APPENDIX O

Groundwater Impact Assessment

Australasian
Groundwater & Environmental
Consultants Pty Ltd

REPORT on

COALPAC CONSOLIDATION PROJECT

GROUNDWATER IMPACT ASSESSMENT

prepared for
HANSEN BAILEY PTY LTD

Project No. G1515
March 2012

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REPORT ON

COALPAC CONSOLIDATION PROJECT
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1.0 INTRODUCTION

The Cullen Valley Mine and Invincible Colliery operations are located adjacent to the Castlereagh Highway, approximately 25km to the north-west of Lithgow, New South Wales (NSW). Both operations are located on lands surrounding the township of Cullen Bullen, with Invincible Colliery and Cullen Valley Mine located approximately 1km to the south-east and north-west, respectively. Both of these mines occur within the Lithgow City Council Local Government Area.

Coalpac Pty Ltd (Coalpac) was established in 1989 and has owned and operated coal mines in the Lithgow district for over 20 years. Coalpac has operated Invincible Colliery using various mining methods since that time, including underground continuous miner, open cut excavator and truck, and highwall mining operations. In February 2008, Coalpac purchased the Cullen Valley Mine and with Invincible Colliery, has operated the two mines in unison since that time.

Coalpac seeks a Project Approval under Part 3A of the *Environmental Planning & Assessment Act 1979* (EP&A Act) to consolidate the operations and management of the Cullen Valley Mine and Invincible Colliery sites under a single, contemporary planning approval to allow coal mining operations within its current mining tenements to continue for a further period of 21 years (the Project). The Project Application Boundary (Project Boundary) is shown on Drawing No. 1.

Hansen Bailey Pty Ltd (Hansen Bailey) has been commissioned to prepare an Environmental Assessment (EA) in support of the Part 3A Project Application for the Project. This groundwater assessment has been undertaken by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) at the request of Hansen Bailey on behalf of their client Coalpac.

2.0 PROJECT OVERVIEW

Coalpac seeks Project Approval from the Minister for Planning under Part 3A of the EP&A Act to consolidate the operations and management of the Cullen Valley Mine and Invincible Colliery sites under a single, contemporary planning approval. The Project would allow coal mining operations within its current mining tenements to continue for a further period of 21 years within the Project Boundary. In regards to mining operations, approval is sought for the following:

- consolidation and extension of the existing Cullen Valley Mine and Invincible Colliery operations to produce up to a total of 3.5 Mtpa product coal, including:
    - the continuation of mining operations at Cullen Valley Mine (the area west of the Castlereagh Highway) via both open cut and highwall mining methods to access an additional resource of approximately 25 Mt ROM; and

(Project No. G1515)

  - the continuation of mining operations at Invincible Colliery including an extension north into the East Tyldesley area via open cut and highwall mining methods to access an additional resource of approximately 45 Mt ROM;
- continuation of coal supply to the local Mount Piper Power Station (MPPS) via a dedicated coal conveyor over the Castlereagh Highway (to be constructed), and (emergency supply to) Wallerawang Power Station, with flexibility for supply to additional domestic destinations and Port Kembla for export;
- upgrades to existing administration, transport and other infrastructure;
- construction and operation of additional Offices at Cullen Valley Mine;
- construction and use of the previously approved Coal De-shaling Preparation Plant (CDPP) at Cullen Valley Mine;
- construction and use of a bridge over the Castlereagh Highway to link operations east and west of the highway and the development of required access roads to the East Tyldesley area;
- construction and operation of a bridge and haul road across the Wallerawang - Gwabegar Railway line to permit access to mine the previously approved Hillcroft resource;
- the extraction of the Marangaroo Sandstone horizon from immediately below the Lithgow Coal Seam in the northern coal mining area of Cullen Valley Mine. This material will to be trucked for crushing on site prior to sale into the Sydney (and surrounds) industrial sand market;
- construction of a rail siding and associated infrastructure to permit transport of product coal and sand products;
- integration of the water management of both sites into a single system; and
- integration of the management of mine rehabilitation and conceptual final landform outcomes for Cullen Valley Mine and Invincible Colliery.

3.0 SCOPE OF WORK

The Director-General's Environmental Assessment Requirements (DGRs) issued by the Department of Planning on 16 December 2010 for the Project include a number of water related issues that have been considered in this assessment. Relevant requirements from the DGRs provided by DoP for the Project are listed below.

Soil & Water

- a detailed Project water balance, including a description of site water demands, water disposal methods, water supply infrastructure and water storage structures;
- a detailed assessment of the potential impacts on:
  - the quality and quantity of existing surface and ground water resources;
  - affected licensed water users and basic landholder rights; and
  - environmental flows.
- a detailed description of the proposed water management system and water monitoring program for the Project and other measures to mitigate surface and groundwater impacts; and

- detailed assessment of the likely impacts on soil and the proposed soil management measures to avoid, mitigate or offset those impacts.

The NSW Office of Water (NOW) also provided a list of assessment requirements for the Project following consultation with the department in November 2010. The NOW requirements for the Project EA considered in the preparation of this assessment are as follows:

Licensing

i) *all proposed groundwater works, including bores and excavations for the purpose of investigation, extraction, dewatering testing or monitoring must be identified in the proposal and an approval obtained from NOW prior to undertaking such works.*

Groundwater Source

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

i) *details of the predicted highest groundwater table within the mine voids and adjacent aquifers.*

ii) *details of any works likely to intersect connect with or result in pollutants infiltrating into the groundwater sources;*

iii) *details of any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes;*

iv) *details of proposed methods of the disposal of waste water and approval from the relevant authority;*

v) *details of the exiting groundwater users within the area (including the environment) and include details of any potential impacts on these users;*

vi) *baseline monitoring or data for a minimum of 2 years monthly sampling for groundwater quantity and quality for all aquifers and mine voids within and adjacent to the mining operation area;*

vii) *describe the flow directions and rates and the physical and chemical characteristics of the groundwater source;*

viii) *impact assessment of mining operations of potential affects to quality of groundwater both in the short and long term;*

ix) *details on preventing groundwater pollution so that remediation is not required;*

x) *details of the predicted impacts of any final landform on the groundwater regime;*

xi) *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; and*

xii) *determine critical thresholds for negligible impacts to groundwater sources.*

Groundwater Dependent Ecosystems

The NSW Groundwater Dependent Ecosystem (GDE) Policy provides guidance on the protection and management of GDE and sets out objectives and principles. The assessment is required to identify any impacts on GDE's and address the following:

i) *identification of potential GDE's within the study area;*

ii) current GDE condition, water quality and quality required by the ecosystems (minimum 2 year monthly baseline data);

iii) determine critical thresholds for negligible impacts;

iv) manage groundwater extraction within defined limits thereby providing flow sufficient to sustain ecological processes and maintain biodiversity;

v) ensure sufficient groundwater of suitable quality is available to ecosystems when needed;

vi) ensure the precautionary principle is applied to protect GDE , particularly the dynamics of flow and availability and the species reliant on these attributes; and

vii) details on protective measures to minimise any impacts on GDE.

Contingency Measures

Where potential impacts are identified the assessment will need to identify limits to the level of impact and contingency measures that would remediate, reduced or manage potential impacts to the existing groundwater resource and any dependent groundwater environment or water users, including information on:

i) details of any proposed monitoring programs, including water levels and quality data;

ii) reporting procedures for any monitoring program including mechanism for transfer of information to NOW;

iii) an assessment of any groundwater source/aquifer that may be sterilised as a consequence of the proposal;

iv) 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 a beneficial use category);

v) description of the remedial measures or contingency plans proposed; and

vi) any funding assurances covering the anticipated post development maintenance cost, for example on-going groundwater monitoring for the nominated period.

The objective of this groundwater assessment was to assess the impact of the Project on the hydrogeological regime and to meet the applicable DGRs. To achieve this objective, a scope of work was developed that included:

- identification of groundwater resources in the vicinity of the Project site which could be impacted by the Project;
- a site visit to discuss the Project with staff at Cullen Valley Mine and Invincible Colliery;
- assessment of the potential for any groundwater impacts resulting from the Project, including predictive calculations of the groundwater impacts of the Project with existing and proposed mining projects (including groundwater impacts on privately owned bores);
- assessment of post-mine groundwater impacts and recovery of groundwater levels;
- the development of groundwater management strategies;
- identification of any groundwater impact mitigation measures necessary for the Project; and
- a recommended groundwater management program.

4.0 LEGISLATION, POLICY AND GUIDELINES

The following section outlines New South Wales State Government legislation, policy and guidelines with respect to groundwater that must be addressed in assessing a mining proposal.

4.1 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 (WSPs) are not in place. This is the case for some areas of the Project site.

4.2 Water Management Act 2000

The objective of the WM Act is 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 for four types of approval:

- water use approval – which authorise the use of water at a specified location for a particular purpose, for up to 10 years;
- water management work approval;
- 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.

For controlled activities and aquifer interference activities, 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.

Under the WM Act, the objectives of the Water Sharing Plans are:

- *protect, preserve, maintain and/or enhance the high priority groundwater dependent ecosystems and high priority river flow dependent ecosystems of these groundwater sources;*
- *protect, preserve and maintain the integrity of aquifers in these groundwater sources (Murray-Darling Basin Porous Rock Groundwater Sources Water Sharing Plan – only);*
- *protect, preserve, maintain and/or enhance the Aboriginal, cultural and heritage values of these groundwater sources;*
- *contribute to the sustainable and integrated management of the water cycle across these groundwater sources;*
- *to supplement the water supply for people of Sydney, the Illawarra, the Shoalhaven, the Southern Highlands, and the Blue Mountains, which comprise approximately 70% of the*

NSW population (Greater Metropolitan Regional Groundwater Sources Water Sharing Plan – only);

- *protect basic landholder rights;*
- *manage these groundwater sources to ensure equitable sharing between users;*
- *provide opportunities for market based trading of access licences and water allocations within sustainability and system constraints;*
- *provide sufficient flexibility in water account management to encourage responsible use of available water;*
- *contribute to the maintenance of water quality;*
- *manage groundwater sources in recognition of surface water and groundwater connectivity;*
- *adaptively manage these groundwater sources; and*
- *contribute to the environmental and other public benefit outcomes identified under the Water Access Entitlements and Planning Framework in the Inter-Governmental Agreement on a National Water Initiative (2004) (Murray-Darling Basin Porous Rock Groundwater Sources Water Sharing Plan – only).*

The Project is located proximal to the boundary between two groundwater management areas, where water sharing plans have been either drafted or commenced, these being:

- the Murray-Darling Porous Rock Groundwater Sources (Sydney Basin) – anticipated commencement in early 2012; and
- the Greater Metropolitan Regional Groundwater Sources – commenced on 1st July 2011.

The Project Boundary is largely contained within the Murray-Darling Porous Rock Groundwater Sources area (which is part of the Central West catchment management area), whilst some of the historical underground workings of the Invincible Colliery are located within the area covered by the Greater Metropolitan Regional Groundwater Sources. The WSP boundaries are shown on Drawing No. 2.

A draft WSP known as the Murray-Darling Basin Porous Rock Groundwater Sources WSP was released for comment between Monday 6th December 2010 and Monday 31st January 2011 but has not been adopted at the time of writing. NOW advises that the Murray-Darling Basin Porous Rock Groundwater Sources WSP is expected to commence in early 2012.

The draft WSP for the NSW Murray Darling Basin Porous Rock Groundwater Sources includes all water contained in porous rock aquifers (but not fractured aquifers nor alluvial aquifers) within the area defined within the plan boundary. The Murray Darling Basin Porous Rock Groundwater WSP applies to a number of identified groundwater sources. One of these groundwater sources is referred to as Sydney Basin Murray Darling Basin (MDB), within which the Project is located. The Sydney Basin MDB has been further subdivided into a number of management zones. The Project is located within the Sydney Basin MDB – Macquarie South management zone as shown in Figure 1.

The Murray Darling Basin Porous Rock Groundwater WSP acknowledges that porous rocks from the Sydney Basin MDB Groundwater Sources contain mineral, coal and gas resources. To obtain these resources, mining companies need to remove water from the groundwater sources. The Murray Darling Basin Porous Rock Groundwater WSP provides additional entitlement to be issued in porous rock aquifers to allow coal mining and gas extraction to proceed. This additional entitlement can be used with the acquisition of an aquifer (storage) access licence.

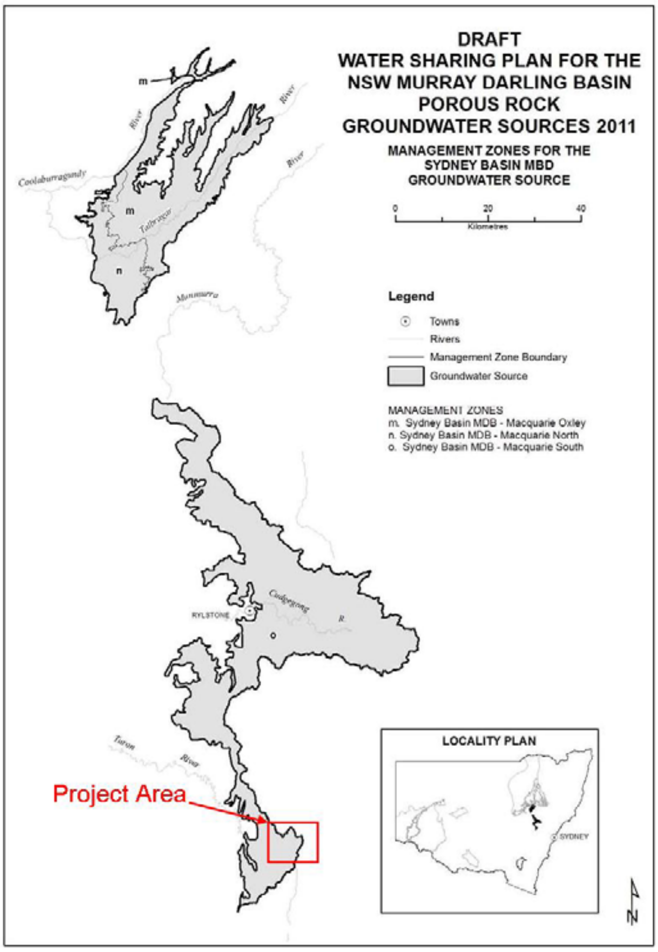

Figure 1: Sydney Basin MDB – Macquarie South Management Zone (after NOW, 2011)

Additionally, the Greater Metropolitan Regional Groundwater Sources WSP was made public on 2nd March 2011 and commenced on 1st July 2011. The WSP for the Greater Metropolitan Regional Groundwater Sources includes all groundwater contained within aquifers beneath the management zones shown in Figure 2. The area immediately to the east of the Project Boundary is included within two management zones (Drawing No. 2), these being:

- Sydney Basin North; and
- Sydney Basin Coxs River.

Some of the eastern historical underground workings of the Invincible Colliery are located beneath the Sydney Basin Coxs River management zone. Coalpac currently hold a licence to discharge water contained within the underground workings of the Invincible Colliery (Licenced Discharge Point (LD) 001 under Environmental Protection Licence (EPL) 1095). This EPL entitles Coalpac to discharge up to 2ML/day of the water stored within the underground workings at the Coxs River Swamp discharge point (via bore LD001). At the request of the NSW Department of Environment, Climate Change and Water the discharge was suspended in June 2007. Coalpac identified a regulatory anomaly, this being, whilst a licence was held that allowed the discharge of the water, a licence under Part 5 of the Water Act was not held which was required to extract the water. Coalpac have applied for a licence under the Water Act with NOW for LD001, which was submitted in October 2008. No reply to this application has yet been received.

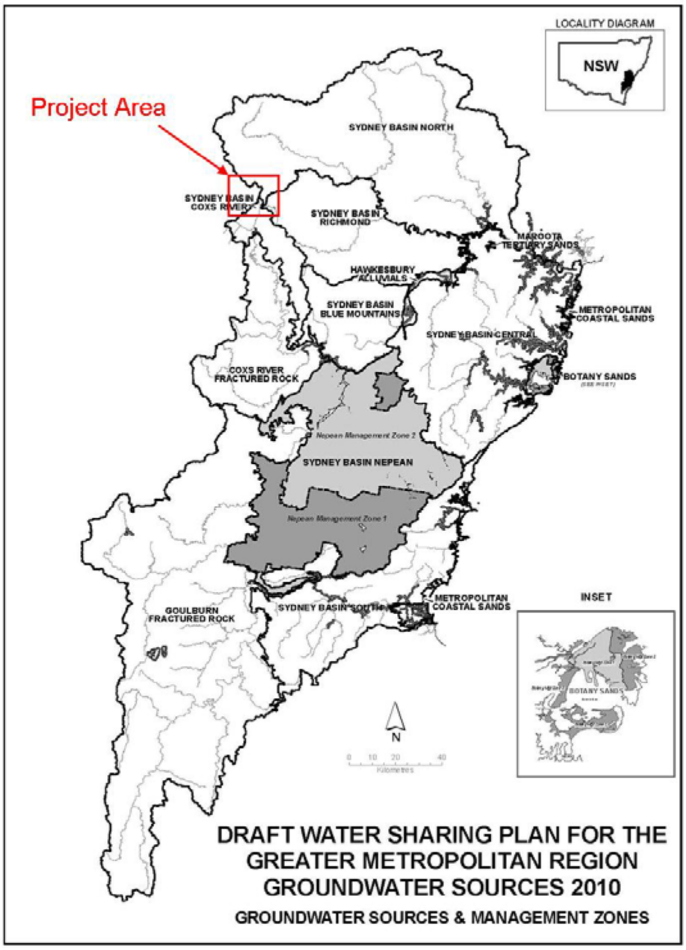

Figure 2: Groundwater Sources in the Greater Metropolitan Region (after NOW 2010)

The Greater Metropolitan Regional Groundwater Sources WSP includes a number of legislative requirements known as rules. A summary of relevant rules for the Project is provided below:

- Except for basic landholder rights, all other water extraction either requires an authorisation under a water access licence or some form of exemption. The WM Act 2000 establishes categories and sub-categories of access licences. Examples include:
    - local water utility – a category of access licence for town water purposes;
    - aquifer – a category of access licence that covers purposes such as irrigation, industry, mining, recreation and general farming;
    - Aboriginal cultural – a specific sub-category of aquifer access licence that allows water to be taken by Aboriginal persons or communities for personal, domestic and communal purposes (generally up to 10ML/year per licence); and
    - Aboriginal community development – a specific sub-category of aquifer access licence that allows water up to specified limits to be taken by Aboriginal persons or communities for commercial purposes.

The total entitlement, or share component, for each category of access licence is provided within the WSP. The share components of specific purpose licences such as local water utility and Aboriginal cultural purposes are expressed as a number of megalitres per year. The share components of aquifer access licences, which are issued in perpetuity, are expressed as a number of unit shares in the available water.

It was estimated that at the time of commencement the Greater Metropolitan Regional Groundwater Sources WSP, the share components of aquifer access licences authorised to take water from the entire groundwater sources totalled 62,204 unit shares. Of this total, 6,926 unit shares were estimated to be authorised from the Sydney Basin Coxs River Groundwater Source.

The long-term average annual extraction limit for the Sydney Basin Coxs River Groundwater Source was defined by the WSP as 17,108 ML/year.

Generally the available water determinations for aquifer access licences will be 1 megalitre per unit share. However, if there is significant growth in water use above the long-term average annual extraction limit, this growth will be managed by reducing the volume per unit share for aquifer access licences.

Other than through the purchase of a water access licence or share component in the water market, applications for granting additional water access licences will generally only be considered for local water utility or town water supply and Aboriginal cultural purposes.

4.3 State Groundwater Policy

The NSW State Groundwater Policy (Framework Document) was adopted in 1997 and aims to manage the State’s groundwater resources to sustain their environmental, social and economic uses. The policy has three component parts, namely:

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

4.3.1 Groundwater Quality Protection

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

1. *all groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained;*
2. *town water supplies should be afforded special protection against contamination;*
3. *groundwater pollution should be prevented so that future remediation is not required;*
4. *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;*
5. *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;*

6. *groundwater dependent ecosystems will be afforded protection;*
7. *groundwater quality protection should be integrated with the management of groundwater quality;*
8. *the cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource; and*
9. *where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.*

4.3.2 Groundwater Dependent Ecosystems

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 Groundwater Dependent Ecosystems 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. A summary of the principles follows:

- *groundwater dependent ecosystems (GDEs) 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 GDEs, 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 GDEs; and*
- *planning, approval and management of developments should aim to minimise adverse affects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater ecosystems where necessary.*

4.3.3 Groundwater Quantity Protection

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 (sic) 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.*

4.4 Aquifer Risk

The "Aquifer Risk Assessment Report" of 1998 used a number of criteria to classify risks to various significant groundwater resources across the State. It classified the Sydney Basin Sandstone, within which the Project is geologically located, as a "medium risk aquifer".

4.5 Federal Government Legislation

The Federal *Water Act 2007* applies to the Murray Darling Basin in which the Project Boundary lies. There is no direct requirement for the licensing of water under this Act; however, Basin Plans and Water Resource Plans for this area are currently being prepared and may impact on how water can be extracted stored and used. Rules for trading or transferring water rights may also be included. The Murray Darling Basin Plan will provide an integrated approach to manage the basin's water resources in a way that can be sustained through time and in the national interest. The Murray Darling Basin Plan will provide legal limits on the amount of water that can be taken from the Basin's water resources. The Project is located within the Macquarie – Castlereagh Basin Plan Region shown on Figure 3. The Murray Darling Basin Plan is scheduled for release in 2011.

Figure 3: Murray Darling Basin Plan Regions (after Murray Darling Basin Authority 2010)

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5.0 REGIONAL SETTING

5.1 Location

Cullen Valley Mine and Invincible Colliery are located on the western slopes of the Great Dividing Range adjacent to the township of Cullen Bullen (see Drawing No. 1), which has a population of approximately 300 people. The closest urban area is the regional centre of Lithgow, situated approximately 25km to the south-east along the Castlereagh Highway.

