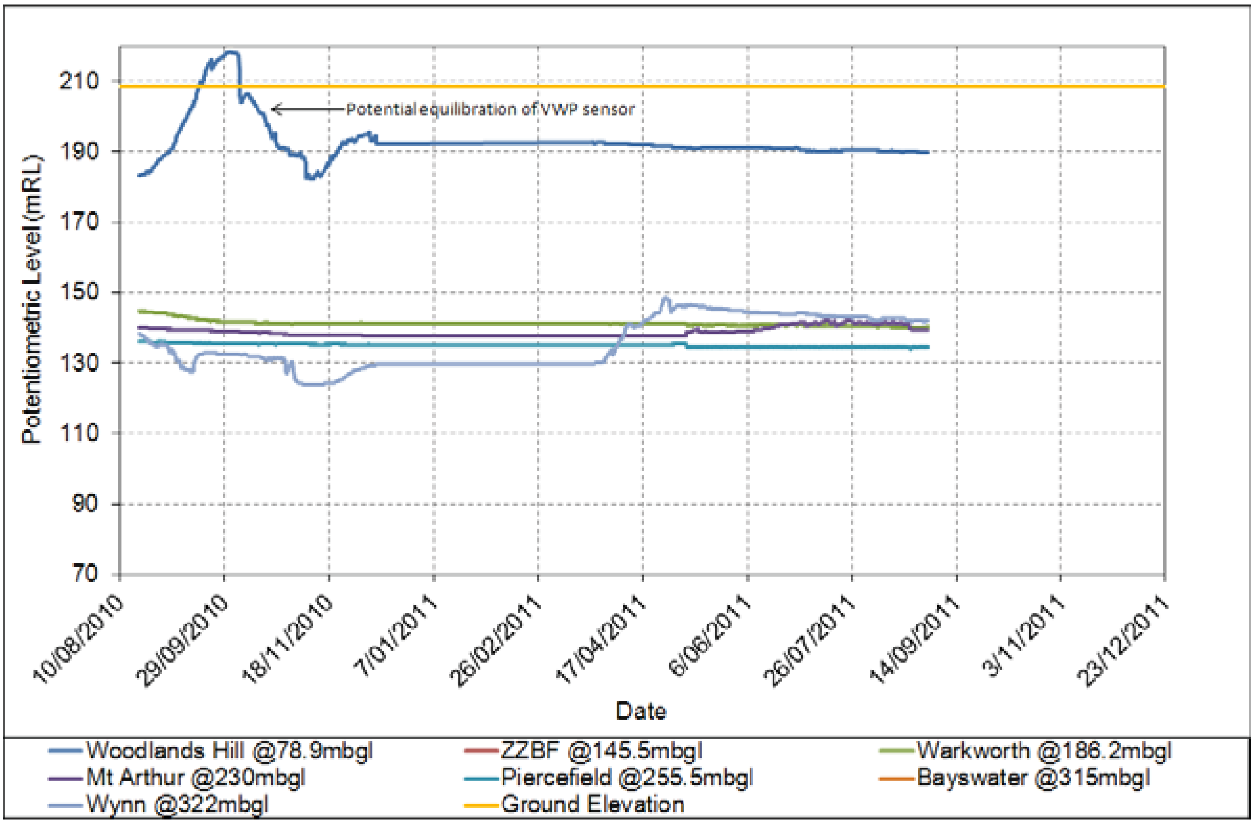

Figure 26: Hydrograph of VWP RD1189 (SD1_DD001)

6.3.6. Groundwater Dependent Ecosystems

Eco Logical[22] completed a stygofauna impact assessment (Appendix O of the EA) to determine the potential for stygofauna to exist proximal to the study area.

Eco Logical[22] confirmed:

> *Due to the depth of the water table, the low hydraulic conductivity and the isolation of the deeper Permian aquifers, these areas were considered as having a very low chance of being suitable for stygofauna habitat. Sampling in September 2011 found no stygofauna in Permian bores, and further sampling of these bores is unlikely to yield any fauna*.

7. PROJECT MINE PLAN

The conceptual mine plan layout for the Project consists of four mining areas, including:

- The Houston mining area;
- The Redbank mining area;
- The Whynot mining area; and
- The Blakefield mining area.

Mining operations are proposed to commence in the Whynot, Redbank and Blakefield mining areas generally progressing in a north to south sequence. In Year 3A (beginning of Year 3), construction of the Houston visual bund will commence to shield views into the Houston and Whynot mining areas as shown in Figure 27. During this period, mining activities will continue in the Whynot, Redbank and Blakefield mining areas. By Year 3B (end of Year 3), mining will commence in the Houston mining area as shown in Figure 28.

From Year 10, highwall mining operations commence in the Houston mining area followed by the Redbank and Blakefield mining areas in Year 15 and the Whynot mining area in Year 27 (see Figure 29 to Figure 33). Open cut mining and progressive rehabilitation continues throughout the life of the operation. The majority of the Redbank and Blakefield mining areas will be rehabilitated by Year 20 with the remainder progressively completed to final landform following Year 27 (final year of mining) (see Figure 34).

A conceptual final landform design has been developed for the Project in the event that mining operations do not continue beyond Year 27, whereby an orderly closure of the Project would then be achieved. A final void will remain at completion of open cut mining with a floor level of RL 70m and a depth of about 135 m. Throughout the life of the Project, all mining areas and activities will not encroach within the minimum required buffer of 150 m between open cut mining and a Schedule 3 stream alluvium, this being the Hunter River alluvium (DIPNR 2005 – refer Section 2.6). In addition, mining areas will also not encroach within the 40 m buffer from Schedule 2 streams, this being Saddlers Creek.

Advance dewatering of the coal seams via bores installed in the mining areas is not required or proposed.

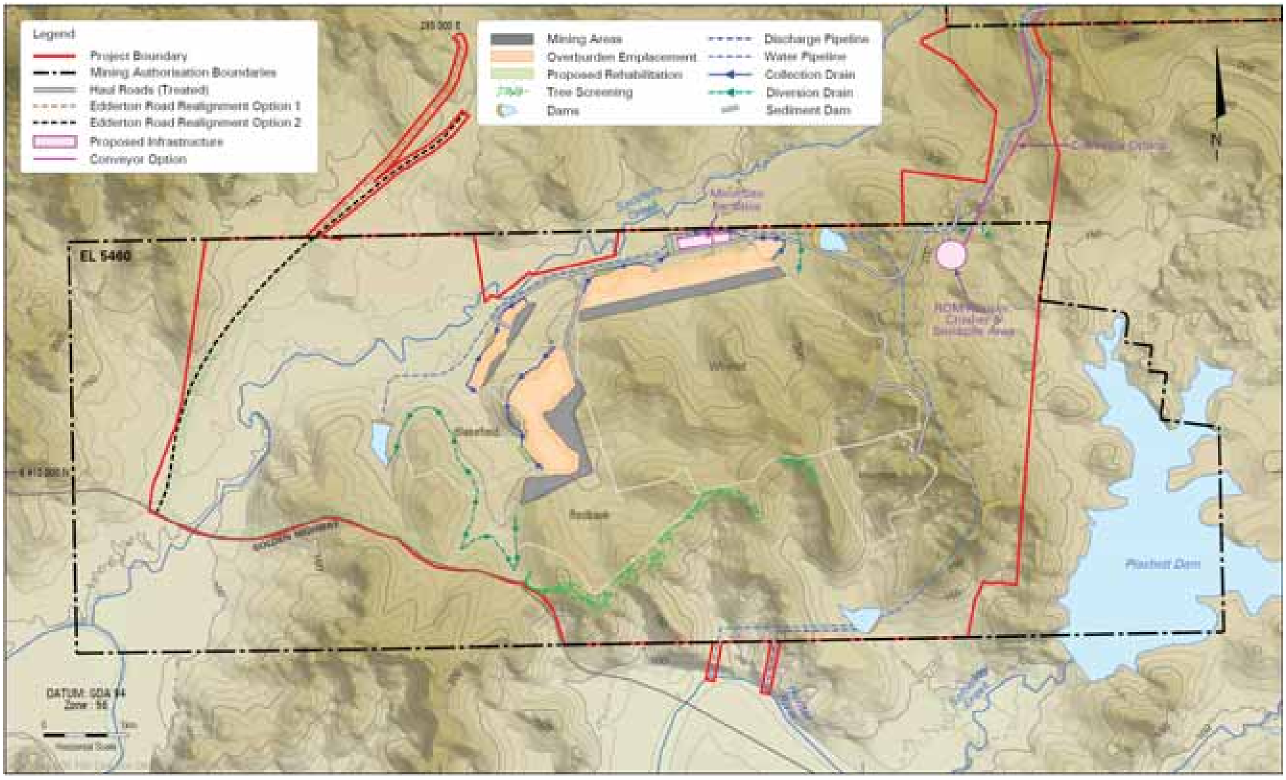

Figure 27: Mine Plan Year 3A

Source: Hansen Bailey, 2012

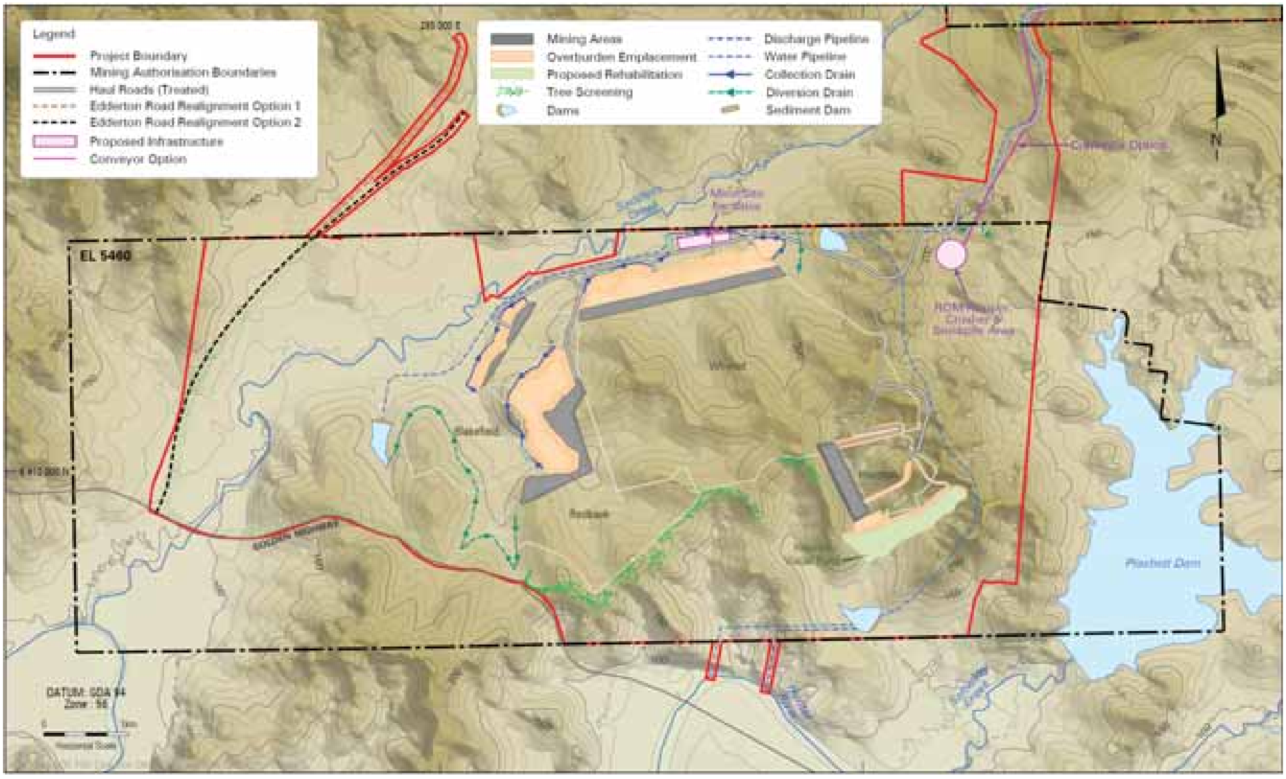

Figure 28: Mine Plan Year 3B

Source: Hansen Bailey, 2012

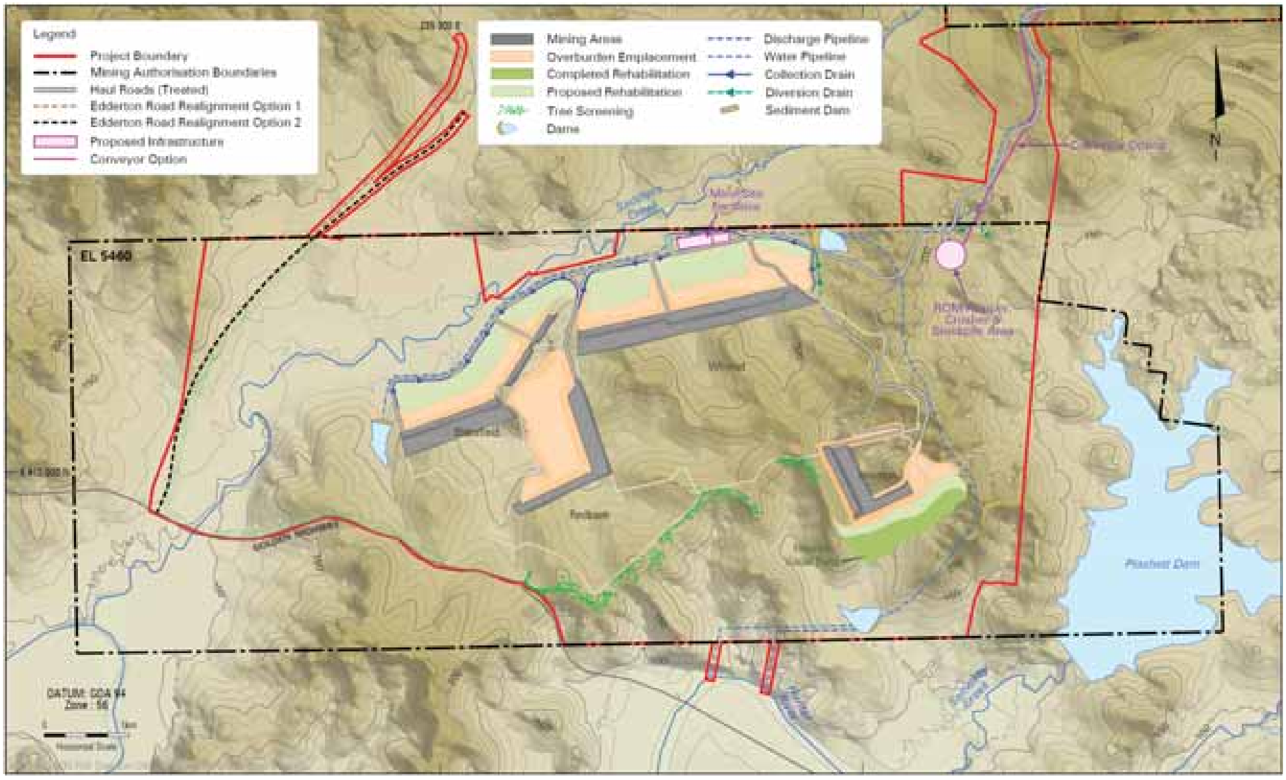

Figure 29: Mine Plan Year 5

Source: Hansen Bailey, 2012

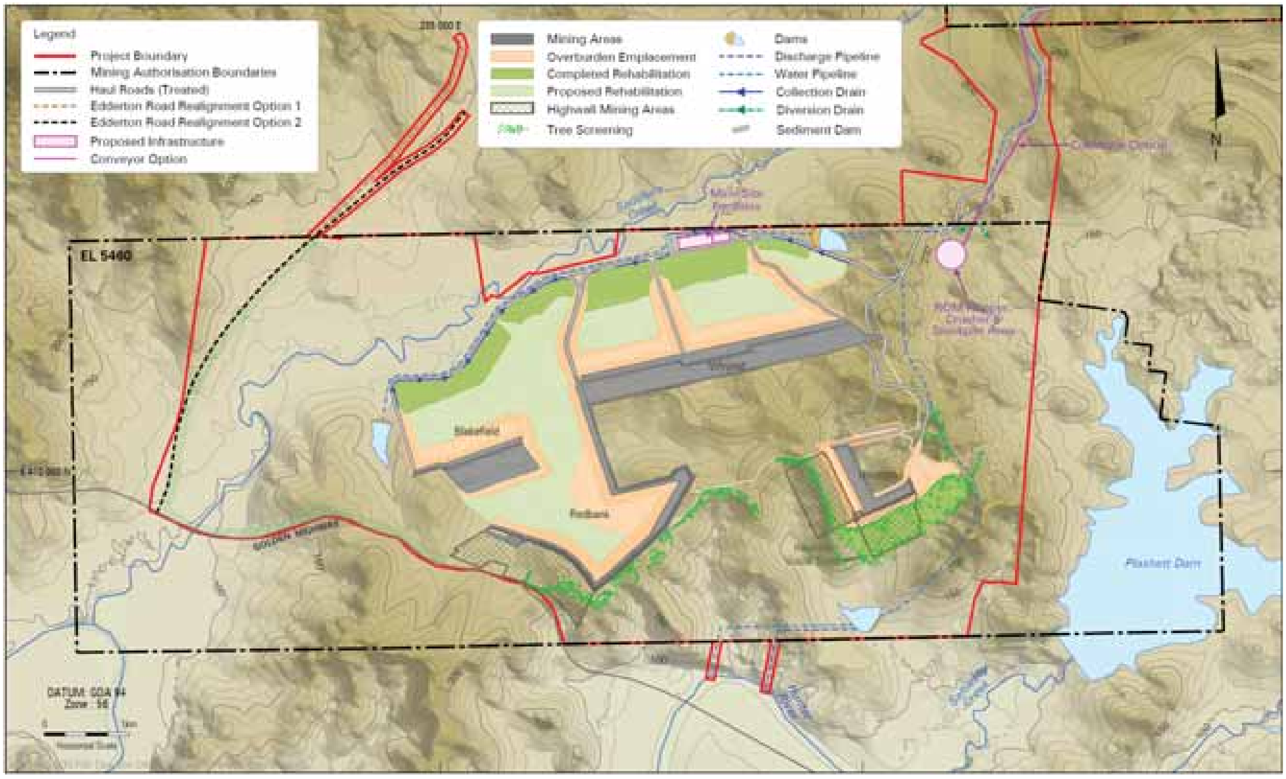

Figure 30: Mine Plan Year 10

Source: Hansen Bailey, 2012

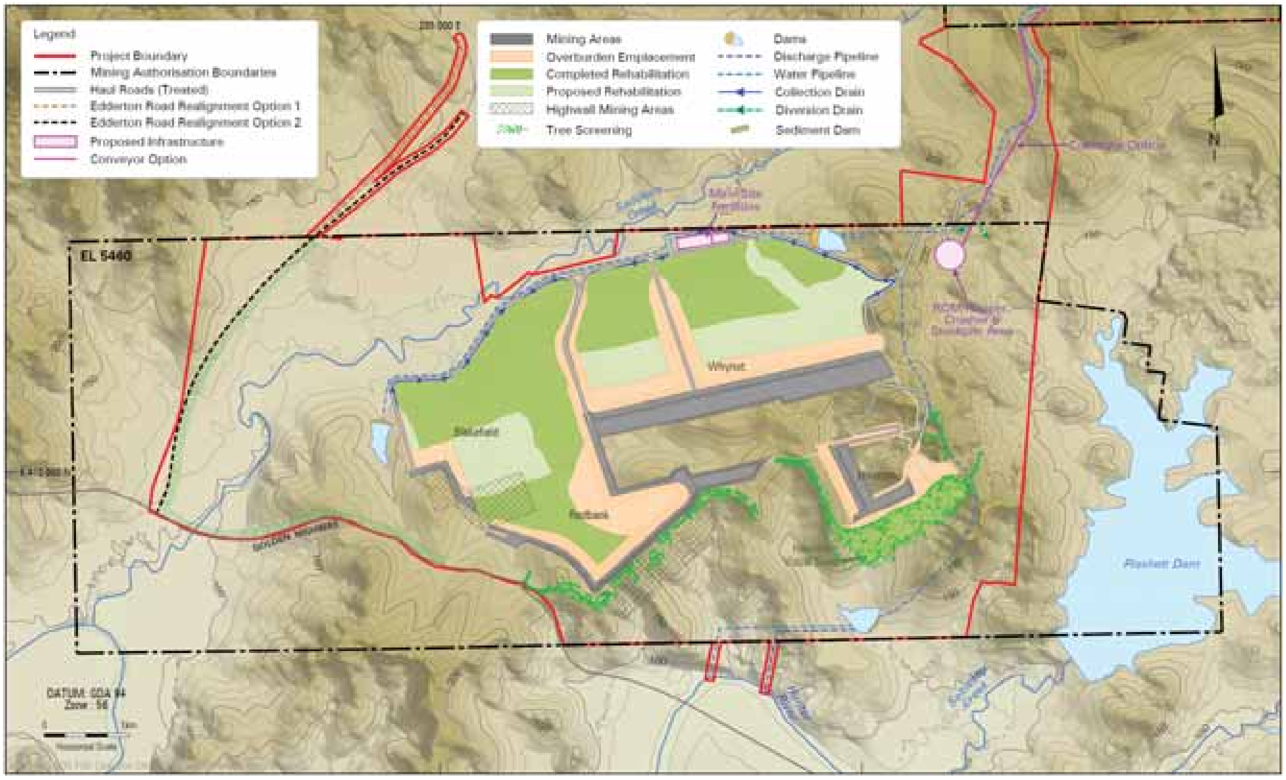

Figure 31: Mine Plan Year 15

Source: Hansen Bailey, 2012

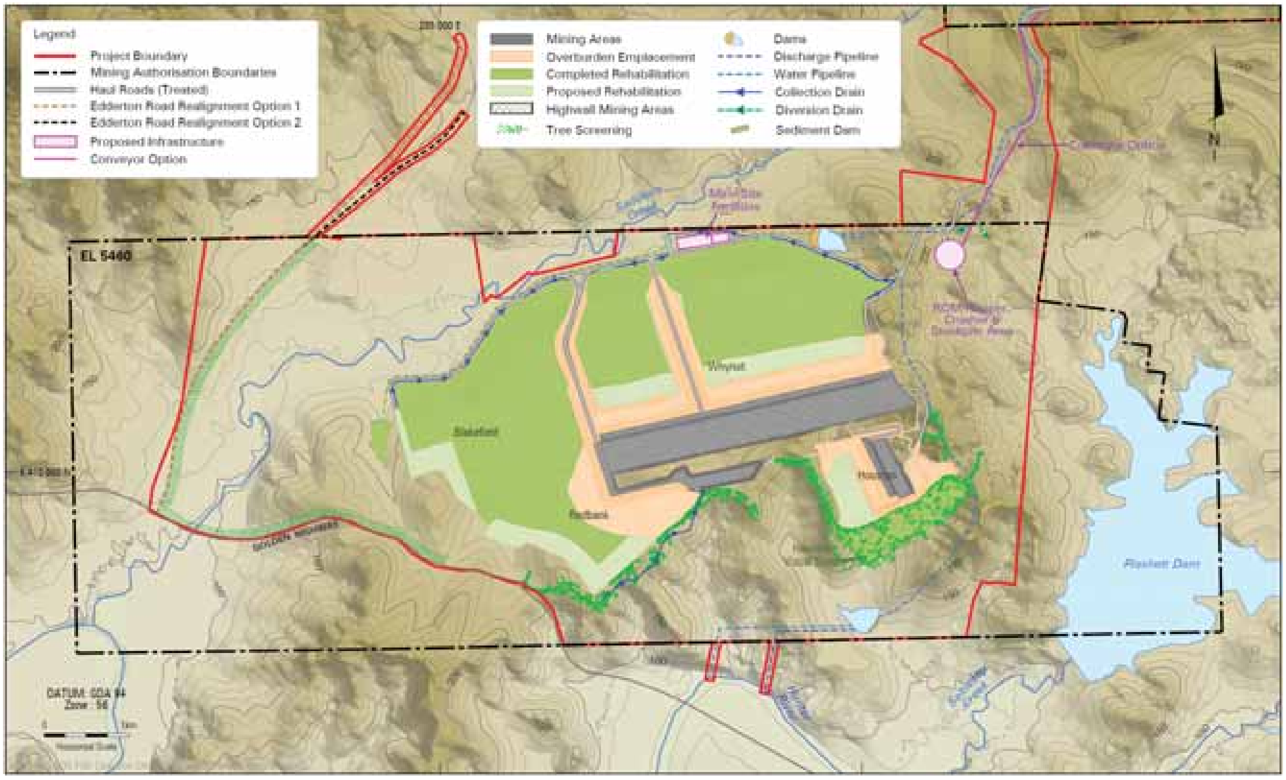

Figure 32: Mine Plan Year 20

Source: Hansen Bailey, 2012

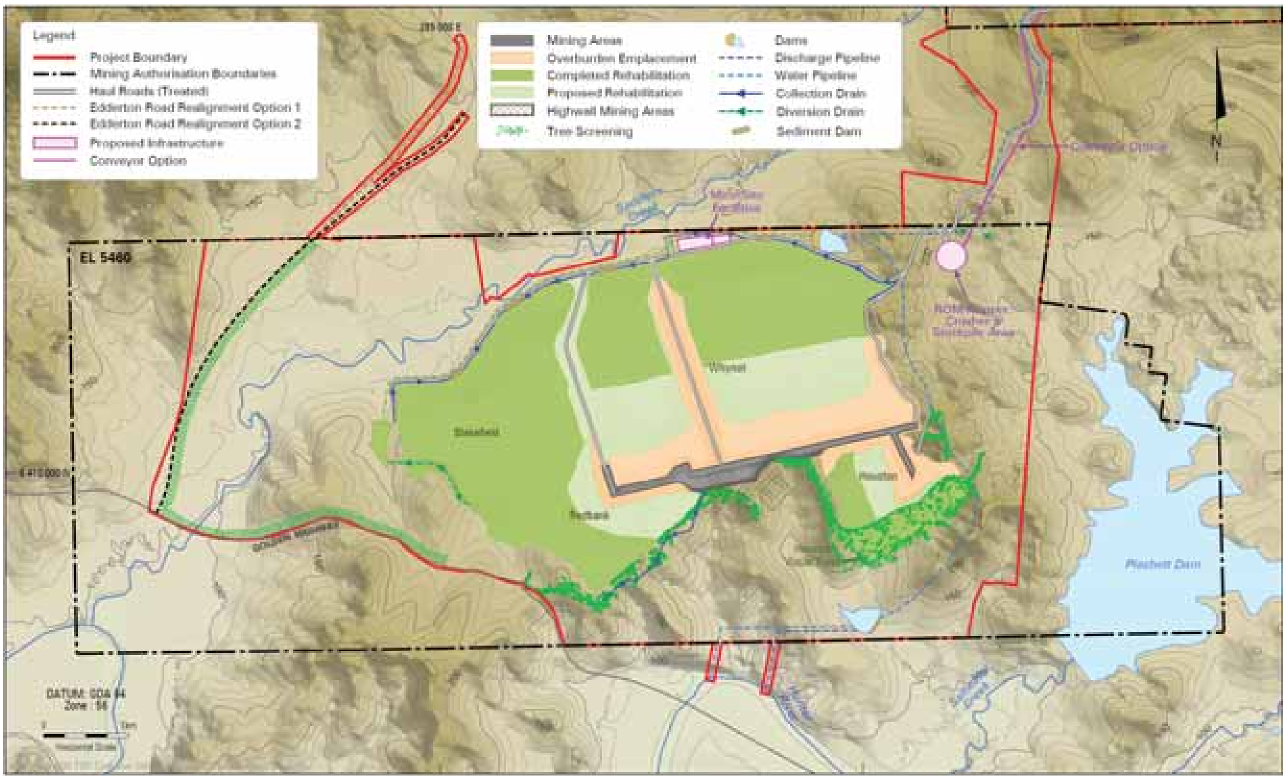

Figure 33: Mine Plan Year 27

Source: Hansen Bailey, 2012

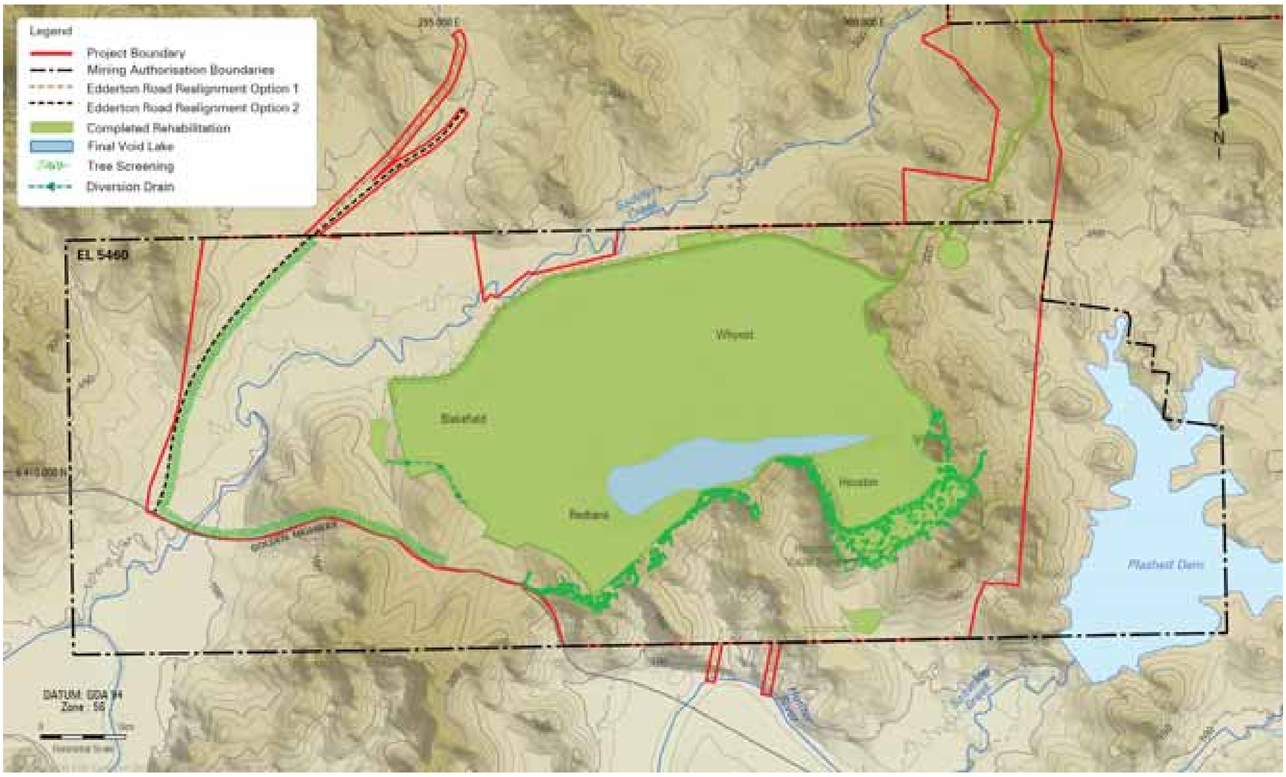

Figure 34: Final Landform

Source: Hansen Bailey, 2012

8. NUMERICAL GROUNDWATER MODEL

8.1 Modelling Objectives

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

- Estimate groundwater inflows to the open cut void over the Project life;
- Predict the zone of influence of dewatering and the level and rate of drawdown at specific locations;
- Predict the magnitude of any drainage from the alluvial aquifers into the underlying Permian strata;
- Predict the impact of mine dewatering on groundwater discharges to surface flows and other groundwater users; and
- Identify areas of potential risk where groundwater impact mitigation/control measures may be necessary.

8.2 Conceptual Model

Every numerical groundwater model has as its foundation a conceptual model. The conceptual model is an understanding of how the groundwater system operates and is an idealised and simplified representation of the natural system.

Extensive information on the natural system is typically required to develop an equivalent and simplified conceptual groundwater model representative of the system. Development of the conceptual groundwater model is a crucial step in groundwater modelling. Care has to be taken during the development of such models since errors in the conceptual model cannot be corrected during the model calibration, or at any later stage of the modelling study, without major revisions. Formulation of the conceptual model often highlights gaps in data or deficiencies in the understanding of the groundwater system.

Zheng and Bennett (1995)[27] note that:

> *A conceptual model contains numerous qualitative and subjective interpretations. The appropriateness of the conceptual model cannot be tested until a numerical model is built and comparisons between field observations and model simulation results are made.*

The following sections present the available information that has been used to develop a model of the hydrogeological regime. This task includes an initial conceptual model and a more detailed numerical model. This conceptual model forms the basis of the assumptions used when developing the more detailed numerical model. MDBC (2000)[28] define a conceptual model as an "*idealised summary of the current understanding of catchment conditions, and the key aspects of how the flow system works…subject to some simplifying assumptions."*

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[27] Zheng C. and Bennett G., (1995), *"Applied Contaminant Transport Modelling"*. Wiley, New York.