The Project is bounded to the north, east and south by the Ben Bullen State Forest and the lower lands of Cullen Valley to the west. There are several other State Forestry areas and National Parks located in the regions adjacent to the Ben Bullen State Forest and the Project Boundary, including the Gardens of Stone National Park approximately 2km north, the Wolgan State Forest approximately 8km to the north-east and the Newnes State Forest, located approximately 12km to the south-east.

The locations of the current operations at Invincible Colliery and Cullen Valley Mine are shown in Drawing No. 3 along with the adjacent mining operations in the local area.

5.2 Historical Mining Operations

5.2.1 Cullen Valley Mine

The Cullen Valley Mine site contains the former operational areas of the Old Tyldesley Colliery, where coal mining via underground methods commenced in the late 1800's. A range of open cut and underground mining operations have been undertaken at the site since this time, with activities suspended at various times in the intervening period.

On 24th December 1997, the Lithgow Coal Company (previous owners of the Cullen Valley Mine) was granted DA 200-5-2003 by the Minister for Planning for the operations described in the *Feldmast Coal Project Environmental Impact Statement 1997* (Feldmast EIS) (IEC, 1997). The Feldmast EIS described and assessed open cut, underground and highwall mining activities at Cullen Valley Mine. Open cut mining consistent with the Feldmast EIS commenced in May 2000.

Following the identification of additional open cut coal reserves, the *Cullen Valley Mine Open Cut Extension EIS* (Cullen Valley Mine EIS) (IEC, 2004) was lodged in April 2004. This modification to DA 200-5-2003 was granted by the Department of Infrastructure, Planning and Natural Resources on 19th August 2004. This approves open cut mining activities on the western side of Tyldesley Hill and continued activities under the Feldmast EIS.

Product coal from Cullen Valley Mine has historically been supplied under contract to Mount Piper Power Station. However, with the failure of the mine to renew a supply contract, the operation was placed on a Care and Maintenance program in June 2007.

In February 2008, when Coalpac acquired Cullen Valley Mine from Lithgow Coal Company, the mine was taken off Care and Maintenance. The open cut mining operations approved under DA 200-5-2003 re-commenced at that time.

5.2.2 Invincible Colliery

Coal mining at Invincible Colliery commenced in 1901, with the establishment of an underground mining operation located on the eastern side of the township of Cullen Bullen. This operation (referred to in this document as the Old Invincible Colliery) continued into the mid 1950's, until the mine entrance was relocated approximately 4km to the south to commence another underground operation (Invincible Colliery) which remained active until 1998, when operations were suspended due to low coal prices.

Limited open cut mining at Invincible Colliery recommenced in 1998 and continued until 2001, when the site was placed on Care and Maintenance.

In May 2005, Coalpac secured a contract from Delta Electricity to supply coal to the Mount Piper Power Station over a three year period. An application for Project Approval under the EP&A Act, supported by the *Environmental Assessment for Proposed Extension of Invincible Open Cut Mine and Rehabilitation Activities* (Craven Elliston Hayes, 2006), was submitted to Department of Planning (DoP) for an extension to the open cut operations at Invincible Colliery to allow this contract to be met. Project Approval (PA 05_0065) was subsequently granted on 7th September 2006 for the mine extension and the Invincible Colliery was taken off Care and Maintenance.

Following the recommencement of open cut mining at the Invincible Colliery being approved, two further successful applications were made for the modification of PA 05_0065. These modifications gained approval to recommence coal washing at the Invincible Colliery Preparation Plant (ICPP) and introduce highwall mining within the open cut mine area.

Invincible Colliery operates under PA 07_0217 which was granted by DoP on 4 December 2008, which also required the surrender of PA 05_0065. PA 07_0127 primarily enables an increase in the volume of ROM coal production at Invincible Colliery to 1.2Mtpa in order to principally secure supply of product to local power stations. This application was supported by the *Environmental Assessment of the Proposed Extension to the Invincible Colliery Open Cut Mine and Production Increase 2008* (Invincible Colliery EA) (R.W. Corkery, 2008).

Three modifications have subsequently been granted for PA 07_0127 and include:

- MOD 1 granted 12th January 2009 to amend a discrepancy in the schedule of land provided in the original EA;
- MOD 2 granted 12th August 2009 which granted for changes to the Project site boundary to allow consistency between this area and the mining tenements held by Coalpac for Invincible Colliery. This modification also approved the amendment of the layout of the open cut pit areas for the site; although the total open cut pit disturbance area did not change; and
- MOD 3, granted 8th October 2010, to allow the transportation of up to an additional 300,000 tonnes per annum (tpa) of product coal by public roads to the currently approved destination of MPPS (up to a maximum volume of 1.2Mtpa product coal).

5.3 Surrounding Mining Operations

The Cullen Valley Mine and Invincible Colliery are bounded to the north, south, east and west by other mining tenements as shown in Drawing No. 4. The adjoining mining tenements include those for Baal Bone Colliery (Xstrata Coal), Angus Place/Springvale JV (Centennial Coal Pty Ltd), Ivanhoe North Mine (Centennial Coal Pty Ltd) and Wallerawang Colliery.

There are a number of other coal mining operations within the Sydney Basin that are distant from the Project Boundary and these have not been discussed further within this document.

5.4 Topography and Drainage

The Project is located on the western slopes of the Great Dividing Range at elevations between RL900m and RL1100m, with several steep sandstone escarpments dividing the site topographically as shown on Drawing No. 5 and Figure 4. The escarpment located in the Ben Bullen State Forest associated with the Great Dividing Range (approximately 500m to the east of the Project Boundary) represents the catchment divide between the Coxs River and Macquarie River Systems.

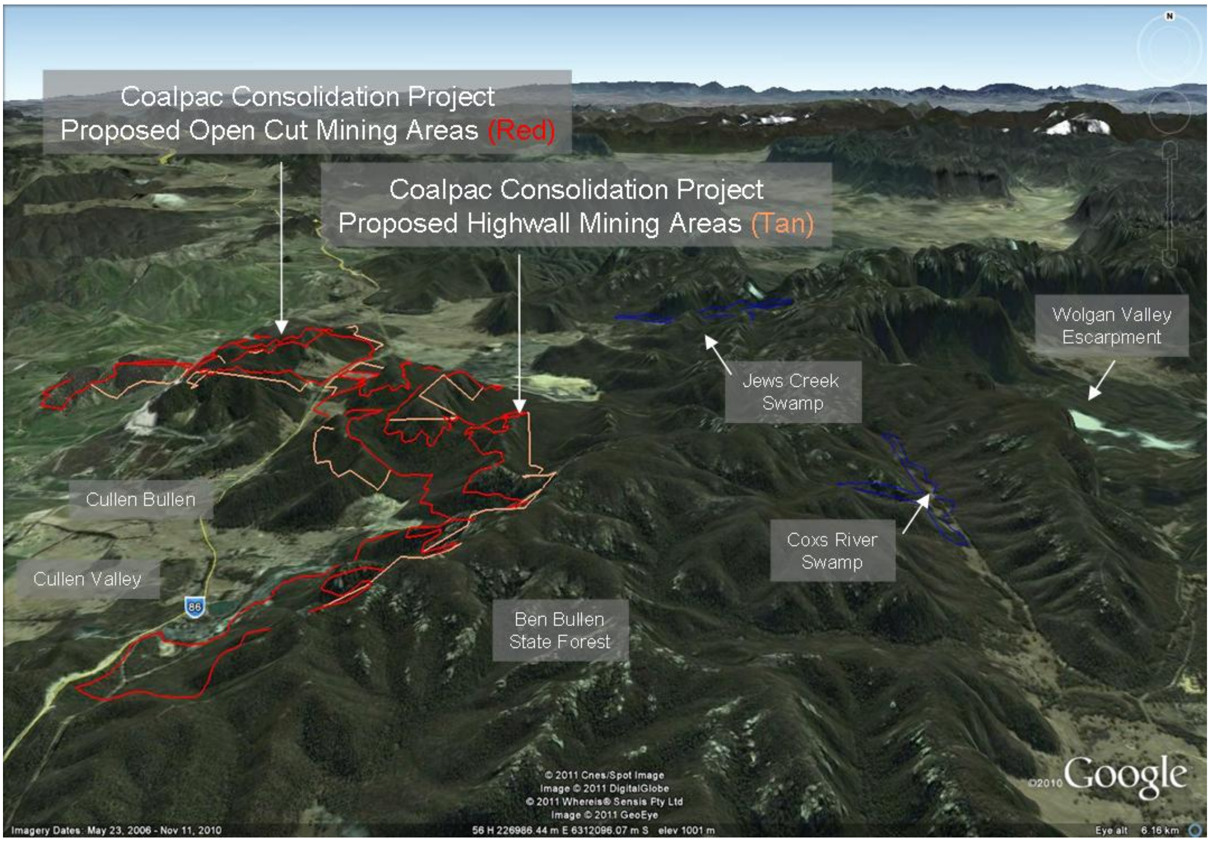

Figure 4: Orthophoto (inclined) of the Project Boundary. (V:H = 3)

With the exception of the steeply rising lands associated with the remnant sandstone escarpment features, the area is typified by moderately undulating terrain. To the west of the Project Boundary, the topography gently slopes downward toward Cullen Valley, to an elevation of approximately RL840m.

Coxs River Swamp and Jews Creek Swamp are likely to constitute groundwater dependent ecosystems. These areas are located approximately 2km and 3.5km outside the Project Boundary. The location of the Coxs River Swamp and Jews Creek Swamp is presented in Drawing No. 5. No other groundwater dependent ecosystems have been identified within or in the vicinity of the Project Boundary.

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The Project Boundary is located in the upper Turon River catchment, a tributary of the Macquarie River, which contributes to drinking water at Burrendong Dam approximately 100km north-west.

As can be seen in Drawing No. 5, there are a number of minor drainage lines in the vicinity of the Project Boundary, with local catchments consisting of ephemeral creeks and watercourses that generally flow into the upper Turon River system. The upper Turon River flows in a north-west direction joining the Macquarie River north of Bathurst.

5.5 Land Use and Ownership

Predominantly, activities within the Project Boundary are associated with the existing operations of Cullen Valley Mine and Invincible Colliery, rural land uses and recreational activities within the Ben Bullen State Forest. Land use in the wider region also includes other mining operations as well as agricultural and forestry activities. The township of Cullen Bullen is located on the Castlereagh Highway to the south-west of Cullen Valley Mine and the north-west of the Invincible Colliery.

5.6 Climate

A meteorological station was operated at the Invincible Colliery between 1999 and 2002, although in that time, a continuous 12 month data set was not obtained. Since recommencement of open cut mining at Invincible Colliery in September 2006, the collection of data from the meteorological station has been continuous. However, site collected rainfall data is currently not sufficient to calculate the long term yearly average owing to the short duration of available measurement.

In addition to the data collected from the Invincible Colliery meteorological station, data has also been derived from the Bureau of Meteorology (BoM) weather stations located at Portland (Station No. 063071), Lidsdale (Station No. 063132), Lithgow (Station No. 063164) and the Bathurst Agricultural Research Station (Station No. 063005). The BoM weather stations are located approximately 6.7km, 10.1km, 29.2km and 55km (respectively) away from Cullen Bullen. The locations of the BoM stations are summarized in Table 1.

Table 1: SUMMARY OF WEATHER STATION DATA

Name	Station Number	Data	Latitude	Longitude	Elevation
Portland	063071	Rainfall	33.35° S	149.99° E	925m
Lidsdale	063132	Rainfall	33.38° S	150.08° E	890m
Lithgow	063164	Rainfall	33.56° S	150.11° E	762m
Bathurst Agricultural Research Station	063005	Pan Evaporation	33.43° S	149.56° E	713m

Monthly rainfall data was obtained from each of the BoM weather stations. The nearest BoM weather station to Cullen Bullen that records pan evaporation is located at the Bathurst Agricultural Research Station.

The climate of the region is defined by its latitude, inland location, and the steep ridge and valley escarpments typical to the western slopes of the Great Dividing Range. Generally, the climate is cool-temperate, characterised by relatively mild summers and cold winters. Rainfall patterns are summer dominant. Fog and frost are common in cooler months, although a range of factors including the ridge and valley topography, altitude, aspect and exposure result in some localised temperature variations across the Project Boundary. Temperature inversions are common in winter months, tending to occur on frosty mornings and on days when fogs are present.

A summary of climate data from nearby BOM stations is provided in Table 2.

Table 2: SUMMARY OF BoM CLIMATIC DATA

Month	**Average Monthly Rainfall (mm)**			**Average Monthly Pan Evaporation (mm)**
	Portland (1904-2011)	**Lidsdale (1959-2011)**	**Lithgow (1959-2011)**	**Bathurst Agricultural Research Station (1908–2011)**
January	77.2	86.3	98.6	210.8
February	64.9	77	84.7	162.4
March	57.2	61.5	74.1	139.5
April	45.2	43	56.5	87
May	47.9	51.5	55.1	52.7
June	54.8	48.6	59.6	33
July	56.2	52.3	52.2	37.2
August	58.8	66.5	65	55.8
September	51.2	53.7	57.4	84
October	67.2	70	71.3	124
November	62.7	72.4	72.5	156
December	60.7	72.9	79.6	201.5
Total	**702.7**	**766.4**	**830.6**	**1343.9**

The average annual rainfall at Lidsdale is 766mm with January typically being the wettest month. Evaporation of about 1350mm/year exceeds rainfall throughout most of the year except for the winter months of June, July and August.

Monthly rainfall records were used to calculate the Cumulative Rainfall Departure (CRD) (Brendenkamp et al., 1995), also referred to as the Rainfall Residual Mass (Griffin, 1963), for the Lidsdale weather station. The CRD graph is shown in Figure 5. The CRD is a summation of the monthly departure of rainfall from the long term average monthly rainfall and provides a historical record of relatively wet and dry periods. A rising trend in slope in the CRD plot indicates periods of above average rainfall, whilst a declining slope indicates periods when rainfall was below average.

The CRD for the area near Cullen Bullen indicates a long cycle of below average rainfall from about 2000 to 2007 as indicated by the falling trend in the graph. From about 2007 to present, the CRD indicates that rainfall patterns have returned to about average conditions.

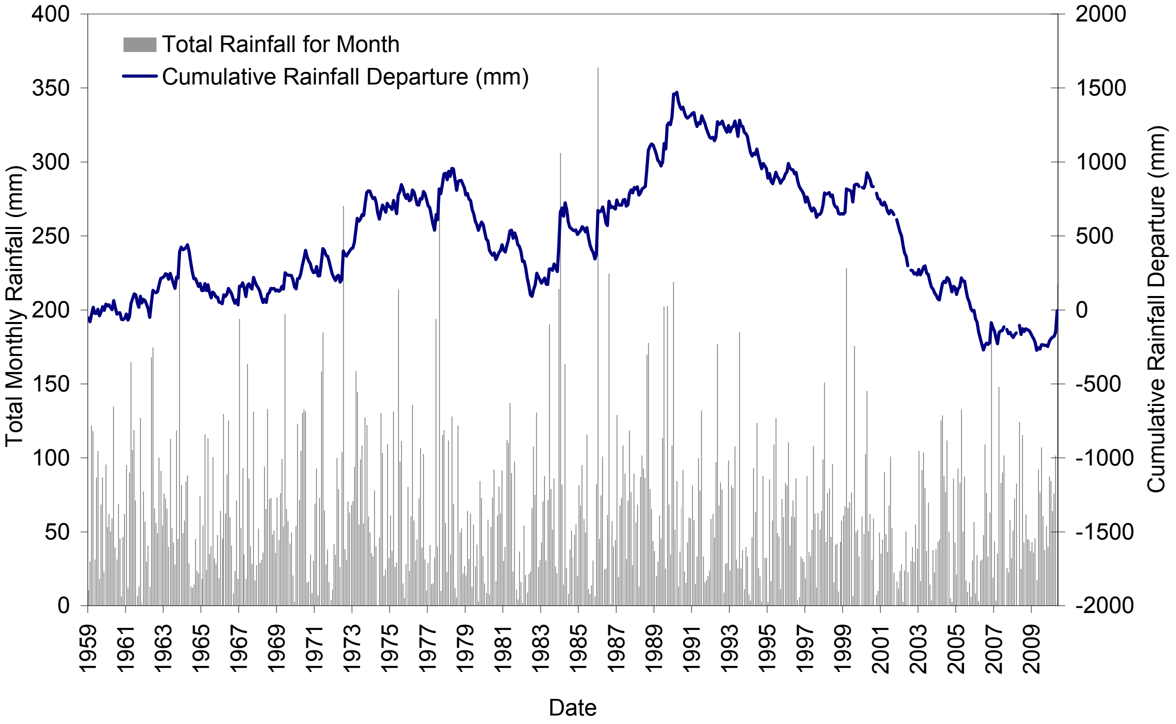

Figure 5: Cumulative Rainfall Deficit – Lidsdale Weather Station (mm)

5.7 Geology

The Project is located within the Western Coalfields of NSW, which is geologically located on the western edge of the Sydney Basin. The Sydney Basin consists of a series of gently dipping sedimentary beds of shale and sandstone of Permo-Carboniferous age capped by massive sandstones of Triassic Age (Yoo, et al. 2001). Directly beneath the Triassic sandstone, these beds contain coal seams and form the Upper Coal Measures. The measures extend from the western boundary of the Western Coalfields in an easterly direction, dipping gently at an angle of 1°-3° to the north-east, towards the coast, and extending out to sea.

The Western Coalfields are characterised by prominent cliffs and eroding plateaus of the Triassic age sandstone and shale of the Narrabeen Group. This group overlies the shale, sandstone, conglomerate and coal of the Permian aged Illawarra Coal Measures, which form the eroded slopes that fall away from the sandstone and shale cliffs.

The Western Coalfield extends from the south of Lithgow to north of Ulan and is bounded to the west by outcroppings of the Lithgow Coal Seam, the deepest coal seam of the measures. There is no defined eastern boundary, given the dipping of the coal measures to the north-east below the Hawkesbury Sandstone of the Blue Mountains.

The basement rocks of the western Sydney consist of folded Palaeozoic metamorphosed rocks of the Lachlan Fold Belt, Late Carboniferous granites and Early Permian Rhylstone Volcanics (Yoo, et al. 2001). The local stratigraphy is summarised in Table 3. The regional geology is shown in Drawing No. 6.

Table 3: MIDDLE PERMIAN TO TERTIARY STRATIGRAPHY OF THE WESTERN COALFIELD
(Yoo, et al. 2001)

Period	Stratigraphy			Lithology	Coal Seams
	Group	Subgroup	Formation		
Tertiary			Basalt	Basalt	
Triassic	Wiannamatta		Ashfield Shale		
	Hawkesbury Sandstone				
	Narrabeen Group	Grose Subgroup	Burralow Formation		
			Banks Wall Sandstone		
			Mt York Claystone		
			Burra-Moko Head Sandstone		
			Caley Formation	Sandstone	
Permian	Illawarra Coal Measures	Wallerawang Subgroup	Farmers Creek Formation	Coal, sandstone, claystone, siliceous claystone	Katoomba Seam
					Middle River Seam
			Gap Sandstone	Sandstone	
		Charbon Subgroup	State Mine Creek Formation	Coal, mudstone, claystone	
			Moolarben Coal Member	Coal	Moolarben Seam
			Watts Sandstone	Sandstone	
			Denman Formation	Interbedded mudstone/sandstone, claystone, mudstone	
			Glen Davis Formation	Coal and claystone bands	Upper Upper Irondale Seam
					Middle Upper Irondale Seam
					Upper Irondale Seam
			Newnes Formation	Coal, sandstone	
			Irondale Formation	Coal	Irondale Seam
			Long Swamp Formation	Interbedded shale, siltstone and sandstone	
		Cullen Bullen Subgroup	Lidsdale Coal	Coal, tuff	Lidsdale Upper Seam
					"Tuffaceous Marker"
					Lidsdale Lower Seam
			Blackmans Flat Formation	Claystone	
			Lithgow Coal	Coal and claystone bands	Lithgow "Tops"
					Lithgow Seam Pillar
			Marrangaroo Formation	Sandstone, conglomerate	
		Nile Subgroup	Gundangaroo Formation	Coal, sandstone claystone	
			Coorongooba Creek Sandstone	Sandstone	
			Mount Marsden Claystone	Claystone	
	Shoalhaven Group		Berry Siltstone		
			Snapper Point Formation		

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The coal seams of the Illawarra Coal Measure are those targeted by the existing operations of Cullen Valley Mine and Invincible Colliery and this is anticipated to continue for the Project. There are seven identified coal seams in the Illawarra Coal Measures, which in descending stratigraphical order are as follows:

- Katoomba Seam;
- Middle River Seam;
- Moolarben Seam;
- Upper Irondale Seam;
- Irondale Seam;
- Lidsdale Seam; and
- Lithgow Seam.

The Lithgow Coal Seam outcrops to the east of the Castlereagh Highway within the vicinity of Invincible Colliery and to the west of Castlereagh Highway within the vicinity of the Cullen Valley Mine. The thickness of the Lithgow Coal Seam ranges from 3.6m down to 0.1m within the Project Boundary. The Lidsdale Coal Seam immediately overlies the Lithgow Coal Seam over the majority of the lease and is typically separated by a distinctive band known as the Blackman’s Flat Conglomerate. The Lidsdale Coal Seam is typically about 0.7m to 1.5m in thickness. The Irondale Coal Seam occurs between 15m and 20m above the Lithgow Coal Seam. The Irondale Coal Seam is separated from the Lidsdale/Lithgow Coal Seam by the Long Swamp Formation which is comprised of interbedded shales, siltstone and sandstone. The workable thickness of the Irondale Coal Seam at the Invincible Colliery varies from 1.5m to 2.3m. The Irondale Coal Seam consists of bands of bright and dull bituminous coal, separated by thin claystone bands.