[28] MDBC, (2000), *"Murray Darling Basin Commission Groundwater Modelling Guidelines".* November 2000, Project No. 125, Final guideline issue January 2001.

The conceptual model of the region encompasses the area shown on Drawing No. 4, and has the following hydrogeological boundaries:

- The Mount Ogilvie Fault to the west;
- The outcrop of the Saltwater Creek Formation, that is the base of the Wittingham Coal Measures in the east;
- The watershed north of the Mt Arthur Coal Mine which is a groundwater divide; and
- The Hunter River located south of the Project.

The data indicate the area supports three distinct groundwater systems:

- Alluvium associated with the Hunter River and its tributaries;
- Weathered bedrock (regolith) near ground surface; and
- Low permeability Permian aquifers associated with the Wittingham Coal Measures.

Alluvial deposits present along the Hunter River (and to a much lesser degree, Saddlers Creek) are the main water producing aquifers in the study area. The Permian Coal Measures are not considered to be a significant aquifer, in comparison. While some coal seams may show an elevated hydraulic conductivity, the dominant interburden sections are of very low hydraulic conductivity. Only the weathered bedrock (regolith) directly below the ground surface may have a somewhat higher hydraulic conductivity due to weathering, compared to the underlying fresh bedrock.

Recharge to the groundwater system is from rainfall and leakage to/from the major rivers and tributaries. The water balance is dominated by recharge to the alluvial aquifer. Recharge to the bedrock basement that forms elevated outcrops is significantly lower than the alluvial areas. Groundwater inflow to the alluvial aquifers from the underlying bedrock is considered to be moderate, as evidenced by modelling undertaken by MER[7] for the site and the moderate salinity levels found in the alluvial aquifers.

Although groundwater levels are sustained by recharge, they are controlled by surface topography, surface water levels and aquifer permeability. Groundwater mounds are present beneath the hill areas, with a hydraulic gradient towards the lower lying alluvial lands. Groundwater flow is from these elevated areas with discharge to the Hunter River in areas where the potentiometric surface is above the head in the river, and removal by evaporation and/or evapotranspiration through vegetation where the water table is within a few metres of ground surface. On a regional scale, irrigation, stock and domestic bores remove a significant amount of water from the alluvial aquifer on an often variable but seasonal basis. However, within the immediate vicinity of the Project, minimal extraction of groundwater from the alluvium occurs. During events of high water flows in the ephemeral creeks, water can discharge or leak into the alluvial aquifers.

In places where mining is proposed, groundwater discharge to the mine workings is expected to be via the mined coal seam and to a lesser extent from the strata above and below at a rate related to the permeability of the strata and the hydraulic gradient in the surrounding aquifer. The conceptual model is illustrated in a cross section in Figure 35.

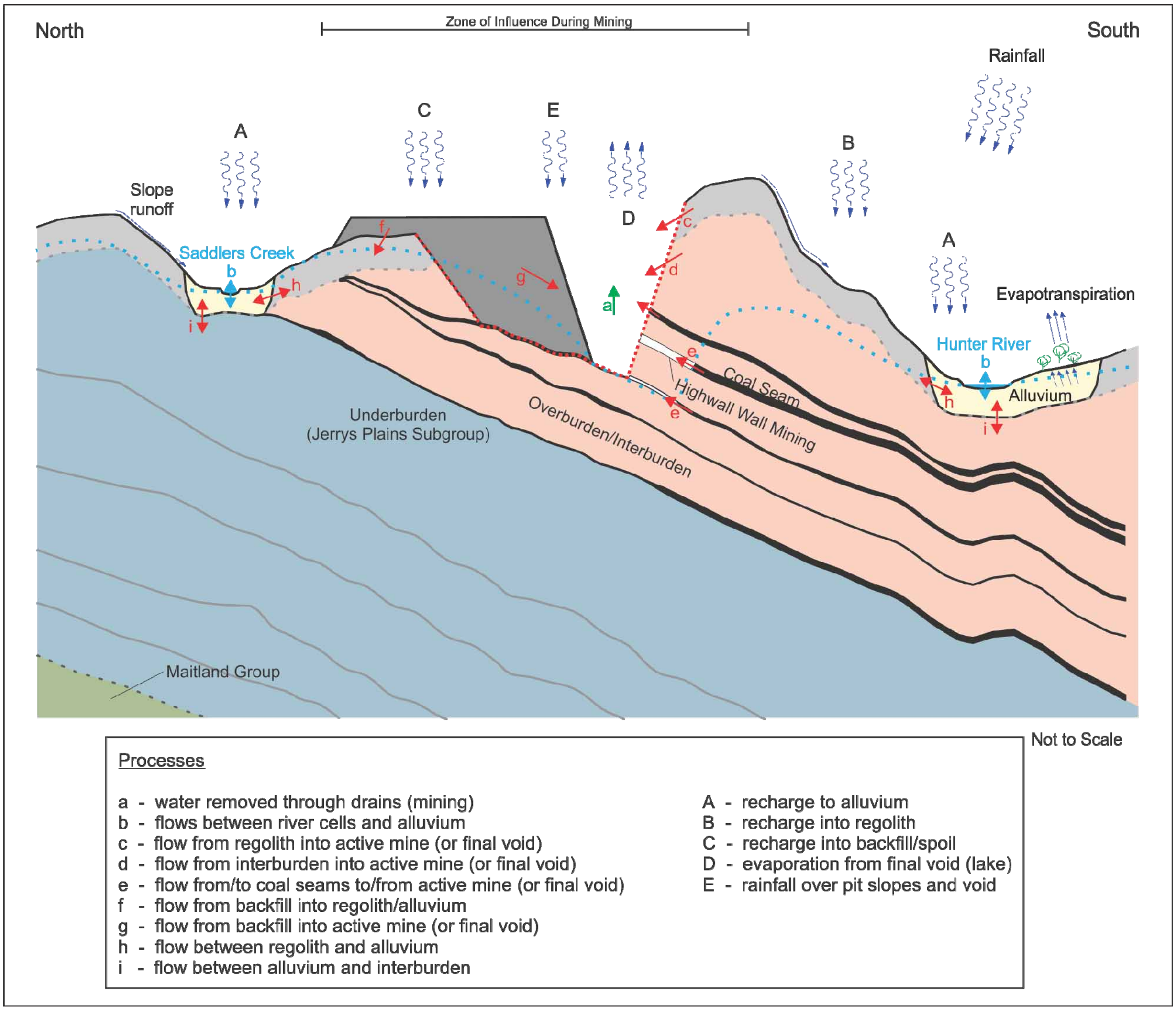

Figure 35: Conceptual Model Cross Section

8.3 Model Development

8.3.1. Model Code

Numerical simulation of groundwater flow in the aquifers was undertaken using the MODFLOW SURFACT code (referred to as SURFACT for the remainder of the report). A commercial derivative of the standard MODFLOW code, SURFACT is distributed by Hydrogeologic Inc and has some distinct advantages over the standard MODFLOW code, that are critical for the simulation of groundwater flow in the vicinity of the study area.

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 becoming increasingly widespread, particularly in mining applications where mine dewatering and recovery are simulated.

SURFACT is capable of simulating variably saturated conditions. This is critical for the requirements of the Project where coal seams will be progressively dewatered with time resulting in desaturated model cells within the mining area dimensions. Then active dewatering will cease, and groundwater recovery will rewet the spoil within the mining area and adjoining dewatered strata. SURFACT is also supplied with robust numerical solution schemes to handle the more complex numerical problem resulting from the unsaturated flow formulation. Added to the 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 MODFLOW pre and post processor PMWIN (Chaing and Kinzelbach, 1996)[29] was used to generate some of the input files for the SURFACT model, such is the similarity between it and the standard MODFLOW. Where files differ to allow for the additional capabilities of SURFACT, these changes were undertaken through manual editing of the model files.

8.3.2. Model Geometry and Boundary Conditions

Drawing No. 14 and Drawing No. 15 shows the model grid overlain on the regional geology. The model domain was dissected into 26,040 rectangular cells comprising 168 rows and 155 columns. The dimensions of the model cell size vary from 50 m x 50 m within the mining area and up to 500 m x 500 m outside the Project Boundary, as shown on Drawing No. 15.

The north-west corner of the grid is located at 284,810 m E and 6,419,254 m N (MGA94, Z56), with the grid oriented directly north-west to align with the principal groundwater flow directions. The model extent is about 17.36 km x 21.73 km covering an area of approximately 377 km^2. The cells located where the Jerrys Plains subgroup crop out were set as inactive.

The ground surface in the model was represented with digital elevation data with a 90 m x 90 m grid spacing. The 90 m x 90 m grid data was spliced with a 25 m x 25 m dataset available over the study area only.

The model comprises 18 layers with the geologic units represented as follows:

- Layer 1 - Alluvium/regolith;
- Layer 2 - Whybrow Seam overburden;
- Layer 3 - Whybrow Seam;
- Layer 4 - Redbank Creek Seam overburden;
- Layer 5 - Redbank Creek Seam;
- Layer 6 - Wambo coal seam overburden;
- Layer 7 - Wambo coal seam;
- Layer 8 - Whynot Seam overburden;
- Layer 9 - Whynot Seam;
- Layer 10 - Blakefield coal seam overburden;
- Layer 11 - Blakefield Seam;
- Layer 12 - Saxonvale claystone to Blakefield coal;
- Layer 13 - Glen Munro Seam + overburden;
- Layer 14 - Woodlands Hill Seam + overburden;
- Layer 15 - Arrowfield Seam + overburden;
- Layer 16 - Bowfield Seam + overburden;
- Layer 17 - Piercefield Seam + overburden; and
- Layer 18 - Maitland Group.

[29] Chaing W.H. and Kinzelbach W., (1996), *"Processing MODFLOW for Windows".*

The model domain extent has the following “no flow” boundary conditions applied (Drawing No. 15):

- Along the eastern boundary where the Jerrys Plains subgroup crops out near the Muswellbrook Anticline;
- Along the southern boundary at the southern limit of the Hunter River alluvium;
- Along the western boundary along the alignment of the Mount Ogilvie Fault Zone; and
- Along the northern boundary adjacent to the Hunter River at an arbitrary distance considered beyond the influence of the mining operations and parallel to the expected regional flow direction.

Figure 36 shows north-south and east-west sections through the model identifying the layers and geological units.

The structure of the groundwater flow model was based on the Anglo American geological model where data was available (Drawing No. 8 to Drawing No. 12, and Drawing No. 15). The Anglo American geological model provided good control of geological structure and coal seam geometry/thickness within the study area and for the area that extends south towards the Hunter River.

However, limited data of coal seam structure was available for the far south-eastern and south-western areas of the groundwater model where the Anglo American geological model did not extend. The groundwater flow model covers a broader area, compared with the geological model, in order to encompass the regional groundwater flow regime. Therefore, geological structure has been extrapolated to the boundaries of the groundwater flow model in areas where the geological model was not present. A three-dimensional view of the model domain and layers is shown in Figure 37.

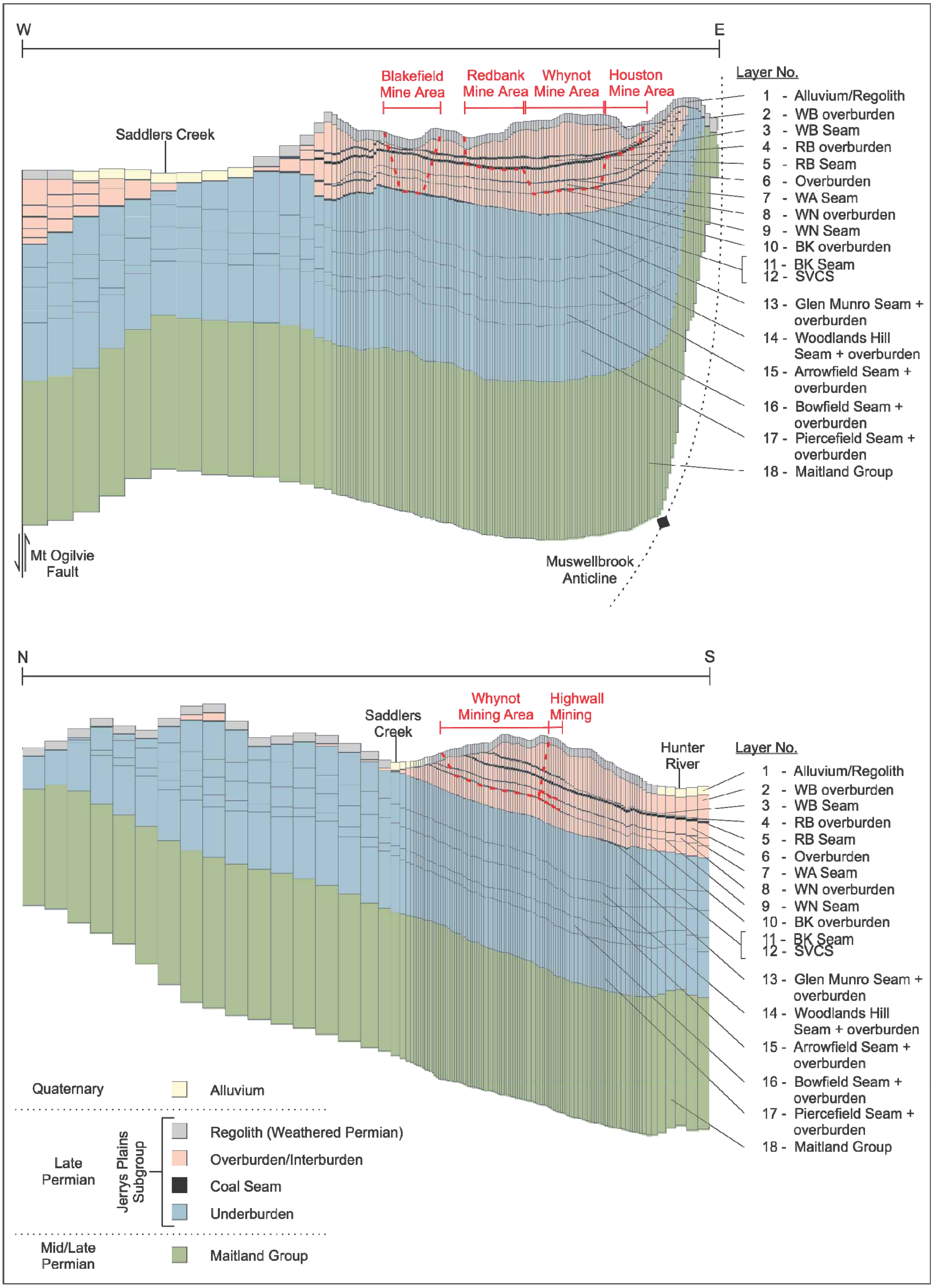

Figure 36: Cross Sections through Numerical Model

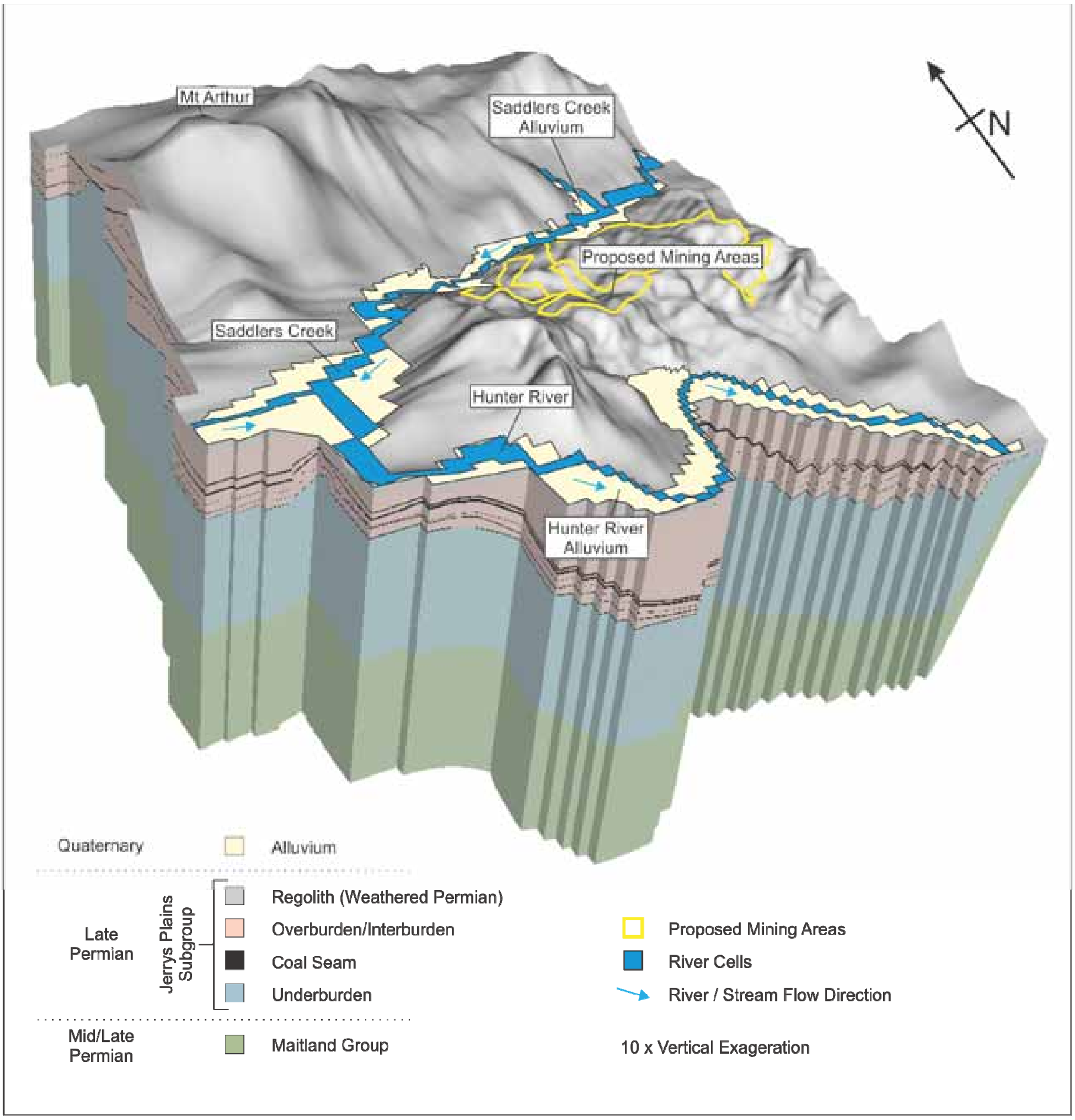

Figure 37: 3D Representation of Model Domain

8.3.3. Recharge and Discharge

Rainfall recharge is represented in the SURFACT model through the recharge (RCH) package. This was applied to the uppermost layer in the model representing the topographic surface and also into the rivers/creeks via the River (RIV) package.

Discharge from the model was via river cells assigned along Hunter River, Saddlers Creek and the major ephemeral drainage alignments. The elevation of the river bed was set by subtracting an inferred river bed depth from the topographic surface elevation. This incision depth of the rivers and creeks in the model was as follows:

- Hunter River - 10 m below topography
- Saddlers Creek - 5 m below topography
- Other ephemeral drainages - 1 m below topography

A head of water of 0.27 m was assigned to represent the observed height of water within the Hunter River. Saddlers Creek and the other ephemeral drainages in the model were assigned a water level equal to the base elevation, hence they only simulated the “drainage” of water out of the aquifer where and when the groundwater levels were high enough.

The effect of evapotranspiration was taken into account by assigning a slightly reduced rate of recharge across the model domain, excluding areas of spoil or where mining was being undertaken. In these areas, a percentage of the pan evaporation rate was applied, these being:

- 20% was applied to the spoil as it was progressively emplaced behind the advancing highwall;
- 60% was applied to the spoil runoff area; and
- 90% was applied to the final void lake surface to account for the effects of sun and wind on the lake surface.

An extinction depth of 0.5 m below ground level was applied to the model using the SURFACT evapotranspiration (EVT) package.

Extraction of water from irrigation bores in the alluvial aquifer was not included in the model as groundwater extraction from the Hunter River alluvium is limited in the immediate vicinity of the Project, and records of pumping extraction have not been collected by NOW for this area. The NOW report card for Jerrys water source does not indicate a total groundwater entitlement for the area.

Notwithstanding this, any extraction from bores is accounted for in the balance of inputs and outputs adopted during the steady state model calibration. Groundwater discharging from the model via drains, river flow and evapotranspiration accounts for water that would also be removed by irrigation from the aquifer to match the observed water levels. In the absence of metered extraction data, it is assumed that irrigation use of groundwater would be restricted to a small percentage of the total flow through the system.

8.4 Model Calibration

The accuracy of the model calibration depends on the data defining the model domain such as aquifer geometry, boundaries, hydraulic properties and stresses imposed on the aquifer. It is considered that the horizontal and vertical extent of the model and model boundaries are sufficiently well defined to construct and calibrate the Drayton South groundwater model. Anderson and Woessner (1992)[30] define the calibration of a groundwater flow model as:

> *A demonstration that the model is capable of producing field measured heads and flows which are the calibration values. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes that match field measured values within an acceptable range of error.*

8.4.1. Calibration Targets

Groundwater levels were collated for monitoring bores within the study area and from publicly available levels measured in registered monitoring bores within the vicinity (Drawing No. 14 and Drawing No. 15). The main objective of model calibration was to reproduce groundwater levels at the individual monitoring bores and hence the general pattern of the groundwater contours and the direction of the groundwater flow.

[30] Anderson, M. P. and Woessner, W., (1992), *“Applied Groundwater Modeling: Simulation of Flow and Advective Transport”*, (2nd Edition ed.). Academic Press.

A 13 year record of water level measurements was available for the monitoring bores located within the study area. The median water level of the available water levels (not obviously impacted by mining) was calculated and adopted as the steady state calibration target. Calibration targets adopted for the monitoring bores at the Mt Arthur Coal Mine's mining operations, located to the north, were selected from pre-mining measurements, or from sites that were relatively distant from the mining operations and hence unaffected by any existing mine dewatering.

The objective of the steady state modelling was to simulate pre-mining conditions and therefore bores which had been potentially affected by mining activities were removed from the calibration process. A total of 95 water level sites were used to calibrate the model (Drawing No. 14 and Drawing No. 15). Where the screen interval of bores/holes was not known, the observed heads were assigned to the model layer within which the bore/hole was terminated.

The parameter estimation software PEST was used to calibrate the model. The software makes small adjustments to the parameter set within bounds determined by the user in order to match the observed and simulated data. PEST adjusted the following properties in the model to improve the match between the observed and simulated water levels:

- Horizontal and vertical hydraulic conductivity;
- Percentage of recharge to each recharge zone; and
- Conductance of the river bed in each river zone.

The hydraulic conductivity of the alluvium and the regolith zone (Layer 1) varied spatially to assist the model in matching the different water level fluctuations in the monitoring bore data. The 'pilot points' procedure in PEST was used for this task. Recharge rates also varied spatially.

The vertical hydraulic conductivity of the river bed was assigned as 10 m/day for Saddlers Creek and 20 m/day for the Hunter River during calibration. These conductivity values were chosen to allow for free drainage of water from the river into (and out of) the underlying alluvium, with hydraulic gradients driving the flow.

8.4.2. Observed and Simulated Heads

Comparison of observed and simulated groundwater levels in the model area are given in Table 21 and as scattergram in Figure 38. The simulated steady state groundwater heads in Layer 1 are presented in Drawing No. 16. The groundwater heads would vary from layer to layer as a result of complex flow distributions established by recharge from the regolith layer (Layer 1) downwards into the underlying strata. The shallowest layer is a subdued reflection of topography with potentiometric highs throughout the central area of the Project Boundary and to the north near Mt Arthur Coal Mine. Ridges of high pressures are evident along the major surface watershed divides. Groundwater flow occurs from areas of high pressure to areas of low pressure and are generally away from prospective mining areas.

As noted above, the Hunter River provides a regional sink for both surface water and groundwater drainage. Aquifer pressures within the shallow coal seams and regolith adjacent to, or immediately beneath, the river will be approximately equal to the river water elevation. Pressures in deeper formations below the river may exhibit higher pressures, greater than the elevation of the base of the river, thereby inducing upward leakage to the river or adjacent alluvial lands. This process is identified in many areas and often results in the occurrence of saline groundwater within the alluvium, especially in areas more distant from the river.

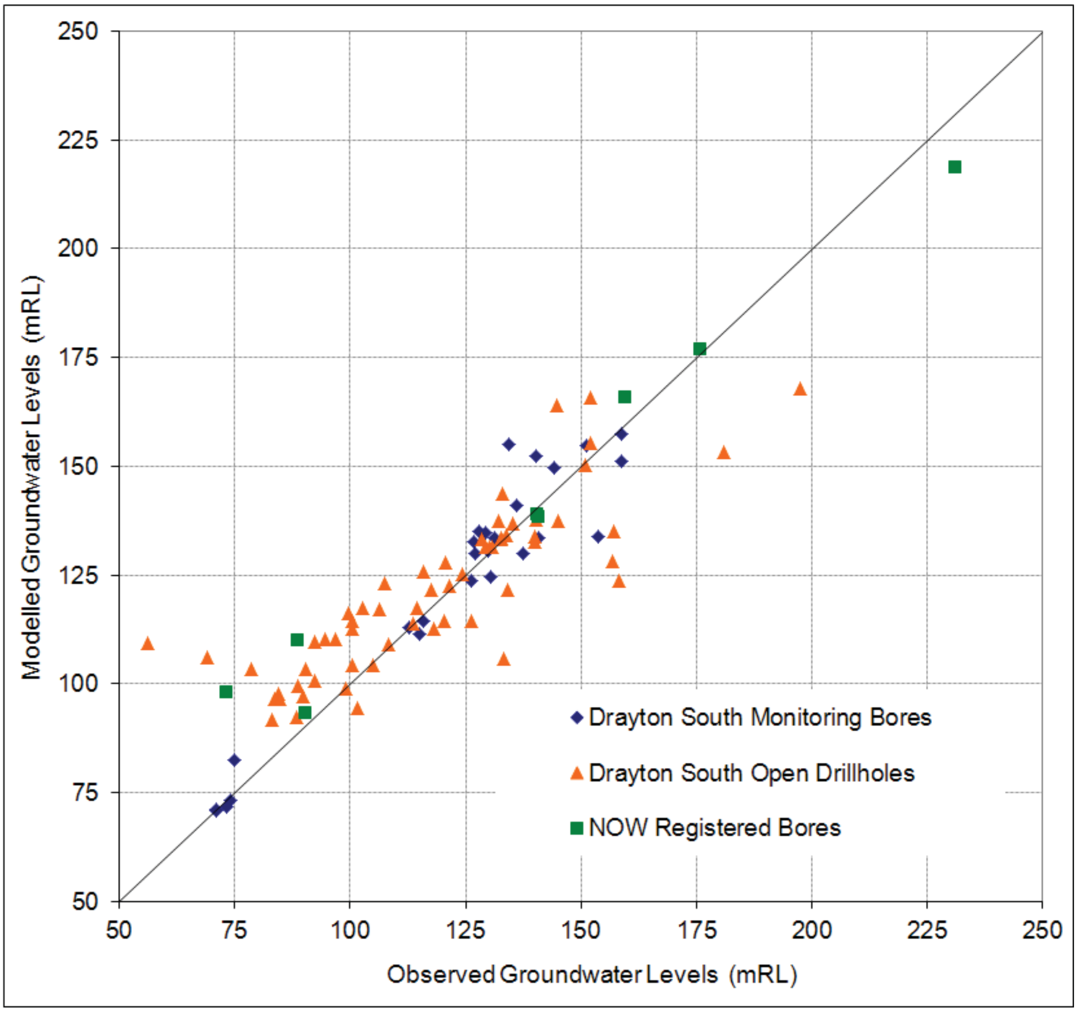

Figure 38: Observed versus Simulated Groundwater Levels – Steady State Model

Table 21: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL

Bore ID	Easting (MGA94, z56) (m)	Northing (MGA94, z56) (m)	Observed Water Level (mRL)	Modelled Water Level (mRL)	Residual (m)	Location
DD1004	299797	6410922	140.4	152.3	11.9	Monitoring Bore
DD1005	298798	6410902	151.3	154.7	3.4	Monitoring Bore
DD1014	296799	6410864	136.0	141.0	5.0	Monitoring Bore
DD1015	298814	6409900	128.0	134.9	6.9	Monitoring Bore
DD1016	297800	6410883	144.2	149.5	5.3	Monitoring Bore
DD1017	297818	6409883	129.2	134.8	5.6	Monitoring Bore
DD1018	298288	6411395	158.9	151.1	-7.8	Monitoring Bore
DD1025	298764	6411902	158.9	157.5	-1.4	Monitoring Bore
DD1026	300321	6409429	137.5	129.8	-7.7	Monitoring Bore
DD1027	301133	6410960	134.5	154.9	20.4	Monitoring Bore
DD1030	301753	6408962	130.5	124.6	-5.9	Monitoring Bore

Table 21: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL

Bore ID	Easting (MGA94, z56) (m)	Northing (MGA94, z56) (m)	Observed Water Level (mRL)	Modelled Water Level (mRL)	Residual (m)	Location
DD1032	297143	6412496	131.4	133.4	2.0	Monitoring Bore
DD1041d	296202	6409476	140.9	133.5	-7.4	Monitoring Bore
DD1041s	296202	6409476	153.8	133.7	-20.1	Monitoring Bore
DD1043	295199	6409459	127.1	129.8	2.8	Monitoring Bore
DD1052	296273	6408514	115.1	111.4	-3.7	Monitoring Bore
DD1057	295180	6410459	126.3	123.7	-2.6	Monitoring Bore
DD1060	296652	6411987	128.4	133.3	4.9	Open Drillhole
DD1061	294668	6410950	113.6	113.8	0.2	Open Drillhole
DD1062	294652	6411950	120.3	114.5	-5.8	Open Drillhole
DD1063	297649	6411993	132.9	143.6	10.7	Open Drillhole
DD1064	298652	6412029	152.0	155.2	3.2	Open Drillhole
DD1065	295671	6410968	121.6	122.4	0.8	Open Drillhole
DD1066	297673	6411010	150.9	150.1	-0.8	Open Drillhole
DD1068	299675	6411038	180.8	153.2	-27.7	Open Drillhole
DD1070	297690	6410006	144.9	137.4	-7.5	Open Drillhole
DD1071	296705	6409987	135.3	136.7	1.4	Open Drillhole
DD1075	297682	6409006	126.2	114.3	-11.9	Open Drillhole
DD1077	296708	6408987	134.2	121.4	-12.8	Open Drillhole
RD1034	301085	6408948	158.2	123.6	-34.7	Open Drillhole
RD1039	301839	6408957	124.4	125.0	0.7	Open Drillhole
RD1040	300823	6408676	114.6	117.3	2.8	Open Drillhole
RD1042	300510	6412680	197.5	167.9	-29.6	Open Drillhole
RD1043	299084	6409900	157.0	134.9	-22.1	Open Drillhole
RD1044	299572	6409678	140.0	132.5	-7.4	Open Drillhole
RD1045	300272	6412677	152.0	165.7	13.7	Open Drillhole
RD1046	299572	6409928	140.3	137.6	-2.7	Open Drillhole
RD1047	300012	6412678	144.8	163.9	19.2	Open Drillhole
RD1048	299829	6409667	140.0	133.8	-6.2	Open Drillhole
RD1086	296530	6409609	133.8	134.2	0.4	Open Drillhole
RD1087	297136	6409622	129.3	131.4	2.1	Open Drillhole
RD1088	296628	6409610	132.7	133.2	0.5	Open Drillhole
RD1089	296579	6409610	132.7	133.4	0.7	Open Drillhole
RD1090	297186	6409620	130.2	131.4	1.1	Open Drillhole
RD1091	297237	6409623	130.8	131.3	0.5	Open Drillhole
RDH0273	299101	6408896	99.7	116.3	16.6	Open Drillhole

Table 21: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL						
Bore ID	**Easting (MGA94, z56) (m)**	**Northing (MGA94, z56) (m)**	**Observed Water Level (mRL)**	**Modelled Water Level (mRL)**	**Residual (m)**	**Location**
RDH0275	299340	6408908	106.2	117.0	10.8	Open Drillhole
RDH0276	298343	6408145	83.0	91.6	8.6	Open Drillhole
RDH0277	298350	6408387	89.9	97.2	7.3	Open Drillhole
RDH0278	298342	6408646	100.6	104.2	3.6	Open Drillhole
RDH0279	298339	6408880	97.0	110.1	13.1	Open Drillhole
RDH0280	298595	6408389	84.5	97.6	13.1	Open Drillhole
RDH0281	298847	6408155	101.6	94.5	-7.1	Open Drillhole
RDH0282	298843	6408404	99.1	99.0	-0.1	Open Drillhole
RDH0283	299091	6408409	133.4	105.7	-27.7	Open Drillhole
RDH0284	299348	6408162	78.5	103.5	25.0	Open Drillhole
RDH0285	299349	6408415	56.3	109.4	53.1	Open Drillhole
RDH0286	299339	6408661	100.4	112.6	12.2	Open Drillhole
RDH0287	299583	6408902	102.6	117.3	14.7	Open Drillhole
RDH0288	299600	6408417	94.6	110.3	15.7	Open Drillhole
RDH0289	299341	6409145	117.5	121.6	4.1	Open Drillhole
RDH0290	299856	6408165	69.1	106.2	37.1	Open Drillhole
RDH0291	296838	6408603	108.2	109.1	0.9	Open Drillhole
RDH0292	296840	6408369	92.4	100.6	8.2	Open Drillhole
RDH0293	297352	6408624	104.9	104.1	-0.8	Open Drillhole
RDH0294	297381	6408394	83.6	96.5	12.9	Open Drillhole
RDH0295	297839	6408604	90.3	103.4	13.1	Open Drillhole
RDH0296	297853	6408394	84.8	96.5	11.7	Open Drillhole
RDH0300	297069	6408399	88.7	99.5	10.8	Open Drillhole
RDH0301	296832	6408092	88.4	92.2	3.8	Open Drillhole
RDH0304	298584	6408898	118.0	112.6	-5.4	Open Drillhole
RDH0309	298817	6409663	156.9	128.2	-28.7	Open Drillhole
RDH0310	298837	6409412	107.5	123.2	15.7	Open Drillhole
RDH0311	299076	6409406	116.0	125.7	9.7	Open Drillhole
RDH0313	299840	6408669	100.6	114.4	13.8	Open Drillhole
RDH0315	295841	6410332	120.6	127.7	7.1	Open Drillhole
RDH0316	296077	6410252	132.2	137.5	5.3	Open Drillhole
RDH0317	293798	6410916	92.4	109.5	17.1	Open Drillhole
Shearers Well	296910	6410280	140.7	138.9	-1.7	Registered Bore
GW029659	289121	6411494	140.8	138.4	-2.4	Registered Bore
GW031623	294122	6417453	231.2	218.7	-12.5	Registered Bore

Table 21: CALIBRATION TARGETS AND SIMULATED WATER LEVELS – STEADY STATE MODEL						
Bore ID	**Easting (MGA94, z56) (m)**	**Northing (MGA94, z56) (m)**	**Observed Water Level (mRL)**	**Modelled Water Level (mRL)**	**Residual (m)**	**Location**
GW033915	294185	6419509	175.8	176.8	1.0	Registered Bore
GW045161	289685	6408064	90.4	93.3	2.9	Registered Bore
GW078026	294351	6419981	159.5	165.9	6.3	Registered Bore
GW271031	298140	6407151	73.2	98.1	24.8	Registered Bore
GW271034	289990	6408087	88.8	110.0	21.2	Registered Bore
MB1_Alluvial	297933	6407459	73.2	71.8	-1.3	Monitoring Bore
MB1_Whybrow	297928	6407449	74.2	73.3	-0.9	Monitoring Bore
MB1_Redbank	297931	6407454	74.9	82.5	7.6	Monitoring Bore
MB2_Alluvial	294999	6411669	112.7	112.8	0.2	Monitoring Bore
MB2_Regolith	295004	6411675	115.9	114.3	-1.7	Monitoring Bore
MB3_Alluvial	297269	6412851	129.9	130.5	0.5	Monitoring Bore
MB3_Regolith	297328	6412729	126.9	132.7	5.8	Monitoring Bore
MB4_Alluvial	300302	6406234	71.1	70.8	-0.3	Monitoring Bore
MB4_Regolith	300307	6406231	70.9	71.1	0.1	Monitoring Bore

The calibrated model provides a good match between the observed and modelled heads within the alluvial aquifer zone. Within the Project Boundary in the Permian measures, the predicted groundwater levels were generally higher than the observed water levels. The average absolute residual between the observed and simulated groundwater levels was 10.1 m. For the information sourced from the NOW registered bores and representing water level measurements in the Hunter River alluvium, this average absolute residual was 9.1 m. The Project monitoring bore subset produced an absolute residual of 7.0 m from the calibration.

An objective method to evaluate the calibration of the model is to examine the statistical parameters associated with the calibration. One such method is by measurement of the error between the modelled and observed (measured) water levels. The root mean square (RMS) error is expressed as follows:

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

where: n = number of measurements

h_o = observed water level

h_m = simulated water level

The RMS error calculated for the calibrated model was 12.1 m. The maximum 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 is small, known as the Scaled RMS (SRMS), the errors are only a small part of the overall model response (Anderson and Woessner, 1992)[30]. The ratio of RMS (12.15 m) to the total head change across the calibration points (174.9 m) indicated a SRMS of 6.9%. The recommended target for SRMS varies between models and is typically lowest in models dominated by porous media such as sands and gravels (i.e. uniform and homogeneous). Typically these homogeneous models would aim to achieve a SRMS of below 5% (MDBC 2000)[28]. However, achieving a low SRMS within models dominated by fractured rock systems, such as the Permian Coal Measures, is not always possible owing to the non-uniformity and heterogeneity of the aquifers. The industry standard SRMS typically varies between 5% and 10% for fractured rock models.

A transient calibration of the Drayton South model was not undertaken. The MDBC[28] guidelines state that:

> *Commonly, the data set used for transient calibration is test pumping data, and/or several years of regular monitoring data that shows the natural seasonal variations and responses to other stresses (i.e. long-term pumping, river-aquifer interaction, etc.).*

The undertaking of a transient calibration of the Project was considered not feasible for the following reasons:

- No metered groundwater extraction data available for the Hunter River alluvium located within the groundwater model domain;
- No definitive assessment of river baseflow available for the Hunter River alluvium located within the groundwater model domain; and
- The long-term groundwater level hydrographs available from the monitoring bores located within the study area show little temporal movement, providing little opportunity for calibration targets.

Notwithstanding the fact that the model was not calibrated to transient data, Appendix 3 presents 17 hydrographs that compare the modelled water levels against observed transient data. This validation assessment illustrates a generally good match to the observed water level measurements. The statistical fit of the data between the transient modelled heads and the measured heads had a Scaled Root Mean Squared (SRMS) of 7.8%.

8.4.3. Hydraulic Parameters

Table 22 presents the hydraulic properties applied to the various geologic units. The hydraulic conductivity values used for the alluvial areas of Layer 1 were distributed and were allowed to vary slightly to reflect the thickness of the unit. Higher values of hydraulic conductivity were applied to areas of greater alluvial thickness, and conversely, lower values were applied in areas of thinner alluvium. This application of hydraulic conductivity was designed to account for the likelihood of more permeable units to exist in thicker sections of the alluvial profile. The maximum hydraulic conductivity (horizontal) calibrated for the Hunter River alluvium was 7.9 m/day, and the maximum value calibrated for the Saddlers Creek alluvium was 0.87 m/day. The different maximum hydraulic conductivity values for the two alluvial areas reflect the less transmissive and silty alluvium associated with Saddlers Creek. The range of hydraulic values applied to alluvial units are summarised in Table 22. The spatial distribution of horizontal hydraulic conductivity for each layer is presented on a series of drawings in Appendix 4.

Table 22: HYDRAULIC PARAMETERS				
Geology	Parameter	Parameter Value		
		Minimum	Mean	Maximum
Hunter River Alluvium (Layer 1)	Kh (m/day)	7.3	7.8	7.9
	Kv (m/day)	0.032	0.033	0.034
	S_y	5.0×10^{-2}	5.0×10^{-2}	5.0×10^{-2}
Saddlers Creek Alluvium (Layer 1)	Kh (m/day)	0.68	0.79	0.87
	Kv (m/day)	0.0029	0.0034	0.0038
	S_y	5.0×10^{-2}	5.0×10^{-2}	5.0×10^{-2}
Regolith (Layer 1)	Kh (m/day)	1.6×10^{-2}	2.4×10^{-2}	2.8×10^{-2}
	Kv (m/day)	7.0×10^{-5}	1.1×10^{-4}	1.2×10^{-4}
	S_y	5.0×10^{-3}	5.0×10^{-3}	5.0×10^{-3}
Interburden (Layers 2,4,6,8,10,12)	Kh (m/day)	2.2×10^{-6}	8.6×10^{-4}	4.4×10^{-3}
	Kv (m/day)	4.6×10^{-9}	2.8×10^{-5}	2.2×10^{-4}
	S_y	5.0×10^{-4}	5.0×10^{-4}	5.0×10^{-4}
	S_s (m^{-1})	5.0×10^{-6}	9.0×10^{-6}	5.0×10^{-5}
Coal Seams (Layers 3,5,7,9,11)	Kh (m/day)	3.4×10^{-5}	2.4×10^{-2}	4.6×10^{-1}
	Kv (m/day)	3.5×10^{-8}	2.0×10^{-4}	1.7×10^{-3}
	S_y	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}
	S_s (m^{-1})	5.0×10^{-6}	5.0×10^{-6}	5.0×10^{-6}
Basement (Layers 13 - 18)	Kh (m/day)	1.0×10^{-7}	1.3×10^{-3}	9.4×10^{-2}
	Kv (m/day)	2.6×10^{-10}	1.5×10^{-5}	9.4×10^{-4}
	S_y	1.0×10^{-5}	9.0×10^{-5}	1.0×10^{-4}
	S_s (m^{-1})	1.0×10^{-7}	9.0×10^{-7}	1.0×10^{-6}

The hydraulic conductivity of the weathered Permian regolith unit was also distributed across the model to reflect topographical influences. Lower values of hydraulic conductivity were applied to elevated areas where competent bedrock, probably being more resistant, crops out. Conversely, higher values of hydraulic conductivity were applied to the regolith in areas of lower elevation where there is potential for colluvium/alluvium to exist. The maximum hydraulic conductivity applied to the regolith was 0.028 m/day.

The hydraulic conductivity of the coal seams was also distributed across the model to reflect their depth below ground surface. Higher values of hydraulic conductivity were applied to areas near where the coal seams sub-crop, this being the northern and eastern sections of the study area. Conversely, lower values of hydraulic conductivity were progressively applied to the coal seams as they increased their depth below the ground surface. This is in response to a reduction of cleat aperture (which provides permeability within the coal) with depth due to increasing pressure and stress. The maximum hydraulic conductivity applied to the coal seams was 0.4 m/day and the lowest was 3.4×10^{-5} m/day, with a mean of 0.02 m/day.

The hydraulic parameters generally fall within the ranges of aquifer parameters determined in the field investigations and by previous testing and modelling studies.

8.4.4. Recharge Rates

The recharge zones and rates adopted in the model were as follows:

- Saddlers Creek alluvial aquifer 26.6 mm/yr - 4.0% of annual rainfall;
- Hunter River alluvial aquifer 34.6 mm/yr - 5.2% of annual rainfall; and
- Permian outcrop 0 - 10.1 mm/yr - 0 to 1.5% of annual rainfall.

Recharge to the Permian was distributed irregularly across the model with a maximum of 1.5% of annual rainfall. Drawing No. 17 shows the recharge rates applied across the model domain.

8.4.5. Water Budgets

The mass balance error, that is, the difference between calculated model inflows and outflows, at the completion of the calibration run expressed as a percentage of discrepancy, was 0.0%, indicating good accuracy of the numerical solution and overall stability of the model. Table 23 summarises the model water budget, and the breakdown of the simulated total losses to the different creeks and river is shown in Table 24.

Table 23: WATER BUDGET – STEADY STATE MODEL

Parameter	Input	Output
Rainfall recharge	3.6ML/day (6.5%)	0ML/day (0%)
River leakage	52.2ML/day (93.5%)	55.8ML/day (100%)
TOTAL	**55.8ML/day**	**55.8ML/day**

Table 24: MODELLED GROUNDWATER DISCHARGE TO CREEKS AND HUNTER RIVER

Creek/River	Net Discharge
Hunter River	2.5ML/day
Saddlers Creek	0.8ML/day
Secondary Creeks and Drainages	0.3ML/day
TOTAL	**3.6ML/day**

The Hunter River is the main sink for groundwater within the study area, followed by Saddlers Creek. Model simulation runs indicate steady state groundwater losses to the Hunter River of about 2,500 m^3/day (2.5 ML/day), to Saddlers Creek of about 800 m^3/day (0.8 ML/day), and to secondary creeks and drainages of about 300 m^3/day (0.3 ML/day). Therefore, of the long-term average of 3.6 ML/day of recharge entering the groundwater system, all of this volume is presumed to be discharged at the surface in drainages.

Flow records exist for Saddlers Creek for the period from 1956 to 1981 from a gauge located on the Bowfield property. While no flow occurred for 35% of the recording period, flow rates less than 1 ML/day were noted across the majority of the recording period. Flow exceeded 1 ML/day for 10% of the recording period and flows above 100 ML/day occurred for 1% of the time with a single event above 1,000 ML/day appearing in the records. However, there is likely to be a high level of uncertainty associated with the data as an accurate relationship between water level and stream flow is not available[31]. Periods of baseflow in Saddlers Creek are evident indicating that the system is fed by groundwater flows as well as surface water.

Assessment of the steady state water budget for the alluvial systems indicated that flow from the surrounding geology into the alluvial units (i.e. flux) was 0.27 ML/day for the Hunter River alluvium and 0.31 ML/day for the Saddlers Creek alluvium, this value being in good agreement with the modelled results of MER[32] (0.34 ML/day). These flux values form a basis from which the impacts on the alluvial systems resulting from the Project can be assessed.

8.5 Model Confidence Level Classification

The degree of confidence with which a model's predictions can be used is a critical consideration. Several factors are considered in order to determine a model confidence-level classification, and typically depend on the following factors:

- Available data;
- Calibration procedures;
- Consistency between calibration and predictive analysis; and
- Level of stresses.

Barnett et al (2012)[33] 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, where:

- Class 1 represents a model that has been developed where there is insufficient data to support an adequate level of conceptualisation and calibration;
- Class 2 represents a model that has been developed with sufficient rigour and accuracy for a particular modelling objective, irrespective of the available data and level of calibration. Class 2 and 3 models are suitable for assessing higher risk developments in higher-value aquifers; and
- Class 3 meets the objectives of a Class 2 model, but at a higher level of accuracy and confidence.

If a model falls into a Class 2 classification for either the data, calibration or prediction sectors, it should be rated a Class 2 model, irrespective of all other ratings. The Project model complies with

[31] WRM Water and Environment Pty Ltd, (2012), "*Surface Water Impact Assessment for the Drayton South Project*", prepared for Hansen Bailey.

[32] Mackie Environmental Research Pty Ltd, (Sept. 2007), "*Mt Arthur Underground Project Environmental Assessment, Groundwater Management Studies*".

[33] Barnett B, Townley L.R, Post V, Evans R.E, Hunt R.J, Peeters L, Richardson S, Werner A.D, Knapton A, and Boronkay A, (2012), "*Australian groundwater modelling guidelines*", Waterlines report, National Water Commission, Canberra

the Class 2 criteria, according to the confidence-level system outlined in Barnett et al (2012)[34] based on the following criteria.

Data:

- Spatial and temporal distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported.
- Aquifer-testing data to define key parameters.
- No available records of metered groundwater extraction or injection.
- high resolution digital elevation data used across the entire model domain.

Calibration:

- Calibration statistics are generally reasonable but may suggest significant errors in parts of the model domain.
- Simple validation of observed data has been demonstrated.
- Scaled Root Mean Squared error (SRMS) is below prescribed limits for the steady state calibration.
- recent calibration data used.
- long-term trends are replicated in all monitoring bores.

Prediction:

- length of prediction model is not excessive compared to the length of the calibration period.
- temporal discretisation and stresses are within the range of those used in the calibration model.
- Level and type of stresses included in the predictive model are outside the range of those used in the transient calibration.

Key indicators:

- calibration statistics meet agreed targets in key areas, but suggest poor calibration in some parts of the model domain.
- the mass balance closure error is less than 0.5% of total.
- model parameters are consistent with conceptualisation.
- appropriate computational methods and spatial discretisation used.

A Class 2 confidence level classification is suitable for predicting the impacts to groundwater of proposed developments in medium value aquifers, and for providing estimates of dewatering requirements for mines and excavations and the associated impacts.

Based on the assessment of model confidence described above, it is evident that the current model is fit-for-purpose for assessment of impacts and risks associated with the Project.

[34] Barnett B, Townley L.R, Post V, Evans R.E, Hunt R.J, Peeters L, Richardson S, Werner A.D, Knapton A, and Boronkay A, (2012), "*Australian groundwater modelling guidelines*", Waterlines report, National Water Commission, Canberra

9. PREDICTIVE SIMULATIONS

After the steady state model was calibrated to the available data, the model was then converted to transient flow conditions to undertake the predictive scenarios. The steady state heads were used as the starting heads in the transient model. The changes or impacts arising from the Project relate to:

- Aquifer depressurisation/drawdown;
- Leakage of groundwater from alluvial lands;
- Loss of groundwater yield at existing bore locations;
- Change in groundwater quality;
- Rising aquifer pressures post mining; and
- Potential impacts on groundwater dependent ecosystems.

To achieve the transient simulation of mine progression, a number of assumptions were made as discussed below.

9.1 Set-up and Assumptions

The transient model was set up with 27 yearly (365 days) stress periods, representing the 27-year mine life.

Specific yield and specific storage values for the alluvial aquifer were set at values similar to those used by MER[32] in previous studies from the region. The effect of the adopted parameters on the model predictions, particularly the low recharge rate in the regolith in the Permian subcrop areas (0 to 1.5%) allows the zone of influence to expand to a greater extent. Therefore these adopted parameters are considered conservative.

Drainage of groundwater into the open cut mining areas was represented in the model by the introduction of drain cells to the floor of the seam being mined. The depth to which the drain cells were set depended upon which coal seams were targeted and the geometry of the mining area. The deepest layer that drain cells were set was Layer 11, which represented the Blakefield Seam.

Mine progression and the placement of spoil within the mining area were simulated through a yearly ‘stop-start’ process. Each stop-start period or ‘stage’ was assigned the length of one year. The SURFACT code incorporates an adaptive time-stepping function which optimises solution stability during difficult and complex numerical situations. The minimum time step was set to one month and the maximum time step was set to three months. A total of 27 stages are used for the mining period simulation. The locations of the mining areas and the yearly rate of advancement used in the transient simulations are shown in Drawing No. 18.

The model cells where active mining was being undertaken were defined with the SURFACT Drain package (DRN). Once a drain boundary condition was applied, it was assumed to be active for the entire year. At the completion of each yearly stage, the drain cells were removed from the area where mining had been completed for that year and were reapplied to the cells representing the stress period in the next year. At this point, the aquifer parameters for the previously mined areas were reset to parameters representing spoil, as shown in Table 25. These parameters were set to values based on a Hunter Valley study undertaken by Mackie[35]. The allocation of spoil hydraulic

[35] Mackie Environmental Research Pty Ltd, (2009), *“Hydrogeological Characterisation of Coal Measures and Overview of Impacts of Coal Mining on Groundwater Systems in the Upper Hunter Valley of NSW”,* PhD Thesis, University of Technology, Sydney.

parameters allowed for the simulation of groundwater level recovery within the spoil as mining progresses, beyond mined out areas, as well as the simulation of potentially increased mining area seepage rates from this recharge.

Table 25: HYDRAULIC PARAMETERS OF SPOIL AND HIGHWALL BACKFILL

Geology Type	Parameter	Value
Spoil	Kh (m/day)	0.8m/day
	Kv (m/day)	0.01m/day
	S_y	0.01
	S_s (m^{-1})	0.01m^{-1}
Highwall Backfill	Kh (m/day)	0.5m/day
	Kv (m/day)	0.25m/day
	S_y	0.25
	S_s (m^{-1})	0.00001m^{-1}

Higher recharge rates to the spoil are also expected, and therefore when model cells were defined as spoil, the recharge applied to the cell was also modified for the next stage. A recharge rate of 22 mm/year (3.3% annual rainfall) was adopted for spoil areas. The increased recharge rate was chosen to simulate increased infiltration through disturbed rock/backfill in these areas.

It is generally accepted there is a lag between when the spoil is placed in the mining area, and when it has sufficiently "wet-up" to allow rainfall recharge to report as seepage to the mining area. The groundwater model does not simulate this lag time required for the wetting up of the spoil, but applies it instantaneously to the top surface of the water table. This is considered a conservative assumption as it is likely to increase the predicted inflow rates.

As discussed previously, highwall mining will be undertaken at various stages during the life of the Project. A number of assumptions were utilised to represent the highwall mining operations within the groundwater model, these being:

- The depth, location, and progression (yearly stress periods) of each of the highwall mining areas was provided by the mine plans;
- The two deepest coal seams within each of the mining areas will be removed by highwall mining;
- Each highwall mine drive is anticipated to be backfilled at the cessation of mining; and
- At completion of highwall mining the horizontal hydraulic conductivity (Kh) was set to 0.5 m/day and vertical hydraulic conductivity was set to 50% of Kh to reflect the limited compaction of backfill material, and specific yield was set to 0.25% to account for partial filling of the highwall mine drives with backfill.

The locations of the mining areas and the rate of advancement used in the transient simulations are shown in Drawing No. 18.

9.2 Inflow to Mined Void

Groundwater flows into drain cells representing in-pit dewatering/evaporation were extracted for each yearly stress period to assess the rate of groundwater inflow to the mining areas. The model simulated inflow rates to each of the Drayton South mining areas are shown in Figure 39 below.

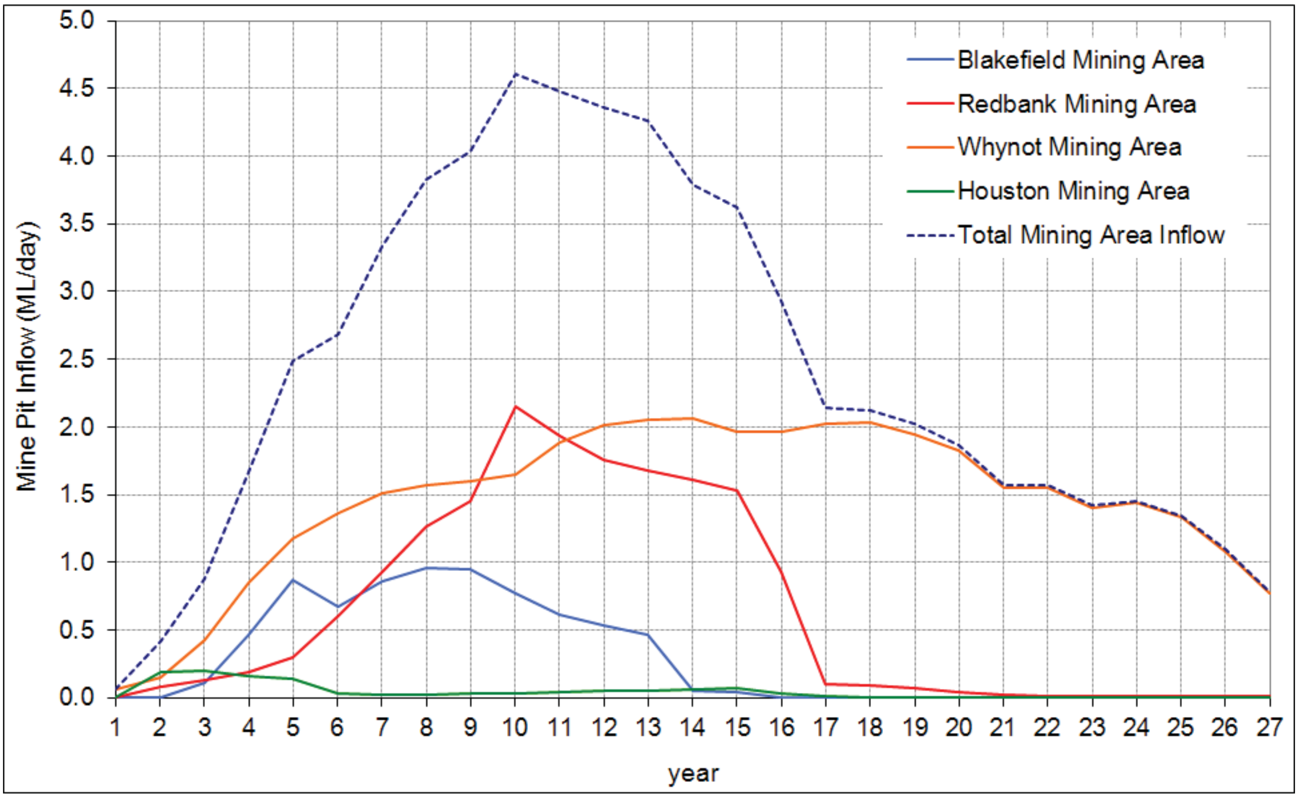

Figure 39: Simulated Seepage into Mining Areas

The predicted mining area seepage rates vary throughout the mining period. This variability in inflow is directly related to the proposed mine plan, the depth/thickness of saturated coal being mined and hydraulic gradients induced by the depressurisation of the coal seam. The peaks in the simulated inflows are partially due to the yearly steps used to represent mining in the model, and in reality the measured seepage rate would not be expected to peak as predicted by the model simulation. Predicted seepage rates peak at about 4.6 ML/day in Year 10. The seepage rate over the life of the mine averages 477 ML/year (1.3 ML/day).

The simulated seepage rate to the Blakefield mining area, Redbank mining area and Houston mining area is reduced as the Whynot mining area deepens, and demonstrates the interaction of the zone of depressurisation created by each mining operation. As the mining areas deepen, the hydraulic gradient will be greater at these locations and therefore mining area inflows will increase. Variances in the rate of mining progression also affect mining area inflow estimates. Each of the three largest mine areas (Blakefield, Redbank, and Whynot) is active in Year 10 resulting in a peak groundwater inflow rate of 4.6 ML/day.

The annual simulated seepage volumes to the Project's open cut mining area are shown in Figure 40 and Figure 41 below. The predicted cumulative inflow of groundwater over the 27 year life of the mine is approximately 23,663 ML, which is an average of 876 ML/yr (27 L/s). The peak year is Year 10 where the annual seepage is predicted at 1,682 ML.

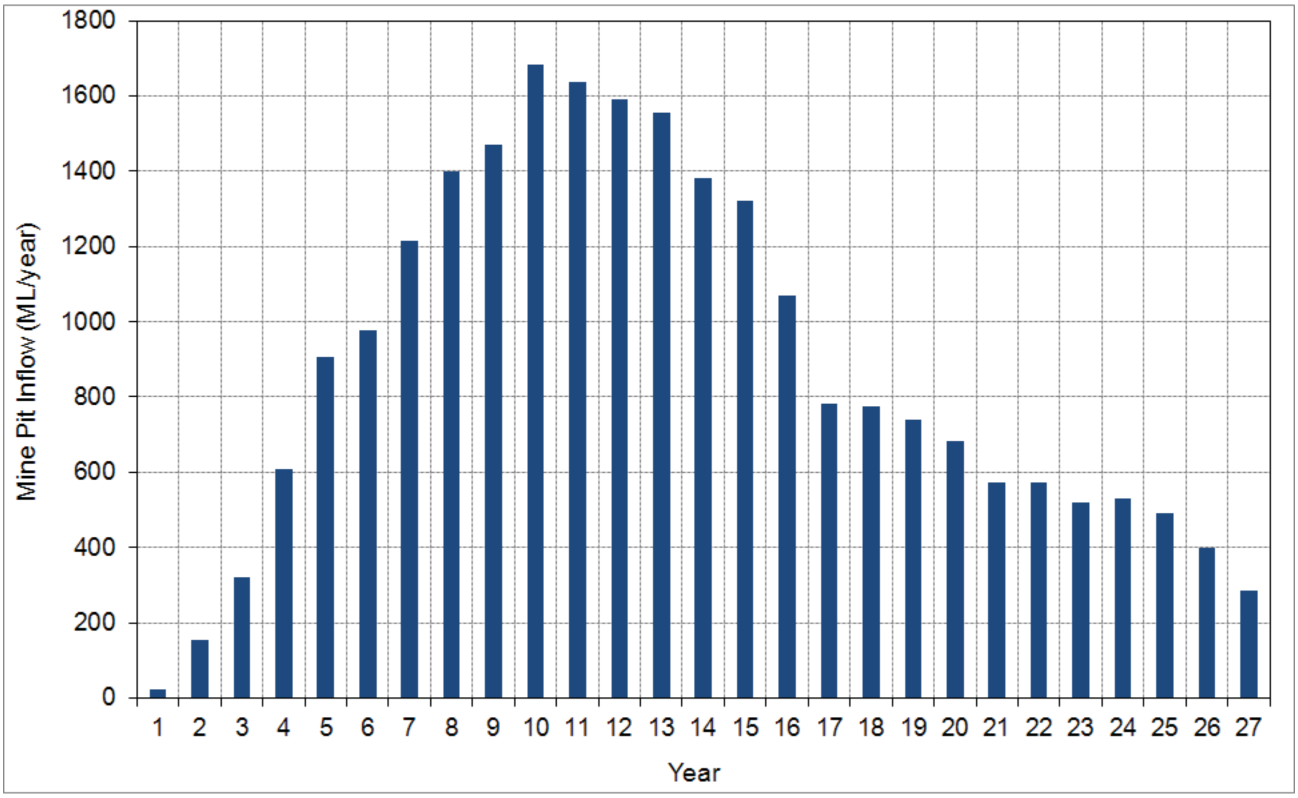

Figure 40: Simulated Annual Seepage Rate

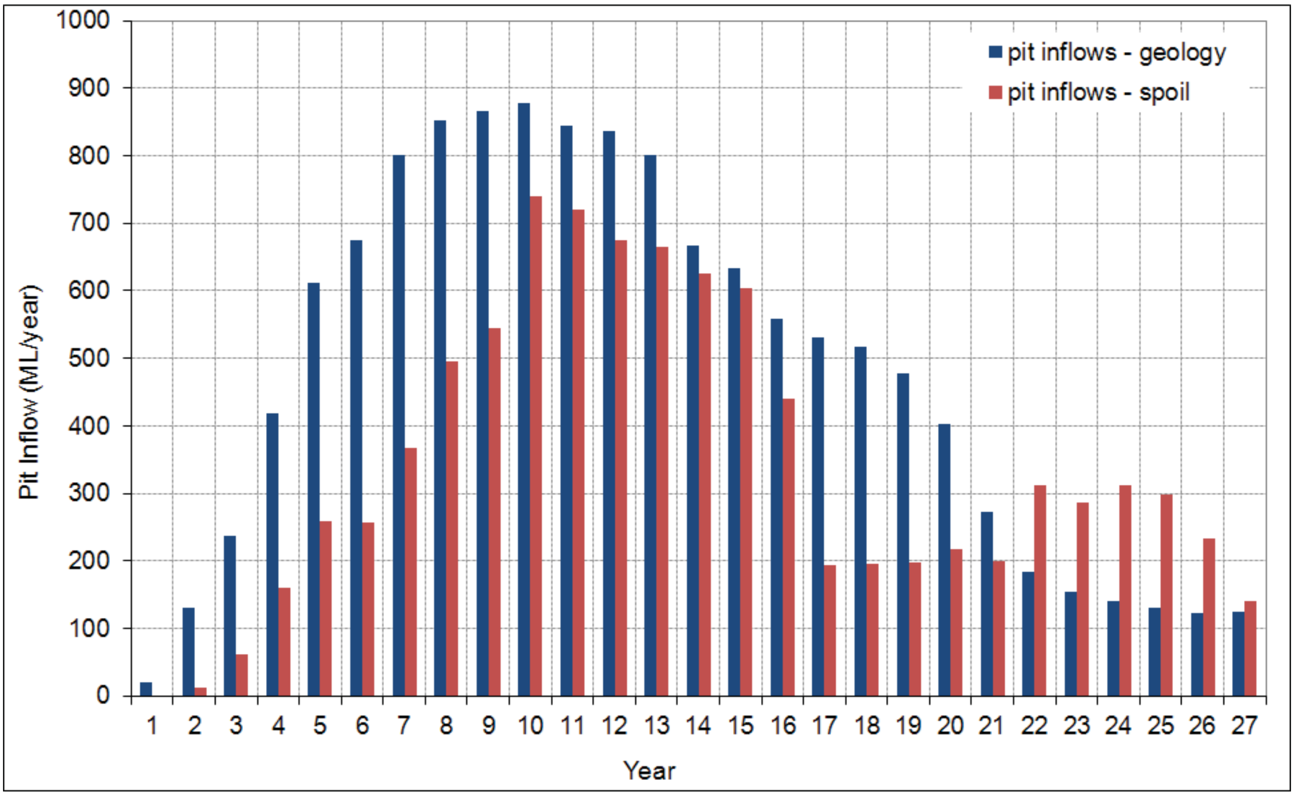

Figure 41: Simulated Groundwater Inflow – Breakdown of Contribution from Spoil and Geology (Permian Coal Measures and Regolith)

The simulated mining area inflows shown in Figure 40 are a combination of contribution from inflow from the Permian coal measures (including the regolith unit) and a contribution from the backfilled spoil. The inflow rates indicated on Figure 41 suggest that groundwater derived from the Permian coal measures will approach a maximum of about 900 ML/year (i.e. 28 L/s) in Year 10.