As occurs elsewhere in the Western Coalfield north of Blackmans Flat, the Lithgow and Lidsdale Coal Seams tend to merge over the Project Site. The Lithgow Coal Seam has been worked extensively in the vicinity of Invincible Colliery by historic underground and open cut workings in addition to current operations; however, mining of the Irondale Coal Seam has only occurred relatively recently.

The Coxs River Lineament Fault Zone follows the valley of the Coxs River and has been identified by seismic surveys at Baal Bone Colliery. The fault zone is a north-south trending graben structure, about 250m wide. The displacement on the eastern structure is about 4-5m, up to the east. The western fault shows a lesser displacement in the seismic survey in the order of 2m. Between these two faults, the seismic data indicates other smaller faults exist, in conjunction with brecciation of the strata (Connell Wagner, 2006).

The Marrangaroo Formation is located immediately beneath the Lithgow Coal Seam (typically separated by carbonaceous mudstone) and crops out persistently throughout the Western Coalfield, ranging in thickness from 2m to 16m. The formation commonly has a sharp erosive basal contact with silty and coaly sedimentary rocks of the Nile Subgroup or sandy siltstone of the Berry Siltstone.

6.0 FIELD INVESTIGATION PROGRAM

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

- construction of five groundwater monitoring bores (piezometers) within the Lithgow Coal Seam (3) and the Marrangaroo Formation (2);
- measurement of groundwater levels in the new monitoring bores;
- collection of groundwater samples from the monitoring bores for water quality analysis; and
- the undertaking of falling head tests within each of the monitoring bores.

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

6.1 Groundwater Monitoring Network

Drilling and installation of the groundwater monitoring network was undertaken between December 2010 and January 2011. Five monitoring bores were constructed in exploration drill holes as part of the hydrogeological investigation program. The sites were selected to provide sufficient spatial coverage over the area proposed to be mined for the Project, as shown in Drawing No. 7. The original exploration bore number was also used to identify each monitoring bore. Key details of the monitoring bore network are summarised in Table 4.

Table 4: MONITORING NETWORK DETAILS

Drill Hole ID	Hole Depth (mbgl)	Screen (mbgl)	Screen Zone Geology
CP114	41.9	36.9 – 41.9	Marrangaroo Formation (sandstone/conglomerate)
CP115	71.2	68.2 – 71.2	Lithgow Coal Seam
CP116	56.8	53.8 – 56.8	Lithgow Coal Seam
CP119*	73.1	70.1 – 73.2	Lithgow Coal Seam
CP123	36.5	33.5 – 36.5	Marrangaroo Formation (sandstone/conglomerate)

Note: mbgl = metres below ground level
* denotes the bore was potentially damaged during installation

In the short term, the monitoring bores were designed to provide water quality information and water level data for the assessment of potential impacts associated with the Project. In the long term, the bores provide locations for monitoring the impact of the Project on groundwater levels and quality during mining. Most of the bores are located within the proposed mining footprint and will therefore be removed during mining; however prior to this, each bore will provide information on any potential impacts on the groundwater regime as a result of the Project.

6.2 Monitoring Bore Construction

The monitoring network was constructed in holes drilled for exploration purposes. Photographs of each of the monitoring bores are included in Appendix 1. The holes were drilled either by coring (96mm OD HQ size) or rotary air blast (150mm OD). Each hole was drilled and logged under the supervision of a Coalpac geologist. The lithological and geophysical logs were then supplied to an

AGE hydrogeologist to design each monitoring bore. The installation of the monitoring bores was undertaken by M.T. McKechnie Drilling services under the supervision of a Coalpac geologist. The details of each monitoring bore were provided to NOW by Coalpac at the conclusion of the installation program. Monitoring bore construction logs are included in Appendix 2.

The boreholes were cased with Class 18, 50mm 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, 3-6mm gravel filter was placed by gravity around the screens and a bentonite seal (1/4" 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 were placed over each of the monitoring bores. Table 5 summarises the construction of the monitoring bores, with more detailed borehole logs included in Appendix 2.

After construction, the monitoring bores were developed using the airlift method, yields permitting, until all drilling fluids were removed and clear sediment free water was being produced. . Of note, monitoring bore CP119 was potentially damaged during installation and bore remained dry after construction. CP119 was filled with clean water following the installation to confirm if it was indeed damaged. The water injected into CP119 fell very slowly over the following 3 months until it stabilised. It is still currently unknown if the bore is damaged; however, results from this bore should be used with caution.

Table 5: MONITORING BORES WATER LEVEL DATA

Bore ID	Target Aquifer	Coordinates		Ground Level (mRL)	TOC (mRL)	Screen Zone (mRL)	Static Water Level		
		Easting (MGA94, z56)	Northing (MGA94, z56)				Date	mbTOC	mRL
CP114	Sandstone	223718.4	6316033.9	905.1	905.2	868.2 - 863.2	27/1/11	36.3	869.7
CP115	Coal	223329.9	6313644.1	950.4	950.5	882.2 - 879.1	27/1/11	58.7	891.8
CP116	Coal	222675.5	6314782.7	941.8	942.6	888.0 - 885.0	27/1/11	50.6	891.9
CP119*	Coal	225710.0	6313323.6	943.8	943.8	874.8 - 870.8	27/1/11	Dry	Dry
CP123	Sandstone	224969.4	6308929.7	926.3	-	882.2 - 879.1	27/1/11	33.0	892.4

Notes: mbTOC – metres below top of casing
mRL – metres Australian Height Datum
Screen zone from base of borehole to top of bentonite/cement seal
Coordinate Projection - MGA94, Zone 56
* denotes the bore was potentially damaged during installation

6.3 Water Sample Collection and Analysis

Groundwater samples were collected by Hydroilex Geological Consultants after development of the monitoring bores. The samples were subsequently analysed by Envirolab Services Pty Ltd.

The groundwater samples were analysed for:

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- general parameters:
  - pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and hardness as $CaCO_3$.
- major ions:
  - cations – sodium (Na), potassium (K), calcium (Ca), magnesium (Mg); and
  - anions – chloride (Cl) and sulphate (SO_4), bicarbonate (HCO_3) and carbonate (CO_3).
- selected metals :
  - aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, selenium, silver, thallium, thorium, tin, uranium, vanadium, zinc and bromine.
- other parameters:
  - nitrate, nitrite, phosphate and fluoride.

The results of the laboratory testing are presented and discussed in Section 7.5.3.

6.4 Permeability Tests

Hydraulic (falling head) permeability tests were conducted in the monitoring bores as part of field investigations. The tests were designed to evaluate the hydraulic conductivity of aquifer material surrounding the bore screen. The falling head tests were conducted by inserting a “slug” of water into each bore which resulted in an almost instantaneous rise in water level within the bore. The subsequent rate of decline in the water level was recorded with pressure transducers. The falling head data for each monitoring bore tested is included in Appendix 3. The data were analysed by the Hvorslev Method (1951) and the Bouwer and Rice Method (1976) using Aquifer Test Version 2.5 software. The results of the analyses are summarised in Table 6 and discussed in more detail in subsequent sections of this report.

Table 6: FALLING HEAD TEST RESULTS

Bore ID	Aquifer	Hydraulic Conductivity	
		m/sec	m/day
CP114	Marrangaroo Formation	7.79×10^{-8} (i) 8.44×10^{-8} (ii)	6.89×10^{-3} (i) 7.29×10^{-3} (ii)
CP115	Lithgow Coal Seam	4.03×10^{-7} 3.30×10^{-7}	3.48×10^{-2} 2.85×10^{-2}
CP116	Lithgow Coal Seam	7.79×10^{-7} 8.51×10^{-7}	6.89×10^{-2} 7.35×10^{-2}
CP123	Marrangaroo Formation	4.38×10^{-9} 4.97×10^{-9}	3.78×10^{-4} 4.29×10^{-4}

Note i = Bouwer-Rice Method (1976)
ii = Hvorslev Method (1951)

The results from the falling head test conducted in CP119 have not been included within the analysis owing to uncertainty regarding the bores construction integrity.

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7.0 HYDROGEOLOGICAL REGIME

7.1 Previous Groundwater Investigations

In order to provide a regional understanding of the groundwater system, a literature review was undertaken. This included a review of previous EA's compiled for the Invincible Colliery and Cullen Valley Mine. The review also included publicly available documents such as EA's and Annual Environmental Management Reports (AEMR) for surrounding mining operations.

Invincible Colliery and Cullen Valley Mine have not previously had a groundwater monitoring program in place (except for the monitoring of groundwater discharge quality, a licence requirement); therefore very limited site specific historical data is available for groundwater levels, and in-situ groundwater chemistry. The previous EA's for the Invincible Colliery and Cullen Valley Mine have provided indicative descriptions of the hydrogeological regime.

The most detailed previous assessment of the groundwater regime of the Project Boundary was undertaken for the Invincible Colliery (RW Corkery, 2008) to gain government approval for the continued development of the coal deposit. This EA provides comments regarding the hydrogeological regime and suggests that the impacts on the regime resulting from the mine would be relatively limited.

A hydrogeological assessment of the groundwater regime surrounding the expansion of the Baal Bone Colliery was undertaken by Connell Wagner (2006) and comprised a characterisation of the site hydrogeology and hydrology. The Baal Bone Colliery hydrogeological assessment focused on predicting the impacts from underground mining activities on the groundwater regime. The assessment identified that coal measure aquifers (i.e. the coal seams) would almost certainly be drained into the goaf void left behind after longwall mining; however, the assessment concluded that any overlying regional aquifers (i.e. the Triassic Narrabeen Group) would experience limited long term impacts due to mining. The assessment also concluded that the risk of significant changes to the groundwater regime in the vicinity of the Coxs River Swamp was low for the assessed mine plan.

A groundwater assessment was undertaken by Aquaterra (2009) for the proposed extension of the existing Pine Dale Coal Mine located to the south of the Invincible Colliery. The assessment identified that the main groundwater source within the mine was the water stored in the old Wallerawang Colliery underground workings. The report estimated that approximately 8,800ML of water was stored within these workings. The impacts of open cut mining on the groundwater regime were assessed with an analytical model which indicated that groundwater drawdown would occur in the Lithgow Coal Seam. However, the assessment predicted that no adverse impacts would occur on adjacent licensed groundwater users.

A groundwater assessment was undertaken by Aurecon (2010) for the proposed extensions of the modification to the Angus Place Project located to the west of the Invincible Colliery. The assessment identified that the subsurface strata comprised mostly of sandstones of the Triassic Narrabeen Group. The Banks Wall Sandstone was identified as a critical local groundwater resource and was found to be up to 200m thick in this region. Ongoing monitoring indicated that the coal measure stratum above the Lithgow Coal Seam has been partially drained of groundwater by previous mining in the area during the past century of operations. Although there has been drainage of coal measure strata, the impact of previous mining on the groundwater regime in the overlying Banks Wall Sandstone Formation above the Mount York Claystone appeared to be negligible. The assessment concluded that that there would be no impact on the aquifers in the Banks Wall Sandstone, and hence there would be no impact on the quality or quantity of the available groundwater resources in this rock unit.

Relevant information from the above reports is provided in the following discussion of the hydrogeological regime.

7.2 Hydrogeological Units

Based on the review of existing data, a conceptual model of the hydrogeological regime has been developed. This section of the report discusses the conceptualisation and the data used to develop this model.

The conceptual groundwater model of the Project was developed based on geological and topographical maps of the area, geological information supplied by Coalpac, and on the results of previous studies.

The groundwater regime can be considered as an independent system encompassing the area between:

- the outcrop of the Illawarra Coal Measures, this being the Lithgow Coal Seam and the Marrangaroo Formation in the west – near the Castlereagh Highway;
- the outcrop areas of the upper Illawarra Coal Measures in the east, these being the coal seams located stratigraphically above the Lithgow Coal Seam – at the escarpment near Ben Bullen Creek and the Wolgan Valley;
- the watershed north of the proposed mining area (near the Baal Bone Rail-loop cutting) which is likely to act as a groundwater divide; and
- the watershed south of the proposed mining area (near Blackmans Flat and the Pine Dale Mine) which is likely to act as a groundwater divide.

Alluvial deposits within this area are present along Coxs River and Neubecks Creek; however, these deposits are limited in areal extent and thickness. Similarly, the Triassic Narrabeen Group (previously identified to contain groundwater resources in areas adjacent to the Project Boundary) is also limited in extent within the Project Boundary as these units have been largely removed from the stratigraphic profile by erosion. Weathering of the upper units directly below the ground surface has resulted in clay-bound sediments which are expected to produce a weathered zone of moderately low hydraulic conductivity.

Underlying the Narrabeen Group are the Permian Illawarra Coal Measures. The coal measures are not considered to be a significant aquifer. While some coal seams may show an elevated hydraulic conductivity, the interburden sections separating the coal seams have a lower hydraulic conductivity. Similar to that of the Narrabeen Group, the upper sections of the Illawarra Coal Measures have also been largely removed by long-term erosion within the Project Boundary. Occurrence and flow of groundwater within the coal seams are governed by the aperture and the degree of interconnection in the cleat network. Groundwater flow in the interburden is controlled by the presence of micro faults, joints, fractures and bedding planes which are often locally discontinuous. Zones of low strength porous sandstones can also occur in the underlying Marrangaroo Formation. Therefore, from a conceptual groundwater model perspective, the groundwater system in the area immediately surrounding the EA boundary is considered to consist of four aquifer systems, including:

- Quaternary alluvium;
- Triassic overburden sediments (sandstone) of the Narrabeen Group;

- coal seams within the Permian Illawarra Coal Measures – (e.g. Irondale Coal Seam, Lidsdale Coal Seam and Lithgow Coal Seam); separated by Permian interburden sediments that act as aquitards (e.g. claystone, mudstone, siltstone and sandstone bands present between the coal seams); and
- the underlying Marrangaroo (sandstone/conglomerate) Formation.

The following sections characterise the different aquifer systems and discuss the available data.

7.3 Alluvial Aquifers

Unconsolidated silts and sand are associated with the Coxs River Swamp, Jews Creek Swamp and Neubecks Creek. Where present, saturated zones are likely to be laterally discontinuous and to occur in relatively isolated pockets, in undisturbed areas such as the Coxs River Swamp (to the east) and Jews Creek Swamp (to the north), and to a lesser extent on the undisturbed ridges. Perched groundwater in these areas is likely to occur in unconsolidated sands, silts and in particular, peat which has a high water retention capacity. Coxs River is located 5.5km to the east of the Project Boundary. Monitoring bore data indicates the thickness of the alluvial material within the Coxs River Swamp ranges from about 6m to 7m.

Neubecks Creek flows from Blackmans Flat (approximately 2.5km south of the Project Boundary) in an easterly direction and is associated with deposition of recent fluvial material. Historic mining along much of the Neubecks Creek valley has led to the alteration of drainage patterns, with much of Neubecks Creek, notably in the Pine Dale Coal Mine area, flowing directly over mine ‘fill’ or ‘spoil’. Monitoring bores installed at the Pine Dale Mine indicate the thickness of the alluvial material ranges from approximately 8m to 10m.

Hydraulic connectivity between the local creeks and underlying Permian strata is considered limited where siltstone and shales are present and higher if directly in contact with minor coal seams or sandstones.

Further investigation of the alluvial groundwater systems was not considered necessary for this assessment owing to their distance from the Invincible Colliery and Cullen Valley Mine (about 4km and 6.5km respectively), their isolated nature and minimal thickness. Hydrogeological assessments undertaken by Aquaterra (2009) and Aurecon (2010) concluded that mining operations located within the immediate vicinity of each of the identified alluvial areas would not result in adverse groundwater impacts, and therefore these aquifers are not considered further in this assessment.

7.4 Triassic Overburden Sediment Aquifers

The Narrabeen Group is the dominant geological unit that outcrops within the Western Coal Fields however, within the Project Boundary it occurs predominantly as ridge tops. The Narrabeen Group contains multiple layered water-bearing zones contained within the Banks Wall Sandstone and the Burra-Moko Head Sandstone underlain by fine grained aquicludes. The water-bearing zones of the Banks Wall Sandstone have been intersected in exploration bores drilled at Baal Bone to the east of the EA boundary, however these units are largely absent within the Project Boundary.

The groundwater systems within the Narrabeen Group of sediments are complex with perched water tables and semi-confined leaky aquifers separated by relatively impermeable claystone layers (Bish, 1999). The water bearing units of the Narrabeen Group have dual porosity characteristics with reported low flow inter-granular primary porosity (<10^{-8}m/s) and greater secondary porosity provided by fractures, bedding partings and fissures within the strata.

The occurrence of the Narrabeen Group within the Project Boundary is best illustrated by a series of cross-sections as show in Figure 6 to Figure 12. The positions of seven cross-section lines (A-A' to G-G') in the context of the Project are also illustrated on Drawing No. 8. The bearing of each cross-section is about perpendicular to the strike of the strata. The cross-sections illustrate that the occurrence of the Narrabeen Group in the north of the Project Boundary is limited only to ridge areas but progressively becomes more dominant towards the south. The thickness of the Narrabeen Group near the south of the Project ranges up to about 100m over the Invincible Colliery. However, the thickness of the Narrabeen Group overburden within the Project is generally much less than 100m.

The water-bearing zones within the Narrabeen Group are heavily influenced by topography. The water-bearing zones in both the Banks Wall Sandstone and Burra-Moko Head Sandstone are exposed in the flanks of the Ben Bullen Creek valley (section B-B' and C-C'), Coxs River Valley (section F-F' to G-G') and in the Wolgan Valley escarpment (section C-C' to G-G') to the east, so that the groundwater flow will ultimately discharge at these locations. Discharge from the water-bearing zones occurs where the Coxs River Valley escarpment intersects the water table, so that the groundwater flow direction is essentially horizontal in the Narrabeen Group strata. Since the strata dip direction is to the north-east, and the escarpment is also located in this direction, most groundwater flow is to the north-east, although since the strata is relatively flat, there will be some local groundwater flow in a westerly direction into the Coxs River Valley. Groundwater recharge to these near-surface sandstone strata occurs almost entirely through diffuse infiltration from the ground surface. The finer grained rocks of the basal Caley Formation (located beneath the Burra-Moko Head Sandstone) limit vertical infiltration into the underlying coal measures.

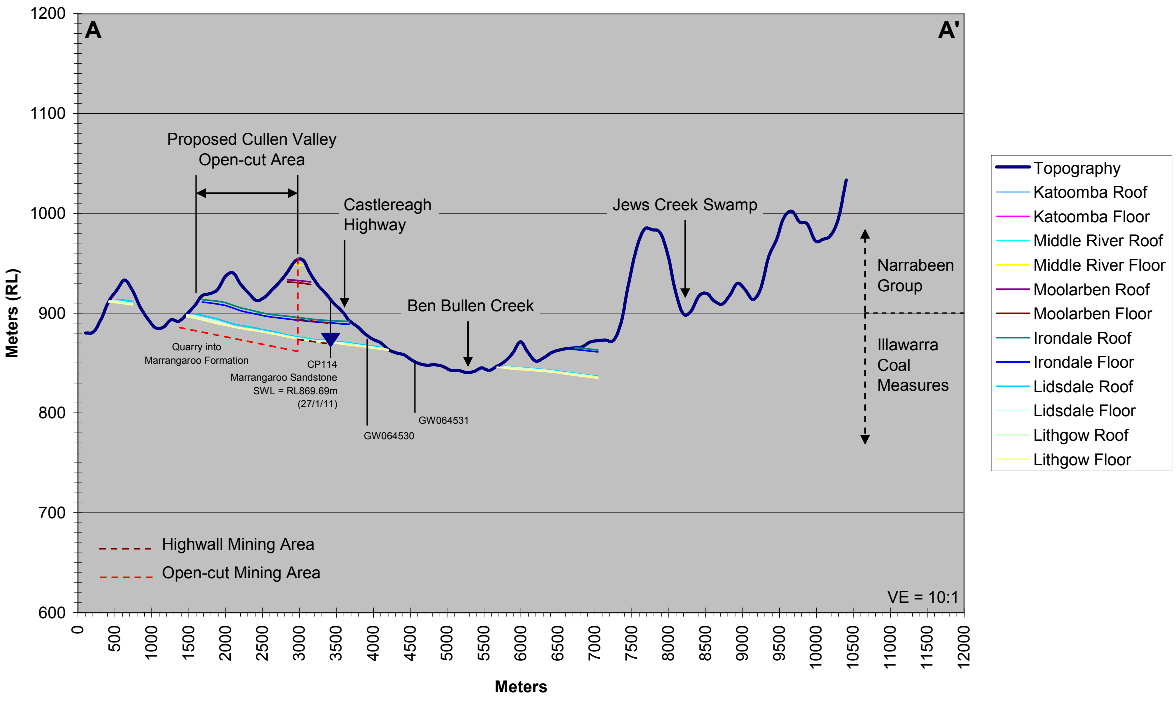

Figure 6: Cross-Section A-A'

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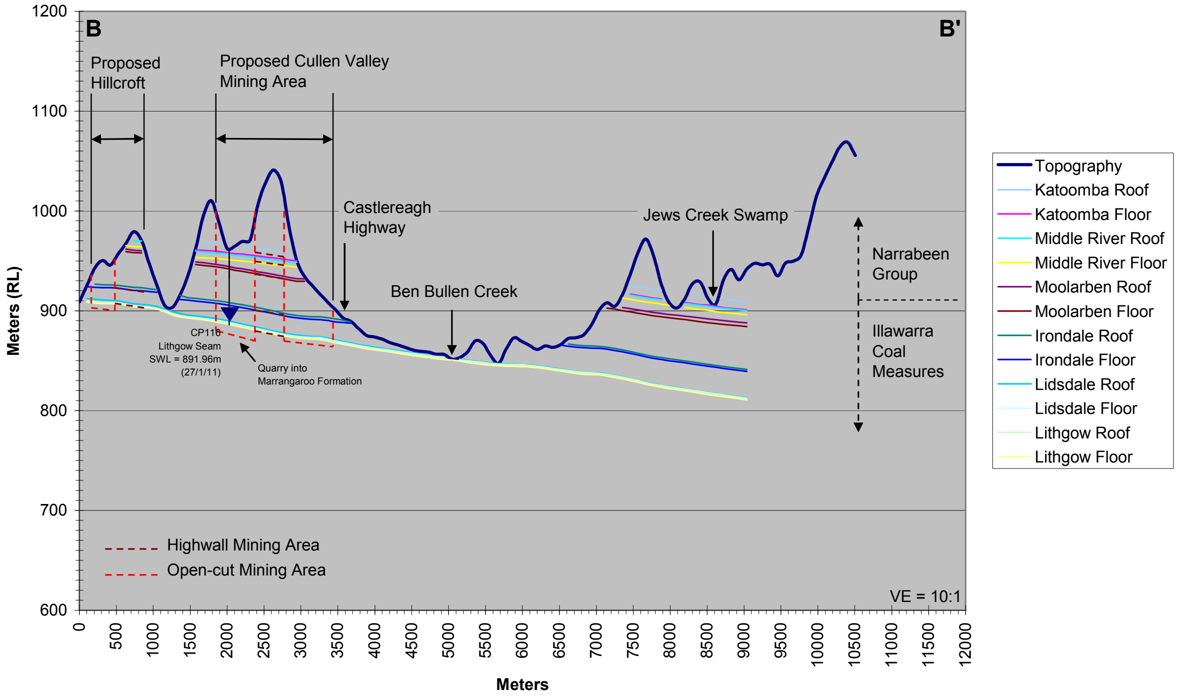

Figure 7: Cross-Section B-B'

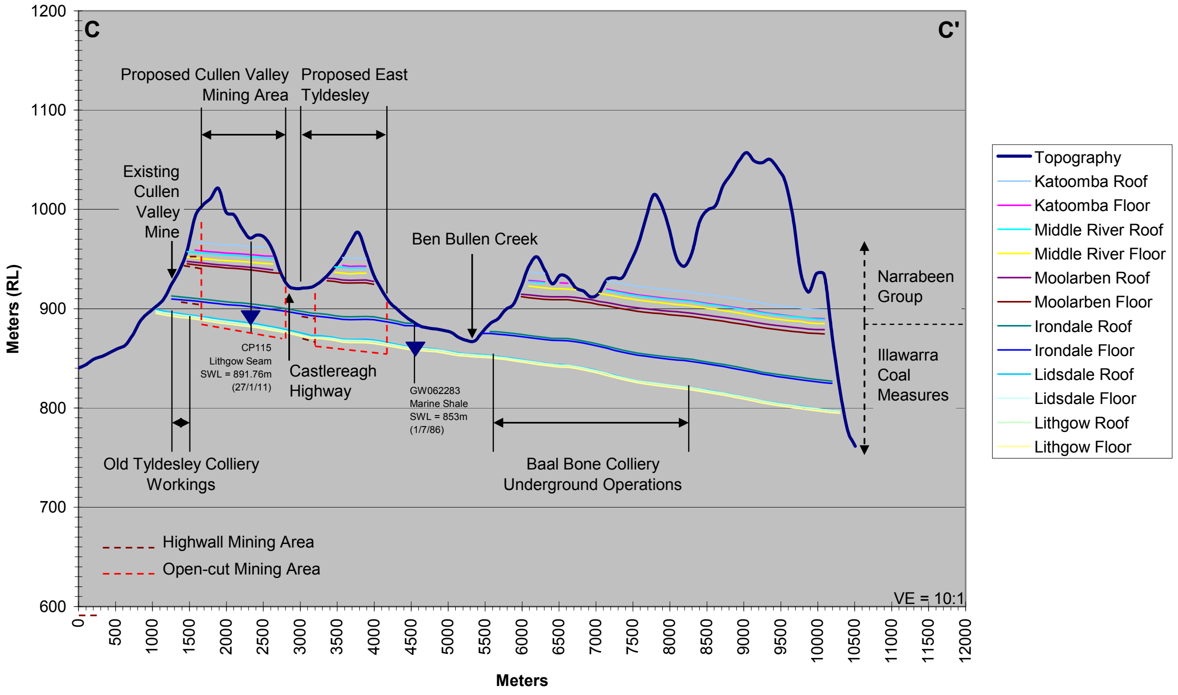

Figure 8: Cross-Section C-C'

(Project No. G1515)

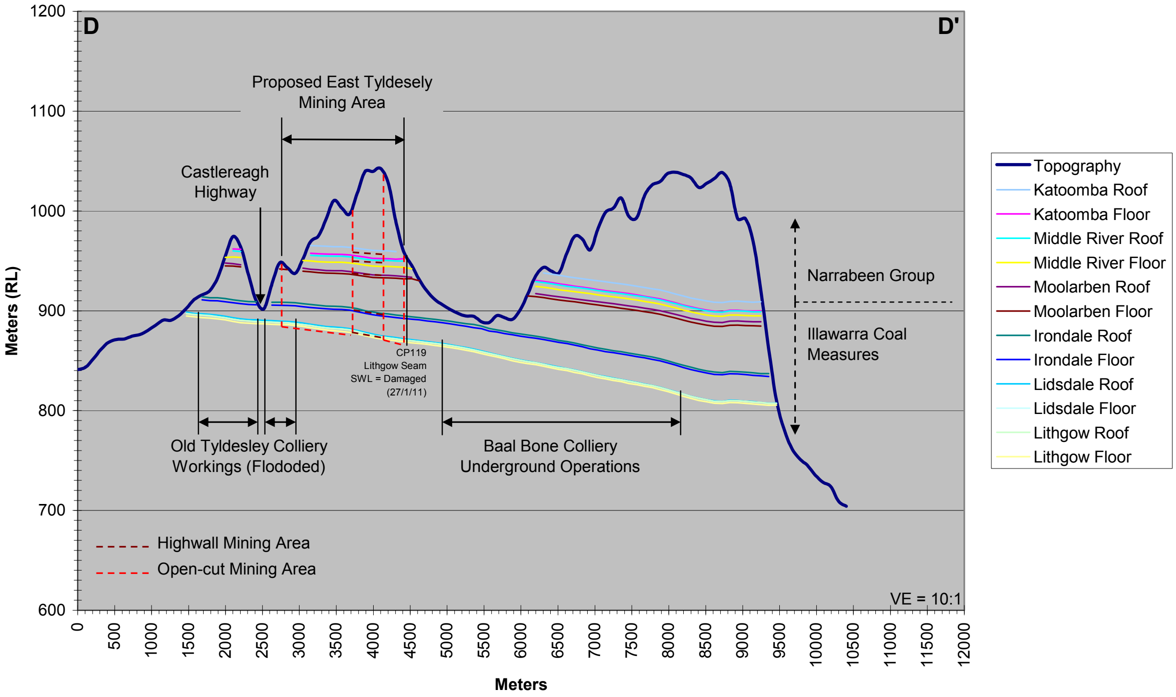

Figure 9: Cross-Section D-D'

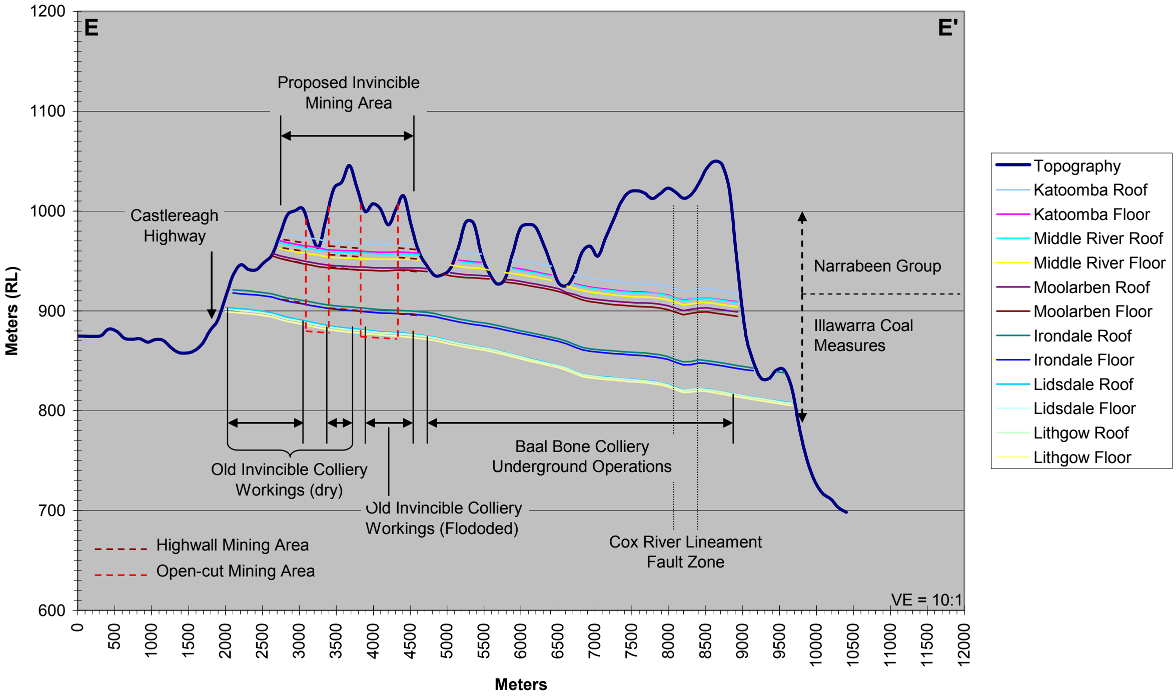

Figure 10: Cross-Section E-E'

(Project No. G1515)

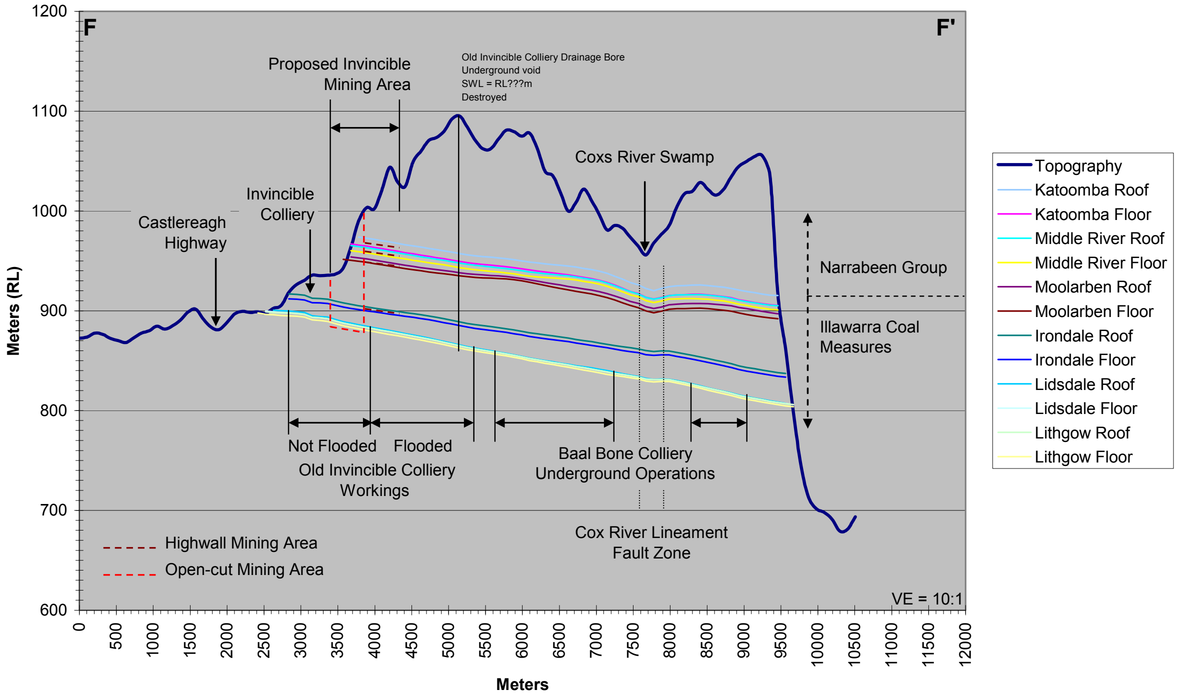

Figure 11: Cross-Section F-F'

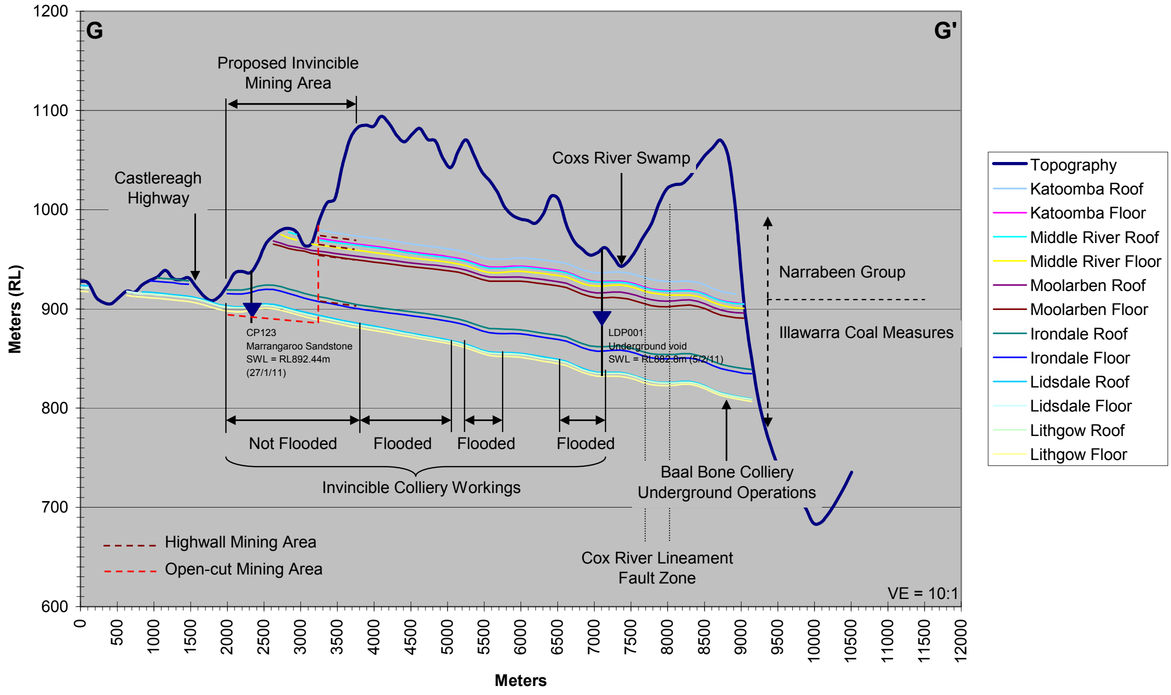

Figure 12: Cross-Section G-G'

(Project No. G1515)

7.4.1 Groundwater Dependent Ecosystems

Coxs River Swamp and Jews Creek Swamp are likely to constitute groundwater dependent ecosystems (GDEs). As described previously, these areas are located approximately 2km and 3.5km outside the Project Boundary, respectively. No GDEs have been identified within the Project Boundary. The location of the Coxs River Swamp and Jews Creek Swamp are shown on Drawing No. 8.

Groundwater contribution to Coxs River Swamp and Jews Creek Swamp is likely to be sourced from vertical infiltration into the overlying sandstone units within the Triassic Narrabeen Group exposed in the adjacent ridges (Connell Wagner, 2006). At various depths in the sandstone are thin layers of claystone, or tightly cemented sandstone, which are relatively impervious to vertical groundwater percolation and form aquitards. The groundwater preferentially flows laterally above the aquitards until it reaches the edge of the impervious layer, which has been exposed by geological erosion in an adjacent valley. At this point the seepage is discharged into the swamp.

The Baal Bone Colliery currently monitors six bores (BBP1-BBP6) within the Coxs River Swamp area as shown on Drawing No. 7. Each of the monitoring bores is shallow with depths ranging between 2.7m and 15m as shown in Table 7.

Table 7: BAAL BONE COLLIERY (COX RIVER SWAMP) MONITORING DETAILS

Monitoring Bore ID	Depth of Bore (mbgl)	Elevation of Measurement Point (mRL)	Easting (MGA94, z56)	Northing (MGA94, z56)
BBP1 – GW108939	12.2	965.16	229920	6312320
BBP2 – GW108932	14.2	956.64	229739	6312080
BBP3 – GW109018	12.2	951.34	229847	6311364
BBP4 – GW108881	15.0	943.44	229580	6311150
BBP5 (Swamp)	3.6	942.91	229637	6311369
BBP6 (Swamp)	2.7	953.14	229671	6311952

Groundwater levels are recorded within each of the monitoring bores on a three-hourly basis. This data has been reduced by Xstrata to a daily average water level for each bore which is presented in Figure 13. Groundwater level data for the Baal Bone Colliery monitoring bores was provided to Coalpac by Xstrata for the period from 2007 to present.

The groundwater level data presented in Figure 13 illustrates the elevation of the groundwater table near the Coxs River Swamp ranges between RL956m and RL937m. The groundwater levels indicate the swamp system is elevated and perched above the aquifer in the Permian Coal Measures.

An assessment of the groundwater level fluctuations observed within the Baal Bone monitoring bores is outside the scope of this report; however, they were previously assessed as part of the Baal Bone Colliery 2009 Annual Environmental Management Report (AEMR). The 2009 Baal Bone AEMR presented four possible scenarios for the groundwater level fluctuations observed within BBP1 and BBP2. The AEMR postulated that they were most likely the result of movement on major fault zones, where small movement resulting from underground mining may have triggered relaxation and the formation of fractures. It appears that the anomalous fluctuations were only temporary in BBP2, and appear to be permanent in BBP1.

The data presented in Figure 13 suggests that some minor water level decline was observed in the Coxs River Swamp following the groundwater level fluctuations, although this impact appears to have been only temporary with water levels in the swamp currently at historical average levels.

The groundwater level variations observed that the Baal Bone monitoring bores is unlikely to be the result of mining activities at the Invincible Colliery or Cullen Valley Mine.

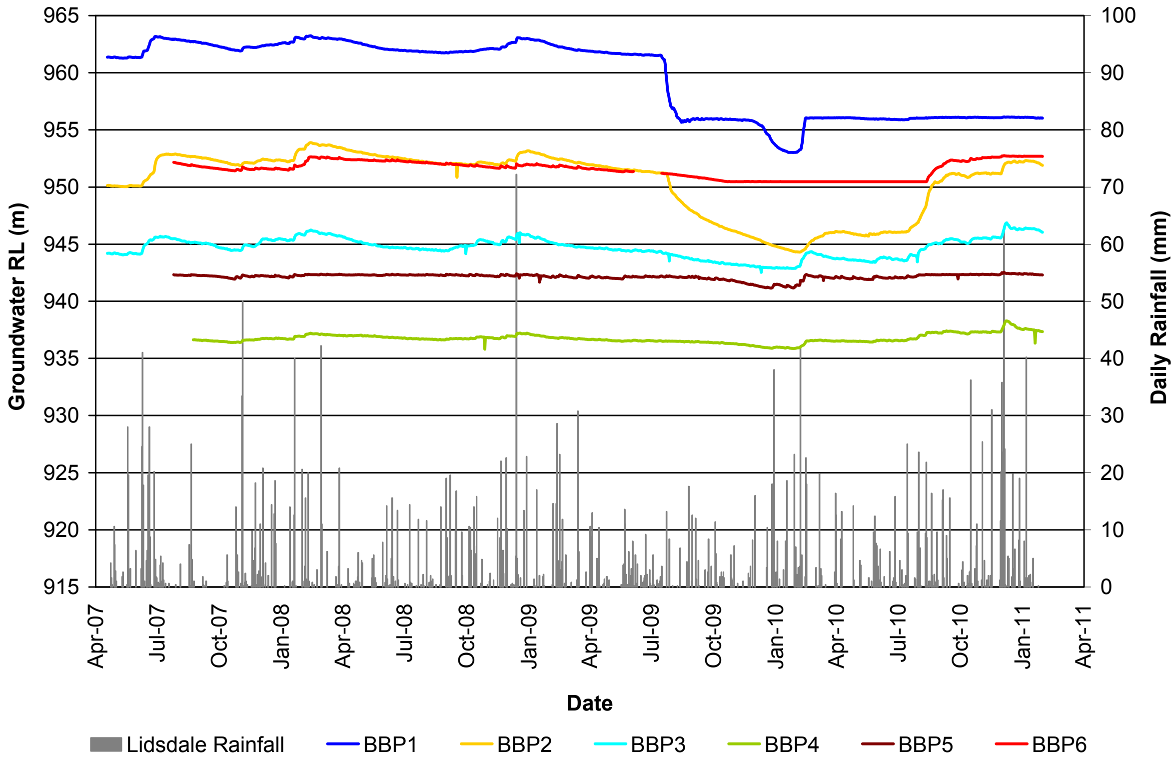

Figure 13: Groundwater Levels near Coxs River Swamp (source: Xstrata)

Water collected by the Baal Bone Colliery within the underground workings is discharged into Jews Creek. Approximately 4.25ML/day is discharged (Connell Wagner, 2006). Groundwater contribution to the swamp was considered by Connell Wagner (2006) to be minor. Connell Wagner (2006) also suggested that if mine water was not discharged to Jews Creek, the swamp would return to its original state prior to the commencement of operations at Baal Bone, excluding varying climatic influence.

Previous groundwater assessments have identified that although groundwater is likely to supply a minor percentage of total water input to the swamps, the groundwater contribution is important in that it may sustain the swamp vegetation in times of prolonged drought (Connell Wagner, 2006).