The representation of mining area dewatering through the SURFACT drain package means that some processes are accumulated into the predicted inflow. In reality, evaporation from the coal face exposed in the highwall and endwall would remove a proportion of the seepage predicted by the modelling and not all of the simulated seepage would flow to sumps for removal by pumping. Similarly, an amount of predicted groundwater inflow is removed as moisture in the coal and overburden.

A simple approximation to the evaporation at the mine face can be achieved by applying the pan evaporation rate of 4.4 mm/day to the surface area of coal seams exposed in the mining area. Table 26 presents an estimate of groundwater that reports to the mining area bottom (i.e. the pumpable volume) after evaporation effects have been accounted for.

Table 26: ESTIMATE OF GROUNDWATER INFLOW AFTER EVAPORATION

Estimated Evaporation from Exposed Coal Seams (ML/year)				
Year	Blakefield Mining Area	Redbank Mining Area	Whynot Mining Area	Houston Mining Area
3	12.91	29.81	28.40	13.26
5	33.45	29.81	40.84	20.65
10	25.00	36.61	46.12	24.18
15	2.35	36.97	46.12	14.43
20	0.00	21.83	43.19	10.86
27	0.00	0.00	32.27	6.34
Estimated Total Groundwater Inflow to Mining Areas (ML/year)				
Year	Blakefield Mining Area	Redbank Mining Area	Whynot Mining Area	Houston Mining Area
3	41.96	49.43	156.95	72.14
5	318.28	109.34	429.00	51.80
10	283.43	784.90	601.64	13.82
15	17.40	559.63	718.85	24.95
20	0.00	16.97	665.96	0.00
27	0.00	3.70	282.07	0.00
Estimated Groundwater Reporting to Mining Area Bottom After Evaporation (i.e. pumpable volume) (ML/year)				
Year	Blakefield Mining Area	Redbank Mining Area	Whynot Mining Area	Houston Mining Area
3	29.05	19.62	128.55	58.88
5	284.83	79.53	388.17	31.15
10	258.44	748.29	555.52	0.00
15	15.05	522.66	672.73	10.52
20	0.00	0.00	622.78	0.00
27	0.00	3.70	249.80	0.00

It should also be noted that for the reasons mentioned previously, the simulated inflows are considered to be a conservative overestimate for the following reasons:

- The model simulates a continuous aquifer system and does not include the minor faults, igneous intrusions and variability in hydraulic conductivity in the area – the impact of these features would be to lower the simulated seepage rate;
- The starting heads used in the model were higher within the Project Boundary than the observed head and this has the effect of increasing the hydraulic gradients between the aquifer and the mining area, increasing inflow rates to the mining area; and
- The expected lag time required for spoil emplacements to wet up and allow rainfall recharge to migrate through into the mining area was not simulated which means seepage from the spoil may be over predicted.

9.3 Potentiometric Surface/Water Table Levels – During Mining

During the life of the Project, the rate of groundwater extraction from the mine workings will exceed the rate that the coal measures can recharge. This process will lead to a drawdown of the potentiometric surface (i.e. depressurisation) surrounding the Project, when compared to the pre-mining potentiometric surface.

Depressurisation of the potentiometric surface will migrate out of the highwall of the mining area (and highwall mined areas) as mining moves from north to south and progressively becomes deeper. The predicted impact of depressurisation on the potentiometric surface groundwater heads at the end of mining are represented by contour maps in Drawing No. 19 for the regolith/alluvium (Layer 1), and Drawing No. 20 for the Redbank coal seam (Layer 5). The model predicts the largest area affected by depressurisation will occur within Layer 5.

The decline in groundwater heads (i.e. drawdown) surrounding the Project mining areas are also represented by drawdown contours, such that the 1 m contour represents the location where a 1 m decline in the potentiometric surface (compared to pre-mining levels) is predicted. These contour surfaces have been calculated by subtracting the potentiometric surface resulting from mining, from the pre-mining (steady state) surfaces. The development of the drawdown zone of influence is shown in a series of maps shown in Drawing No. 21 to Drawing No. 32.

Drawing No. 21 to Drawing No. 26 present potentiometric head changes in response to mine progression for Years 3, 5, 10, 15, 20, and 27 (end of mining) for Layer 1. The drawings illustrate the rapid decline in groundwater levels in Layer 1, as the pit progresses from north to south. Layer 1 represents the regolith and alluvial areas of Saddlers Creek and the Hunter River. Impacts in this shallow zone are restricted to the immediate vicinity surrounding the mining areas, this being a maximum distance of about 600 m to the west and south of the mining areas at Year 27. The zone of drawdown influence within the regolith is predicted to not extend to the Hunter River alluvials. The zone of drawdown influence within the regolith is predicted to extend marginally into the Saddlers Creek alluvium as shown on Drawing No. 26.

Drawing No. 27 to Drawing No. 32 present potentiometric head changes in response to mine progression for Years 3, 5, 10, 15, 20, and 27 for Layer 5 (the Redbank Creek coal seam), this layer having the largest areal extent of drawdown. Similar to Layer 1, the drawings illustrate the rapid decline in groundwater levels in Layer 5, as the mining area progresses from north to south. Impacts in this coal seam are restricted to a maximum distance of about 1 km to the west and south of the mining areas at Year 27. The zone of drawdown influence within the coal seams is predicted to slightly extend under Saddlers Creek alluvium as shown on Drawing No. 32. The zone of drawdown influence within the coal seams is not predicted to extend under the Hunter River alluvium at the end of mining. The predicted drawdown impacts after the completion of mining are discussed in Section 9.4 below.

Drawing No. 33 shows a comparison between the drawdown surfaces at the end of mining for the regolith/alluvium Layer 1 and each target coal seam (i.e. Whybrow Seam – Layer 3, Redbank

Seam – Layer 5, Wambo Seam – Layer 7, Whynot Seam – Layer 9, and the Blakefield Seam – Layer 11).

In general, the modelled zone of drawdown surrounding the Project is predicted to be limited as expected for the prevailing low permeability coal measures.

Appendix 3 presents the predicted potentiometric heads on a series of cross-sections. Cross sections were developed through each of the mining areas. Drawing No. 35 shows the locations of the cross sections. The cross sections show the predicted potentiometric surface for both Layer 1 (alluvium/regolith) and layer 5 (Redbank Creek coal seam). The cross sections show the steady-state (pre-mining) potentiometric surface and surfaces at the end of mining (Year 27) and at the end of 1000 years post mining. The sections demonstrate that the potentiometric surface is only appreciably depressed beneath the alluvium of Saddlers Creek but not depressed beneath the Hunter River at the end of mining.

9.4 Potentiometric Surface/Water Table Levels – Post Mining

The main features of the final landform after mining ceases will consist of spoil in the north and west of the mining area, and a final void in the southern extent of the Whynot mining area. The final void will have an approximate surface area of 214 ha and have a depth up to 135 m below surface topography.

The void will collect and accumulate water from groundwater seepage sourced from the surrounding regolith and coal seams, seepage from the backfilled material, direct rainfall into the void, and from the slopes of the spoil draining into the void. All undisturbed catchment flows will be diverted around the void, to limit the impact on overland flow. Water inflow and losses from the final void, post mining, is conceptually illustrated in Figure 35.

Generally, the water balance of an open void post mining consists of:

- Inflows:
    - Surface runoff;
    - Leakage from the spoil;
    - Direct rainfall into the open void; and
    - Groundwater inflow or outflow.
- Outflows:
    - Evaporation from the lake surface.

The moderate levels of evaporation experienced in the Hunter Valley will slow the rate of recovery of water in the void by constantly removing water from the final void water surface. Average evaporation in the region is almost two and a half times the average annual rainfall.

Due to the exposure of the mining area lake surface to the effects of evaporation, the rising water level within the void is likely to be impeded and would be expected to reach a state of 'quasi' equilibrium conditions at a lower than the pre-mining potentiometric surface elevation. The rate of recovery of the final void water level will be dependent on rainfall, with years of below average rainfall extending the recovery period and wet years reducing the time for stabilisation.

Modelling of the open void area was achieved by assigning the open area an arbitrary high horizontal and vertical hydraulic conductivity (1000 m/day) and storage parameters (specific yield and storage coefficient) of 1.0, in order to simulate free water movement within the void. This approach is often referred to as 'high K lake'. Rainfall recharge rates of 90%, assuming potential transmission losses within the mining area, of average historical rainfall were applied to the final void lake area to simulate a direct input of rainfall to the mining area lake surface and surrounding mining area walls. The simulation of evapotranspiration was modified to simulate direct evaporation from the mining area lake. The maximum evapotranspiration rate adopted across the final void surface was 1084 mm/year (3 mm/day) to simulate the evaporation from a surface water body.

Parameter changes to the spoil areas result in recovery of groundwater levels higher than the void area, thus there is a seepage of groundwater from the spoil to the void.

The simulated water level recovery in the final void is presented in Figure 42. The simulated groundwater level recovery is based on a hypothetical bore located within the depression/final void area. Figure 43 presents water balance data for the model cells representing the final void within the model. The predicted net evaporative loss (total evaporation minus long-term average rainfall across the mining area) from the final void is approximately 0.5 ML/day after year 400. The open void is controlled by the ongoing evaporative losses from the final void lake. The higher recharge rate applied to the spoil assists the recovery of the water level in the lake, but as the lake area increases, the evaporative losses increase and prevent further recovery. These water balance processes are presented Figure 43.

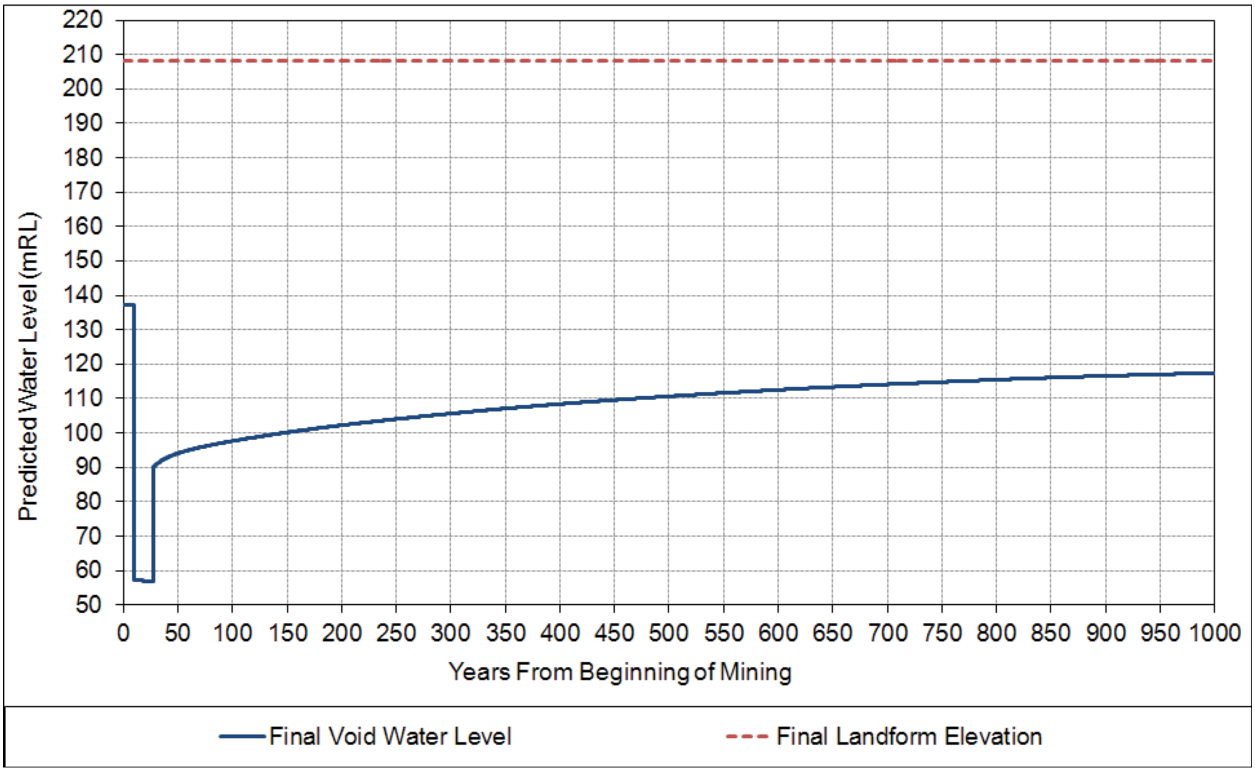

Figure 42: Simulated Water Level in Final Void

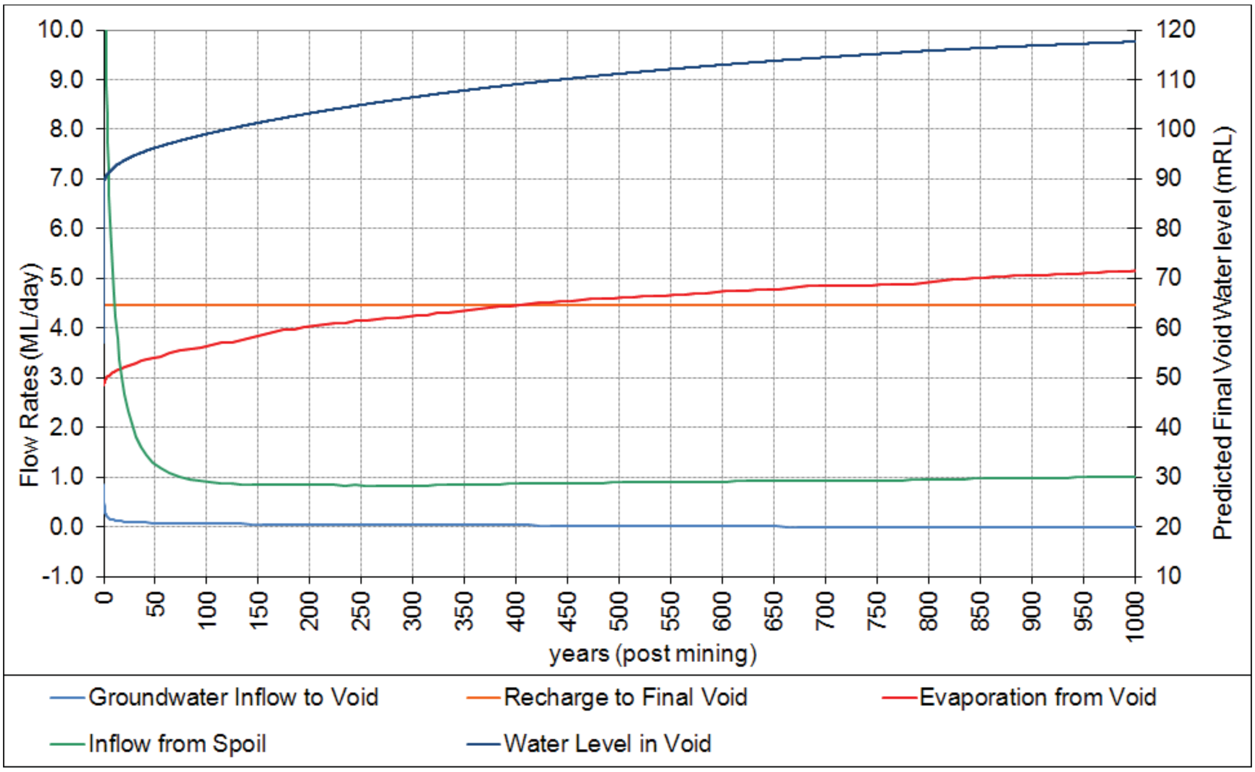

Figure 43: Final Void Model Budget and Predicted Water Level

The water level within the void will vary in height in response to climatic conditions (i.e. increasing with above average rainfall and decreasing due to evaporative processes). The water level response will be largely centred on an equilibrium condition. The water balance of the final void dictates the volume of stored water and hence the water level in the final void.

The void will receive groundwater inflow from the Permian coal measures via inflow through the walls of the final void. Groundwater inflow will also occur from areas of spoil material into the final void.

During early stages of recovery, there will be a steep hydraulic gradient between the water level within the final void and the groundwater levels within the surrounding aquifers and spoil. The steep hydraulic gradient will result in significant groundwater contribution to the final void during the early stages of recovery. However, as the water level within the final void rises, the hydraulic gradient between the void and the surrounding aquifer will become shallower resulting in a reduced inflow of groundwater into the void.

Water levels in the final void are predicted to reach 85% of their final stable water level (post-mining equilibrium level) within 147 years after cessation of mining as illustrated in Figure 42. This water level is equivalent to approximately RL 100 m. Water levels within the final void attain their post-mining equilibrium level (of approximately RL 117 m) after approximately 1000 years (Figure 42). Effectively, at this level the amount of water entering the void via runoff and inflow is equivalent to the evaporation that can be expected given the area of the void lake surface.

The freeboard between the water level surface and the void spill height is approximately 90 m. Hence, the final void is never likely to fill (nor spill), as a rainfall event causing enough catchment runoff to fill the void is unlikely.

The final void water level recovery model results suggest that the post-mining equilibrium void water level is approximately 20 m lower than the pre-mining potentiometric surface surrounding the mining area. The predicted final void water balance suggests that the depression of the potentiometric surface around the void will act as a “sink”, not permitting water within the final void to flow outwards into the regional system, for about 700 years after mining as shown on Figure 43.

Appendix 3 presents the simulated heads for the steady-state (pre-mining) potentiometric surface and surfaces at the end of mining (Year 27) and 1000 years post mining. Appendix 3.3a and 3.3b shows sections through the final void and show potentiometric levels for Layer 1 and Layer 5. The sections illustrate the potentiometric surface within the coal measures on the southern side of the final void is predicted to recover to a level that approaches RL 114 m (Figure 43) during the first 700 years after mining. As the recovering potentiometric head approaches RL 114 m, the rate of groundwater inflow to the mining area is predicted to decline very gradually until no groundwater inflow will occur. As the groundwater heads continue to recover above RL 114 m (reaching RL 117 m by 1000 years after mining), it is predicted that the hydraulic gradient will be slightly reversed away from the final void as shown in Appendix 3.3b. This is predicted to result in a slight loss of final void water back into the Permian coal measures. The loss of water from the final void into the coal measures may rise from 0.001 ML/day up to 0.02 ML/day during the period from year 700 up to year 1000. This is illustrated in Figure 43 as a slightly negative groundwater inflow flux from year 700 to year 1000.

The long term build-up of salts in the Drayton South final void was assessed by WRM (2012)[31] using an OPSIM water balance model which was configured to replicate the final void behaviour. The OPSIM model was run using a historical rainfall data sequence from 1889 to 2010. The water balance model showed that salt concentrations are predicted to gradually increase with TDS concentrations peaking at 5600 mg/L at the end of the simulation period (120 years). It is likely that TDS concentrations will continue to increase over time as water evaporates from the surface of the water body and salt loads increase.

The travel time of water from the final void can be estimated using the average linear velocity of groundwater. The average linear velocity was calculated by assuming an effective porosity of 1%, a bulk hydraulic conductivity of 6×10^{-3} m/day, and a hydraulic gradient of 0.016 from the stabilised final void water surface towards the elevation of the Hunter River. It is estimated that the travel time for a particle of water to move from the final void to the Hunter River will take about 600 years after the initial 700 years of void recovery, totalling about 1400 years post mining. A conservative assumption would be to assume that all of the water would move through the coal seams which have a higher hydraulic conductivity than the bulk value used in the calculation above. In this scenario, increasing the hydraulic conductivity to 2×10^{-2} to reflect a coal seam aquifer, will reduce the travel time to about 200 years. However, as long as the cone of depression has not recovered around the mine and the water level within the final void remains below the surrounding groundwater level, no outflow of leachate is expected.

The extent of the zone of depressurisation for the regolith (Layer 1) at 1000 years after mining is shown in Drawing No. 36 and the Redbank coal seam (Layer 5) in Drawing No. 37. The zone of depressurisation extends upwards from the coal seams, through the interburden, and regolith. The small depressurisation impact that propagates up into the Hunter River alluvium is compensated by the significantly higher specific yield and hydraulic conductivity of the alluvial unit. The overall impact zone predicted by the model simulations for the regolith (Layer 1) extends to about 1 km south of the mining operation and is restricted by the higher permeability unit of the Hunter River alluvium. The impact zone is predicted to extend between 1.5 km and 2 km to the south-east and south-west where the drawdown influence is not limited by the presence of Hunter River alluvium. The overall impact zone predicted by the model simulations for the Redbank Creek Seam (Layer 5) extends to about 1.3 km south of the mining operation. The impact zone is also predicted to extend between 3.8 km to the south-west and 3.3 km to the south-east.

9.5 Impact on Groundwater Users

A total of two registered bores/wells are encompassed within the zone of influence (excluding monitoring bores) as defined by the 1m drawdown contour at the end of mining. These registered bores are known as Shearers Well (regolith) and Shearers Well Bore (Permian coal measures). The locations of the registered bores within the zone of depressurisation at the end of mining are shown in Drawing No. 34. Both of these bores are located on land owned by Anglo American, and will be destroyed by mining.

No other registered bores are located within the predicted zone of influence at the end of mining. Similarly, no other registered bores are located within the predicted zone of influence at the end of 1000 years post mining.

The minimal impact considerations in the Aquifer Interference Policy require the cumulative water table and pressure head decline not more than 2m at any water supply work. The modelling indicated that the drawdown at all private bores (except those listed above which are owned by Anglo American) is less than the 2 m trigger in the Aquifer Interference Policy.

Notwithstanding the above predictions, it is recommended that Anglo American develop a mitigation plan to monitor any possible impacts of the Project upon private landholders bores and to ensure there is a mechanism in place for falling water levels that are directly attributable to the Project.

9.6 Impact on Alluvial Aquifers

As MER[32] has previously described:

> *The current hydrogeological regime favours elevated groundwater levels and pressures within the coal measures which dissipate regionally through upward leakage into the low lying alluvial systems along the Hunter River and Saddlers Creek. This flow regime leads to a generally brackish or saline environment in basal sections of the alluvium. Shallower sections (in the alluvium) generally exhibit improved quality groundwater through the downward migration of rainfall recharge and river/creek recharge*.

The groundwater model predicts the migration of the zone of depressurisation southwards towards the Hunter River, but not measurably beneath these alluvial lands. Consequently very limited leakage impacts are predicted to affect the alluvial lands associated with the Hunter River as a result of the proposed Project. The predicted interception of flow to the alluvial aquifer is shown in Figure 44 below.

Figure 44 excludes rainfall recharge, and therefore represents the net inflow (i.e. flux) from the underlying bedrock aquifers into the alluvial aquifers. Analysis of fluxes indicates a pre-mining net upward seepage for the Hunter River alluvium of the order of 0.27 ML/day. However, the model is likely to under-predict the amount of upward leakage into the Hunter River alluvium as a no-flow boundary exists along the southern boundary of the Hunter River alluvium. Assuming that the Permian unit located on the southern side of the Hunter River alluvium will provide a comparable flux, it may be appropriate to assume that the Hunter River alluvium will receive a seepage flux of the order of about 0.5 ML/day. Seepage fluxes determined at the cessation of mining indicate that the Hunter River alluvium will continue to receive seepage flux at a rate comparable to pre-mining conditions. However, as time progresses and the zone of depressurisation expands, the seepage flux to the Hunter River alluvium may be reduced by about 0.01 ML/day (i.e. 0.1 L/s) at about year 400. The flux reduces by an average 2 ML/year post mining. This reduced seepage flux is not likely to impact groundwater levels within the alluvial aquifer by a measurable amount (i.e. minimal harm). Numerical modelling predicts a net change in the leakage balance of about 0.01 ML/day with the maximum change potentially inducing downward leakage at a rate of about 0.0005

L/m^2/day at about year 400. The downward loss rates will be matched by rainfall recharge which is calculated to be at least 34 mm/yr in alluvial lands or approximately 0.09 L/m^2/day (more than three orders of magnitude higher).

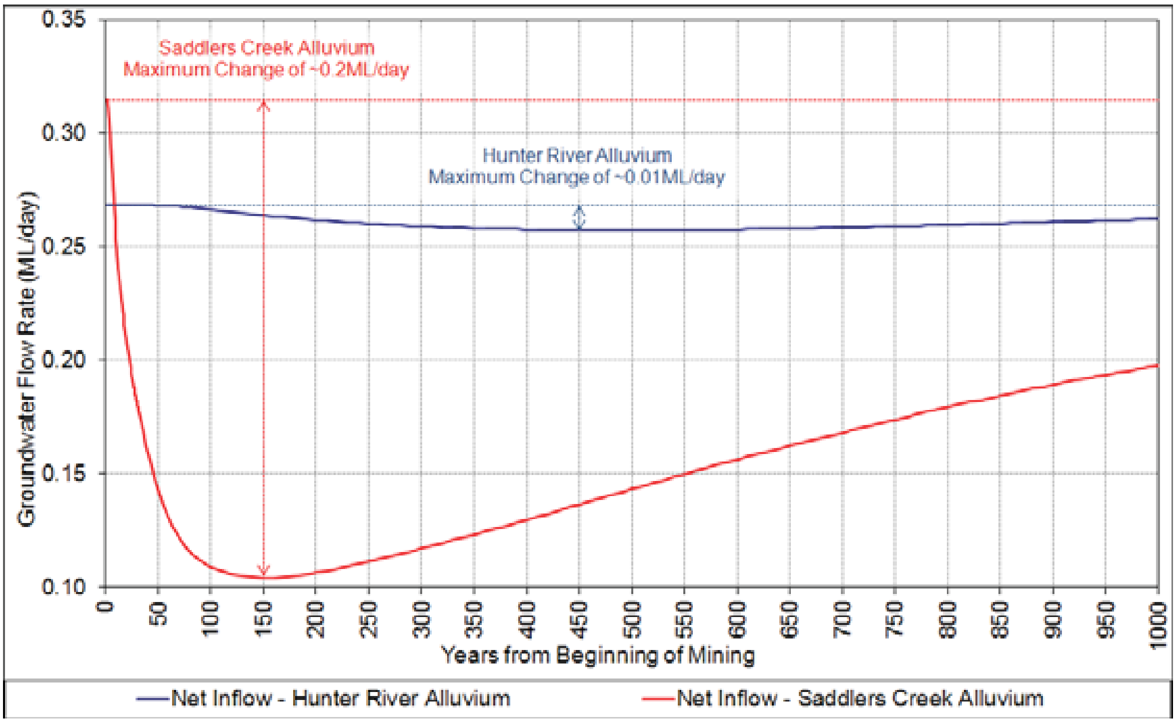

Figure 44: Simulated Net Flow to Alluvial Aquifers

Vertical leakage fluxes between the alluvial deposits associated with Saddlers Creek and the underlying coal measures may be more affected due to their proximity to the Project. Analysis of fluxes indicates that a pre-mining net upward seepage flux is in the order of 0.31 ML/day. This flux is comparable to the rate identified by MER[32] for Saddlers Creek which equates to seepage flux of about 0.1 L/m^2/day over an area of about 3.4 km^2. Seepage fluxes determined at the cessation of mining indicate the net upward flux would reduce to about 0.19 ML/day, and would continue to decline to about 0.1 ML/day, over a period of 150 years after the cessation of mining. This equates to a total reduced flux of about 0.2 ML/day. The continuing decline in flux to Saddlers Creek is predicted to be in response to depressurisation of the coal measures and adjacent regolith following mining. Consequently, the flux to Saddlers Creek is anticipated to recover as water levels within the adjacent backfilled spoil recover as indicated in Figure 44. The flux reduces by an average 58 ML/year over the mining and post mining phases.

9.6.1. Cumulative Impact on Alluvial Aquifers

The impacts resulting from the Project are likely to combine with impacts from adjacent mining projects. These cumulative impacts have been assessed by utilising the results from previous modelling conducted for the Mt Arthur Underground (MER[32]) and for the Saddlers Pit (AGE[11,12]), both located immediately north of Saddlers Creek. Both of these projects have been approved by the NSW State Government. Both of the predictive models are considered fit for purpose and appropriate to assess the potential impacts resulting from mining at Mt Arthur Coal Mine.

The available data shows that current mining activities at Mt Arthur Coal Mine, located to the north of the study area, have the potential to impact the regional groundwater regime[32]. Following review of the available data the following has been noted:

- The depressurisation of aquifers resulting from the Mt Arthur Coal Mine operations will be limited to the coal seams of Woodlands Hill, Piercefield, Vaux, Bayswater, Edinglassie and Ramrod Creek, the Hunter River alluvial aquifer north of Mt Arthur Coal Mine, and Saddlers Creek alluvium to the south. The impacted coal seams are located stratigraphically beneath the target seams for the Project;
- The Mt Arthur North Mine (MAN), Bayswater No. 2 Mine, and Drayton Mine do not influence the aquifer systems of the study area as they are structurally isolated and their mining activities are confined to the Greta Coal Measures that are stratigraphically lower than the Wittingham Coal Measures. Bayswater No. 2 Mine closed in 1998;
- The Bayswater No. 3 Mine is expected not to have a significant impact on the surrounding groundwater table owing to its shallow mining depth;
- Re-activation of Saddlers Pit at Mt Arthur Coal Mine, which is located immediately to the north of Saddlers Creek, targeting the Glen Munro Seam and Woodlands Hill Seam, was assessed by AGE[12], and is expected to influence groundwater levels in the Saddlers Creek alluvium; and
- Numerical groundwater flow modelling predictions undertaken by MER[32] indicate that the cumulative impacts of existing and proposed operations of the Mt Arthur Coal open cut mine and Mt Arthur Underground operations will result in cumulative depressurisation of the Permian aquifers within the immediate vicinity of these operations. MER[32] notes that the depressurisation surface associated with the underground operations varies with depth as expected, owing to complex flow and pressure distributions resulting from vertically enhanced conductivity (connective cracking) within the failure regimes above the extracted panels. The potential impacts associated with the adjacent Mt Arthur Underground operation and Saddlers Pit are discussed in further detail below.

Underground mining at Mt Arthur was anticipated to commence in 2007 and continue for approximately 21 years. However, only initial development works have been undertaken to-date and the project is currently on-hold[36]. Key findings of the previous detailed study undertaken by MER[32] are reproduced below.

> *Model predictions support the evolution of a complex depressurisation of strata as a result of multi-seam extractions. Impact in the shallow regolith zone is mostly within the subsidence zone (within the longwall panel footprint) where loss of the water table is predicted by vertically downwards drainage induced by subsidence cracking. Beyond the subsidence zone, the shallow water table, or zone of unsaturated flow is predicted to be maintained essentially through long-term rainfall recharge to, and storage within the regolith-weathered bedrock. However, beneath this zone the rock mass will be variably but significantly depressurised with pressure losses extending about 3 to 4 kilometres beyond parts of the panel footprint. This range of depressurisation is consistent with observations at other mine sites throughout the region.*

MER[32] also concluded:

> *Vertical leakage rates between the alluvial deposits associated with Saddlers Creek and the underlying coal measures may be affected. Analysis of localised groundwater flow generated by the aquifer model, indicates a pre-mining net upward seepage in the order of 0.34 ML/day which, when averaged over an area of some 3.4 km^2 yields a rate of about 0.1 L/day/m^2 of surface area. Seepage fluxes determined at the cessation of mining indicate the net upward flux would continue at a reduced rate of 0.26 ML/day, over the same area – a reduction of*

[36] BHP Billiton, (2011), "*Environmental Management Strategy – Draft*", MAC-ENC-MTP-041.

0.08 ML/day. No large scale reversal to downward leakage is indicated, hence the alluvial lands associated with Saddlers Creek are expected to continue to receive saline seepage from the surrounding coal measures and to remain relatively unimpacted by the proposed mining operations.

Maps illustrating the predicted head losses resulting from the Mt Arthur Underground, developed by MER[32], for the regolith/alluvial areas are reproduced below in Figure 45, and for the Permian coal measures above the Glen Munro Seam in Figure 46, at the end of mining.