7.5 Permian Coal Measure Aquifers

The data gathered from recent hydrogeological investigations undertaken at the adjacent Baal Bone Colliery and the Pine Dale Mine, indicate that that the Permian Formations at the Invincible Colliery and Cullen Valley Mine have the following properties:

- the overburden/interburden sandstones, siltstones and mudstones are tightly consolidated with little primary porosity;
- secondary porosity is greater from jointing and sometimes from localised faulting where this occurs;
- the coal seams are the main aquifers in the Permian sequence; and
- the weathered profile is largely unsaturated.

These conclusions have been confirmed with subsequent data collected from recently installed monitoring bores within the Project Boundary, and the Permian strata can be categorised into the following hydrogeological units:

- hydrogeologically “tight” and hence very low yielding to essentially dry sandstone, siltstone and mudstone that comprise the majority of the Illawarra Coal Measures;
- low to moderately permeable coal seams which are the prime water bearing strata within the Illawarra Coal Measures; and
- the underlying Nile Subgroup (underlying the Marrangaroo Formation) acts as a low permeability claystone basal unit to the overlying coal measures.

These units are discussed below.

7.5.1 Distribution

The Permian sedimentary deposits occur as a regular layered north-easterly dipping sedimentary sequence that overlie Late Carboniferous granites and folded Late Devonian strata of the Lachlan Fold Belt. The basal igneous and metamorphic units subcrop to the west of the Project Boundary (refer Drawing No. 6).

Coal seam surface elevations have been mapped by Coalpac utilising data sourced from historical exploration at the Invincible Colliery and Cullen Valley Mine and other adjacent mines on a data sharing agreement. The drilling data was used to interpolate the coal seam surfaces on a regional scale using the VULCAN software package. Seven individual coal seams have been named within the Project Boundary, with each seam splitting into a number of individual plys.

Cross-sections of the interpolated seam surface contours for the roof and floor of each of the seam groups are shown in Figure 6 to Figure 12. On a regional scale the coal seams dip gently to the north-east at an angle of 1° - 3°.

It can be seen from the cross-sections in Figure 6 to Figure 12 that the upper seams in the Illawarra Coal Measures outcrop at the Wolgan Valley escarpment. Therefore, these coal seams are limited in extent and controlled by topography. This means that the shallow coal seams have limited groundwater resource potential on a regional scale.

Historical underground mining at the Old Tyldesley Colliery, Old Invincible Colliery, the Invincible Colliery and Baal Bone Colliery have all targeted only the Lithgow Coal Seam, this being deepest seam.

7.5.2 Hydraulic Parameters

The hydraulic properties of the Illawarra Coal Measures have not previously been measured at either the Invincible Colliery or the Cullen Valley Mine. Site specific data has been collected as part of this current assessment.

Hydraulic (falling head) permeability tests were conducted in the recently constructed monitoring bores as part of field investigations which were described in Section 6.4. The results of falling head tests undertaken within the recently constructed monitoring bores within the Project Boundary indicate the Lithgow Coal Seam hydraulic conductivity ranges between 0.03m/day to 0.07m/day.

Recent groundwater investigations undertaken at the nearby Pine Dale Mine included a program of aquifer hydraulic tests (Aquaterra, 2010). Five monitoring bores were hydraulically tested by a falling head test to determine values of aquifer hydraulic conductivity. Four tests were undertaken within the Lithgow Coal Seam and one test was undertaken within the Middle River Coal Seam. Other hydraulic tests were undertaken at Pine Dale Mine in 1999 and 2004. Table 8 details the range of hydraulic conductivity values obtained from the 2010 Pine Dale Mine falling head tests and the older tests. The test results were compiled by Aquaterra (2010).

Table 8: HYDRAULIC TESTING RESULTS FOR AQUIFERS – PINE DALE MINE
(Sourced: Enhance Place Pty Ltd)

Aquifer	Hydraulic Conductivity Range (m/day)	Mean Hydraulic Conductivity (m/day)
Lithgow Coal Seam	0.002 – 8.6	0.09
Workings (Lithgow Coal Seam)	33	NA
Middle River Coal Seam	0.016 – 0.022	0.019
Goafed Areas	408	NA

NA – Insufficient number of tests to derive mean value

Limited investigations at the Springvale Colliery have shown that the strata overlying the Lithgow Coal Seam in this area has a low hydraulic conductivity of the order of 0.001m/day; however, one or two layers may have a slightly higher hydraulic conductivity up to 0.01m/day (Aurecon, 2010).

In addition, limited permeability testing undertaken at the Angus Place Mine confirmed that the three major coal seams at this location (Katoomba, Irondale and Lithgow) all have a relatively low hydraulic conductivity on the order of 0.01m/day (Aurecon, 2010).

To summarise the results above, it is evident that the Permian Coal Measures throughout the region have variable permeability. Permeability is generally higher in the coal seams and occasionally in the interburden sediments (generally sandstone, siltstone and mudstone) due to localised fracturing. The coal seams are classified as aquifers due to their relative higher permeability in comparison to the properties of the interburden sediments.

The interburden sandstones, siltstones and mudstones are typically of significantly lower permeability than the coal seams (by one or more orders of magnitude) and they generally act as aquitards. These aquitards may be locally fractured which may enhance their permeability.

7.5.3 Water Quality

Groundwater samples were collected after development of the new monitoring bores installed by Coalpac during the 2010/2011 drilling campaign. The results of the laboratory analyses are summarised in Table 9 and the laboratory reports are presented in Appendix 4. Groundwater quality was compiled and compared with the following guidelines:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000):
  - aquatic ecosystems: protection of upland river aquatic ecosystems in south-east Australia, and using the 90% protection levels for toxicants due to the modified nature of the catchment;
  - water quality for irrigation and general water use; and
  - livestock drinking water quality.
- Australian Drinking Water Guidelines (NHMRC and ARMCANZ, 1996).

The measured groundwater quality is representative of the unit which is screened by the monitoring bore, in this case, being either the Lithgow Coal Seam (CP115 and CP116), the underground workings of the Invincible Colliery (LD001), or the Marrangaroo Formation (CP114 and CP123).

The groundwater chemistry datasets demonstrate that groundwater quality is similar for both aquifers, although the sample taken from the Invincible Colliery is less saline. This is illustrated by the data presented in Table 9.

The groundwater samples collected from the Permian aquifers recorded a fresh to brackish water quality with an average EC value of about 500µS/cm. Of particular interest is the lower salinity of the sample taken from the Invincible Colliery void via the bore LD001. Anecdotal evidence suggested that the water stored within the flooded underground works was of good quality. The analytical results confirm that the water stored within the underground workings is very fresh, low salinity water with an EC value of 150µS/cm. The lower salinity of the water stored within the Invincible Colliery void is most likely the result of higher recharge rates into underground workings compared with lower recharge rates to outcrop areas of the Lithgow Coal Seam and the Marrangaroo Formation. The higher recharge rate is possibly the result of vertical fractures extending above collapsed longwall panels. Direct rainfall infiltration from surrounding areas and the existing mine pits can also enter the workings directly.

The pH of the water stored within the underground workings is slightly acidic at 5.9. Notwithstanding the low pH the water in the flooded underground, the water appears to be of good quality and does not exceed most of the guidelines listed within Table 9 (the other exception being for elevated manganese).

Table 9: GROUNDWATER QUALITY SUMMARY

Parameter	Unit	Drinking Water (ADWG)	Irrigation (ANZECC)	Stock Water (ANZECC)	ANZECC Aquatic Ecosystems (90% protection)	Monitoring Data (filtered/dissolved samples)				
						CP114	CP115	CP116	CP123	LD001
Electrical Conductivity	µS/cm	-	1250	-	**30-350**	350(i) 330(ii)	**550**(i) **370**(ii)	**840**(i) **530**(ii)	**780**(i) **940**(ii)	150(i) 130(ii)
pH		6.5 – 8.5	-	-	6.5-7.5	**6.3** **6.2**	6.6 6.8	7.2 6.7	7.3 7.2	**5.9** **6**
Hardness (as $CaCo_3$)	mg/L	200	**60**	-		**97** **94**	**210** **130**	**210** **160**	**280** **280**	37 45

Table 9: GROUNDWATER QUALITY SUMMARY

Parameter	Unit	Drinking Water (ADWG)	Irrigation (ANZECC)	Stock Water (ANZECC)	ANZECC Aquatic Ecosystems (90% protection)	Monitoring Data (filtered/dissolved samples)				
						CP114	**CP115**	**CP116**	**CP123**	**LD001**
Total Dissolved Solids	mg/L	**500**	Highly dependant on crop type and soils	4000 (beef) 2500 (dairy) 5000 (sheep) 4000 (horses) 4000 (pigs) 2000 (poultry)	-	230 200	370 250	**510** **320**	**590** **840**	76 96
Bicarbonate Alkalinity as $CaCO_3$	mg/L	-	-	-	-	98 120	170 72	220 180	200 250	33 32
Carbonate Alkalinity as $CaCO_3$	mg/L	-	-	-	-	<1 <1	<1 <1	<1 <1	<1 <1	<1 <1
Total Alkalinity as $CaCO_3$	mg/L	-	-	-	-	98 120	170 72	22 180	200 250	33 32
Chloride	mg/L	250	175 (sensitive crops) to >700 (tolerant crops)	-	-	31 27	12 12	38 19	20 11	6 5
Calcium	mg/L	-	-	1000	-	23 27	53 28	57 39	77 93	7.8 8.3
Magnesium	mg/L	-	-	2000	-	9.4 6.4	19 14	17 15	21 12	4.3 6
Potassium	mg/L	-	-	1000	-	6.7 6.4	9.7 14	17 15	9.3 12	6.2 6
Sodium	mg/L	-	115 (sensitive crops) to >460 (tolerant crops)	-	-	28 16	14 15	80 47	56 87	7.1 6.2
Sulphate	mg/L	250	-	-	-	28 16	100 78	140 57	190 220	25 15
Sulphide	mg/L	-	-	-	-	<0.5 <0.5	<0.5 <0.5	<0.5 <0.5	<0.5 <0.5	<0.5 <0.5
Nitrite as N	mg/L	9	-	9	0.03	<0.005 <0.005	<0.005 <0.005	0.008 <0.005	<0.005 <0.005	<0.005 <0.005
Nitrate as N	mg/L	10		90	**0.03**	<0.005 0.029	0.01 **0.058**	**0.06** 0.021	<0.005 <0.005	0.01 **0.064**
Fluoride	mg/L	-	1	-	-	0.13	0.19	0.38	0.35	<0.1

Table 9: GROUNDWATER QUALITY SUMMARY

Parameter	**Unit**	**Drinking Water (ADWG)**	**Irrigation (ANZECC)**	**Stock Water (ANZECC)**	**ANZECC Aquatic Ecosystems (90% protection)**	**Monitoring Data (filtered/dissolved samples)**				
						CP114	**CP115**	**CP116**	**CP123**	**LD001**
Phosphate	mg/L	-	0.05	-	0.01	<0.005	<0.005	<0.005	<0.005	<0.005
Aluminium	µg/L	200	5000	5000	**80**	<10 24	<10 <10	<10 14	**160** **150**	<10 <10
Antimony	µg/L	500	-	5000	-	<1	<1	<1	<1	<1
Arsenic	µg/L	7	100	500	42	<1 <1	<1 <1	<1 <1	6 4	<1 <1
Barium	µg/L	700	-	-	-	170	200	99	140	73
Beryllium	µg/L	-	100	-	-	<0.5	<0.5	<0.5	<0.5	<0.5
Boron	µg/L	300	500	5000	680	11	11	25	27	7
Cadmium	µg/L	2	10	10	0.4	<0.1 <0.1	<0.1 <0.1	0.2 0.3	<0.1 <0.1	<0.1 <0.1
Chromium	µg/L	50	100	1000	6	<1 <1	<1 <1	<1 <1	5 10	<1 <1
Cobalt	µg/L	-	50	1000	-	6 1	5 3	2 <1	10 2	4 2
Copper	µg/L	1000	200	-	1.8	<1 <1	<1 9	5 2	5 6	2 4
Iron	µg/L	**300**	**200**	-	-	**790** 12	**9000** 20	<10 <10	**1200** **2900**	56 <10
Lead	µg/L	**10**	2000	100	5.6	<1 <1	<1 <1	<1 <1	**13** **33**	<1 <1
Lithium	µg/L	-	2500	-	-	25	45	100	39	29
Manganese	µg/L	**100**	**200**	-	2500	**650** **380**	**860** **590**	**1000** **530**	**1700** **2300**	**500** **510**
Molybdenum	µg/L	50	**10**	150	-	<1	1	5	**13**	1
Nickel	µg/L	**20**	200	1000	13	18 3	15 4	**21** 8	19 9	**21** **27**
Selenium	µg/L	10	20	20	18	<1	<1	<1	<1	<1
Silver	µg/L	100	-	-	0.1	<1	<1	<1	<1	<1
Thallium	µg/L	-	-	-	-	<1	<1	<1	<1	<1
Thorium	µg/L	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5
Tin	µg/L	-	-	-	-	<1	<1	<1	<1	<1
Uranium	µg/L	**2**	**10**	200	-	<0.5	0.7	**14**	1.1	<0.5
Vanadium	µg/L	0	100	-	-	<1	<1	<1	5	<1
Zinc	µg/L	3000	2000	20000	**15**	**21** 11	**44** **18**	**59** **48**	**19** **36**	**66** **79**
Bromine	µg/L	-	-	-	-	70	40	140	70	30

Note: Bold values indicate an exceedance of guideline value

(i) Samples collected on 16/2/2011

(ii) Samples collected on 17/8/2011

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Groundwater in the Lithgow Coal Seam is typically near neutral ranging from slightly alkaline to slightly acidic with pH ranging between 6.6 and 7.2. Total dissolved solids (TDS) content ranged between 370mg/L and 510mg/L indicating a fresh to very slightly brackish water quality. The major anion / cation data is presented as a Piper Diagram in Figure 14.

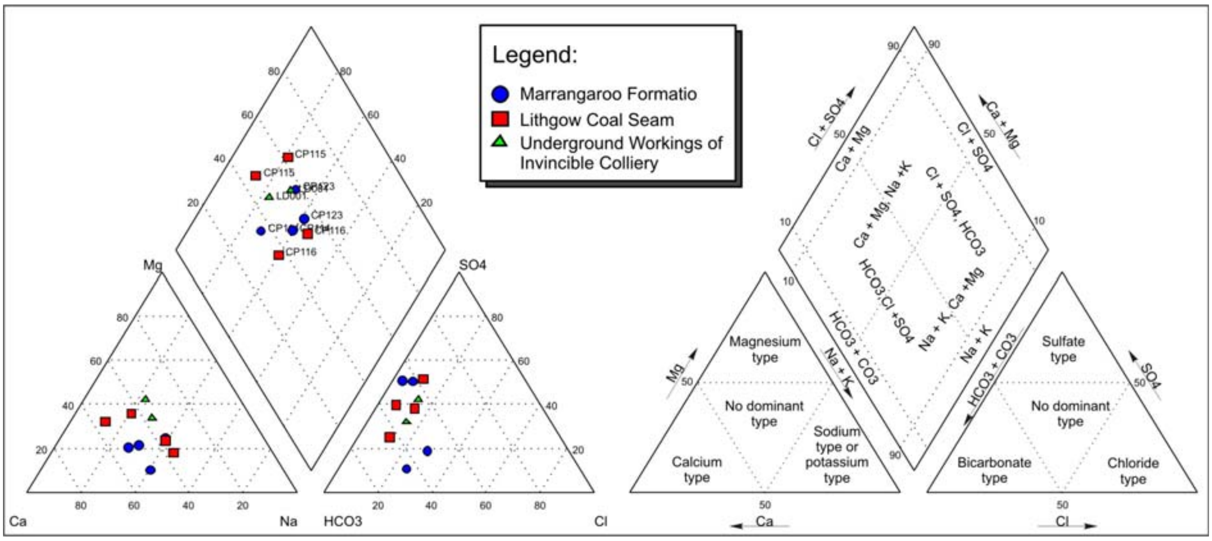

Figure 14: Piper Diagram of Permian Groundwater

The piper diagram shows a slight scatter in the data with the most common ionic composition being Ca+Mg, Na – HCO_3, SO_4 dominant water types. There does not appear to be any trends in the water types associated with geology.

Moderately elevated dissolved metal concentrations are reported in groundwater surrounding the Project Boundary. Dissolved metal concentrations in bores which exceed ANZECC (2000) guideline values are detailed in Table 9.

While most exceedances are not excessive, the samples show that concentrations of iron and manganese range up to one order of magnitude higher than the ANZECC guideline values for drinking water and irrigation. Zinc is also elevated in all samples and does not meet the ANZECC guideline values for aquatic ecosystems. These elevated concentrations are expected to be representative of background conditions.

7.5.4 Groundwater Levels

The groundwater monitoring bores commissioned by Coalpac in 2010/2011 within the Cullen Valley Mine and Invincible Mine are monitored for water level on a four-hour basis and are monitored for water quality on a three-monthly basis. 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 mRL. The water levels within the bores reflect the regional potentiometric surface.

Despite the short monitoring period, the hydrograph of the bores monitoring the Lithgow Coal Seam and the Marrangaroo Formation illustrate little temporal variability in the potentiometric surface over time. This limited fluctuation suggests recharge to the groundwater system may be limited and slow.

(Project No. G1515)

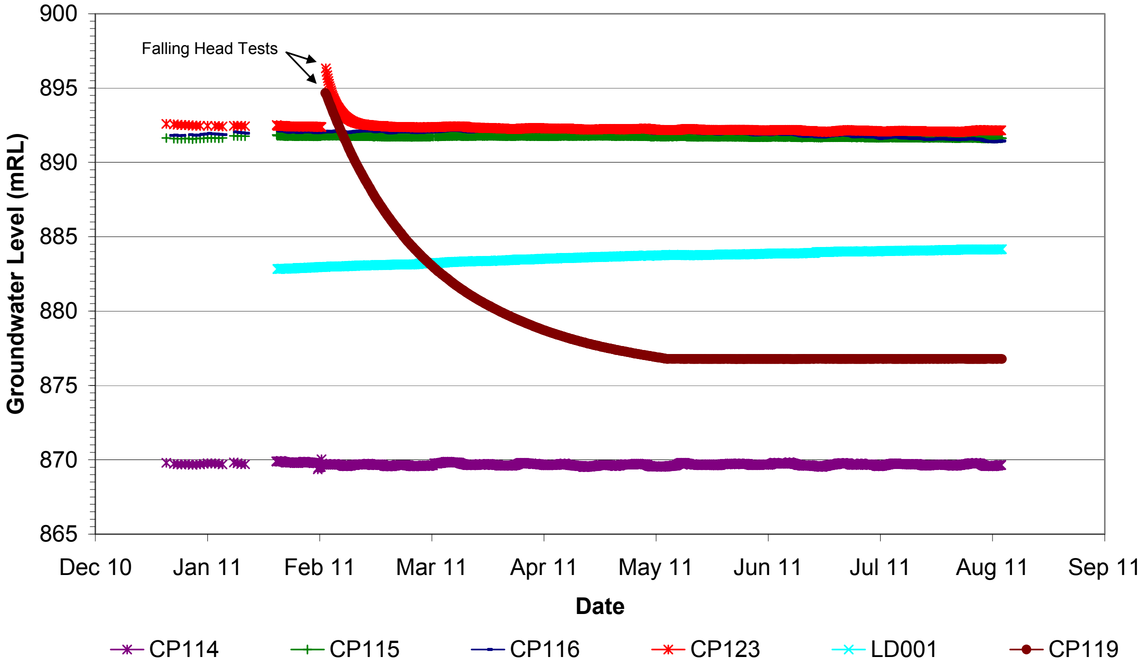

Figure 15: Hydrograph of Groundwater Potentiometric Head

Groundwater levels are not anticipated to have large fluctuations owing to the relatively short distance between the bores and the outcrop area, the shallow gradient of the aquifers and the relatively short distance to discharge areas, these being either the adjacent Baal Bone Colliery or at gully/valley escarpments.

As indicated above, the potentiometric surface is the result of interactions between rainfall recharge over a very long period of time and topographic discharge areas. Groundwater recharge is by direct rainfall infiltration and local runoff into the outcrop areas.

A groundwater level (potentiometric) surface contour plan is shown on Drawing No. 9. Unfortunately, the NOW groundwater database does not contain any recent records of groundwater levels for the Permian aquifers (as described in Section 7.5.3). Notwithstanding this, the potentiometric heads derived from the monitoring bores shows a hydraulic gradient towards the north-east, following the coal seams down-dip towards the Wolgan Valley escarpment (via Baal Bone Colliery).

The monitoring bores within the Project Boundary indicate that the potentiometric surface is approximately RL892m near the Lithgow Coal Seam outcrop in the east (refer Figure 15). Underground mining at Baal Bone has occurred since about 1982. It is therefore, reasonable to assume that there has been some impact on the local hydrogeological regime. The extraction of the longwall panels in the Baal Bone Colliery will have caused fracture zones above the longwall panels which are likely to have extended up to at least 100m above the workings, this being into the overlying coal seams (Connell Wagner, 2006). These fracture zones allow for the draining of overlying coal seam aquifers into the underlying coal mine workings. Since the Project Boundary is bordered by extensive longwall extraction on the eastern side (and the Wolgan Valley escarpment further to the east), and the coal seam outcrop area to the west, it is likely that the potentiometric head in the coal measure aquifers has been drawn down significantly, and the groundwater resource largely depleted.

7.5.5 Recharge, Discharge and Groundwater Flow

Recharge occurs by diffuse rainfall infiltration and local runoff into the outcrop in low-lying areas and into the weathered and fractured surface units in more elevated areas. Recharge rates are a function of rainfall intensity, evaporation, vegetation coverage and density, topography and soil properties of the surface material.

The Permian and Triassic aquifers within the Coalpac Project Boundary are primarily recharged at their outcrop areas. The primary recharge to the coal seams is via direct rainfall recharge through the coal seam outcrop, where the aquifer is unconfined.

A preliminary attempt to quantify the groundwater recharge rate was undertaken using the chloride mass balance method. This method involves determining the ratio of the chloride concentrations in rainfall and dry deposition to the concentration present in pore water in the unsaturated zone.

Rainwater samples were not collected on site; however, it is anticipated that the chloride concentration will be low and may be less than about 1mg/L.

The concentration of chloride in the groundwater samples from the Lithgow Coal Seam varies from 12mg/L to 38mg/L. Assuming a concentration of 0.5mg/L chloride in rainfall and no significant dry deposition, a recharge rate of between 4% to 1.3% (about 32mm/year to 10mm/year) can be approximated. It should be noted this is an extremely crude estimate but it does suggest recharge rates to the Permian are relatively low.

Groundwater levels within the Permian and Triassic aquifers have been shown at the adjacent Pine Dale Mine to have a downward hydraulic gradient. This is most likely the result of higher stratigraphic layers outcropping at higher topographic elevations (Aquaterra, 2010).

Substantial recharge could occur into the weathered zone of the Permian or Triassic units, in particular where intense fracturing occurs such as at lineaments to the east (i.e. Coxs River Lineament) and where subsidence has occurred above the area where coal seams have been extracted. However, in general, layering of mudstones and siltstones within the Permian Coal Measures restricts the vertical movement of water within the coal measures, and this formation is considered to have a low overall rate of recharge.

Natural groundwater discharge occurs through evapotranspiration, seepage through coal pillars into adjacent mine workings and lateral flow to outcrop areas (i.e. hillsides and gullies including the escarpment of the Wolgan Valley).

Groundwater flow within the coal seams is almost exclusively horizontal, since they are bounded by fine-grained sediments which act as aquicludes. Under pre-mining conditions, it would be anticipated that groundwater levels would generally appear to be a subdued reflection of topography with a hydraulic gradient to the north-east within the Project Boundary.

Local groundwater flow in the historic underground mine workings at the Old Tyldesley Colliery and the Old Invincible Colliery is inferred to be in a north to north-easterly direction towards the Baal Bone Colliery. Immediately to the south of the current location of Invincible Colliery, four underground mine working areas exist, these are:

- Ivanhoe Colliery;
- Wallerawang No.1 Colliery;
- Wallerawang No.2 Colliery; and
- Wallerawang No.3 Colliery.

The mining areas of these collieries are generally separated by pillars of coal which have either not been mined due to seam discontinuities (faults or rolls) and/or to provide a hydraulic barrier to retard seepage from adjacent abandoned underground mine workings. Previous studies state that water held within the Wallerawang No.3 Colliery flows into the Wallerawang No.1 and No.2 Collieries and then into the Invincible Colliery located to the north (Bish, 1999). The rate of groundwater seepage into the Invincible Colliery is currently unknown.

Prior to mining taking place at Baal Bone Colliery, the Lithgow Coal Seam (and the upper coal seams of Katoomba Coal Seam, Middle River Coal Seam, Moolarben Coal Seam and Irondale Coal Seam) would have drained towards the escarpment to the east where they are exposed at the base of the cliff face (refer to Figure 8 to Figure 12).

As previously discussed and illustrated in Drawing No. 8, the Lithgow Coal Seam has been mined extensively in the region and is largely drained of groundwater (excluding water held within flooded mine workings). Continuous pumping has lowered the groundwater level surrounding the Baal Bone Colliery in order to keep the underground mine workings dry (Connell Wagner, 2006). The elevation of the floor of the Baal Bone Colliery southern workings, taken to be the base of the Lithgow Coal Seam, ranges from about RL871m on the western longwall panel to about RL827 on the eastern side of the southern panels beneath the Coxs River.

Details regarding underground mine water management for the Baal Bone Colliery was not available for this assessment. As such, it is unknown whether some goafed areas of the Baal Bone Colliery have been sealed. Sealing-off goafed areas is sometimes undertaken to allow these areas to re-saturate with groundwater and flood over time. Alternatively, if all goafed areas within the mine are not sealed then water may drain to the lowest elevated areas via roadways and dedicated water management drains. Details regarding the routing of mine water to discharge areas via dedicated drains were also not available for this assessment. In the absence of these data, it has been conservatively assumed that none of the goafed areas have been sealed-off and that all underground mine water reports to the lowest elevated area, this being about RL827m (Connell Wagner, 2006).

Water received at the Baal Bone Colliery collection point will therefore be a combination of:

- water released from storage within the mined coal seam (Lithgow Coal Seam);
- vertical leakage of water from overlying strata, which have been fractured by the formation of the goaf above the extracted longwall panels; and
- seepage from the adjacent Old Tyldesley Colliery, the Old Invincible Colliery and the Invincible Colliery.

Groundwater is currently being pumped from the southern area of the Baal Bone Colliery at a rate of about 2.4ML/day (876ML/year). Previous studies have suggested that the major proportion of extracted water is sourced from the overlying coal seam aquifers in the upper coal measure strata (Connell Wagner, 2006). Mine dewatering records indicate that on average 4.25ML/day is dewatered from both the north and south Baal Bone Colliery pumps, combined. The proportion of seepage sourced from the old underground workings of Tyldesley Colliery and Invincible Colliery was not calculated by the Connell Wagner (2006) study.

7.5.6 Faulting

The near-surface hydrogeology may also be influenced by major geological structures, which could disrupt the normal horizontal flow regime and increase vertical flow between aquifer systems. The Coxs River Fault Zone (refer to Figure 10 to Figure 12) to the east of the Project Boundary may serve as a barrier to horizontal groundwater flow in the coal seams, or also a conduit for groundwater in either the horizontal or vertical direction. There are currently no data available that give any indication of the influence of this fault zone on the local hydrogeology (Connell Wagner, 2006).

As previously discussed, the Coxs River Lineament Fault Zone follows the valley of the Coxs River, and has been identified by seismic surveys at Baal Bone Colliery. The fault zone is a north-south trending graben structure, about 250m wide. The displacement is not large and on the eastern structure is about 4-5m, up to the east. The western fault shows a lesser displacement in the seismic survey in the order of 2m. Between these two faults, the seismic data indicates other smaller faults exist, in conjunction with brecciation of the strata (Connell Wagner, 2006).

7.6 Permian Marrangaroo Formation Aquifer

The Marrangaroo Formation crops out persistently throughout the Western Coalfield, ranging in thickness from 2m to 16m. The formation commonly has a sharp erosive basal contact with silty and coaly sedimentary rocks of the Nile Subgroup or sandy siltstone of the Berry Siltstone.

In outcrop, the Marrangaroo Formation forms characteristic, easily recognisable sandstone benches that can be up to several metres high. The unit is present sporadically along the western margin of the Western Coalfield (Yoo, et al. 2001).

The Marrangaroo Formation fines upward from a quartz-lithic pebbly sandstone or conglomerate to a medium to fine grained quartzose sandstone, and occasionally contains a series of upward fining sandstone beds. Locally the Marrangaroo Formation is dominantly quartzose in composition grading from granular sandstone to pebble conglomerate. The thickest conglomerate occurs between Lithgow and Ben Bullen (Yoo, et al. 2001).

The hydraulic parameters of the Marrangaroo Formation have not previously been calculated at either the Invincible Colliery or the Cullen Valley Mine. Similarly, no hydraulic parameters for the Marrangaroo Formation were available from surrounding mines. In this case, site specific data has been collected as part of this current assessment.

Hydraulic (falling head) permeability tests were conducted in the recently constructed monitoring bores as part of field investigations which were described in Section 6.4. The results of falling head tests undertaken within the recently constructed monitoring bores within the Project Boundary range between 0.0004m/day to 0.007m/day for the Marrangaroo Formation. These values for hydraulic conductivity are considered very low and are at the lower limits of the expected range for the Marrangaroo Formation which is described in core logs as porous and permeable. The Marrangaroo Formation is considered to have higher average hydraulic conductivity than the falling head test results suggest. The low values may have been the result of “skin effects” within the bore hole owing to remnant drilling fluid remaining in the hole after bore installation and development. The effective average hydraulic conductivity for the Marangaroo Formation is expected to be between 0.05m/day up to about 0.5m/day.

Groundwater in the Marrangaroo Formation is typically near neutral ranging from neutral to slightly acidic with pH ranging between 6.3 and 7.3 (Table 9). TDS content ranged between 230mg/L and 590mg/L indicating fresh water quality. The major anion / cation data is presented as a Piper Diagram in Figure 14.

Two groundwater monitoring bores (CP114 and CP123) were installed within the Marrangaroo Formation in December 2010 (refer Drawing No. 7). A hydrograph of the groundwater potentiometric head levels over the monitoring period are shown in Figure 15. The hydrographs of the bores monitoring the Marrangaroo Formation illustrate little temporal variability in the groundwater level over time. The groundwater levels within CP114 and CP123 are separated by about 22m (RL869.69m and RL892.44m respectively - 21/01/2011). The difference in head is large; however not un-reasonable considering that CP114 and CP123 are separated by about 7.2km (refer Drawing No. 7) and are located within different catchments.

Notwithstanding the different head elevations, the position of the water level within CP114 and CP123 are similar, this being located within the upper section of the aquifer (refer to Appendix 2). In both of these cases, the water level was located below the top of the formation indicating unconfined conditions which are to be expected considering the proximity to out crop areas.

Similar to the Permian coal seam aquifers, recharge to the Marrangaroo Formation is likely to occur by direct rainfall infiltration and local runoff into the outcrop in low-lying areas.

Similar to the Permian coal seam aquifers, groundwater within the Marrangaroo Formation is expected to flow towards the north-east (down-gradient) and discharge at outcrop areas (i.e. hillsides and gullies including the escarpment of the Wolgan Valley).

There is very little information regarding structural defects such as faults within the Marrangaroo Formation; however, it is anticipated that the Coxs River Fault Zone is likely to persist through this unit as suggested in Figure 10 to Figure 12.

8.0 GROUNDWATER USE, QUALITY AND ENVIRONMENTAL VALUE

A search of the NSW Office of Water (NOW) database of registered bores and wells within a 3km radius of the Project Boundary indicates that there are twenty-seven registered bores within this radius, as shown on Drawing No. 7 and summarised in Table 10. Owing to the high and varying topographic relief throughout much of the region, groundwater bores tend to be restricted to areas more easily accessible. Drawing No. 7 indicates that most of the registered bores are concentrated in the valley areas adjacent to creek water courses, these being Ben Bullen Creek and Coxs River. The majority of the registered bores access water from the shallow fractured shale and sandstone of the Permian Illawarra Coal Measures including the Wallerawang/Charbon/Cullen Bullen Subgroups.

The majority of the registered bores are located more than 1km away from the Project Boundary with the exception of eight bores, two of which are dewatering bores associated with the Old Tyldesley Colliery and Invincible Mine as shown on Drawing No. 7. The registered bores are primarily licensed for monitoring purposes (10 bores) and mining/industrial activities (8 bores) while the remaining 30% of the bores are licensed for domestic/stock/irrigation use (9 bores). There would also appear to be one bore (LD001) which is not registered and for which there is no construction data available except for the depth of the bore and the fact that it sources water held within the underground workings of the Invincible Colliery.

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Usage of groundwater from the Permian strata via bores is limited, due to poor yields. The yields recorded from domestic/stock/irrigation, bores range from less than 1L/s up to about 3L/s. On occasion, bores licensed to mining operations have a much higher recorded yield. However, these high rates are likely to be due to location of the bores, this being within underground mining areas where they draw water from large open void areas.

Approximately half of the registered bores were drilled/installed during the 1980's whilst the remaining bores have all been drilled/installed since 2000. Long term groundwater level records are not available from the NOW groundwater database for any of the surrounding registered bores. Notwithstanding this, a single groundwater level was recorded at the time of drilling/ installation within twelve of the registered bores as shown in Table 10. The groundwater levels range from 4.6 metres below ground level (mbgl) up to 41mbgl with the average being about 13mbgl.

Table 10: SUMMARY OF REGISTERED BORES ADJACENT TO EA BOUNDARY

Work No.	Date	Licence Status	Drilling Method	Completed Depth (mbgl)	Standing Water Level at Installation (mbgl)	Salinity	Yield (L/s)
GW030898	1981	Industrial – lapsed	Rotary	232	-	-	-
GW045638		Domestic/Stock – active	Unknown	61	-	Hard	-
GW053949	1982	Domestic/Irrigation/Stock – cancelled	Rotary Air	23.8	4.6	Good	2.27
GW054003	1981	Domestic – active	Rotary Air	91.4	13.7	Good	0.01
GW059350	1983	Mining – cancelled	Rotary Air	24.1	12.2	500ppm	0.75
GW059358	1983	Mining - cancelled	Rotary Air	24.4	-	Good	1.5
GW062283	1986	Mining – active	Rotary Air	59.8	31.8	-	12.5
GW062284	1986	Mining – lapsed	Rotary Air	90.2	6.1	500ppm	3.8
GW062285	1987	Mining – active	Rotary Air	91.5	6.1	-	3.3
GW064530	1987	Domestic/Stock – active	Rotary Air	85.4	-	Good	0.3
GW064531	1987	Domestic/Stock – active	Rotary	48.8	-	Good	3.1
GW064610	1987	Domestic/Stock – active	Rotary Air	36.3	8	Good	3.1
GW064611	1987	Domestic/Stock – active	Rotary	24.3	7	-	5
GW106258	2003	Domestic/Stock – active	Hammer	122	41	480ppm	2.1
GW108881	2008	Monitoring Bore – active	Unknown	21	-	-	-
GW108932	2008	Monitoring Bore – active	-	17.5	-	-	-
GW108939	2008	Monitoring Bore – active	-	15.5	-	-	-
GW109018	2008	Monitoring Bore – active	-	12	-	-	-
GW111203	2010	Monitoring Bore – active	-	84	-	980ppm	-
GW111204	2010	Monitoring Bore – active	Coring	16	-	419ppm	-
GW111205	2010	Monitoring Bore – active	Rotary Air	87.6	-	-	-
GW111206	2010	Monitoring Bore – active	Coring	38.9	-	991ppm	-
GW111207	2010	Monitoring Bore – active	-	50.4	-	-	-
GW111208	2010	Monitoring Bore – active	Coring	105	-	-	-
GW801861	2002	Test Bore – cancelled	Rotary	72	15	270ppm	1.26
GW802827	2004	Domestic/Stock – active	Rotary Air	30	7	-	1.5
GW804393	2000	Mining – active	Unknown	27	11.5	10.1ppm	16.67

mbgl – metres below ground level

ppm – parts per million

L/s – Litres per second\

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Data for groundwater chemistry is very limited within the NOW groundwater database for the bores surrounding the Project Boundary. A measure of salinity has been recorded for fifteen bores and this value is typically recorded as being ‘good’.

8.1 Groundwater Quality and Environmental Value

An assessment was made of the groundwater quality in terms of Australia New Zealand Environment Conservation Council (ANZECC) criteria and environmental value. The ANZECC (2000) guideline refers to “environmental value” rather than “beneficial use” which is often used, and state that the term beneficial use has lost favour because of its exploitative connotations. For this reason the term “environmental value” has been adopted by the National Water Quality Management Strategy (NWQMS). The following environmental values are recognised in the NWQMS Guidelines:

- 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.

The guidelines state that “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”. The assessment of “environmental value” given in this report is based on this guideline.

Groundwater in the Permian aquifers and the water contained within the underground workings of the Invincible Colliery, have concentrations of iron and manganese that exceed Australian Drinking Water Guideline values and the ANZECC guideline for irrigation. In addition, the groundwater resources appear to have a slightly elevated zinc concentration which may make this water unsuitable for aquatic ecosystems. However, it should be noted that it is unlikely that mining operations have caused the elevated concentrations of iron, manganese and zinc as these metals can be naturally occurring at elevated concentrations.

In addition, during pre-mining conditions, groundwater is likely to have naturally discharged to low elevation areas where the water is likely to have entered watercourses, and diluted with surface water flows to some degree. However, given the guideline recommendations and the measured quality of the groundwater in the Permian aquifers and the water contained within the underground workings of the Invincible Colliery, these resources are best allocated for industrial purposes and use in primary industries.

9.0 MINE PLAN

The Project seeks to consolidate mining operations of Cullen Valley Mine and Invincible Colliery under a single contemporary planning approval to allow the continuation of open cut and highwall mining activities.

In addition, the Project seeks approval for the commencement of quarry operations targeting the Marangaroo Sandstone below the Lithgow Coal Seam.

Coalpac has divided the Project mine plan into three areas, these being:

- the Cullen Valley mining area:
- the Invincible Colliery mining area;
- the East Tyldesley mining area; and
- the Hillcroft mining area.

The proposed mining areas are shown on Drawing No. 10. Owing to the high relief within the Project Boundary, the mine plan has been designed to target specific areas of coal outcrop. The schematic cross-section shown in Figure 16 illustrates the mining process. Mining is proposed to start as an open cut operation where the upper coal seams outcrop. When the strip ratio gets too high, open cut mining is followed by highwall mining within the same seam previously targeted by the open cut mine. Highwall mining is anticipated to advance into the coal face on average 300m and occur at the locations shown on Drawing No. 10. Once highwall mining has been concluded, the area is rehabilitated and the process is continued on the next lower coal seam outcrop.

Open cut mining will not proceed through the abandoned and flooded Tyldesley underground workings nor the flooded Invincible underground workings at the Lithgow seam level.

It is anticipated that sand quarrying operations will involve traditional excavation works.

The actual mine plan schedule is more complex than described above and a year by year mine schedule is shown on Drawing No. 11. No open voids will remain at the conclusion of mining operations proposed for the Project. The mining methods and timing for each of the three mining areas are detailed below.

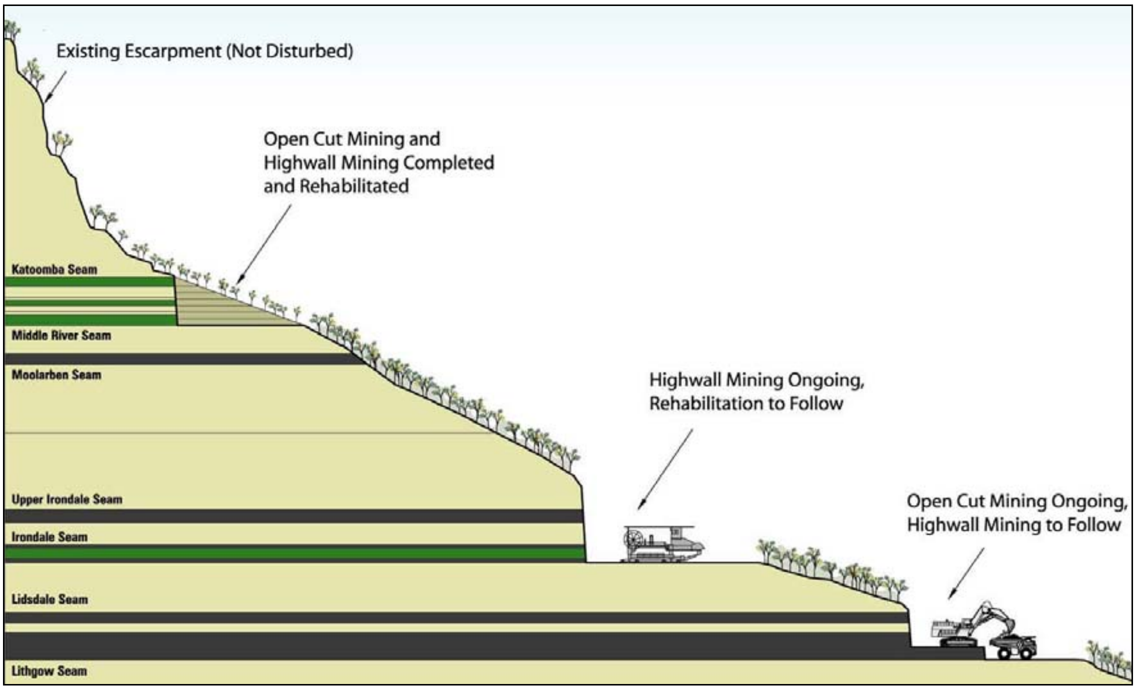

Figure 16: Schematic Cross-section of Mine Design (Source: Hansen Bailey)

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10.0 GROUNDWATER IMPACT ASSESSMENT

10.1 Impact Assessment Objectives

Predictive analytical assessment was undertaken to assess the impact of the Project on the surrounding groundwater regime. The objectives of the predictive assessment were to:

- estimate groundwater discharge from the flooded workings of the Old Tyldesley Colliery, and Old Invincible Colliery into the adjacent (down hydraulic gradient) Baal Bone Colliery;
- estimate groundwater inflow rates to open cut mining areas over the life of the Project;
- estimate groundwater inflow rates to the areas where open cut pits are in close proximity to flooded underground workings;
- estimate groundwater inflow rates to the open pit developed during quarrying of the Marrangaroo Formation;
- predict the zone of influence of dewatering;
- predict the impact of the Project 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.

10.2 Conceptualisation of Hydrogeological Regime

Every groundwater model, be it numerical or analytical, 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 the groundwater impact assessment. 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 assessment, without major revisions. Formulation of the conceptual model often highlights gaps in data or deficiencies in the understanding of the groundwater system.