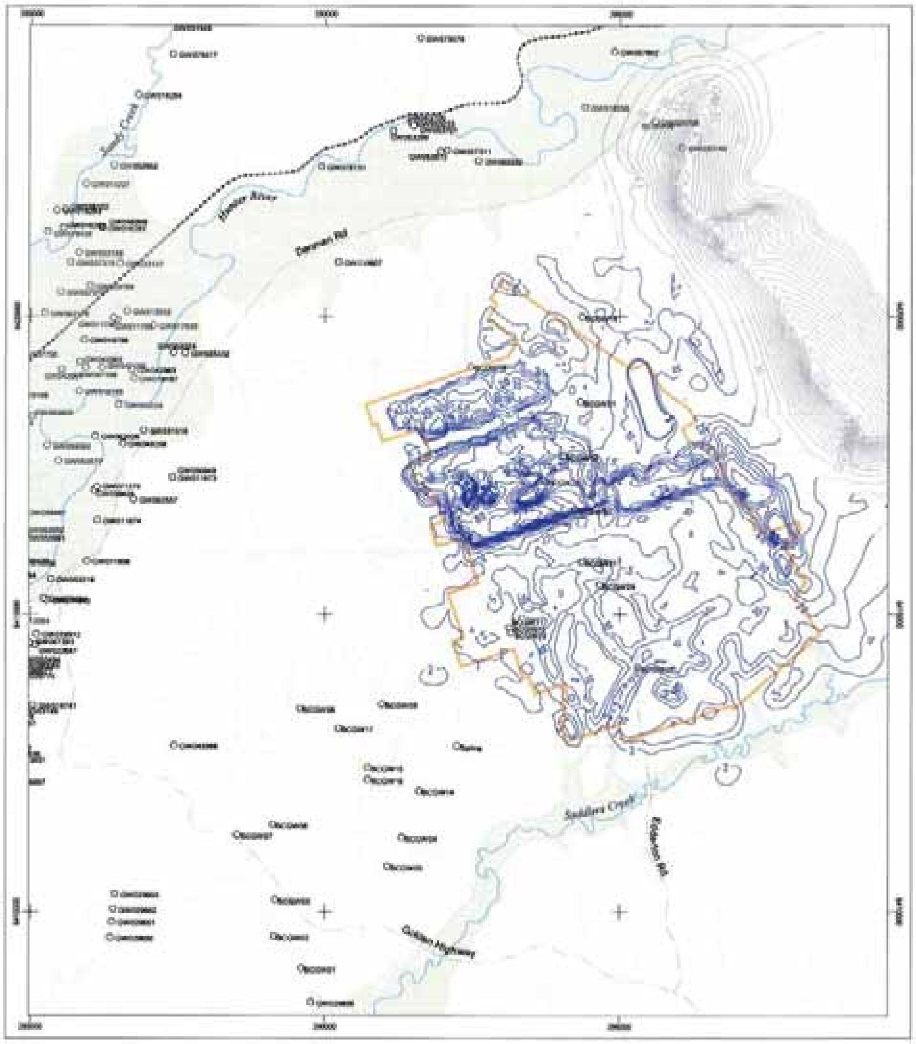

Figure 45: Regional Drawdown Impacts in the Shallow Regolith Zone – End of Mining
Source: MER, 2007

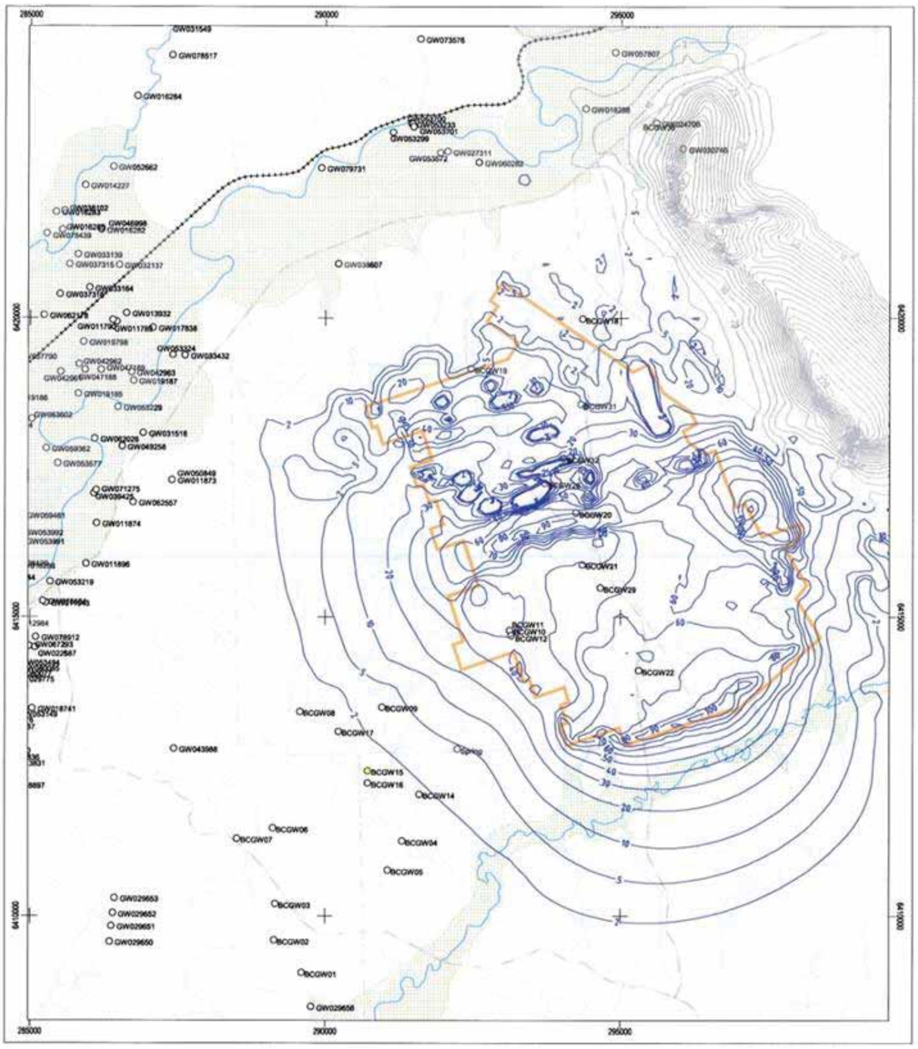

Figure 46: Regional Drawdown Impacts in the Coal Measures above the Glen Munro Seam – End of Mining Source: MER, 2007

Key findings of the previous detailed study undertaken by AGE[12] are reproduced below.

> *Mining in the Saddlers Creek area will reduce the rate of the groundwater discharge from the Permian aquifers to the alluvial aquifer of Saddlers Creek. Simulation indicates that up to the year 2011 this reduction will be caused mainly by the advancing cone of depression developing around the MAN Pit and South Pit Extension, which will affect the Saddlers Creek alluvium over a length of around 3 km.*

The section of impacted Saddlers Creek alluvium is located wholly within the Mt Arthur Coal Mine lease and is approximately 1.5 km north of the proposed Drayton South mining areas.

> *By 2011 the flow direction in the Permian aquifer is reversed with flow being from Saddlers Creek towards the South Pit Extension, stabilising on a rate of 0.09 ML/day (1.04 L/s) by about 2019. At this time the northern part of the Saddlers Creek alluvium will be hydraulically separated from the underlying Permian aquifer due to the ongoing groundwater drawdown. The creek alluvium however will still receive direct recharge from rainfall and surface runoff, and will retain some of its natural ephemeral surface flow.*

By 2016 an additional minor impact on Saddlers Creek is caused by dewatering and depressurisation associated with mining of the Glen Munro and Woodlands Hill Seams in the southern part of Saddlers Pit, leading to a reversal of groundwater flow into the Pit. Predictive modelling indicates that the flow rate from Saddlers Creek towards the Pit never exceeds 0.02 ML/day.

The simulation results indicate that the impact of the MAU Project may add to the reduction of flow and discharge towards Saddlers Creek along a 6 km long section, directly downstream of the South Pit Extension. The simulated discharge rates to Saddlers Creek alluvium as a result of MAU are reduced from 0.1 ML/day (1.16 L/s) along this section to 0.01 ML/day (0.12 L/s), in 2022, however groundwater drawdown does not exceed 2 m at the creek.

This assessment of changes to the alluvial seepage flux compare favourably with the predictions made by MER[32].

In the lower reaches, towards the Hunter River, the Saddlers Creek alluvium will continue to receive groundwater discharge from the coal seams even during peak mining activities within the MAN Pit, South Pit Extension and MAU. This is because the cone of depression around the Pits and underground mine is quite steep and limited to the immediate surrounds of the Pits and underground mine.

It should be noted that the reduction of groundwater discharge from the Permian aquifer to the Saddlers Creek alluvium may lead to improvement in the quality of groundwater along the affected section of the creek since the Permian groundwater is known to have a higher salt content.

Maps illustrating the predicted head losses resulting from the combined modelling of the Saddlers Pit and the MAU, developed by AGE[12], for the regolith/alluvial areas are reproduced below in Figure 47, at the end of mining.

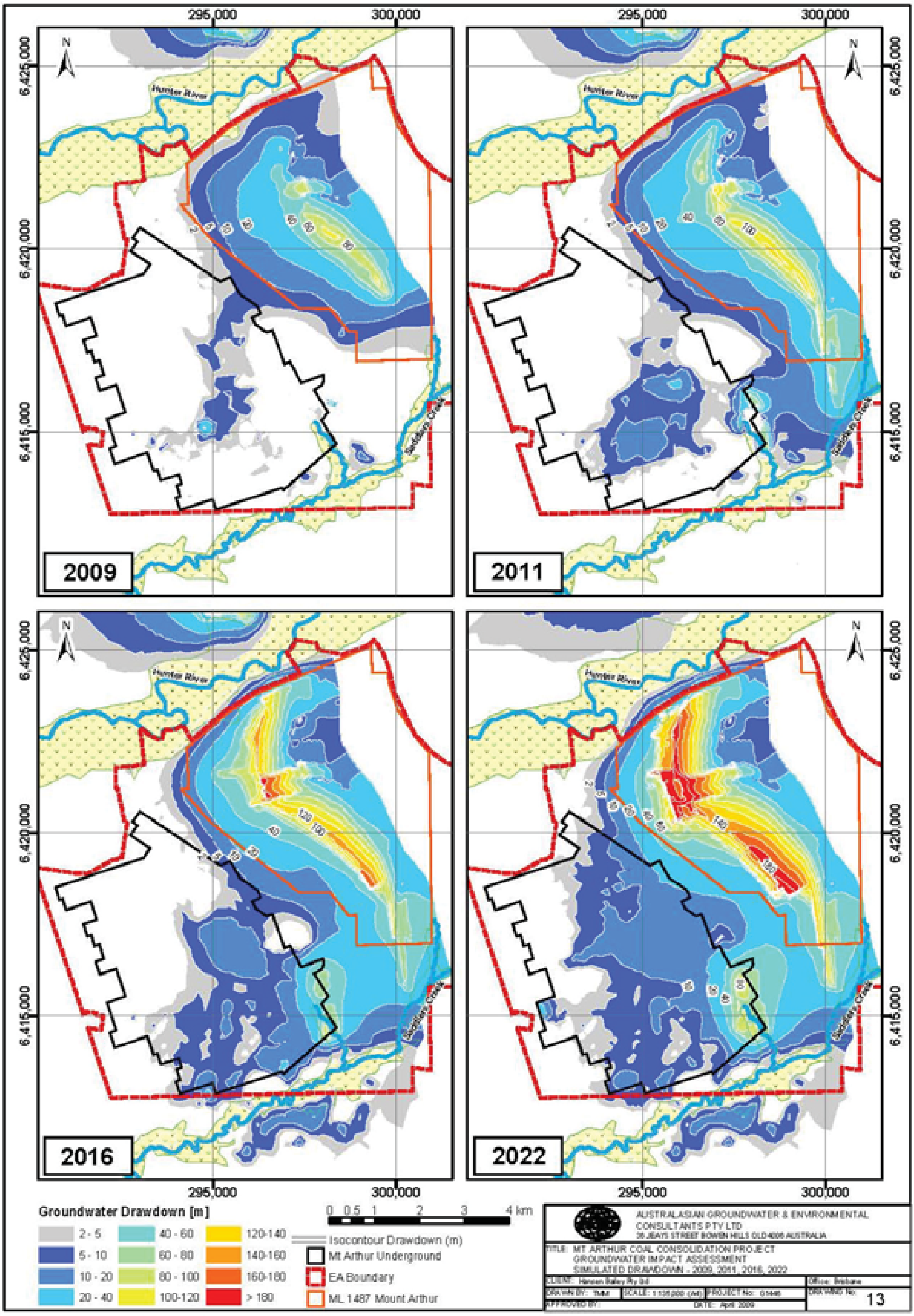

Figure 47: Regional Drawdown Impacts – End of Mining

Source: AGE, 2009

As discussed above, MER[32] predicted a reduction of seepage flux to the Saddlers Creek alluvium of about 0.08 ML/day as a result of the Mt Arthur Underground project and AGE[12] predicted a reduction of seepage flux to the Saddlers Creek alluvium of about 0.11 ML/day as a result of open cut mining at Saddlers Pit. The maximum predicted reduction in net flux to the Saddlers Creek alluvium resulting from the Mt Arthur Coal Mine operations was predicted to be about 0.19 ML/day, over a length of about 6 km, at the end of mining. Therefore, it is predicted that the pre-mining flux of water into the Saddlers Creek alluvium (~0.31 ML/day) will be reduced to about 0.12 ML/day by the Mt Arthur Coal Mine operations. The remaining influx to the Saddlers Creek alluvium along the same 6 km section (~0.12 ML/day) may therefore be reduced to zero as a result of the Project. A reversal of flow resulting in downward leakage from the alluvium into the surrounding bedrock is illustrated by the drawdown contours shown in Drawing No. 36.

In the lower sections of Saddlers Creek, towards the Hunter River, it is anticipated that the Saddlers Creek alluvium will continue to receive groundwater discharge from the coal seams even during peak mining activities associated with the Project and the Mt Arthur Coal Mine operations.

9.6.2. Impacts on Highly Productive Groundwater

Biophysical Strategic Agricultural Land is defined by Strategic Regional Land Use Plans (SRLUP). The NSW Government has released strategic regional land use plans for the Upper Hunter region of the state. The Strategic Regional Land Use maps have used the extent of the Hunter River alluvium to designate the Biophysical Strategic Agricultural Land (BSAL) located nearest to the Drayton South Coal Project.

The maps within the SRLUP indicate that there is no BSAL located with the Project Boundary. Further site verification conducted as part of the EA Soil and Land Capability Impact Assessment (Appendix Q of the EA) has confirmed that this is the case as the land does not meet the criteria for BSAL. As such the EA is not required to address the gateway criteria for BSAL.

Regardless it has been determined that the Project will not have any measurable impact on the Hunter River alluvial aquifer which would more than likely constitute ‘highly productive groundwater’. It is reasonable to conclude that the Saddlers Creek alluvial aquifer is not ‘highly productive groundwater’. Therefore, the Project will not reduce the agricultural productivity of BSAL through impacts to highly productive groundwater.

9.7 Impact on Groundwater Dependent Ecosystems

The Minimal Impact Considerations in the Aquifer Interference Policy require that *“less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:*

(a) high priority groundwater dependent ecosystem; or

(b) high priority culturally significant site;”

The Hunter River Unregulated and Alluvial Water Sources Water Sharing Plan does not define any high priority groundwater dependent ecosystem or high priority culturally significant sites within the Project area or surrounds.

Cumberland Ecology[21] has identified the presence of River Red Gum and River Oaks along sections of Saddlers Creek and the Hunter River, and these species are known to rely on groundwater from underlying aquifers. As previously stated by Cumberland Ecology[21]:

> *It is difficult to ascertain the degree of dependence of terrestrial ecosystems on groundwater. In the Hunter region where watercourses are typically ephemeral*

and historically have been degraded due to surrounding land use and water extraction, it is likely that communities characterised by Eucalyptus camaldulensis (River Red Gum) and Casuarina cunninghamiana (River Oak) trees have a moderate reliance, but not a complete dependence, on groundwater.

Eco Logical[22] also identified that the:

Alluvial aquifer of Saddlers Creek appears to be sparsely populated with stygofauna. All stygofauna collected from the aquifer are known from other locations.

The following impacts to groundwater and seepage flux may occur as a result of the Project:

- Groundwater drawdown will occur within Saddlers Creek resulting from cumulative impacts associated with the Project and the Mt Arthur Coal Mine operations. A 2 m drawdown is simulated to occur along the length of Saddlers Creek upstream from a position that is proximal to the current Edderton Road easement (approximately 6 km). The modelling results are considered to be conservative, thus predicting a worst case scenario for groundwater level drawdown and reduced seepage flux; and
- An upward flux of water from the Permian units into the Saddlers Creek alluvium may be reduced as a result of the Project and by cumulative impacts with nearby mining operations. However, the Saddlers Creek alluvial aquifer is expected to still receive groundwater recharge via rainfall, and as a result, it is anticipated that the groundwater quality may improve as a result of the rainfall dominated recharge.

The groundwater model predicts the migration of the zone of depressurisation southwards towards the Hunter River, but not measurably beneath these alluvial lands. Consequently very limited impacts are predicted to affect the alluvial lands associated with the Hunter River as a result of the Project.

Cumberland Ecology[21] has concluded that:

It is unlikely that the Project will have a significant impact on GDEs.

Eco Logical[22] has confirmed that:

A reduction in the seepage flux from the Permian aquifer, in conjunction with drawdown effects may degrade or diminish the local habitat required for known stygofauna in the Saddlers Creek alluvium… and as a result are expected to be impacted by the drawdown.
and

… there will be very limited, if any, impact to the Hunter River alluvium and associated stygofauna as a result of the Project.

9.8 Impact on Groundwater Chemistry

The Minimal Impact Considerations in the Aquifer Interference Policy for highly productive groundwater require that:

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

b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a “reliable water supply” is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b).

c) No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100 m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”.

d) Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200 m laterally from the top of high bank and 100 m vertically beneath a highly connected surface water source that is defined as a “reliable water supply”.

As the proposed mining activity will not occur near the Hunter River alluvium during mining, and post mining the void will remain a sink to groundwater in the very long-term, no impact on the beneficial use category of the Hunter River alluvium or the long-term average salinity of the Hunter River is considered likely.

No mining activity will occur within 200 m laterally from the top of high bank of the Hunter River, and no alluvial material will be excavated. The Project is therefore considered to comply with Minimal Impact Considerations in the Aquifer Interference Policy.

As discussed in Section 6.3.4, groundwater within the Permian coal measures is generally of poor quality and the environmental value has been assessed as being “primary industry”; with low yield and low quality generally limiting the usage. During mine operations:

- Groundwater sourced from the Permian coal measures will be continually extracted from the void to ensure a safe working environment within the mining area. Extraction of groundwater within the mining area will create a depression in the potentiometric surface at this location, and groundwater surrounding the mining activities will migrate towards this depression. The net movement of groundwater towards the mining area during mining activities will stop the movement of potentially poorer quality water (that may have been impacted by mining) from moving out of the study area and into the surrounding units; and
- Permian coal measures outside of the study area will continue to receive recharge via the same processes that occurred pre-mining.

As discussed in Section 6.1.4, discharge of saline coal measures groundwater can result in pockets of variably saline quality groundwater in the Hunter River alluvium and the Saddlers Creek alluvium. Based on the simulated impacts described above, the changes to alluvial groundwater quality may occur:

- The groundwater quality may improve in the Saddlers Creek alluvium as discharge of higher salinity groundwater into the alluvium is simulated to be reduced. This may result in a freshening of groundwater resulting from downward migration of rainfall recharge and creek recharge; and
- The groundwater quality is not expected to measurably change within the Hunter River alluvium as a result of Project. Coal measures groundwater is simulated to continue to discharge into the Hunter River alluvium at a similar rate to pre-mining conditions.

During mine operations, water quality within aquifers surrounding the study area will continue to be suitable for the same purposes applicable prior to the development of the Project. It is assumed that the construction of all water/spoil storage and holding facilities will be suitably engineered to include a low permeability base layer which will restrict seepage of mine water to groundwater aquifers.

There is potential for spills and contamination by metals and hydrocarbons from mine workshop, waste disposal and above ground fuel storage areas; however, adequate bunding and immediate clean-up of spills (which is standard practice and a legislative requirement at mine sites) should prevent contamination of shallow strata and subsequent leakage to the groundwater system.

To assess the potential for the overburden and reject material from the Project to contaminate groundwater, reference was made to the geochemical assessment report prepared by RGS

Environmental[37]. The assessment provided a geochemical characterisation of the overburden, interburden and potential coal reject material and concluded that:

- Overburden and most coal reject materials are expected to have very low oxidisable sulphur content, significant excess acid neutralising capacity, and be classified as non-acid forming;
- Overburden and most coal reject materials are likely to have a high factor of safety with respect to potential acid generation;
- The concentration of total metals in overburden materials is well below applied guideline criteria for soils and is unlikely to present any environmental issues associated with revegetation and rehabilitation;
- Overburden and coal reject materials reporting to emplacement areas will generate pH neutral to slightly alkaline run-off/seepage with low and moderate salinity values, respectively, following surface exposure. The salinity of run-off/seepage from these materials is expected to decrease with time;
- The concentration of trace metals in run-off and seepage from most overburden and coal reject material is likely to be low with some minor exceptions (molybdenum and selenium);
- Overall, the risk of potentially significant water quality impacts from overburden and coal reject materials is low; and
- Some overburden and most coal reject materials may be sodic and have structural stability problems related to potential dispersion and erosion.

9.9 Sensitivity Analysis

A sensitivity analysis was undertaken to assess the model responses to variations in uncertain input parameters. The parameters with the highest uncertainty and those most likely to affect the magnitude of the predictions are the un-calibrated storage parameters and the adopted recharge rates. The following perturbations were assessed in the sensitivity analysis:

- A ±50% change in the rainfall recharge rate across the model domain;
- A ±50% change in the specific yield for all model layers;
- A ±50% change in the specific storage for all model layers; and
- A ±50% change in the horizontal and vertical hydraulic conductivity values for all model layers.

Table 27 summarises the variation of key model outputs with changes in the listed model parameters.

[37] RGS Environmental Pty Ltd, (2011), "*Geochemical Impact Assessment of Overburden and Coal Reject Materials – Drayton South Coal Project*", Prepared for Hansen Bailey Pty Ltd

Table 27: SENSITIVITY ANALYSIS SUMMARY

Parameter	Units	Baseline	Kh & Kv -50%	Kh & Kv +50%	RCH -50%	RCH +50%	Sy -50%	Sy +50%	SS -50%	SS +50%
SSQ	m^2	14022.2	30364.3	17871.6	23544.7	19999.6	-	-	-	-
RMS	m	12.2	18.0	13.8	15.8	14.6	-	-	-	-
SRMS	%	7.0	10.3	7.9	9.0	8.3	-	-	-	-
Steady state RCH	ML/day	3.6	6.4	6.4	3.2	9.7	-	-	-	-
Net RIV outflow	ML/day	3.6	6.4	6.4	3.2	9.7	-	-	-	-
Avg daily inflow – mine	ML/day	2.4	2.2	2.6	1.7	3.1	2.5	2.5	2.0	2.8
Max daily inflow – mine	ML/day	4.6	4.2	4.9	3.2	5.9	4.7	4.7	3.9	5.3
Precent decrease of flow - Hunter River alluvium	%	4.2	6.0	3.4	8.9	3.8	4.5	4.5	7.8	3.0
Percent decrease of flow - Saddlers Creek alluvium	%	68.2	68.2	46.4	99.7	49.5	63.2	63.2	70.6	58.2

Note: Kh = horizontal hydraulic conductivity
Kv = vertical hydraulic conductivity
RCH = recharge, Sy = specific yield
SS = specific storage
FH = Constant head
RIV = River leakage
SSQ = Sum of Squares residuals – a measure of calibration performance
RMS = Root Mean Square residual – a measure of the difference between modelled and predicted values
SRMS = Scaled RMS - ratio of the RMS error to the total head change

As can be seen from Table 27, a very limited change in the steady state model outputs and in the key transient model outputs occurred during the sensitivity analysis. The largest change in the steady state model budget occurred when varying the recharge rate to the model by ±50%. Changes to the recharge volume must be distributed to the other boundary packages in the steady state model, hence the results.

The increase and decrease in the recharge rate was made to the baseline recharge rates across the model domain. If recharge is modified through the simulation process, that is, increased recharge is applied to areas converted to spoil, then the sensitivity run leaves these modifications unchanged.

The adopted recharge rate for the spoil was also investigated for its impact on the predicted groundwater inflow rates (Table 28). It was found that there was no significant change to the predicted mine inflow for both an increase and decrease in the recharge rate by 50%. However, the inflow to the mining areas was most sensitive to changes in overall recharge, specific yield, and hydraulic conductivity in decreasing order of influence as illustrated in Figure 48.

Table 28: SENSITIVY OF SPOIL RECHARGE RATE TO MINE INFLOW

Component	Baseline	Spoil RCH - 50%	Spoil RCH + 50%
Spoil Recharge Rate (mm/yr)	22	11	33
Peak Predicted Mine Inflow (ML/day)	4.60	4.60	4.62
Average Predicted Mine Inflow (ML/day)	2.40	2.39	2.41

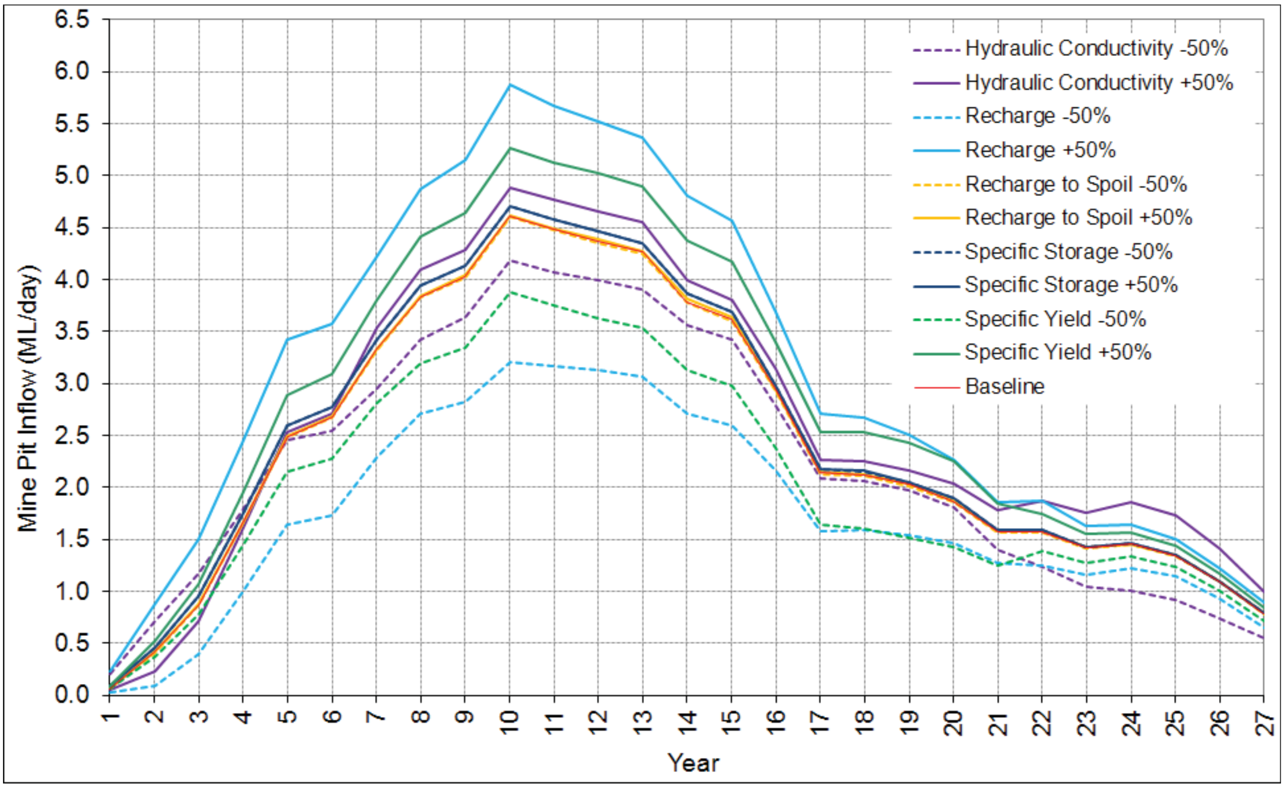

Figure 48: Sensitivity Analysis of Predicted Mine Groundwater Inflow

One key model prediction is the amount of water that becomes recharge to the alluvial aquifers from the Permian hard rock aquifers. The sensitivity of the predicted changes in this flow due to mining, are presented in Figure 49 for the Hunter River alluvium and Figure 50 for the Saddlers Creek alluvium.

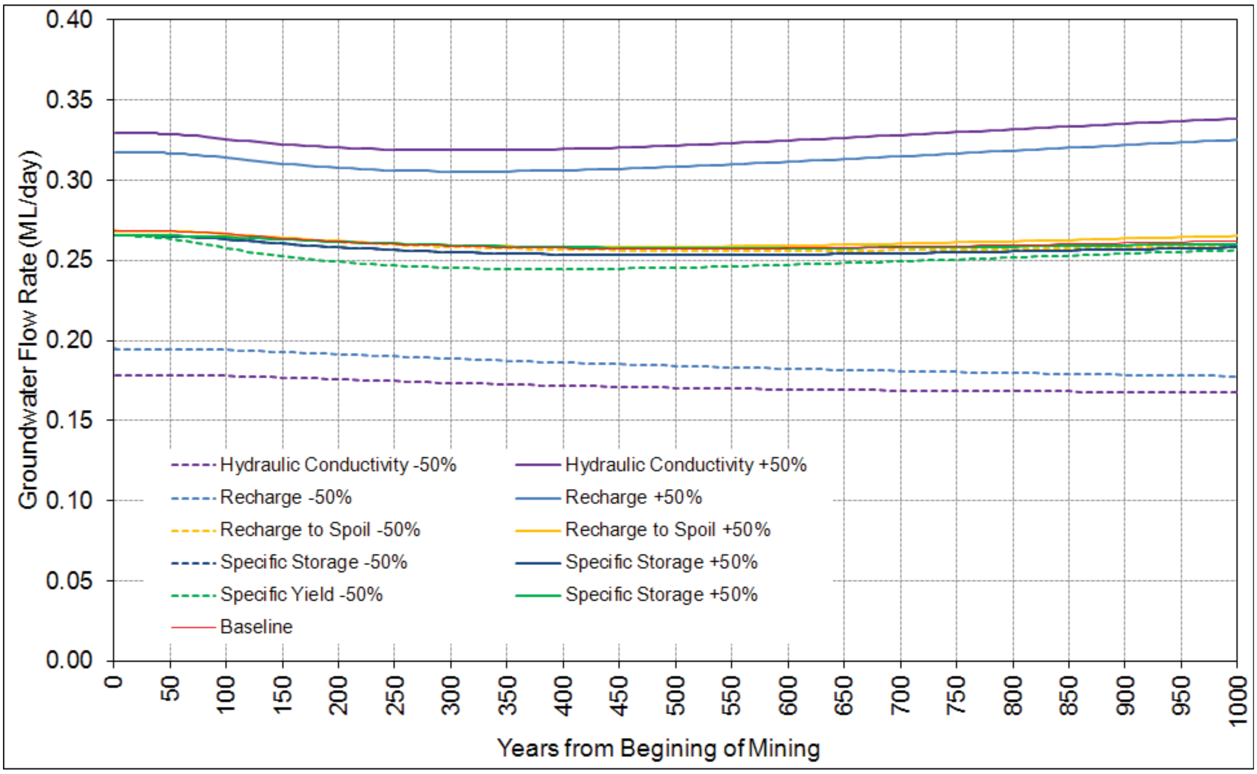

Figure 49: Simulated Flow to the Hunter River Alluvium

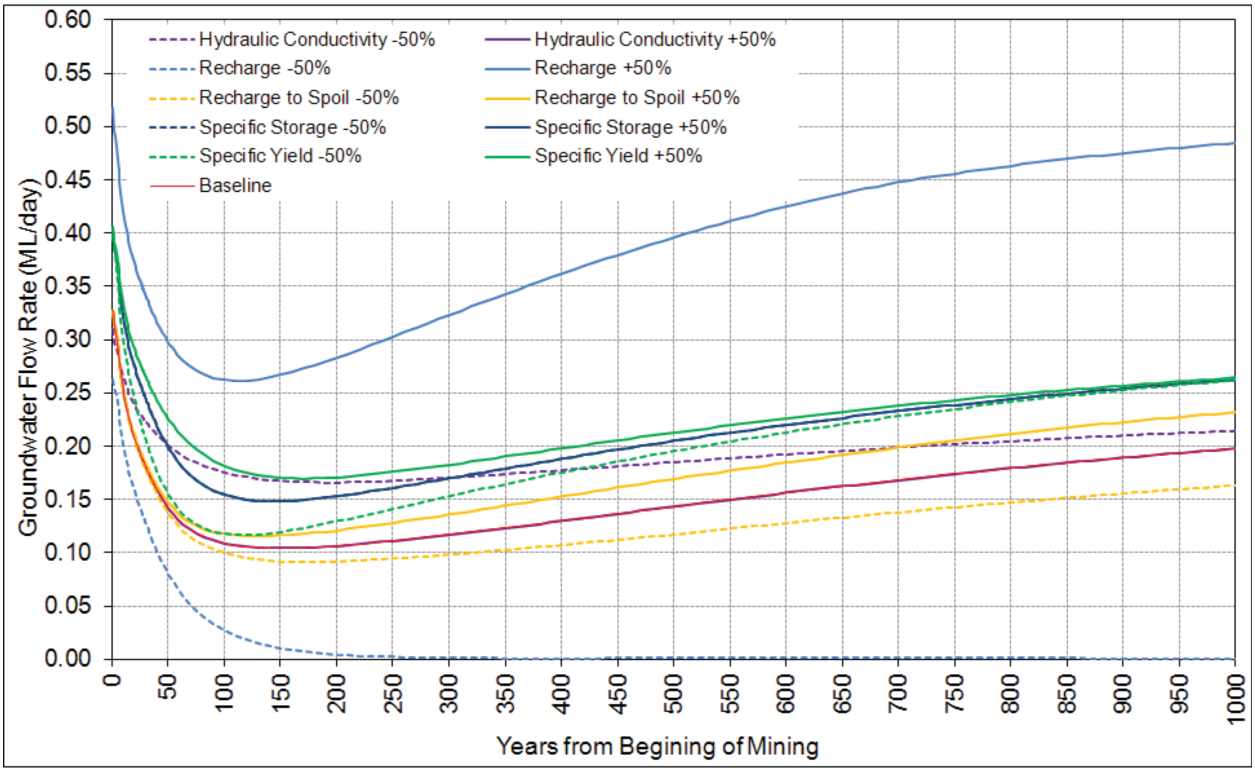

Figure 50: Simulated Flow to the Saddlers Creek Alluvium

The simulation of the interception of flow from the Permian to the alluvial aquifer is most sensitive to the parameters of hydraulic conductivity and recharge. The majority of the flow to the alluvium is through the weathered Permian regolith layer. Figure 49 and Figure 50 illustrate that even when other hydraulic parameters are used within the model a similar overall impact trend is observed, this being:

- The upward flux from the coal measures into the Saddlers Creek alluvium is likely to be significantly impacted; and
- The upward flux from the coal measures into the Hunter River alluvium is not expected to be measurably affected.

The changes made to the values of hydraulic conductivity, recharge, and specific storage resulted in minor changes to the extent of the groundwater drawdown impact zone as shown in Drawing No. 38, Drawing No. 39, and Drawing No. 40 respectively.

9.10 Model Uncertainty and Limitations

Development, calibration and the results of predictive simulations from any groundwater model are based on available data characterising the groundwater system under investigation. It is not possible to collect all the data characterising the whole aquifer system in detail and therefore various assumptions have to be made during development of the groundwater model. These assumptions and their impact on the simulation results are discussed in this report. Where an assumption was necessary, a conservative approach was taken, such as adopting model parameters from plausible ranges, so that the model would likely over predict impacts or be representative of the worst case scenario.

The model assumed variable hydraulic properties where they were considered appropriate. However, in reality, the permeability of the aquifers is likely to be variable and this variability can result in a less uniform zone of depressurisation than that predicted by the numerical model.

Individual coal seams will comprise a number of plys. The plys for each coal seam at the site were grouped into separate layers for the purposes of the groundwater modelling. The floor of each group was set to the level of the lowest ply in the seam group and the thickness based on the combined thickness of all the coal seam plys.

9.11 Model Conclusions

The results of the modelling in relation to the stated objectives (refer Section 8.1) is outlined below:

Objective 1 - estimate groundwater inflows to the open cut void over the Project life - during the 27 year mining period, the modelling indicates the cumulative seepage rate to the open cut voids will be on average 2.4 ML/day inflow. This will vary throughout the mining period with a predicted peak of 4.6 ML/day in Year 10.

Objective 2 - predict the zone of influence of dewatering and the level and rate of drawdown at specific locations - the modelling indicates the zone of depressurisation attributable to the Project will expand to the south, south-west and south-east of the open cut and highwall mining areas, but will be restricted by outcropping coal measures located towards the east and north, and the Saddlers Creek alluvium towards the north. The predicted drawdown attributable to the Project is shown in Drawing No. 21 to Drawing No. 36.

Objective 3 - predict the magnitude of any drainage from the alluvial aquifer into the underlying Permian strata - the modelling predicted that there would be a very limited reduction of the seepage flux from the Permian units into the Hunter River alluvium. The maximum reduction in flux to the Hunter River alluvium was predicted to be 0.01 ML/day. The modelling also predicted that the seepage flux to the Saddlers Creek alluvium would be reduced by a maximum rate of about 0.2 ML/day.

Objective 4 - predict the impact of mine dewatering on groundwater discharges to surface flows and other groundwater users - the impact of the Project on flows within Saddlers Creek is expected to be measurable as groundwater base flow to the creek is a significant contribution to the creeks water balance. The model results indicate a reduction of net flux into the Saddlers Creek alluvium will occur, and when combined with flux estimates from neighbouring mines, suggest that flux to the alluvial unit may be reversed. Only a small reduction of seepage flux to the Hunter River alluvium is likely and is not expected to measurably reduce flux to the Hunter River alluvium. Only two existing bores are anticipated to be encompassed within the zone of influence by the Project. These bores are located on land owned by Anglo American and are likely to be destroyed by mining. GDEs identified along the length of Saddlers Creek (east of Edderton Road) may be impacted by reduced availability to groundwater resulting from groundwater drawdown within the alluvial unit. However as reported by Cumberland Ecology these GDE's are not likely to be solely dependent on groundwater.

Objective 5 - identify areas of potential risk where groundwater impact mitigation/control measures may be necessary. – Anglo American does not intend to mine through any areas of alluvium. The existing network of monitoring bores and VWPs located near Saddlers Creek and the Hunter River will need to be monitored on a frequent basis to identify if actual impacts trend towards the modelled predictions. Monitoring of groundwater levels and quality in all key monitoring bores will need to be undertaken in accordance with the recommendations provided in Section 12.

10. DRAYTON MINE VOID TAILINGS AND REJECTS DISPOSAL

At the completion of coal mining operations within the presently operated Drayton Mine area, three voids will remain including the North, East and South Voids. It is proposed that rejects and tailings generated at the CHPP from the Drayton South operation will be deposited in two of these voids and the third will be used for water storage.

Rejects will be trucked from the CHPP whilst tailings will be pumped via a pipeline and deposited within an allocated void. Decant water recovered in this process will be recycled within the site water management system.

Contingent upon a commercial agreement with Macquarie Generation, there are three possible scenarios for rejects and tailings disposal for which approval is being sought. These scenarios are outlined below. For this report, scenario one has been assessed as the base case with scenarios two and three considered as part of a sensitivity analysis. . For each scenario, Drayton Mine will dispose of tailings in the East (South) Void as currently approved to a level of RL104 m, which is forecast to occur in 2017. This area will then be capped and rehabilitated by Drayton Mine at RL 106 m as per the Deed of Agreement with Macquarie Generation.

10.1 Scenario One

In Scenario One, occupation and utilisation of the East (South) Void will be transferred to Macquarie Generation following capping and rehabilitation by Drayton Mine in 2017 as per the current Deed Agreement between the two parties. The void, which is situated on land owned by Macquarie Generation, will then be used at their discretion, potentially for the deposition of power station ash. Macquarie Generation will be responsible for the rehabilitation of East (South void) under Scenario 1.

The North Void will be allocated as a co-disposal emplacement area for rejects and tailings generated from the processing of Drayton South coal. The North Void will be separated into two cells for emplacement of each coal waste stream then filled, graded to be free draining, capped and rehabilitated at RL 202 m. Some rejects will also be trucked to the southern side of the North Void and blended with the final landform to assist with infill of existing ramps and roads in this area.

The South Void will be utilised as a water storage area for the life of the Project. This void is situated on land owned by Macquarie Generation. Currently Drayton Mine has a legal agreement with Macquarie Generation to utilise the South Void until 1 January 2023. As such Anglo American will consult further with Macquarie Generation regarding the utilisation of the South Void, and enter into a commercial arrangement which satisfies the needs of both parties prior to 2023.

The utilisation of the voids at Drayton Mine under Scenario 1 is illustrated in Figure 51.

10.2 Scenario Two

This scenario assumes that Macquarie Generation is granted planning approval to raise their current ash dam wall to increase its storage capacity or make other arrangements and confirm that they will no longer require the East (South) Void for ash disposal.

As such the East Void will be utilised for tailings disposal during the life of the Project and capped and rehabilitated at RL 140 m.

Given that East (South) Void is located on land owned by Macquarie Generation, Anglo American will enter into a new commercial arrangement for the Project to occupy this void until closure of operations. Anglo American will be responsible for the rehabilitation of East (South void) under Scenario 2.

Under Scenario Two, the North Void will be utilised as a rejects emplacement area and capped and rehabilitated at RL 181 m.

The South Void will be utilised as a water storage area for the life of the Project. This void is situated on land owned by Macquarie Generation. Currently Drayton Mine has a legal agreement with Macquarie Generation to utilise the South Void until 1 January 2023. As such Anglo American will consult further with Macquarie Generation regarding the utilisation of the South Void, and enter into a commercial arrangement which satisfies the needs of both parties prior to 2023.

The utilisation of the voids at Drayton Mine under Scenario 2 is illustrated in Figure 52.

10.3 Scenario Three

This scenario assumes that Macquarie Generation decide to utilise both the East (South) and South Voids which are located on their land. As such water will be stored in the South Void until 1 January 2023 when the current commercial agreement with Macquarie Generation expires. Occupation and utilisation of the East (South) and South Voids would then be transferred back to Macquarie Generation. The voids, which are situated on land owned by Macquarie Generation, will then be used at their discretion, potentially for the deposition of power station ash or storage of water.

From 2023 water for the Drayton Complex will be stored in East (North) Void to RL 100 m and within the Drayton South area.

The North Void will be allocated as a co-disposal emplacement area for rejects and tailings generated from the Drayton South mining areas. The North Void will be separated into two cells for emplacement of each coal waste material and then filled, graded to be free draining, capped and rehabilitated at RL 202 m. Some rejects will also be trucked to the southern side of the North Void and blended with the final landform to assist with infill of existing ramps and roads in this area.

The utilisation of the voids at Drayton Mine under Scenario 3 is illustrated in Figure 53.

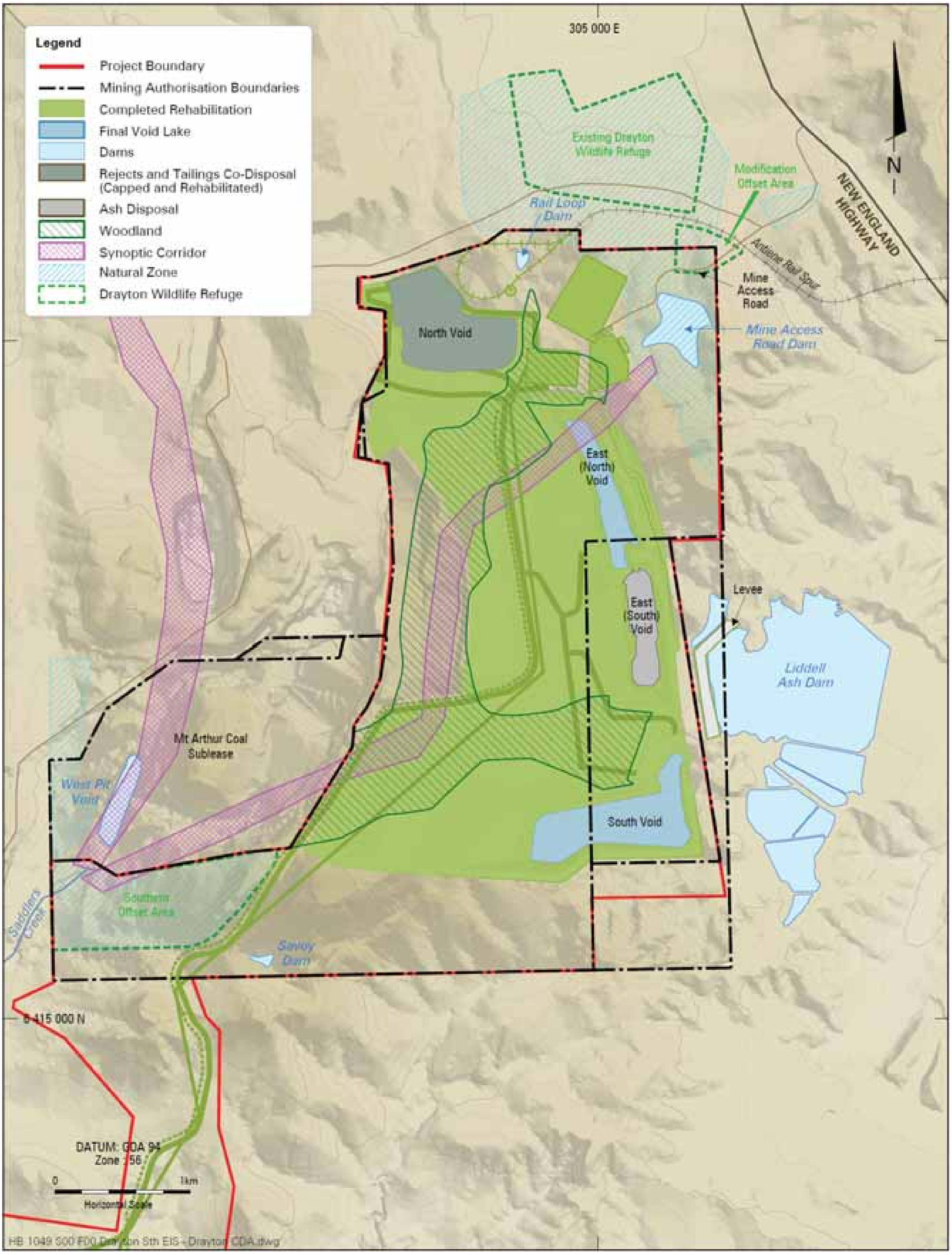

Figure 51: Drayton Mine Conceptual Final Landform (Mine Closure) – Scenario 1

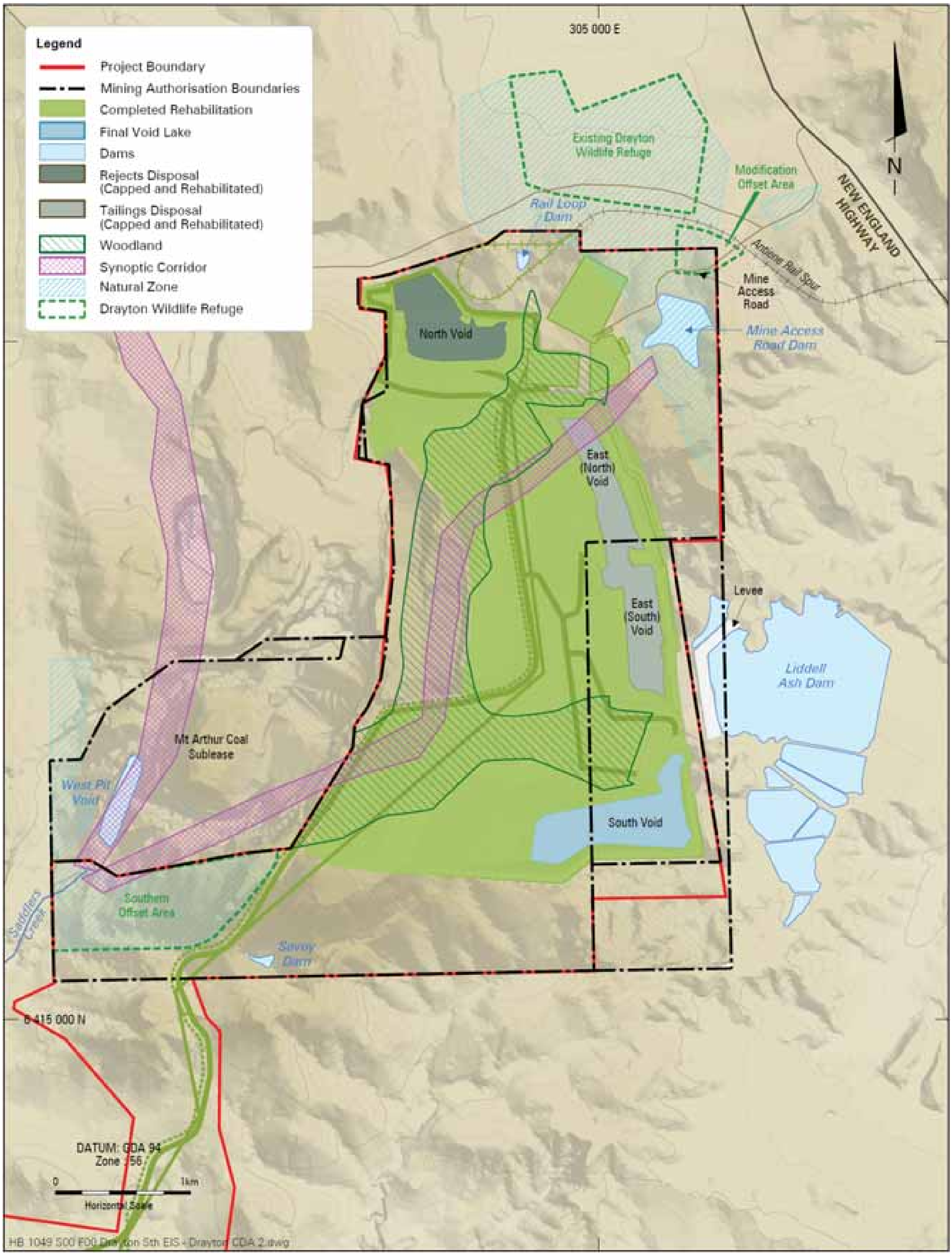

Figure 52: Drayton Mine Conceptual Final Landform (Mine Closure) – Scenario 2

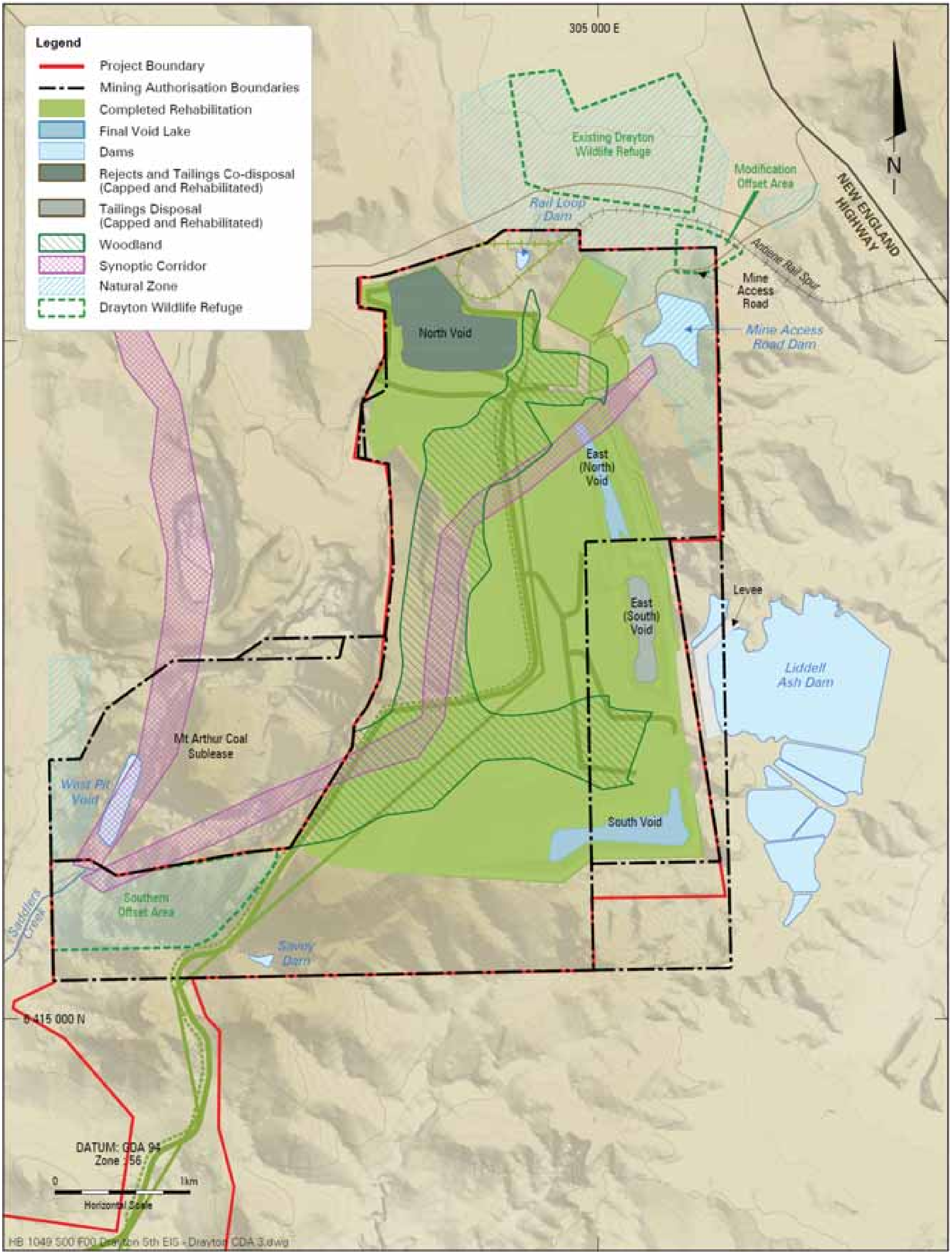

Figure 53: Drayton Mine Conceptual Final Landform (Mine Closure) – Scenario 3

10.4 Previous Groundwater Studies – Eastern Void

AGE (2006)[13] undertook a detailed groundwater impact study as part of an EA under which Project Approval 06-0202 for the current mining operations was granted. The hydrogeological study involved development of a three-dimensional, transient, groundwater flow model of the study area, and predictive simulations of the impact of the Project on the groundwater regime. With respect to the Eastern Void, two options were modelled:

- Option 1, which described the recovery of the water table under the assumption that all mining areas would remain as open voids and would develop final void lakes; and
- Option 2, which assessed the long-term impact of ash disposal from the Macquarie Generation Power Station to the Eastern Void.

Option 2 is of significance to the current Project, and therefore *Section 12.5.3, Ash Disposal and Final Voids* from the AGE (2006)[12] report is repeated below.

> ***Section 12.5.3 – Ash Disposal and Final Voids***
>
> *Option 2 analyses the impact of the disposal of ash from the Macquarie Generation Power Station in the Eastern final void of the Extension Project. Essentially the ash, produced as a by-product during the combustion of coal by the Power Stations, consists of fly ash, which is collected from the air during combustion. However, a minor proportion consists of bottom ash which is collected at the bottom of the combustion chamber. The ash is mixed with water forming a slurry that is proposed to be pumped to the Eastern Void for disposal via pipeline.*
>
> *Woodward Clyde (1997)[38] compared the hydraulic properties of fly ash to a silty sediment with a hydraulic conductivity of 1 x 10^{-7} m/s to 1 x 10^{-9} m/s and a total porosity of 23% to 27%.*
>
> *An investigation carried out for fly ash disposal from Bayswater Power Station in the Ravensworth Mine void, south east of Lake Liddell in 1993[39] rated the chemical properties of the ash as being similar to the mineral material of the coal seams, and the neighbouring hardrock.*
>
> *The Ravensworth Mine study indicated that the short-term quality of ash leachate is characterised by a pH of 10 to 12, salinity of around 5500 mg/L, concentration of specific minor elements in the milligram per litre range, and others in the sub milligram per litre range. Leachate tests on weathered ash resulted in a pH of 6 to 7, a salinity of 2000 mg/L and a concentration of fluoride in the milligram per litre range. Concentrations of minor elements were in the sub milligram per litre range.*
>
> *It is therefore concluded from a hydrochemical point of view, that the above data indicates that ash disposal may cause additional input of salt and of specific minor elements into the groundwater system. Furthermore the hydrochemical equilibrium in the surroundings of the ash disposal may be disturbed by the high alkalinity of the leachate. These conclusions are based on the assumption that the geological settings at Ravensworth Mine and the ash quality of Bayswater Power Station are similar to Drayton.*

---

[38] Woodward Clyde (May 1997), *"Investigation of Environmental Impact of Ash Disposal Facilities Stanwell Power Station."*

[39] Pacific Power (August 1993), *"Bayswater Power Station Fly Ash Disposal n Ravensworth No.2 Mine Void and Mine Rehabilitation."*

A numerical groundwater flow simulation was conducted to analyse the long-term movement of leachate from the ash disposal into the surrounding groundwater system, independently of its actual hydrochemistry. It is assumed that the Eastern Void will be completely filled with ash and that the top of the fill will be sealed to avoid any additional seepage of rainwater and leaching of the disposed ash. Any transport of leachate products will take place by groundwater flow through the ash filled voids. To simulate a worst-case scenario it is assumed that the Northern and Southern final voids are filled with inert material of low hydraulic conductivity. For this scenario the Northern and Southern Voids cannot act as sinks for groundwater flow and leachate from the Eastern Void.

Based on a long-term, steady state, post mining groundwater table, pathlines were simulated that track the movement of groundwater from the ash filled void to the nearest groundwater sink, as shown in Appendix A - Drawing No. 12, (Figure 54). *To estimate the travel time of the leachate it is assumed that the transport-effective porosity of the aquifer system is equal to the storativity assigned to the groundwater flow model. A porosity of 5% was assumed for the ash, which is higher than for typical silt sediment, since the ash has been disposed as a fully saturated slurry.*

*The simulation results indicate that discharge of leachate from the Eastern Void flows partially towards Liddell Ash Dam and discharges into small unnamed creeks running towards the dam. However, as the Liddell Ash Dam itself infiltrates water into the ground it cannot act as a groundwater sink. In fact the groundwater mound that has developed beneath Liddell Ash Dam diverts the leachate outflow towards Lake Liddell. It is estimated the ash leachate from the dam will take around 50 to 100 years to reach Lake Liddell. The simulated travel times assume that the cone of depression caused by the mining operation has already totally recovered. Thus the scenario described above starts at a time that may be more than 100 years after mine closure, as the results of the first final void scenario (*Figure 54*) suggest. As long as the cone of depression has not recovered around the mine and the water table within the Eastern final void remains below the surrounding groundwater level, no outflow of leachate is expected.*

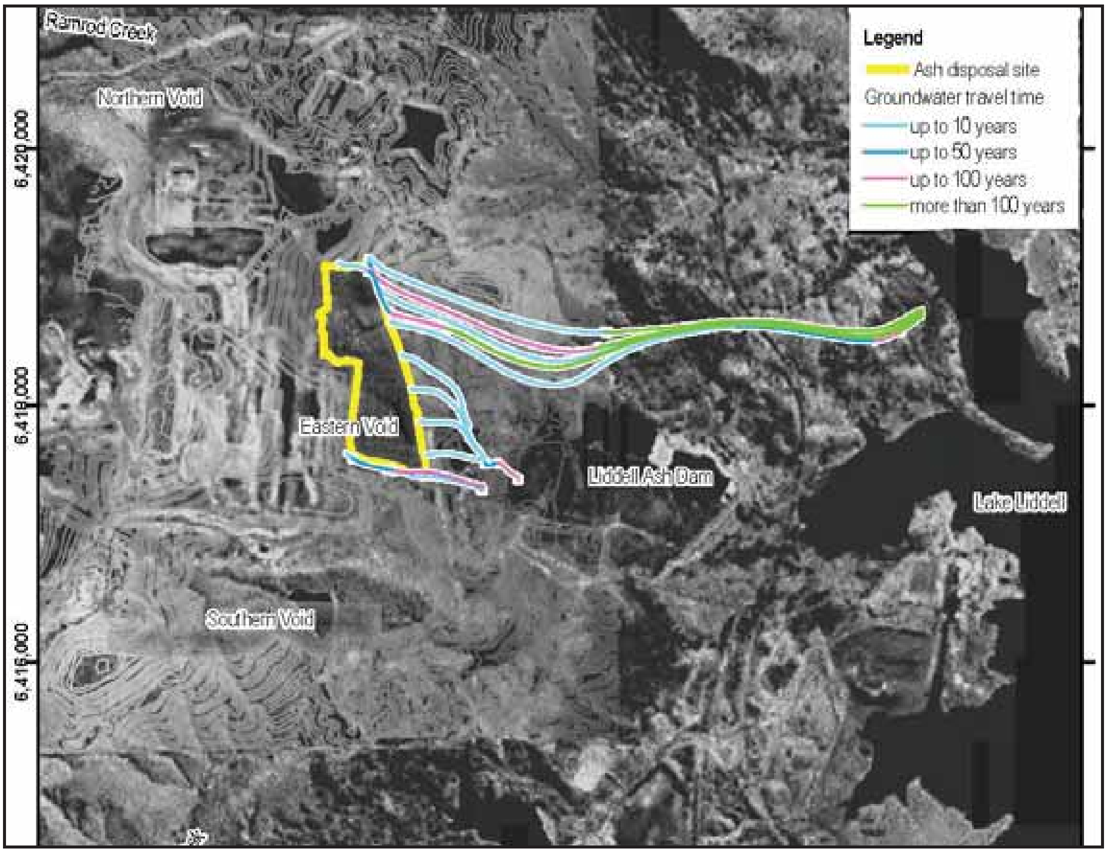

Figure 54: Ash Disposal in Eastern Void – Leachate/Groundwater Travel Times

Another assessment of disposal options was undertaken by AGE (2010)[40] as part the approvals process for a Modification to the existing Project Approval 06-0202, under Section 75W of the Environmental Planning and Assessment Act 1979. The modification was sought to allow for the disposal of wet tailings via a pipeline into the Eastern Void.

The disposal of wet tailings is of significance to the current Project, and therefore *Section 3.0, Impact of Proposed Wet Tailings Disposal* from the AGE (2010)[40] report is repeated below.

> ***3.0 Impact of Proposed Wet Tailings Disposal***
>
> *It is proposed that the wet tailings be disposed in the Eastern Void as discussed. Based on the above discussion of the predicted fly ash leachate travel directions and time, on which Project Approval for the current operations was granted, it is assessed that leachate generated from tailings disposal in the same void will have the same flow path and travel time if the voids were completely filled with tailings and ash.*
>
> *The prime difference in impact between the disposal of wet tailings and a fly ash slurry will therefore be associated with the quality of the leachate. Leachate from the tailings was analysed by ALS Laboratory Group on 11 November 2010 as summarized in Table 29 below.*

[40] Australasian Groundwater and Environmental Consultants Pty Ltd, (Nov. 2010), *"Drayton Mine – Tailings Disposal Modification EA Groundwater Impact",* Letter report, Project No. G1535.

Table 29: ***LEACHATE TAILINGS ANALYSIS***					
Compound	***LOR***	***Unit***	***Tailings Thickener***	***Tailings Pipe***	***Tailings – End of Pipe***
pH Value	*0.01*	*pH*	*7.62*	*7.64*	*7.68*
Electrical Conductivity @ 25º	*1*	*µS/cm*	*4630*	*5220*	*3700*
Total Dissolved Solids @ 180ºC	*1*	*mg/L*	*4500*	*4680*	*4400*
Arsenic	*0.001*	*mg/L*	*0.089*	*0.074*	*0.032*
Barium	*0.001*	*mg/L*	*5.17*	*5.20*	*0.088*
Beryllium	*0.001*	*mg/L*	*0.020*	*0.017*	*0.110*
Cadmium	*0.0001*	*mg/L*	*0.0053*	*0.0044*	*0.0283*
Cobalt	*0.001*	*mg/L*	*0.560*	*0.455*	*3.20*
Chromium	*0.001*	*mg/L*	*0.533*	*0.444*	*0.578*
Copper	*0.001*	*mg/L*	*1.22*	*1.00*	*1.89*
Manganese	*0.001*	*mg/L*	*6.22*	*5.26*	*26.5*
Nickel	*0.001*	*mg/L*	*1.31*	*1.08*	*7.90*
Lead	*0.001*	*mg/L*	*0.362*	*0.312*	*<0.010*
Selenium	*0.01*	*mg/L*	*0.11*	*0.10*	*<0.10*
Vanadium	*0.01*	*mg/L*	*0.86*	*0.69*	*0.91*
Zinc	*0.005*	*mg/L*	*1.96*	*1.56*	*10.5*
Mercury	*0.0001*	*mg/L*	*<0.0001*	*<0.0001*	*<0.0001*

> *The analyses indicate a pH of between 7.62 and 7.68 which is slightly alkaline compared to a highly alkaline pH of fresh fly ash of 10 - 12 and a slightly acid to neutral pH of weathered fly ash of 6-7.*
>
> *The salinity or Total Dissolved Salts (TDS) of the tailings leachate varies between 4400 – 4680 mg/L which is less than the salinity of the fresh fly ash leachate of around 5500 mg/L but higher than leachate generated from weathered fly ash of 2000 mg/L. With the exception of Copper (1.0 – 1.89 mg/L), Nickel (1.08 -7.90 mg/L), Zinc (1.56 -10.5 mg/L) and Manganese (5.26 – 26.5 mg/L), metals in the tailings leachate are in the sub milligram per litre range similar to the fly ash leachate.*

In conclusion, the AGE (2010)[40] assessment found that:

> *… leachate generated by the wet tailings will have a similar flow path and travel time… and …that the leachate from wet tailings is of overall better quality than the fly ash leachate… and … therefore it is concluded that disposal of tailings in the Eastern Void will not create an impact that is worse than that of the currently approved fly ash disposal in the void.*

10.5 Rejects Geochemical Composition and Seepage Quality

The composition of the overburden and reject material and the potential quality of seepage water was recently assessed by RGS[5].