This conceptual model forms the basis of the assumptions used when developing numerical and analytical models. MDBC (2000) 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".*

The data indicate the area within the Project Boundary supports three distinct groundwater systems:

- Triassic overburden sediments (sandstone) of the Narrabeen Group which contain perched aquifers above low permeability layers;
- coal seams within the Permian Illawarra Coal Measures – (e.g. Irondale Coal Seam, Lidsdale Coal Seam and Lithgow Coal Seam); separated by Permian interburden

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sediments (e.g. claystone, mudstone, siltstone and sandstone bands present between the coal seams); and

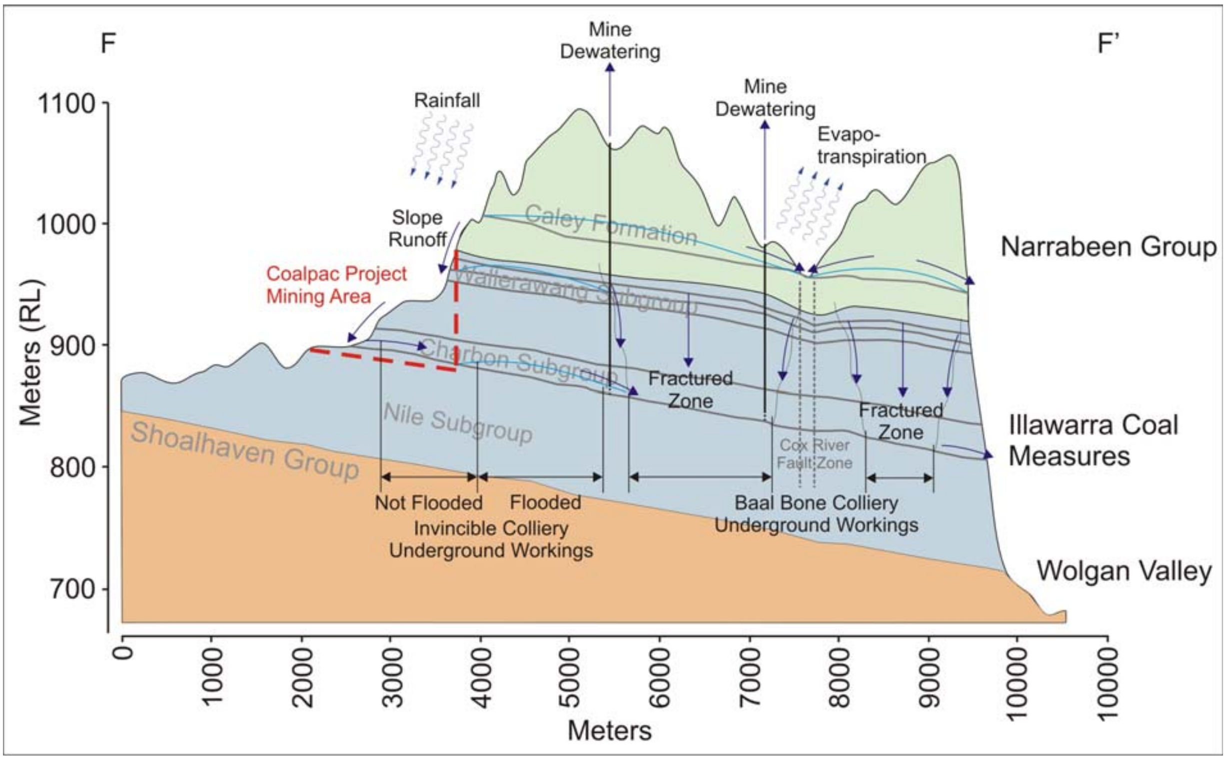
- the underlying Marrangaroo Formation.

Recharge to the groundwater system is from rainfall on areas of outcrop. Although groundwater levels are sustained by recharge, they are controlled by surface topography and aquifer permeability. Groundwater mounds are most likely to be present beneath the ridge areas, with a hydraulic gradient towards the lower lying areas located to the north-east. Groundwater flow is from these elevated areas with discharge occurring (pre-mining) at the Wolgan Valley escarpment located to the north-east.

Irrigation, stock and domestic bores remove an insignificant amount of water from the Permian coal measure aquifers. Perennial swamps occur where perched groundwater is fed to lower lying areas.

In places where mining has occurred, groundwater discharge is expected to be via the mined seam and from the strata above and below at a rate related to the permeability, the hydraulic gradient and the degree (and height) of fracturing above underground workings.

The conceptual model is illustrated in a schematic cross section in Figure 17. The location of the cross section is shown on Drawing No. 8. It should be noted this figure displays the key concepts in the hydrogeological regime but does not represent localised detail in the geological surfaces.



Note this figure is conceptual only and has ~10 x vertical exaggeration

Figure 17: Conceptual Groundwater Flow Model (Section F-F')

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10.3 Groundwater Discharge to Adjacent Mines

Under current conditions, a large volume of water is held within the abandoned underground workings of the Old Tyldesley Colliery, the Old Invincible Colliery and the Invincible Colliery. The majority of the Old Tyldesley Colliery and the Invincible Colliery are saturated as shown on Figure 18. However, the abandoned workings of the Old Invincible Colliery are partially saturated. The calculated total volume of water stored within the flooded workings is about 6,245ML.

Water stored within the underground flooded workings has the potential to seep through the remaining coal separating the adjoining mine down gradient, this being Baal Bone Colliery (Connell Wagner, 2006 and Bish, 1999). Groundwater is currently being pumped from both a southern area and a northern area of the Baal Bone Colliery. A rate of about 2.4ML/day (876ML/year) is pumped from the southern area and about 1.85ML/day is pumped from the northern area. Connell Wagner (2006) previously suggested that the major proportion of extracted water from the Baal Bone Colliery was sourced from the overlying coal measure strata. These seams are typically discontinuous within the Project area as illustrated in Figure 6 to Figure 10 (sections A to E). The discontinuous nature of the upper coal seams in the Project area is likely to result in these units being mostly unsaturated within the Project area. However, the upper coal seams are more laterally continuous above the Baal Bone Colliery (refer Figure 17, section F) and this increases the likelihood that these seams will be saturated and able to contribute groundwater to the underling mine when goaf induced fracturing occurs. Neither the quantity of water nor the proportion of the contribution derived from seepage from adjacent flooded underground workings has previously been estimated.

The Project intends to retain the flexibility to utilise the water stored underground within the Old Invincible Colliery to augment surface water supplies to meet the water requirements. There is also the intention to recycle water by pumping water into as well as pumping water out of the Old Tyldesley Colliery.

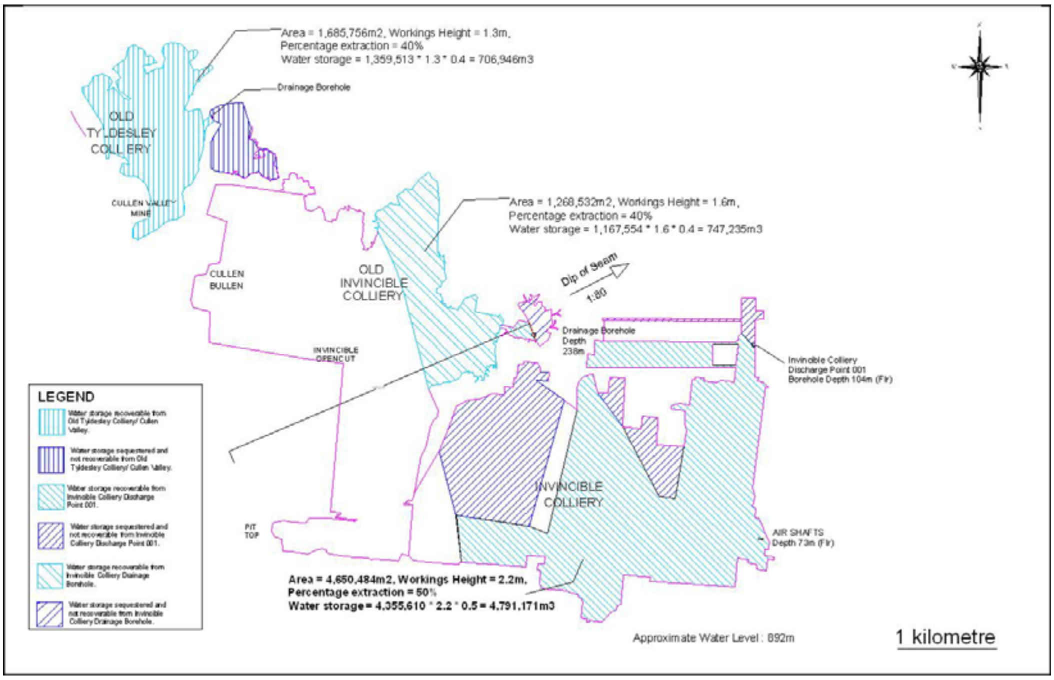

Figure 18: Estimate of Water Storage in Underground Mine Workings (Source: Coalpac)

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The water level within each of the flooded mine workings is sporadically measured and recorded. Anecdotal evidence suggests that the water level within the voids has little temporal variation. This observation is supported by water level records taken from a bore that intercepts the Old Tyldesley Colliery workings. The bore is registered with NOW (GW804393) and is located adjacent to the Castlereagh Highway as shown on Drawing No. 7. The water levels within GW804393 have periodically been monitored since 2000 and range from 7.5mbgl to 11.5mbgl. The groundwater level records from GW804393 were reduced to the Australian Height Datum (mRL) and shown in Figure 19.

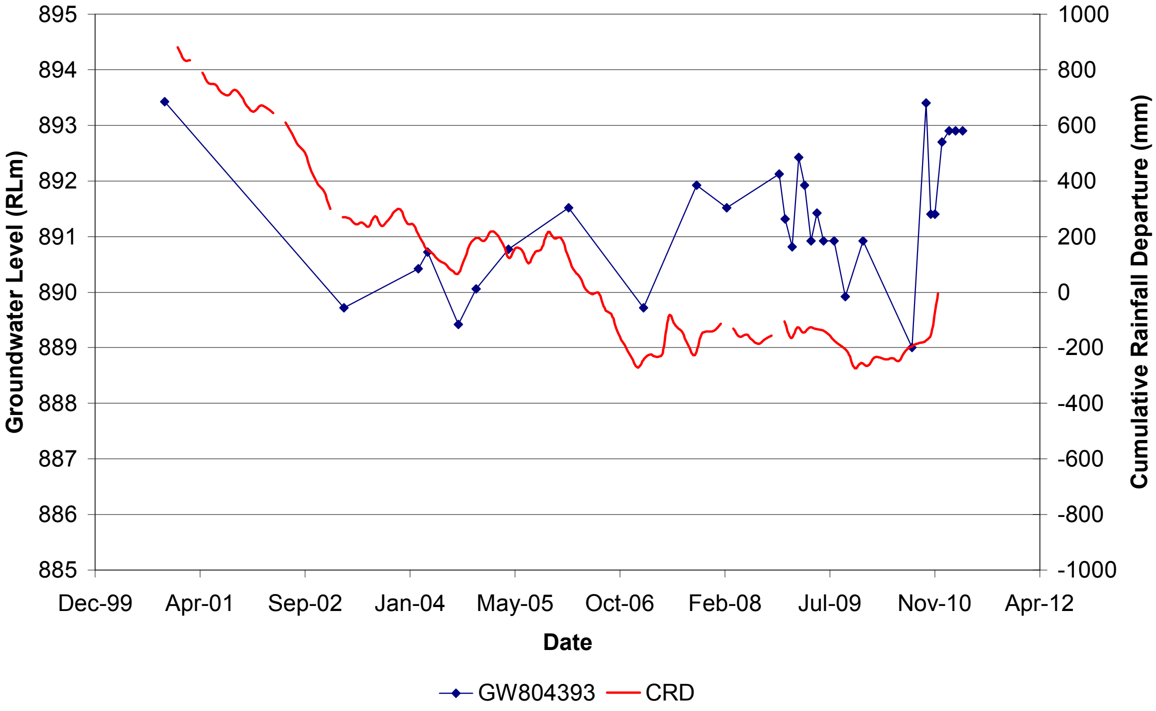

Figure 19: Hydrograph of GW804393 Groundwater Potentiometric Head

Water has been pumped out of the Old Tyldesley underground workings since about 2000 and used for dust suppression. An unknown volume of water sourced from open cut pit accumulations of rainwater has also been pumped back into the underground mine workings. These activities may have resulted in the relatively small fluctuations observed within the hydrograph of Figure 19.

Owing to the relatively static water level within GW804393, it is therefore assumed that the water level within the flooded workings has reached steady state equilibrium where water seepage (outflow) is approximately equalled by recharge (inflow). Therefore, the amount of recharge to the mine workings may be back-calculated by estimating the amount of seepage from the workings. In this case a broad assessment of the steady state seepage from the abandoned underground mine workings was made using the form of the Darcy Equation:

$$Q \quad = \quad Ki \ A \quad (m^3/day)$$

Where: Q = seepage from the coal seam face (m^3/day)

K = hydraulic conductivity/permeability of the coal seam

I = steady state hydraulic gradient

A = cross section area of coal seam aquifer (m^2)

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In order to provide a higher degree of accuracy, the seepage calculations were performed separately for three zones, these being:

- Zone A – the Old Tyldesley Colliery,
- Zone B – the Old Invincible Colliery; and
- Zone C – the Invincible Colliery.

Zones B and C were further divided to capture the irregular shape of the flooded workings and the widths of the coal pillar between the flooded and dry workings. A conceptual illustration of the key components controlling the rate of seepage from the flooded workings into the adjacent mine is shown on Figure 20.

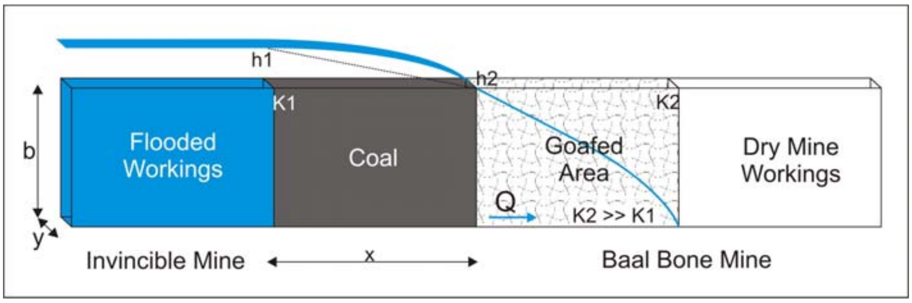

Figure 20: Conceptual Model for Seepage of Water from Flooded Mine Workings

The hydraulic conductivity of the Lithgow Coal Seam has been tested during this assessment (Section 6.4). A representative hydraulic conductivity for the Lithgow Coal Seam of about 0.09m/day is in good agreement with studies undertaken throughout the region (Connell Wagner, 2006). However, the hydraulic conductivity of the Lithgow Coal Seam does vary either side of this mean. In addition, historical mining works within the coal seam may have contributed to secondary porosity in the form of fractures owing to the collapsing of adjacent mining areas at Baal Bone Colliery. Owing to the natural variability (and also potential mining induced variability) of hydraulic conductivity within the coal seam, using a single value of hydraulic conductivity would not adequately represent the likely range of seepage rates. A range of seepage rates resulting from a range of hydraulic conductivity has therefore been calculated as shown in. In this case, the likely range of hydraulic conductivity anticipated for the coal seam pillar would be from a lower limit of about 0.07m/day to an upper limit of about 0.2m/day.

The assessed inflow of seepage from the flooded workings into the Baal Bone Colliery is summarised in Table 11 and shown graphically in. The data indicates that groundwater seepage rates are sensitive to the width of the coal seam pillar separating the flooded and dry mine workings, and is also sensitive to the coal seam hydraulic conductivity.

Using the hydraulic conductivity range, it would be expected that water seepage from the Old Tyldesley Colliery to be about one to two orders of magnitude less (ranging from 3ML/year to 8ML/year) than the rates derived from the Old Invincible Colliery and the Invincible Colliery. The higher rates of seepage from the Old Invincible Colliery and the Invincible Colliery are likely to result from their near proximity (i.e. thinner separating zones of coal) to the Baal Bone Colliery underground workings.

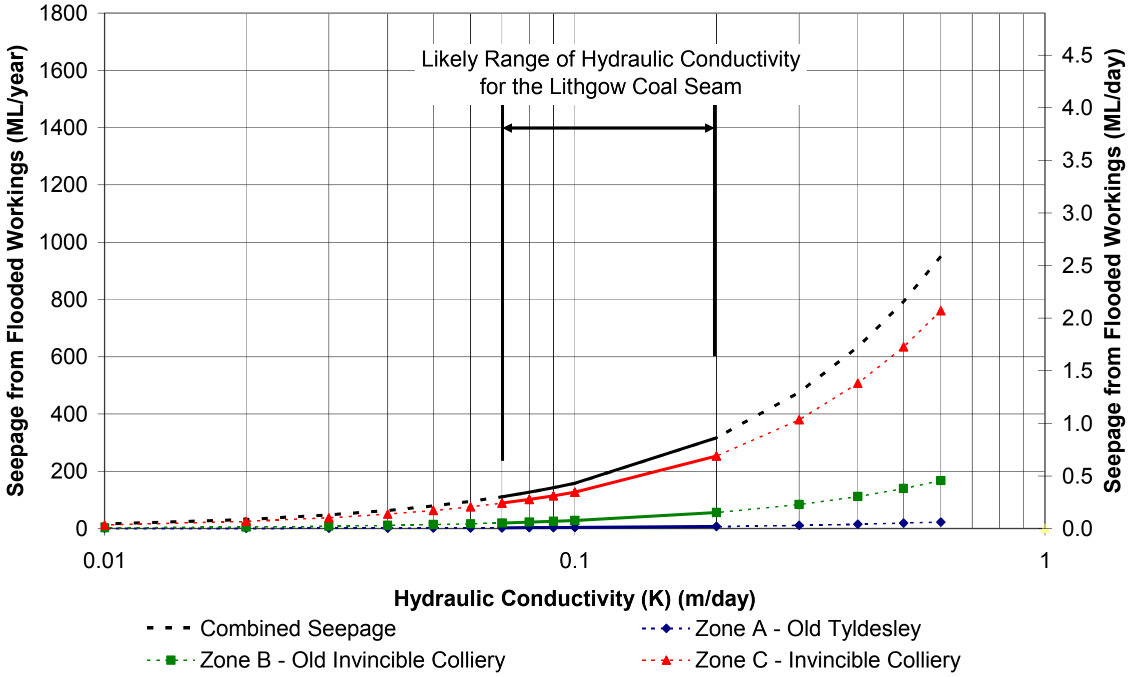

Figure 21: Groundwater Seepage Rates from Flooded Workings to Baal Bone Colliery

Table 11: SUMMARY OF GROUNDWATER SEEPAGE FROM FLOODED WORKINGS

Zone	Range	Hydraulic Conductivity (K) (m/day)	Coal Seam Barrier Width (m)	Lithgow Coal Seam Seepage (m^3/day)	Lithgow Coal Seam Seepage (ML/year)	Percent of 2.4ML/day (876ML/yr)	Percent of 4.25ML/day (1551ML/yr)
Zone A – Old Tyldesley Colliery	Upper limit	0.2	1800	21	8	-	-
	Representative Limit	0.09		9	3		
	Lower Limit	0.07		7	3		
Zone B – Old Invincible Colliery	Upper limit	0.2	100-330	153	56	-	-
	Representative Limit	0.09		69	25		
	Lower Limit	0.07		54	20		
Zone C – Invincible Colliery	Upper limit	0.2	50-700	695	254	-	-
	Representative Limit	0.09		313	114		
	Lower Limit	0.07		243	89		
Total Combined from Zone A, B and C	Upper limit	0.2	-	978	317	36	21
	Representative Limit	0.09		440	143	16	10
	Lower Limit	0.07		342	111	13	7

The total seepage rates into the Baal Bone Colliery appear to be predominantly sourced from the Old Invincible Colliery and the Invincible Colliery. The seepage rate from the Old Invincible Colliery ranges from about 20ML/year to 56ML/year (0.05ML/day to 0.15ML/day) and the seepage rate from the Invincible Colliery ranges from about 89ML/year to 254ML/year (0.24ML/day to 0.69ML/day).

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The total combined outflow from the flooded workings into the Baal Bone Colliery is therefore likely to range between 111ML/year to 317ML/year (0.3ML/day to 1ML/day) depending upon the hydraulic conductivity of the coal seam pillar. This range of combined seepage to the Baal Bone Colliery is equivalent to between 13% and 36% of the total water volume pumped from the southern Baal Bone Colliery area and between 7% and 21% of the total water volume pumped from both the southern and northern Baal Bone Colliery.

A number of simplifying assumptions were required to undertake the assessment outlined above. These assumptions are detailed within Appendix 5.

10.4 Groundwater Inflow to Proposed Open Cut Mining Areas

The rate at which groundwater seeps from the coal face is governed by the permeability of the coal (hydraulic conductivity) and hydraulic gradient. As mining progresses to the east and down dip from the subcrop area, the coal seam is mined out. Groundwater seepage to the highwall face is primarily derived from storage within the coal seam as it is mined, and from flow in the seam from the east of the highwall.

The flow from the Lithgow Coal Seam to the open cut mining areas proposed for the Project was estimated using the form of the Darcy Equation discussed in Section 10.3.The seepage rate was estimated within the observed range of coal seam hydraulic conductivities. When seepage rates from the coal face are relatively low, evaporation can remove the seepage before it collects at the toe of the highwall and as the pit is dry it is often concluded there is no groundwater seepage occurring. The seepage estimates were therefore corrected for evaporation to determine if there will be any visible seepage to the pit that would require management in the mine water circuit.

The assessed groundwater seepage range from the Lithgow Coal Seam to the open cut mine pits is summarised in Table 12 and shown graphically in Figure 22.

The range of estimated seepage rates demonstrates the sensitivity to the hydraulic conductivity of the coal seam. However, of more significance is the amount of groundwater seepage lost to evaporation. The results presented in Figure 22 illustrate that for a coal seam with an average hydraulic conductivity of about 0.06m/day (or less), evaporation from the seepage face accounts for 100% of groundwater seepage. Where the Lithgow Coal Seam may have a hydraulic conductivity greater than 0.06m/day the inflow rates are expected to be minor as a result of the shallow hydraulic gradient.