Thirty overburden samples and six potential coal reject (coal seam roof and floor) samples were obtained from five drill holes selected to provide lateral and vertical coverage of the overburden and potential coal reject materials likely to be generated by the Project. In addition, a further two composite samples of roof and floor materials and coal reject materials were obtained.

All of the 38 samples were subjected to initial Acid Base Account (ABA) geochemical testing as part of an initial screening process and a total of five KLC tests were completed on various overburden and coal reject materials.

The ABA geochemical testing of the coal rejects undertaken by RGS[5] found that

> *The results of the ABA tests indicate that the overwhelming majority of the coal reject material tested is non-acid forming (NAF) and has a high factor of safety with respect to potential acid generation. In particular, the composite coal reject samples, which provide the most representative samples of coal reject material, have very low total oxidisable sulfur content (< 0.1 %). The composite samples also have significant acid buffering capacity (moderate to high ANC value), which is more than enough to buffer the negligible amount of acidity that could theoretically be generated from these materials. Overall, from an acid-base perspective, the coal reject material tested can also be regarded as a NAF unit containing excess neutralising capacity… Overall it is expected that the overburden and coal reject materials generated at Drayton South will have a very low risk of generating Acid and Metalliferous Drainage (AMD).*

The static and KCL testing of the coal rejects undertaken by RGS[5] found that:

> *Initial and ongoing surface run-off / seepage from overburden and coal reject materials is likely to be pH neutral to slightly alkaline. The dominant major soluble cation is sodium and the dominant major soluble anions are typically bicarbonate, chloride and sulfate. The concentration of all of these ions in run-off and seepage is expected to decrease over time. In addition, the salinity of surface run-off and seepage from overburden is expected to be low and from coal reject is expected to be elevated, although the salinity of surface run-off and seepage from both materials is likely to decrease with time. The concentration of soluble sulfate in surface run-off and seepage is expected to be low for overburden and remain well within the applied (ANZECC, 2000)[20] water quality guideline concentration for this anion. For coal reject, the sulfate concentration in surface runoff and seepage is expected to be higher, but still remain within the guideline value. Hence, the risk of potential impact on the quality of surface and groundwater from the Project should be low for overburden and coal reject materials, although this finding should be confirmed by the ongoing water quality monitoring program for surface water and groundwater at the site.*
>
> *Most trace metals in overburden and coal reject are sparingly soluble at the predicted neutral to slightly alkaline pH of surface run-off / seepage and dissolved concentrations are expected to be low compared to the applied water quality guideline criteria (ANZECC, 2000; and NEPC, 1999[41]) livestock drinking water guidelines. Minor exceptions include soluble molybdenum and selenium concentrations, which could be slightly elevated in initial surface runoff and seepage from overburden and coal reject materials. It is therefore recommended that these elements are included in the water quality monitoring program for overburden and coal reject emplacement areas. A review of available groundwater and surface water data at Saddlers Creek indicates that the water extract results described above are reasonably consistent with background water quality data.*

10.6 Assessment of Tailings Disposal

Based on the above description of the aquifer systems and environmental value, the prime risk (albeit low) to the groundwater regime is potential seepage of water from the emplacement areas into the surrounding Permian coal measures. The Permian coal measures (including the coal

[41] National Environment Protection Council (NEPC), (1999), "*National Environmental Protection (Assessment of Site Contamination) Measure (NEPM). Guideline on investigation levels for soil and groundwater. Groundwater Investigations Levels (Agricultural: Livestock)*".

seams) are relatively deep, are poor aquifers with low yields, contain brackish to saline groundwater, and therefore do not have a high environmental value.

Notwithstanding this however, groundwater monitoring surrounding the emplacement areas should be undertaken to confirm the results obtained by the geochemistry assessment.

Considerations for emplacement of tailings and rejects into the Drayton Mine voids are provided below.

10.6.1. East Void

Previous assessments indicated that as long as the cone of depression does not recover around the void to pre-mining levels, and the water table within the void remains below the surrounding groundwater level, it is expected that no outflow of leachate from the void will occur[12]. Therefore, considering the pre-mining groundwater level surrounding the East Void was at an elevation of about RL 180 m and the elevation of the tailings is proposed to be RL 106 m for Scenarios 1 and 3 and RL 140 m (Scenario 2), it is expected that a cone of depression will be retained around the East Void. As long as this cone of depression is maintained, it is unlikely that leachate will migrate from the void.

10.6.2. North Void

Previous assessments of groundwater levels surrounding the North Void indicate a pre-mining groundwater level of about RL 180 m[12]. The previous modelling of the North Void water level recovery (assuming that the void was not filled with tailings/rejects) showed that a final steady state water level would be at an elevation of about RL 160 m[12]. It was therefore concluded that the open void would act as a groundwater sink and no contamination of the surrounding aquifer expected.

However, the current disposal designs suggest the void will be filled with rejects and tailings and capped at RL 202 m for Scenarios 1 and 3 and filled and capped with rejects only at RL 181 m for Scenario 2. It is therefore, assessed that the disposal designs do not provide conditions which will promote the development of a long-term cone of depression around the North Void.

If a cone of depression is not maintained surrounding the North Void, the hydraulic gradients within this area may promote the movement of leachate away from the void to the north-west, towards the catchment of Ramrod Creek.

Groundwater quality and groundwater levels must therefore be monitored near the tailings and reject emplacement areas located at the Drayton Mine to confirm if seepage is migrating away from the emplacement areas. Further discussion regarding monitoring and mitigation options is provided in Section 12.6.

11. WATER ALLOCATIONS AND LICENCING

Due to the staged roll out of water sharing plans across NSW, it is possible for the Water Act to apply in a groundwater source and the WM Act to apply in a connected surface water source. Where this occurs and the aquifer interference activity (i.e. mining) is effectively taking water from both water sources then an appropriate licence will be required under each Act.

In water sources where water sharing plans do not yet apply (i.e. the Permian coal measures), a water licence is required under the Water Act to account for the groundwater seepage to the open mining areas and the highwall mined areas. The numerical modelling predicts that inflow over the mine life will rise from 0 ML/day to a maximum of 4.6 ML/day (1642 ML/year) in Year 10. However, not all of the groundwater seepage that reports to the mining area will be derived from the Permian coal measures. It is anticipated an average of 477 ML/year will be derived from the Permian aquifers, and the remainder will come from rainfall recharge seepage through the backfilled spoil. Where an aquifer interference activity is taking groundwater, a water licence is required under Part 5 of this Act.

Licensing relating to groundwater seepage from the alluvial aquifers will be required by the *Water Management Act 2000.* The Jerrys Water Source, to which the Project applies, is a component of Hunter Unregulated and Alluvial Water Sources and is limited by an entitlement of 2,573 units (ML/year). The groundwater model predicts an average annual loss of 2 ML/year from the Hunter River alluvium (post mining) and 58 ML/year from the Saddlers Creek alluvium (including post mining) over the life of the Project. Under the Water Sharing Plan, it will be necessary to purchase an allocation of 60 ML/year, or seek this from an existing groundwater allocation to account for the water loss. The predicted average annual impact on the total share component for the Jerrys Water Source under the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources is negligible.

As the Project is predicted to take water from the Hunter River alluvium and this take of water is predicted to cause movement of water from a connected regulated river water source, the Hunter River, a water access licence is required under the Water Sharing Plan for the Hunter Regulated River Water Source, and with the requirements of the Aquifer Interference Policy. Conservatively, an annual average of 2 ML/year will be taken from the Hunter Regulated River Water Source as a result of the Project.

Anglo American currently hold two general security water access licences under the Water Sharing Plan for the Hunter Regulated River Water Source (WAL 491 and 1066), which provide an allocated share of 99 units each (198 units combined) for irrigation purposes. These water access licences may be transferred from use for the purpose of irrigation to use for the purpose of mining. The total share component for the regulated river (general security) access licences in Management Zone 1 is 75,035 units. The predicted average annual impact on the total share component for the regulated river (general security) access licences in Management Zone 1 under the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources is negligible.

Table 30 shows the estimated average volume of groundwater take and the predicted average impact on the relevant water source for the life of the Project.

Table 30: GROUNDWATER ALLOCATIONS						
Legislative Act	**Water Sharing Plan**	**Water Source**	**Predicted Average Annual Take (ML/year)**	**Predicted Average Annual Impact on Water Source (%)**	**Current Licences**	**Licences / Allocations Required**
Water Act 1912	N/A	Permian Coal Measures	477	N/A	Nil	477 ML/year
Water Management Act 2000	Hunter Unregulated and Alluvial Water Sources	Jerrys Water Source (Hunter River Alluvium)	2	0.08	Nil	2 ML/year
		Jerrys Water Source (Saddlers Creek Alluvium)	58	2.25	Nil	58 ML/year
	Hunter Regulated River Water Source	Management Zone 1	2	0.003	WAL 491 WAL1066	2 ML/year

12. MANAGEMENT, MITIGATION AND MONITORING

The ongoing management of groundwater levels and groundwater quality surrounding the Project should be undertaken with the aim of limiting potential harm to the environment. Groundwater levels and groundwater quality should therefore be monitored so that any deviation from the predictions made within this report can be identified and mitigated in a timely manner.

12.1 Monitoring Bore Network

The Drayton Mine currently undertakes a groundwater monitoring program in accordance with their approval. This monitoring program will be continued and expanded with addition of the Drayton South groundwater monitoring program. Therefore, a common groundwater monitoring program will be undertaken for the entire Drayton Complex.

The groundwater monitoring network for Drayton South consists of 15 bores installed in the 1990s and early 2000s in the Permian formations, augmented by four new monitoring bore sites installed in 2011 along the alignments of Saddlers Creek and the Hunter River. The network also incorporates seven VWPs, most of which are located between the study area and the Hunter River.

The majority of the Permian monitoring bores are located within the footprint of the proposed mining areas and will therefore be removed by mining. The newly installed alluvial monitoring bores will remain and serve to augment the existing network and allow the alluvial aquifer to be monitored as the mining advances in this direction.

The design of the existing monitoring network is deemed suitable for long term monitoring of depressurisation of the coal measures strata and determine the zone of influence created by the mining area, and the potential for it to interact with the Hunter River alluvium and the Saddlers Creek alluvium. The existing monitoring network is shown on Drawing No. 5. Drawing No. 36 and Drawing No. 37 also show the existing monitoring network in relation to drawdown impacts at Year 1000.

12.2 Water Level Monitoring Frequency

The Annual Environmental Management Report for the Drayton Mine indicates that 14 monitoring bores are currently being monitored for water levels on a monthly basis[42].

Groundwater levels within the Drayton South monitoring bores will also be manually measured on a monthly basis. Manual monitoring at monthly intervals is suitable for identification of long-term trends in groundwater levels.

Pore pressures within the coal seams and interburden are automatically measured via VWPs on a six-hourly basis. Automatic monitoring at six-hourly intervals is suitable for identification of both short and long-term trends in groundwater levels, and is particularly suited to capture a response (if any) to rainfall events.

The current monitoring frequency will continue into the future.

[42] Anglo Coal (Drayton Management) Pty Ltd, (2010), "*Annual Environmental Management Report 2010*".

12.3 Water Level Triggers

Trigger levels should be determined for the bores monitoring the Hunter River and Saddlers Creek alluvial aquifers (MB1, MB2, MB3, MB4). The trigger levels should be set after a baseline data set of two years of water level data has been collected. The baseline monitoring period will allow the natural fluctuations in alluvial water levels due to variability in rainfall recharge and surface water flow to be assessed, and a method for separating mining induced water level fluctuations developed. Trigger levels for the monitoring bores installed in the Permian aquifer are not considered appropriate as the Permian units within and immediately surrounding the proposed mining area will be depressurised.

12.4 Water Quality Monitoring Plan

It is recommended that water samples are collected from the Drayton Complex monitoring bores outlined in Section 4 and Section 0, and analysed for pH and EC in the field on a six monthly basis. Samples should also be collected six monthly from these bores and analysed in the laboratory for pH, EC, TDS, major ions (Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4) and trace elements (As, B, Br, F, Fe (soluble), Li, Mn, Mo, P, Se, Si, Sr, Zn). This analysis may assist in identifying future mixing, if any, of groundwaters from the alluvial and Permian aquifers. The monitoring should continue on a six monthly basis until mine closure in Year 27 and then for a period of five years post closure.

Trigger levels for water quality should be developed only for the monitoring bores installed in the Hunter River and Saddlers Creek alluvial aquifers (MB1, MB2, MB3, MB4). A unique trigger for each bore will be required due to the variability in the groundwater quality in the alluvial aquifers. Trigger levels should be developed after a minimum of two years of baseline data has been collected.

12.5 Mine Water Seepage Monitoring

The seepage monitoring program for the Drayton Complex should include:

- Regular geological and geotechnical mapping of fractures in the highwall and endwall;
- Recording of the time, location and volume of any unexpected increases in groundwater outflow from the highwall and endwall;
- Recording of the location and cause of any highwall/endwall stability issues;
- Measurement of water pumped from the mining areas using flow meters or other suitable gauging apparatus; and
- Monitoring of coal moisture content.

12.6 Tailings and Rejects Emplacement Management

There are no guidelines and regulatory criteria specifically related to seepage from coal tailing and reject materials since guidelines (and regulatory criteria) will depend upon the end-use and receiving environment of the seepage. Therefore, to provide relevant context, the soluble concentration of each element extracted from all mineral waste materials should been compared to NEPC (1999)[43] investigation levels for groundwater and ANZECC (2000)[20] livestock drinking water guidelines. These guidelines allow for higher concentrations of individual parameters

[43] NEPC (1999) [National Environment Protection Council]. *National Environmental Protection (Assessment of Site Contamination) Measure. Guideline on investigation levels for soil and groundwater*. Groundwater Investigations Levels.

(appropriate for an industrial facility in a rural area) and are less prescriptive and more appropriate (in the context of the Project) than guidelines designed for water to be used for human consumption or being directly discharged into an aquatic environment (e.g. stream, river, lake, etc).

Groundwater quality and groundwater levels must therefore be monitored near the tailings and reject emplacement areas located at the Drayton Mine. The geochemistry assessment indicates that reject material has sufficient buffering capacity, and does not present a significant risk to the environment with respect to total metal concentrations. Therefore, management of the emplacement area should include a monitoring program to ensure that key water quality parameters remain within appropriate criteria.

The monitoring program should include the installation of monitoring bores in strategic locations which are capable of detecting the movement of seepage water away from the emplacement areas. Water levels should be recorded on a quarterly basis and groundwater samples should be collected and analysed on a six monthly basis. The groundwater samples should be analysed for the same suite as listed above, which will enable direct comparison with groundwater samples collected from areas located away from the emplacement areas.

In the event that seepage water exceeds water quality criteria or is found to be moving significantly into the Ramrod Creek catchment, the installation of a pump and treatment system is recommended. This will involve the strategic placement of low flow bores into the strata to intercept and capture the seepage water plume. Seepage water would then be pumped to and treated at an allocated facility.

The design strategy of the tailings and rejects emplacement will be coordinated by qualified engineers and will be undertaken to relevant statutory guidelines and requirements. In general, the emplaced material should be graded such that it has the capacity to drain freely, limiting the amount of ponded water, reducing the opportunity for water infiltration into the emplaced material. In addition, engineered control strategies should be investigated with the aim of reducing surface water drainage to the emplacement areas.

A closure strategy for the emplacement areas should also consider options for a cover (i.e. capping) system. A 'cover system' is the general term for materials installed over mineral wastes to limit the exposure of the mineral wastes, in this case tailings or coarse rejects, to atmospheric conditions. 'Store and release' cover systems are best suited to environments such as the Drayton Mine, where pan evaporation exceeds rainfall for most of the year. A 'store and release' cover system is recommended, as this is best suited to cater for extreme rainfall and/or drought events without compromising the integrity of the cover system.

The main design objectives of the 'store and release' cover system would be to:

- Sustain a long-term revegetated cover that will stabilise the surface of the tailings and coarse rejects;
- Retain/store rainfall from most precipitation events within the cover;
- Shed excess rainfall from extreme rainfall events;
- Control the flow of excess surface water across the cover such that significant erosion does not occur; and
- Reduce long-term infiltration of moisture and (potentially) ingress of oxygen into the tailings and coarse rejects beneath the cover.

A mitigation strategy of interception/pump-back bores should be considered if the groundwater monitoring program surrounding the emplacement areas identifies excessive seepage with water quality parameters above guideline levels.

12.7 Data Management

The data collected from the groundwater monitoring program should be stored in a suitable database, with Quality Assurance protocols to enable data to be assessed when uploading. The database should store the data in a format that is suitable for electronic transfer to NOW on an annual basis. NOW should be consulted to determine the most desirable format for the data.

12.8 Data Reporting

It is recommended that data management and reporting include:

- Annual assessment of departures from identified monitoring data trends. If consecutive, six monthly monitoring campaigns exhibit departure from the established or predicted trend, then such departures should initiate a detailed review. This may include a need to conduct more intensive monitoring or to seek professional advice to compare against model predictions and/or instigate mitigative measures;
- Formal review of depressurisation of coal measures and alluvial aquifers should be undertaken annually by a suitably qualified hydrogeologist. The validity of the model predictions should be reassessed every five years, and if the data indicate significant divergence from the model predictions, an updated or new groundwater model should be developed for simulation of mining. If future modelling predictions indicate losses from the alluvial water sources could exceed previous predictions, mitigation measures including purchase and retirement of existing water licences should be evaluated; and
- Annual reporting (including all water level and water quality data) as part of the Annual Review.

12.9 Contingencies and Remedial Measures

Mitigative measures for any identified negative impacts beyond those predicted, may include replacement in water supply or relinquishment of groundwater or surface water allocations as an offset to monitored leakage from the alluvial aquifers in excess of predictions.

Impacts to groundwater supplies on neighbouring properties are not anticipated. However, should impacts occur that are attributable to the Project, Anglo American must reach a mutually agreeable arrangement with the landholder for the provision of alternative water supplies. Options for alternate water supplies may include:

- Installation of new pumps capable of extracting groundwater from greater depth within the existing bore(s);
- Deepening of existing bores;
- Installation of a new bore at another location on the property; and
- Provision of piped water sourced from the mine.

Regular review of the groundwater model is important to ensure that the model can continue to reliably predict ongoing impacts on the regional groundwater system, given that such predictions are used to determine the extent and timing of mitigation issues.

AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD

Reviewed by:

TIMOTHY J ARMSTRONG
Senior Hydrogeologist

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Principal Hydrogeologist / Director

ANDREW M DURICK
Principal Groundwater Modeller / Director

13. GLOSSARY

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

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.

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.

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.

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

LIMITATIONS OF REPORT

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) has prepared this report for the use of Anglo American Metallurgical Coal Pty Ltd in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated the 19 January 2011 and Variation dated 27 November 2011.

The methodology adopted and sources of information used by AGE are outlined in this report. AGE has made no independent verification of this information beyond the agreed scope of works and AGE assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to AGE was false.

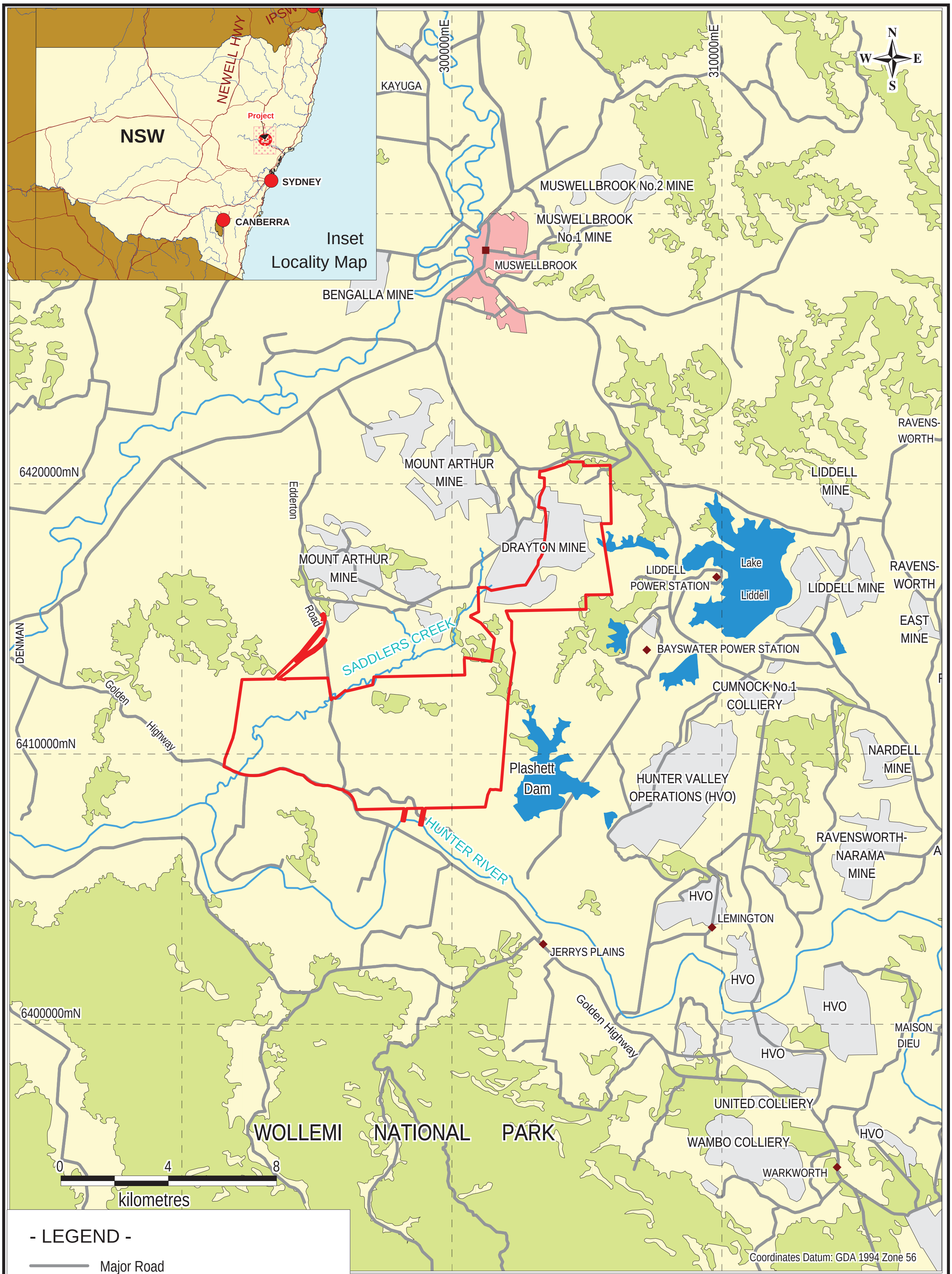
This study was undertaken between 24 January 2011 and 30 October 2012 and is based on the conditions encountered and the information available at the time of preparation of the report. AGE disclaims responsibility for any changes that may occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. It may not contain sufficient information for the purposes of other parties or other users. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing and other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. Where borehole logs are provided they indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of the site, as constrained by the project budget limitations. The behaviour of groundwater is complex. Our conclusions are based upon the analytical data presented in this report and our experience.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, AGE must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

Whilst to the best of our knowledge, information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.



- LEGEND -

- Major Road
- Project Boundary
- Existing Mine
- Built-up Area
- Major River
- Creek
- Dam / Reservoir

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT REGIONAL LOCALITY			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 200,000 (A4)	PROJECT No: G1544	DRAWING No: 1
APPROVED BY:	DATE: April 2012		

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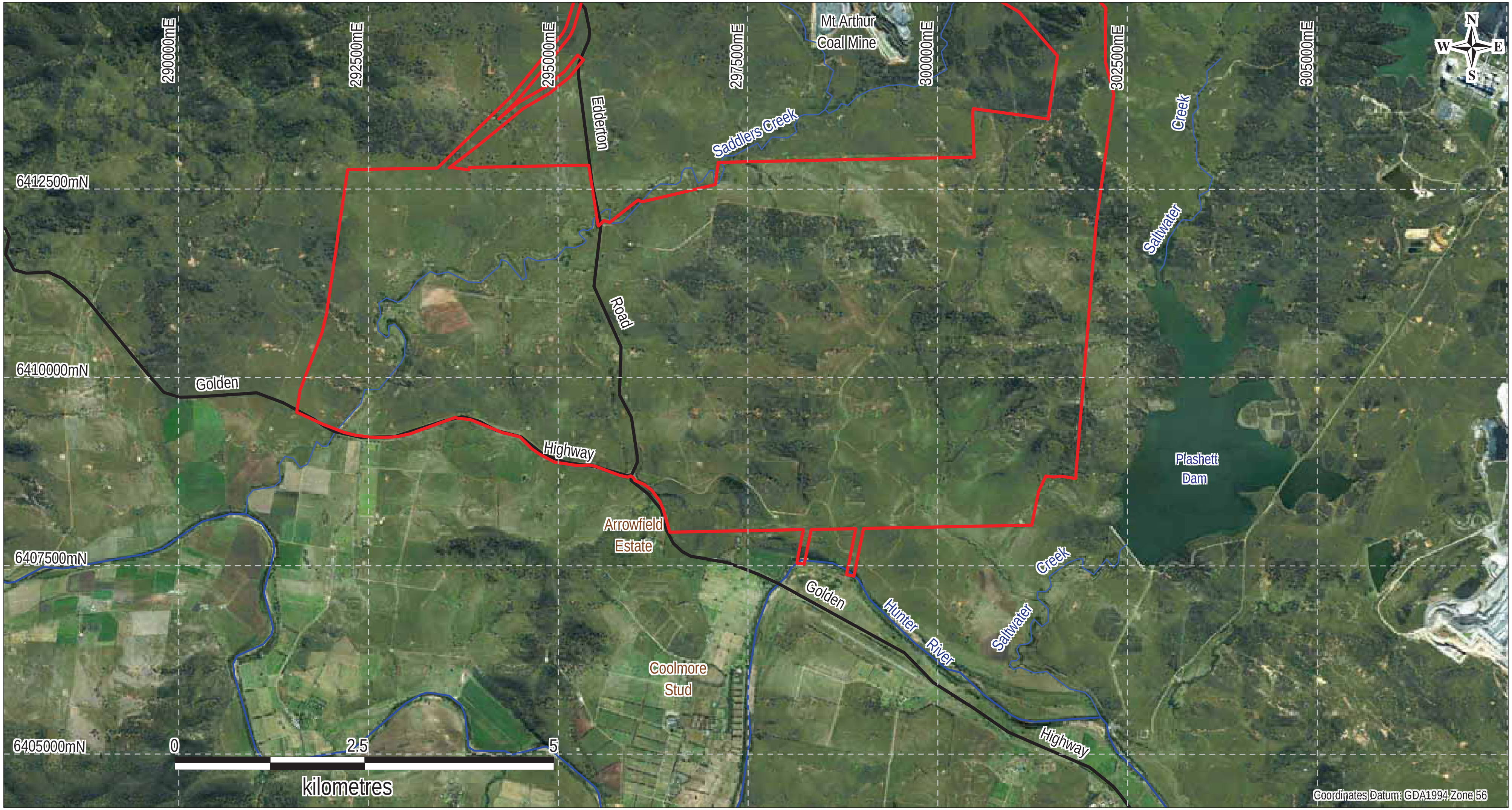

- LEGEND -

Project Boundary	Major River
Major Road	Creek

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT TENEMENT BOUNDARIES			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 2
APPROVED BY:		DATE: April 2012	

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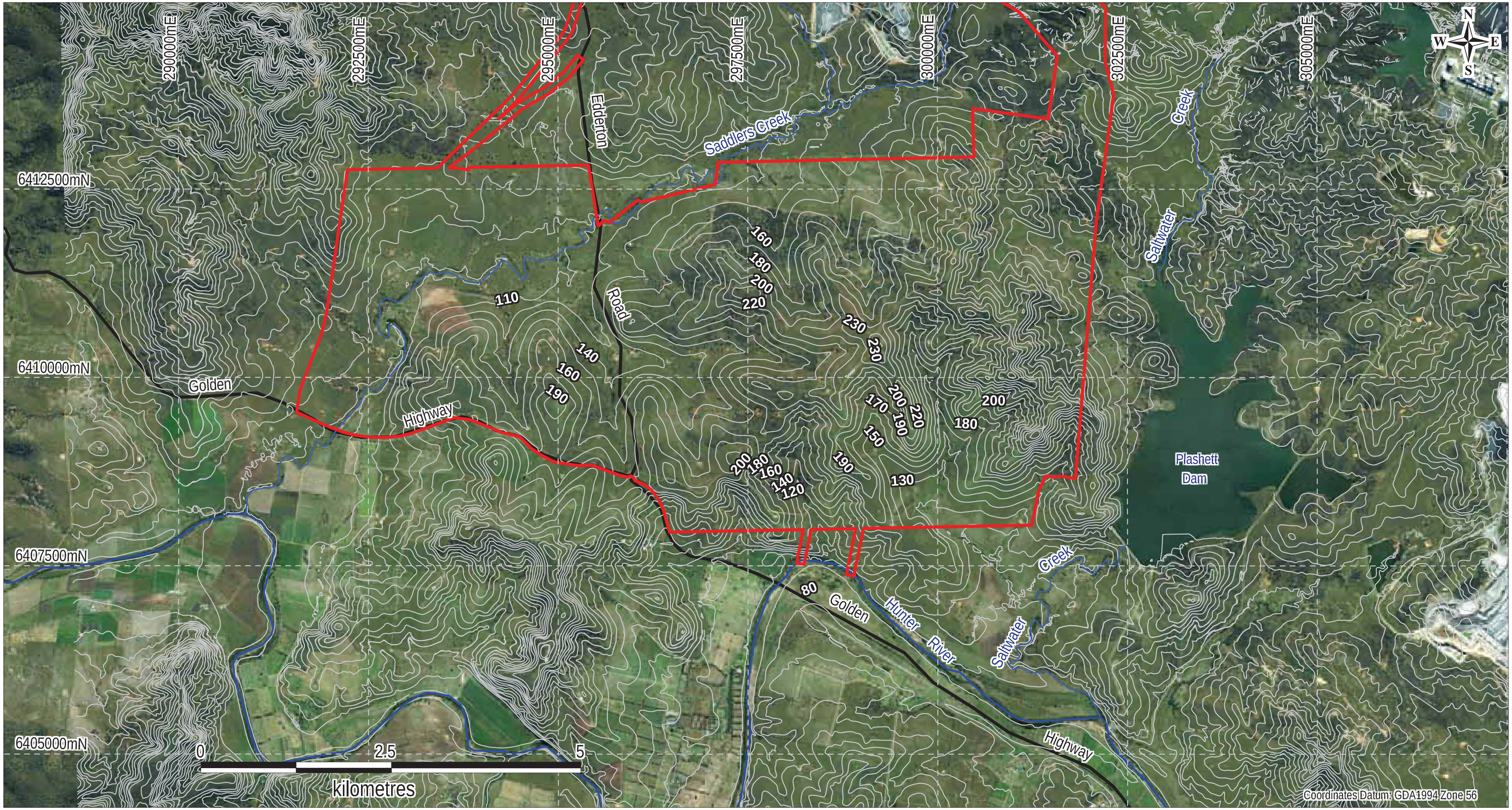

- LEGEND -

Project Boundary	Major River
Major Road	Creek
	Topography Contour (10m interval)

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LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT REGIONAL TOPOGRAPHY AND DRAINAGE			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 3
APPROVED BY:		DATE: April 2012	

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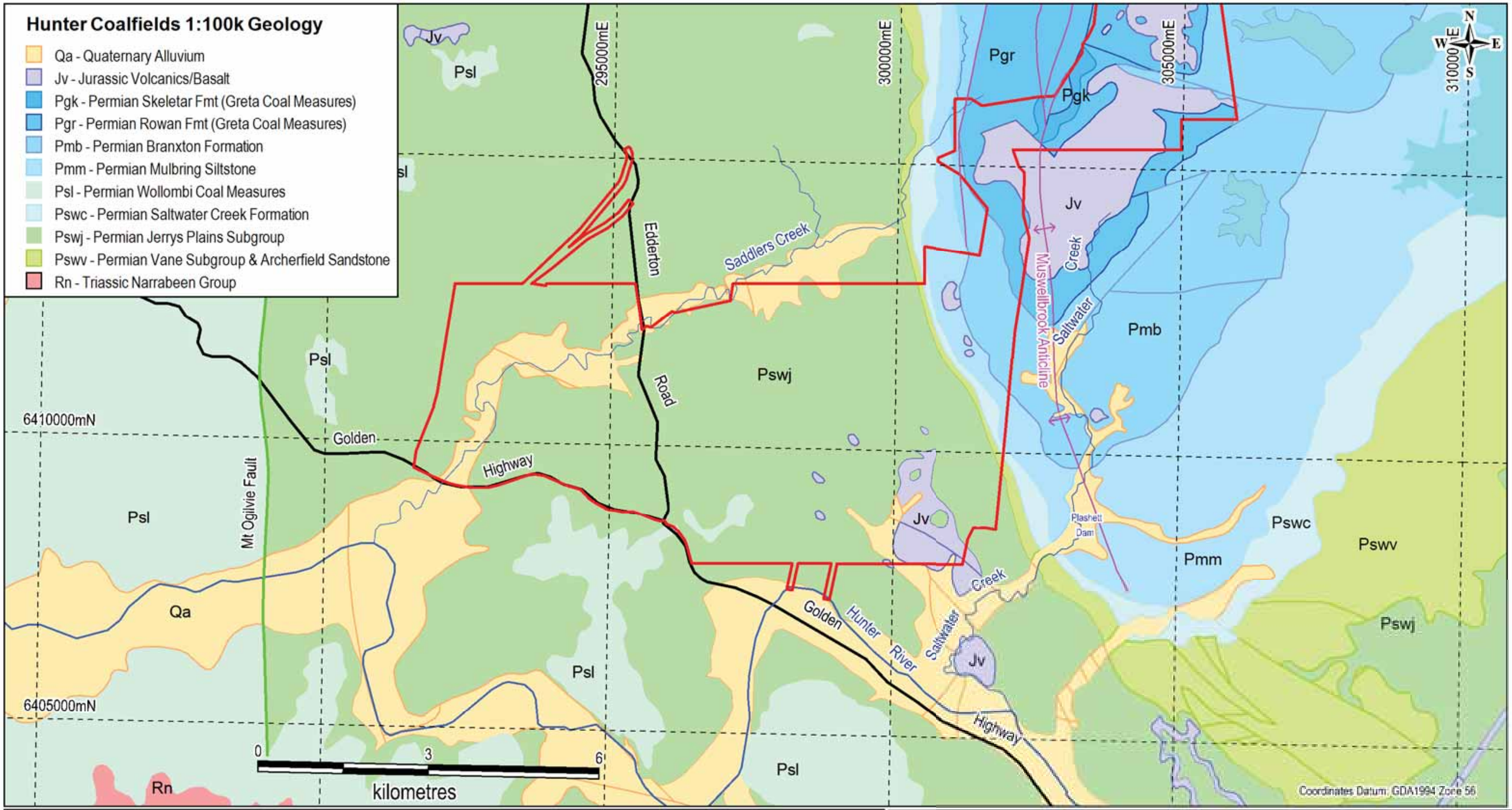

- LEGEND -

Project Boundary

Major Road

Major River

Creek

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT REGIONAL GEOLOGY			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 100,000 (A4)	PROJECT No: G1544	DRAWING No: 4
APPROVED BY:		DATE: April 2012	

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- LEGEND -

Project Boundary

Monitoring Bore Location

VW Piezometer Location

Major Road

Major River

Creek

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT MONITORING BORE LOCATIONS			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 :75,000 (A4)	PROJECT No: G1544	DRAWING No: 5
APPROVED BY:		DATE: April 2012	

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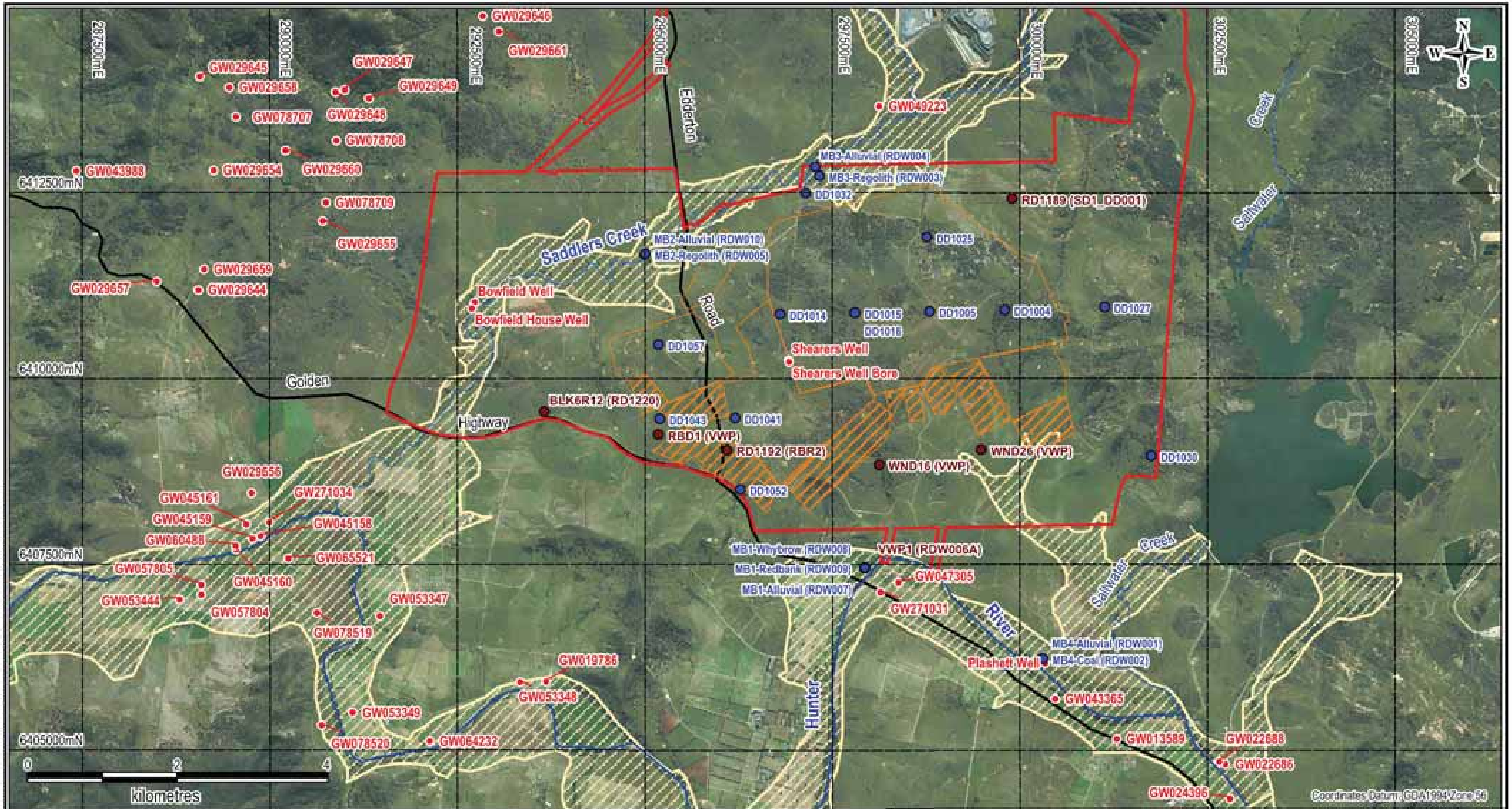

- LEGEND -

- Project Boundary
- Area of Alluvium (Qa)
- Major Road
- Proposed Open Cut Mining Area
- Proposed Highwall Mining
- Major River
- Creek
- NOW Registered Bore
- Monitoring Bore Location
- VW Piezometer

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT REGISTERED BORES			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 6
APPROVED BY:		DATE: April 2012	

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- LEGEND -

Project Boundary

Area of Alluvium (Qa)

Major Road

Major River

Creek

NOW Registered Bore

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LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT REGISTERED WATER BORES YIELDS	
CLIENT: Anglo American	OFFICE: Brisbane
DRAWN BY: TMM · SCALE: 1 : 75,000 (A4) · PROJECT No: G1544	DRAWING No: 7
APPROVED BY: · DATE: April 2012	

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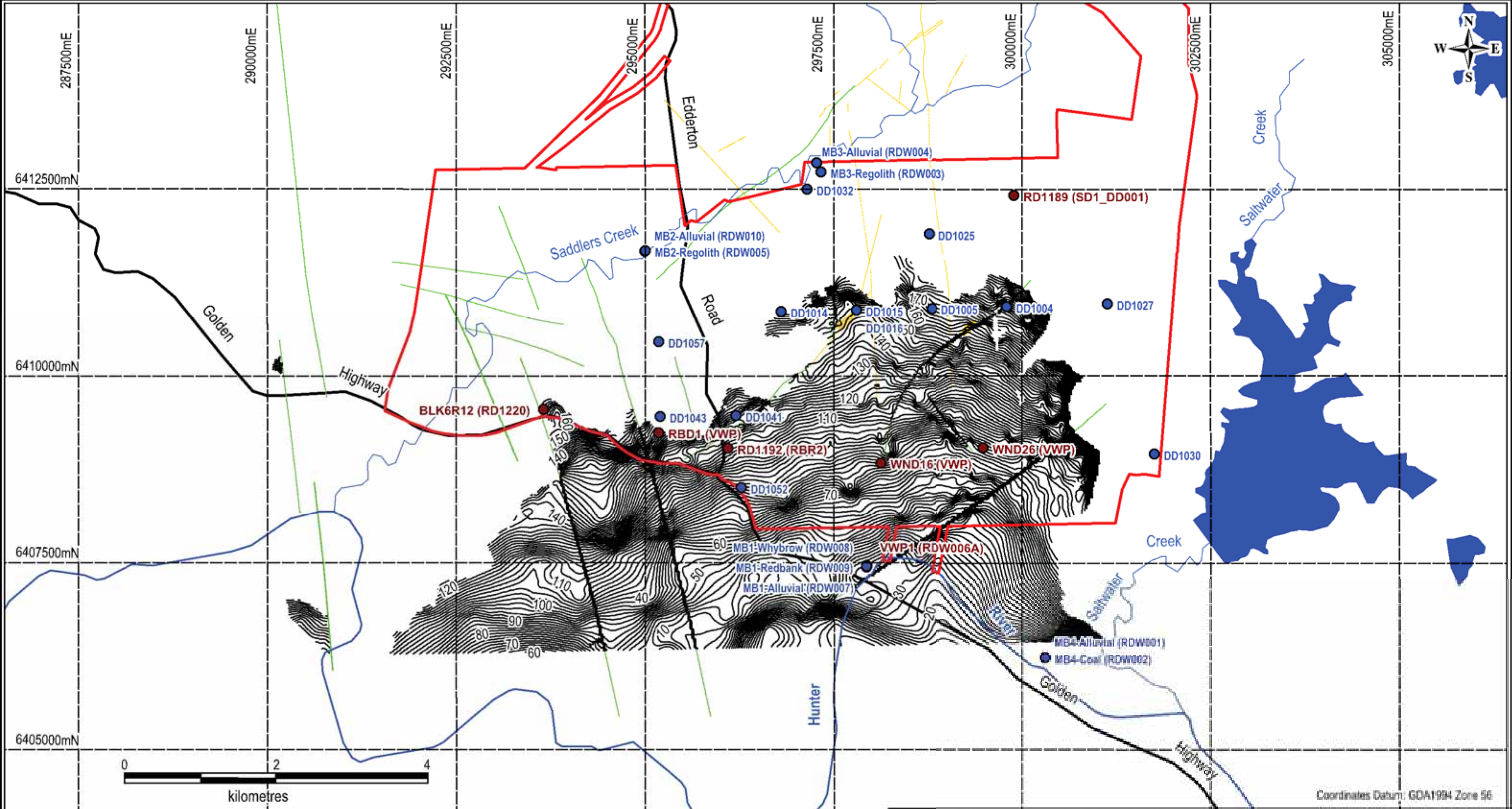

- LEGEND -

	Project Boundary		Monitoring Bore Location		Seam Elevation Contour (mAHD)
	Dam / Reservoir		VW Piezometer		Fault
	Major Road		Major River		Dyke / Sill
			Creek		

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD

LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA
GROUNDWATER ASSESSMENT
INTERPOLATED FLOOR ELEVATION WHYBROW SEAM

CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 8
APPROVED BY:	DATE: April 2012		

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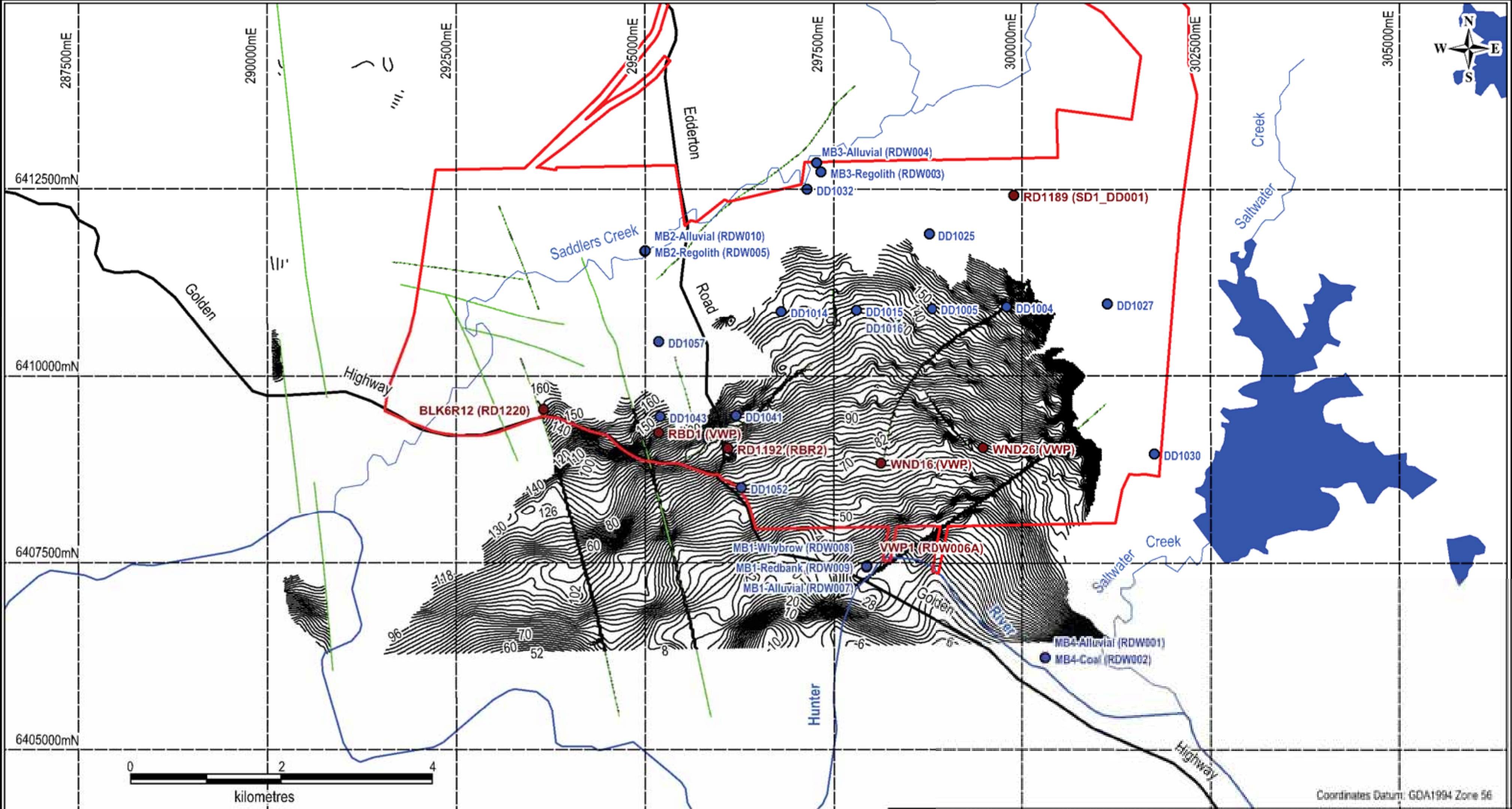

- LEGEND -

Project Boundary
Dam / Reservoir
Major Road
Monitoring Bore Location
VW Piezometer
Major River
Creek
Seam Elevation Contour (mAHD)
Fault

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA
GROUNDWATER ASSESSMENT
INTERPOLATED FLOOR ELEVATION REDBANK SEAM

CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 9
APPROVED BY:		DATE: April 2012	

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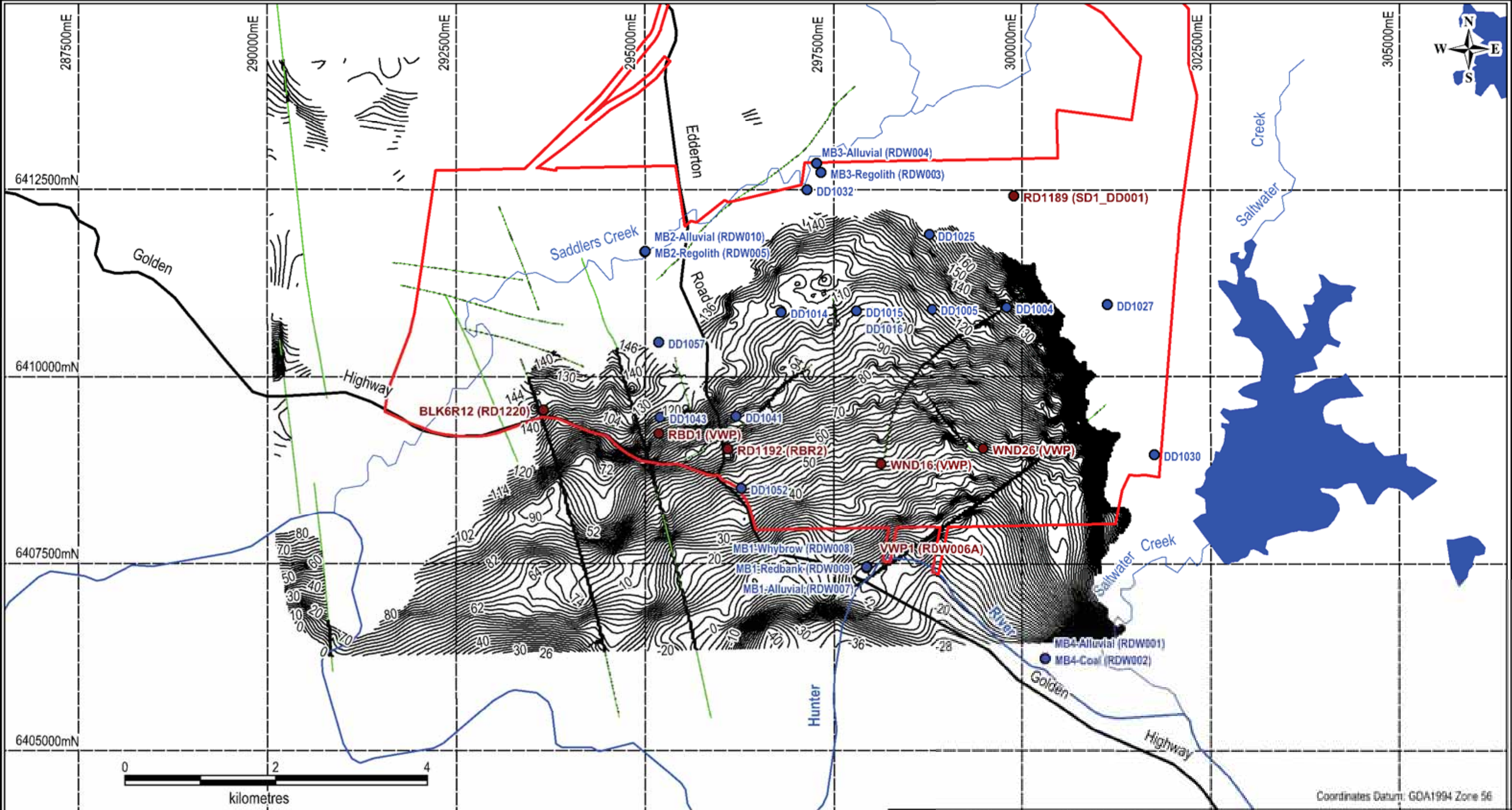

- LEGEND -

Project Boundary	Monitoring Bore Location
Dam / Reservoir	VW Piezometer
Major Road	Major River
	Creek
Seam Elevation Contour (mAHD)	Fault

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LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA
GROUNDWATER ASSESSMENT
INTERPOLATED FLOOR ELEVATION WAMBO SEAM

CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 10
APPROVED BY:		DATE: April 2012	

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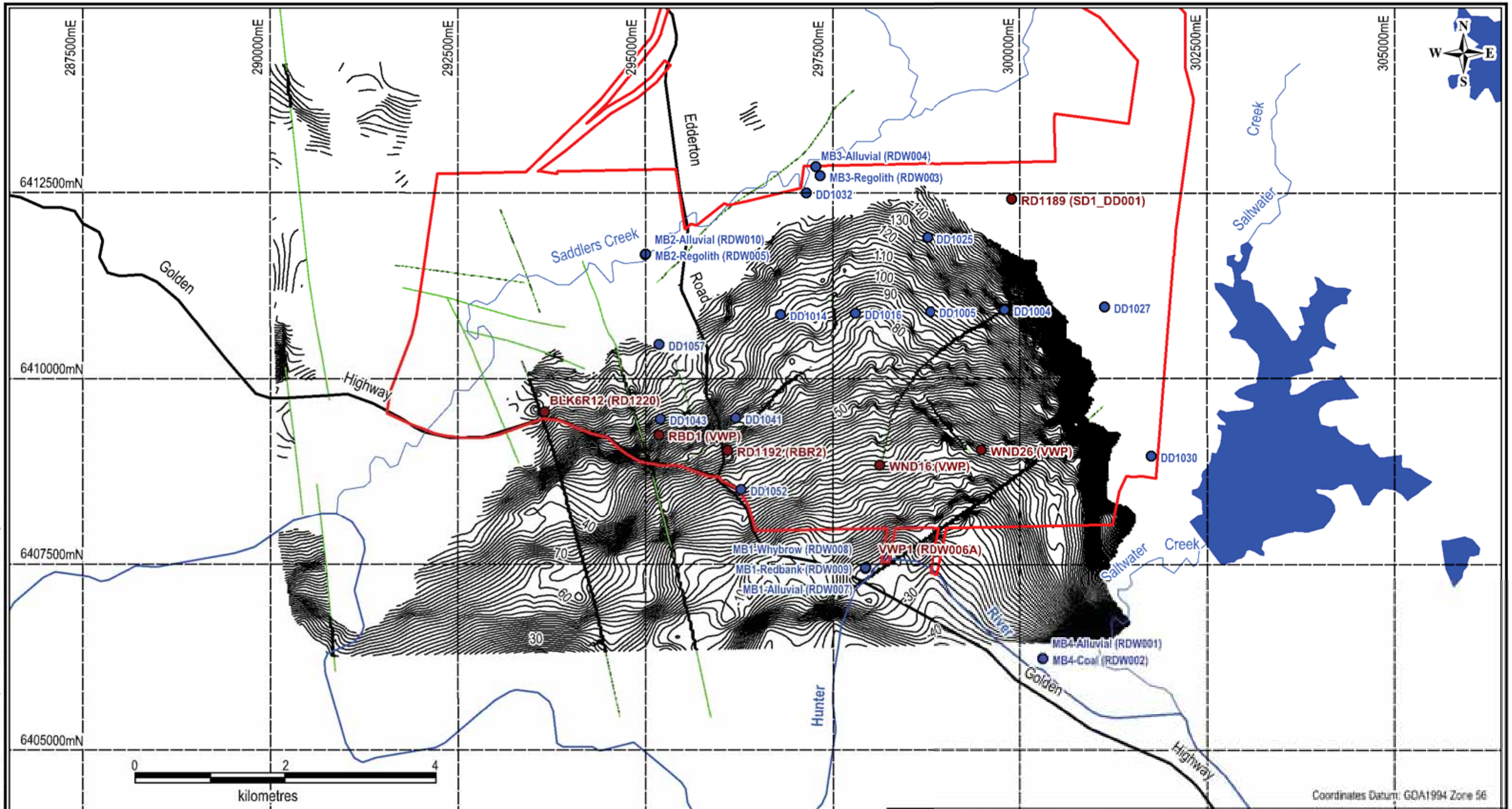

- LEGEND -

Project Boundary
Dam / Reservoir
Major Road
Monitoring Bore Location
VW Piezometer
Major River
Creek
Seam Elevation Contour
Fault

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT INTERPOLATED FLOOR ELEVATION WHYNOT SEAM			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 11
APPROVED BY:	DATE: April 2012		

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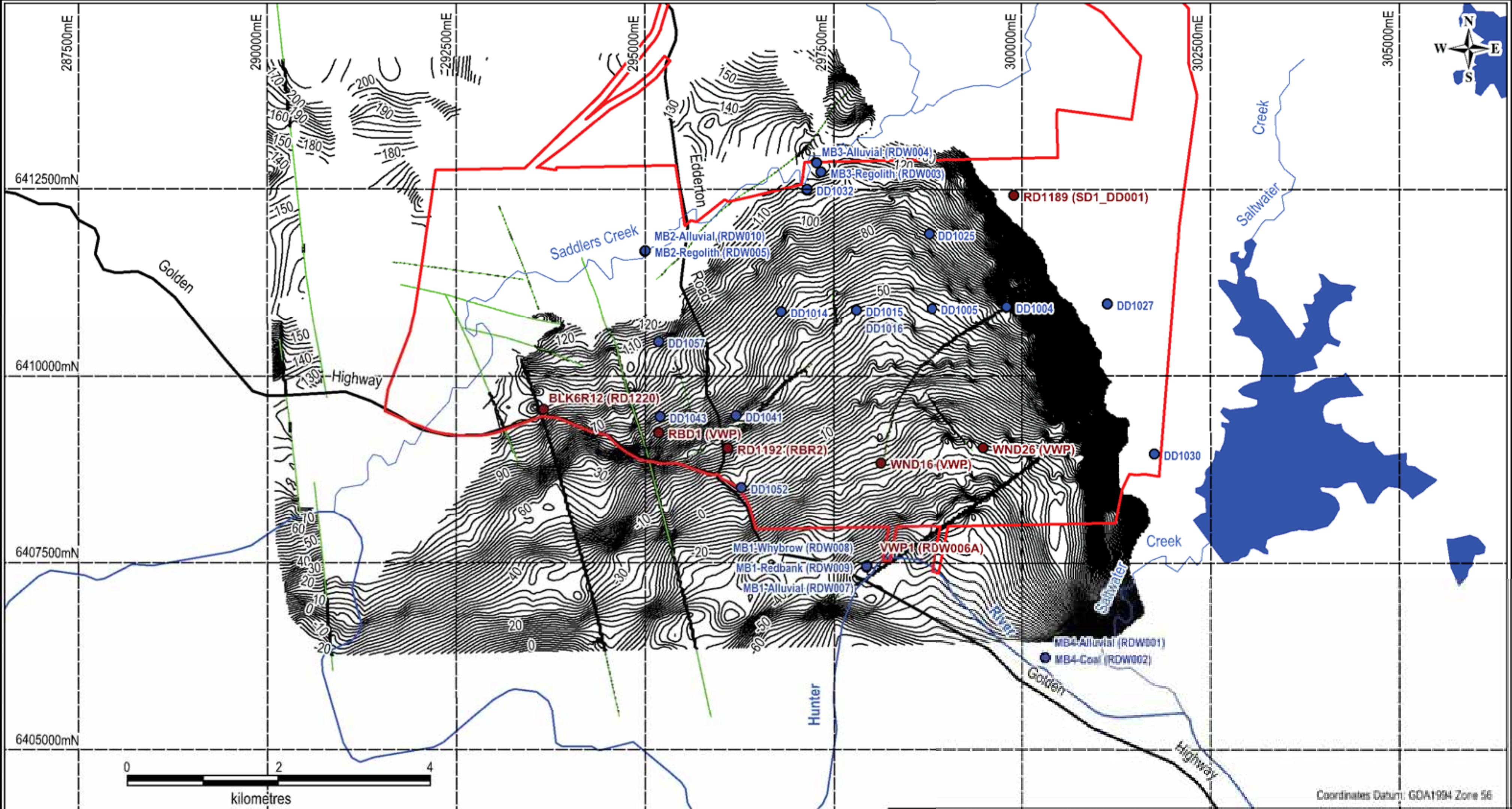

- LEGEND -

Project Boundary

Dam / Reservoir

Major Road

Monitoring Bore Location

VW Piezometer

Major River

Creek

Seam Elevation Contour

Fault

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD

LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA
GROUNDWATER ASSESSMENT
INTERPOLATED FLOOR ELEVATION BLAKEFIELD SEAM

CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 75,000 (A4)	PROJECT No: G1544	DRAWING No: 12
APPROVED BY:		DATE: April 2012	

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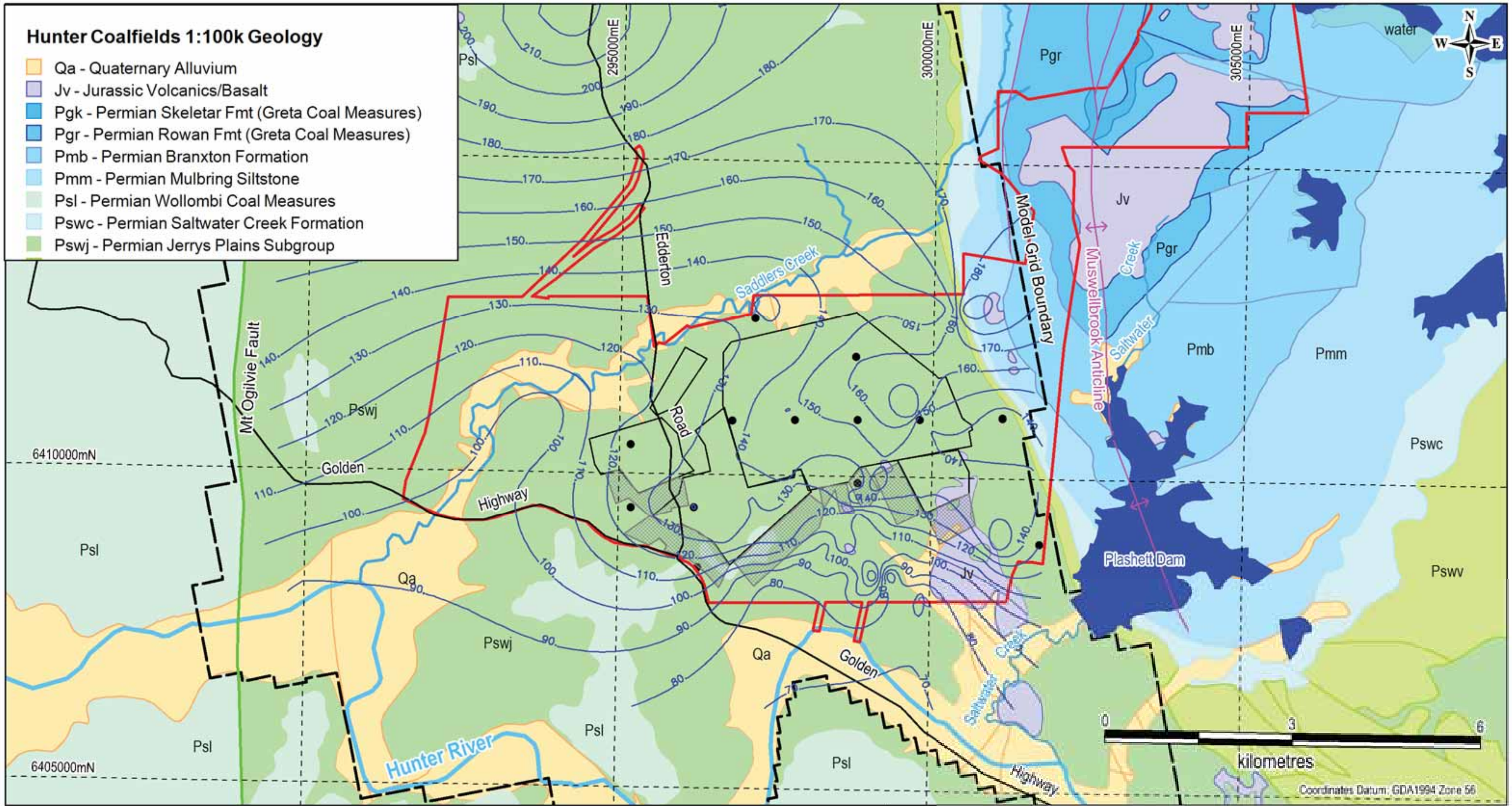

- LEGEND -

- MonitoringBores
- Predicted Groundwater Heads (mAHD)
- Model Grid Boundary
- Project Boundary
- Proposed Highwall Mining
- Proposed Open Cut Pit
- Major Road
- Major River
- Creek
- Dam / Reservoir

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
LEVEL 2, 15 MALLON ST, BOWEN HILLS, 4006, AUSTRALIA

TITLE: DRAYTON SOUTH MINE PROJECT EA GROUNDWATER ASSESSMENT INTERPOLATED GROUNDWATER HEADS			
CLIENT: Anglo American			OFFICE: Brisbane
DRAWN BY: CJ	SCALE: 1 : 90,000 (A4)	PROJECT No: G1544	DRAWING No: 13
APPROVED BY:		DATE: October 2012	

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