Table 12: SUMMARY OF GROUNDWATER SEEPAGE TO OPEN CUT PITS

Range	Hydraulic Conductivity (K) (m/day)	Radius of Influence (m)	Gross Groundwater Inflow from Seepage Face / Metre (m^3/day/m)	Evaporation from Seepage Face / Metre (m^3/day/m)	Net Face Seepage / Metre (m^3/day/m)	Net Face Seepage / Metre (ML/year/m)	Net Face Seepage of 1000m (ML/year)
Upper limit	0.2	250	0.04	0.013	0.03	0.01	10
Representative Limit	0.09		0.019		0.006	0.002	2
Lower Limit	0.07		0.015		0.002	0.001	1

This assessment indicates seepage rates will be minor and this agrees with observations from the existing open cut pits at both the Cullen Valley Mine and the Invincible Colliery that have not recorded any significant rate of groundwater seepage to date.

It should be noted that during mining into new areas, inflows may be initially higher (perhaps up to 2 to 3 times above the rates shown in Table 12 and Figure 22), reducing to a lower steady state seepage rate over time.

A number of simplifying assumptions were required to undertake the assessment outlined above. These assumptions are detailed within Appendix 5.

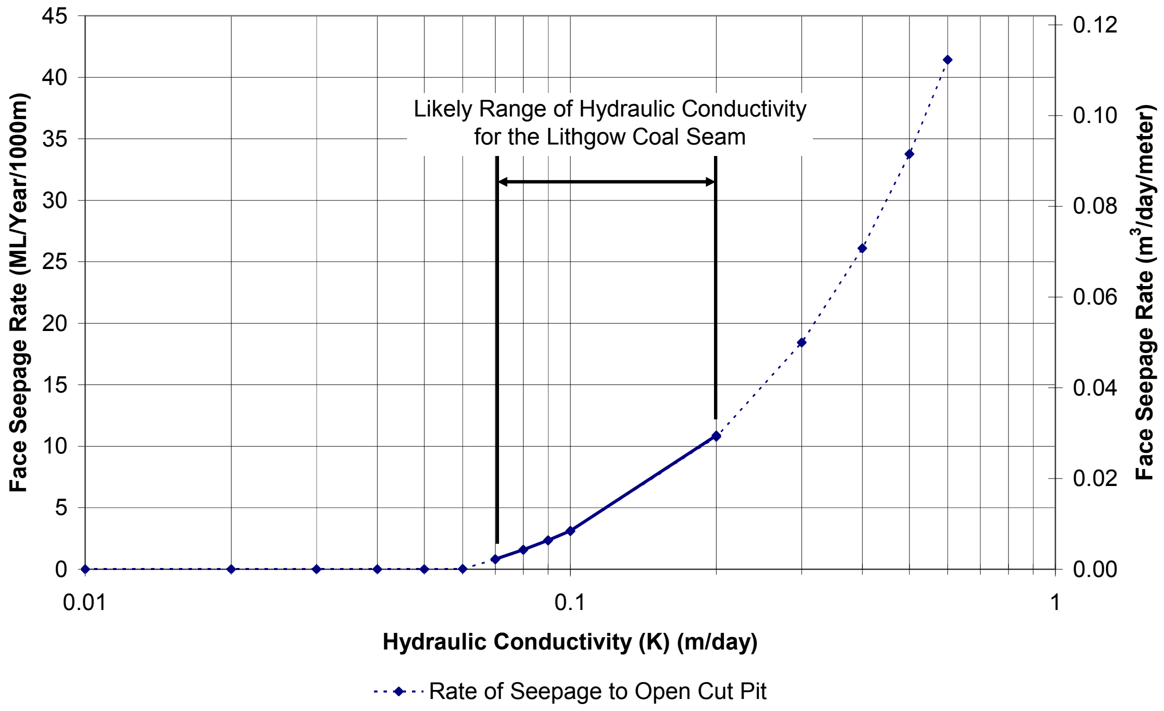

Figure 22: Groundwater Seepage Rates to Open Cut Pits

10.5 Groundwater Inflow to Open Pits Near Flooded Workings

The proposed open cut mine plan for the Cullen Valley and East Tyldesley mining areas are located proximal and down-hydraulic-gradient from the flooded underground Old Tyldesley Colliery. The open cut mine plans will be designed such that mining of the Lithgow Coal Seam will not intersect the flooded underground workings and a barrier of solid coal of a specified width will be left in place between the flooded underground mine and the open cut pits. The open cut pit will be further developed above the flooded underground workings where the upper coal seams will be targeted.

This being the case, the potential exists for water stored within flooded underground mine workings to seep through the coal seam barrier separating the flooded underground mine and into the adjacent open cut mining areas. The width of the coal seam barrier will be specified such that coal seam removal will be maximised whilst still providing a barrier of sufficient width to retard seepage from the underground workings into the open cut pits.

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The cross-section presented in Figure 9 illustrates an example were there is overlap between the flooded underground workings and the proposed open cut mine plan. The width of the coal seam barrier will influence the hydraulic gradient between the saturated underground mine and the open cut pit such that a wider coal seam barrier will result in a lower hydraulic gradient, inturn resulting in lower seepage rates.

The potential for seepage of water from the flooded underground mine workings of the Old Tyldesley Colliery into the Cullen Valley and East Tyldesley open cut pits was assessed using the form of the Darcy Equation discussed in Section 10.4.

The assessed inflow of seepage from the flooded workings into the Cullen Valley and East Tyldesley open cut pits is summarised in Table 13 and shown graphically in Figure 23.

Table 13: SUMMARY OF GROUNDWATER SEEPAGE FROM FLOODED WORKINGS

Range	Hydraulic Conductivity (K) (m/day)	Barrier Width (m)	Gross Groundwater Inflow from Exposed Face / Metre (m^3/day/m)	Evaporation from Seepage Face / Metre (m^3/day/m)	Face Seepage / Metre (m^3/day/m)	Face Seepage / Metre (ML/year/m)	Face Seepage of 1000m (ML/year)
Upper limit	0.2	25	0.14	0.013	0.13	0.05	42
Representative Limit	0.09		0.06		0.05	0.02	17
Lower Limit	0.07		0.05		0.04	0.01	12
Upper limit	0.2	50	0.07		0.06	0.02	19
Representative Limit	0.09		0.03		0.02	0.01	6
Lower Limit	0.07		0.025		0.01	0.004	4
Upper limit	0.2	75	0.05		0.03	0.01	11
Representative Limit	0.09		0.02		0.01	0.003	3
Lower Limit	0.07		0.016		0.004	0.001	1

As expected, the data indicates that groundwater seepage rates are sensitive to the width of the coal seam barrier separating the flooded underground workings and the open cut pits.

The proposed Cullen Valley and East Tyldesley mining areas are anticipated to be separated from the flooded Old Tyldesley Colliery by a coal seam barrier of about 50m. The data indicates that when a coal seam barrier of 50m is incorporated into the mine design, the expected range of seepage from the flooded underground workings would be from 0.025m^3/day/m up to about 0.07m^3/day/m over a range of coal seam hydraulic conductivity (0.07m/day to 0.2m/day) as shown in Table 13.

Evaporation, estimated at about 0.013m^3/day/m will reduce the amount of seepage that ultimately accumulates at the pit face. Where the mine plan incorporates a coal seam barrier width of 50m the rate at which water will potentially seep into the pit ranges from 0.01m^3/day/m to 0.06m^3/day/m over a range of coal seam hydraulic conductivity (0.07m/day to 0.2m/day).

A number of simplifying assumptions were required to undertake the assessment outlined above. These assumptions are detailed within Appendix 5.

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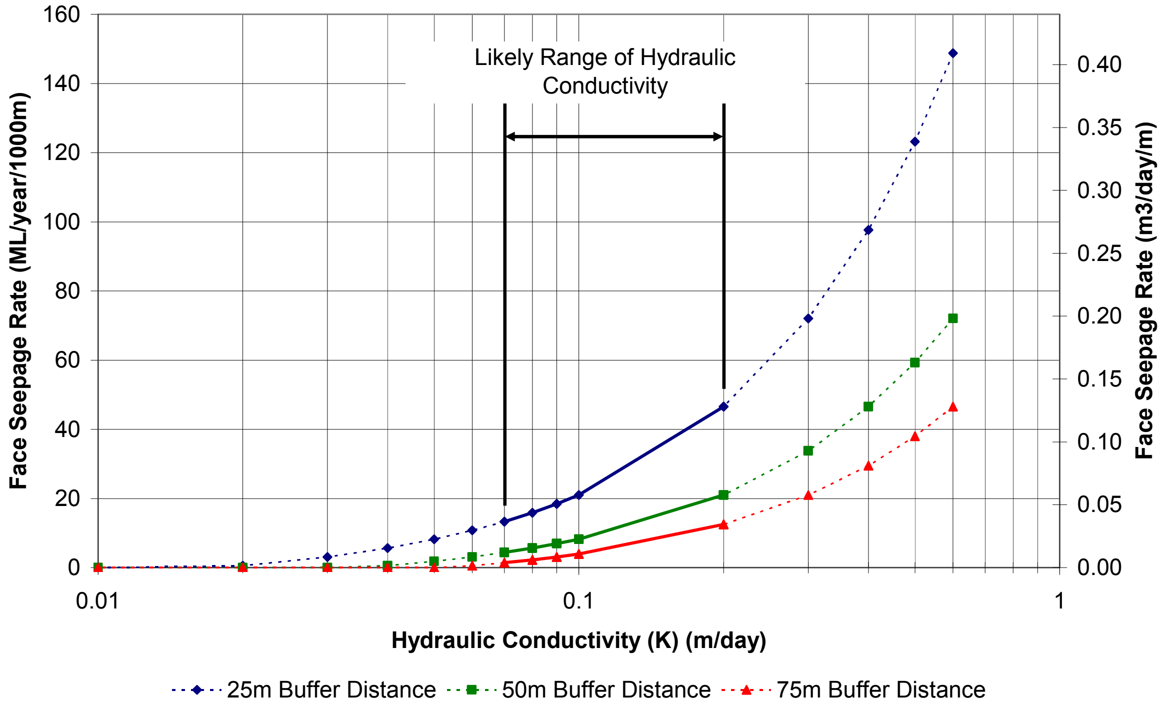

Figure 23: Groundwater Seepage Rates from Flooded Workings to Open Cut Pits

10.6 Groundwater Inflow to Highwall Mining Areas

Highwall mining will occur throughout the areas indicated in Drawing No. 11. As highwall mining progresses, the coal seam is mined out by a coal auger or other highwall mining machine. Groundwater losses from highwall mining are primarily derived from moisture within the coal seam as it is removed by highwall mining, and from inflow into the highwall mining void from the surrounding coal seam aquifer.

Highwall mining is not planned for the Lithgow Coal Seam in areas of flooded underground workings. Therefore, highwall mining will not occur within the Invincible Colliery underground workings or the Cullen Valley mining area in the Old Tyldesley Colliery underground workings. At these locations only the upper coal seams (assumed to be mostly unsaturated) will be highwall mined. It is anticipated that negligible groundwater inflow will occur into the highwall mining drives within the upper seams owing to the unsaturated state of the upper coal seams.

In addition, the open cut mining plan is designed such that it follows topographic contours along ridge lines. This mining method will leave the ridge top intact in Cullen Valley, East Tyldesley, and Hillcroft mining areas (Drawing No. 11). The coal seams under the ridge tops will be separately removed via highwall mining. In this case, groundwater seepage is not expected to occur from surrounding coal seam aquifers because the surrounding seams have either been removed by open cut mining (in the case of the Cullen Valley and some of the East Tyldesley mining areas) or they are expected to be above the zone of saturation (as in the case of the Hillcroft mining area). It is therefore anticipated that negligible seepage to the highwall mining drives will occur in the Cullen Valley and Hillcroft, and some of the East Tyldesley mining areas.

Seepage into Lithgow Coal Seam highwall mining drives is therefore only anticipated to occur within the East Tyldesley highwall mining area where no open cut mining will be undertaken to the

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east (Drawing No. 11). The rate of groundwater inflow to the East Tyldesley highwall mining drives and the time taken to fill the highwall mining drive voids have been assessed based on Darcy's groundwater flow equation discussed in Section 10.3.

The rate at which groundwater seeps into highwall mining drives is governed by the permeability of the coal (hydraulic conductivity) and the hydraulic gradient, similar to the hydraulic processes occurring during open cut mining.

An analytical assessment of the highwall mining impacts was undertaken utilising a number of simplifying assumptions for the following two scenarios:

- the groundwater inflow rate to a single highwall mining drive; and
- the groundwater inflow rate to a series of highwall mining drives that have been developed simultaneously.

Analysis of a single highwall mining drive (with a height of 2.5m, width of 3m, a length of 300m) and the surrounding coal seam with a hydraulic conductivity of about 0.09m/day, indicates that there may be groundwater inflow of approximately 6.5m^3/day. Based on the dimensions described above, a single highwall mining drive will have a void volume of about 2.25ML and will fill by groundwater seepage from the coal seam in approximately one year assuming a constant seepage rate of 6.5m^3/day and the open end of the drive is sealed soon after completion.

The rate of groundwater seepage to each highwall mining drive will be reduced by the progressive development of adjacent highwall mining drives. Owing to the progressive nature, each highwall drive length will have only a short period of time (perhaps a few days) to receive groundwater inflow prior to the next drive in the series being developed. Development of the adjacent highwall mining drive dewaters the aquifer, reducing the seepage rate to the adjacent previous drive.

In this case, it is appropriate to assess groundwater inflow to the highwall mining drives in a single "snap-shot", that is, a hypothetical situation where all highwall mining drives have been developed simultaneously. In this case, groundwater will seep through the end-face of each highwall mining drive and also through the length of the outermost drives.

The length of the East Tyldesley highwall mining area that is assumed to receive groundwater seepage has a length of about 1000m. Each highwall mining drive is anticipated to be about 3m wide and be separated from the next drive by about 3m. About 167 highwall mining drives are anticipated to be developed within the available area. In this case, the total groundwater seepage will be a combined volume derived from 167 highwall mining drive end-faces and the two lengths of the outermost drives. Based on the highwall mining layout described above, the total groundwater inflow calculated for all highwall drives is about 12m^3/day, assuming a hydraulic conductivity of about 0.09m/day. Knowing that 167 highwall mine drives will have a void volume of about 375ML, the total volume will fill by groundwater seepage from the Lithgow Coal Seam in approximately 86 years.

The examples described above illustrate the short-term (single highwall drive) and long-term (simultaneous highwall drive development) scenarios with regard to the time taken for the highwall mining drives to fill by groundwater inflow. The analytical assessment illustrates two end members, where the likely scenario lies somewhere between. Despite the limitations associated with the analytical assessment of groundwater inflow rates, the results illustrate that the time taken to fill these voids is most likely to range on a scale of many years to decades.

A number of simplifying assumptions were required to undertake the assessment outlined above. These assumptions are detailed within Appendix 5.

10.7 Groundwater Inflow to the Sand Quarry Operation

An analytical method was used to assess the zone of depressurisation in the Marrangaroo Formation and the seepage rate to the sand extraction areas proposed. The equation developed by Marinelli and Niccoli (2002) for inflow to a mine pit was used for the assessment. The analytical model presented by Marinelli and Niccoli is shown Figure 24.

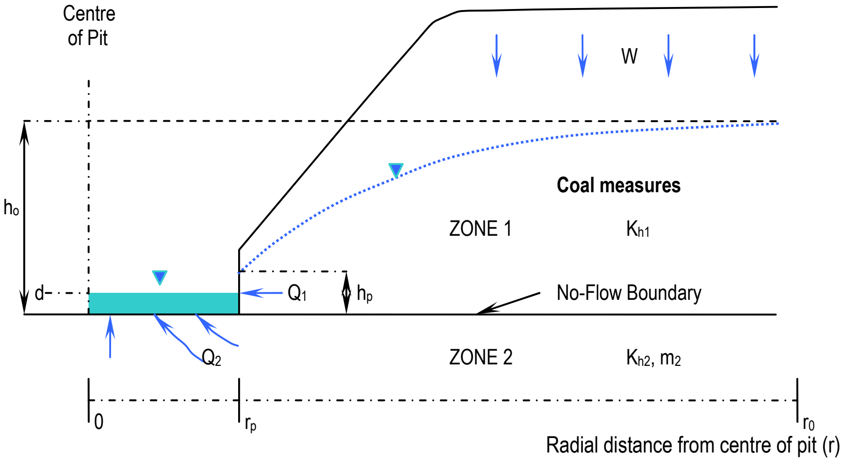

Figure 24: Pit Inflow Analytical Model (after Marinelli and Niccoli [2000])

The radius of influence 'r_o', that is the maximum extent of drawdown in the potentiometric surface of Marrangaroo Formation was obtained by iteration and was assessed to range up to about 550m within the likely range of hydraulic conductivity over the likely range of recharge rates as shown in Figure 25.

The rate of inflow to the quarry pits was determined from the following equation.

$$Q \quad = \quad W\pi\left(r_o^2 - r_p^2\right) \quad (m^3/day)$$

Where: Q = seepage from the pit face (m^3/day)
W = Distributed recharge flux (i.e. rainfall) (m^3/day/m^2)
r_o = Radius of influence from the pit (m)
r_p = Effective radius of pit

Steady state groundwater inflow to the quarry pits is likely to be sourced only from the east owing to the out crop of the Marrangaroo Formation in the west. In this case, only half of the exposed perimeter (i.e. 628m) of the quarry pit wall is likely to receive groundwater inflow.

The equation indicates that the long term additional steady-state inflow to the quarry pits from the Marrangaroo Formation (from the eastern pit walls only) ranges from 0.004m^3/day/m up to 0.058m^3/day/m. Assuming a quarry pit radius of about 200m each year (equalling a 628m long seepage face), groundwater inflow to the pit may range between 0.8ML/year up to about 13ML/year depending upon the value of hydraulic conductivity and recharge rate as shown within Table 13 and graphically on Figure 26. These inflow rates are corrected for evaporative losses.

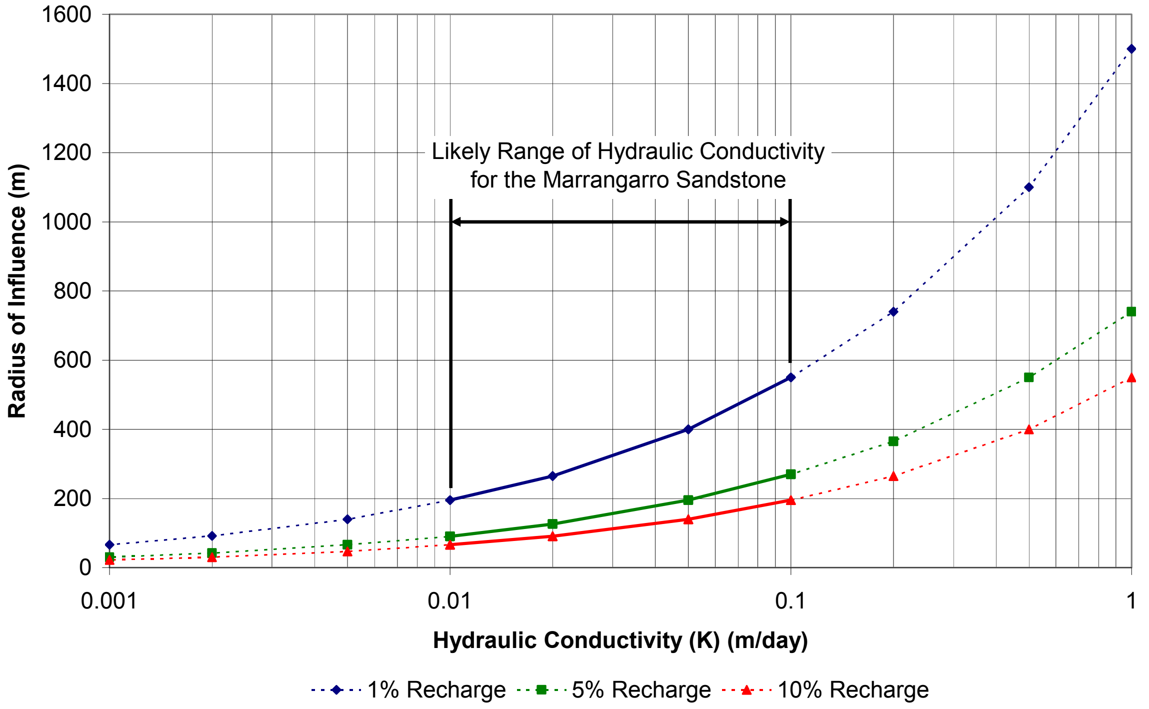

Figure 25: Drawdown Radius of Influence within the Marrangaroo Formation

It should be noted that during mining into new areas, inflows may be initially higher (perhaps up to 2 to 3 times above the rates shown in Table 14 and Figure 26), reducing to a lower steady state seepage rate over time. A number of simplifying assumptions were required to undertake the assessment outlined above. These assumptions are detailed within Appendix 5.

Table 14: SUMMARY OF GROUNDWATER SEEPAGE FROM MARRANGAROO FORMATION

Range	Hydraulic Conductivity (K) (m/day)	Recharge Rate %	Gross Groundwater from Exposed Face / Metre (m^3/day/m)	Evaporation from Exposed Face / Metre (m^3/day/m)	Face Seepage / Metre (m^3/day/m)	Face Seepage / Metre (ML/year/m)	Face Seepage of 628m (ML/year)
Upper limit	0.1	1	0.027	0.0025	0.025	0.009	6
Representative Limit	0.05		0.017		0.014	0.005	3
	0.02		0.009		0.007	0.002	2
Lower Limit	0.01		0.006		0.004	0.001	1
Upper limit	0.1	5	0.047		0.045	0.016	10
Representative Limit	0.05		0.030		0.028	0.010	6
	0.02		0.017		0.015	0.005	3
Lower Limit	0.01		0.012		0.009	0.003	2
Upper limit	0.1	10	0.061		0.058	0.021	13
Representative Limit	0.05		0.040		0.037	0.014	9
	0.02		0.023		0.021	0.008	5
Lower Limit	0.01		0.016		0.014	0.005	3

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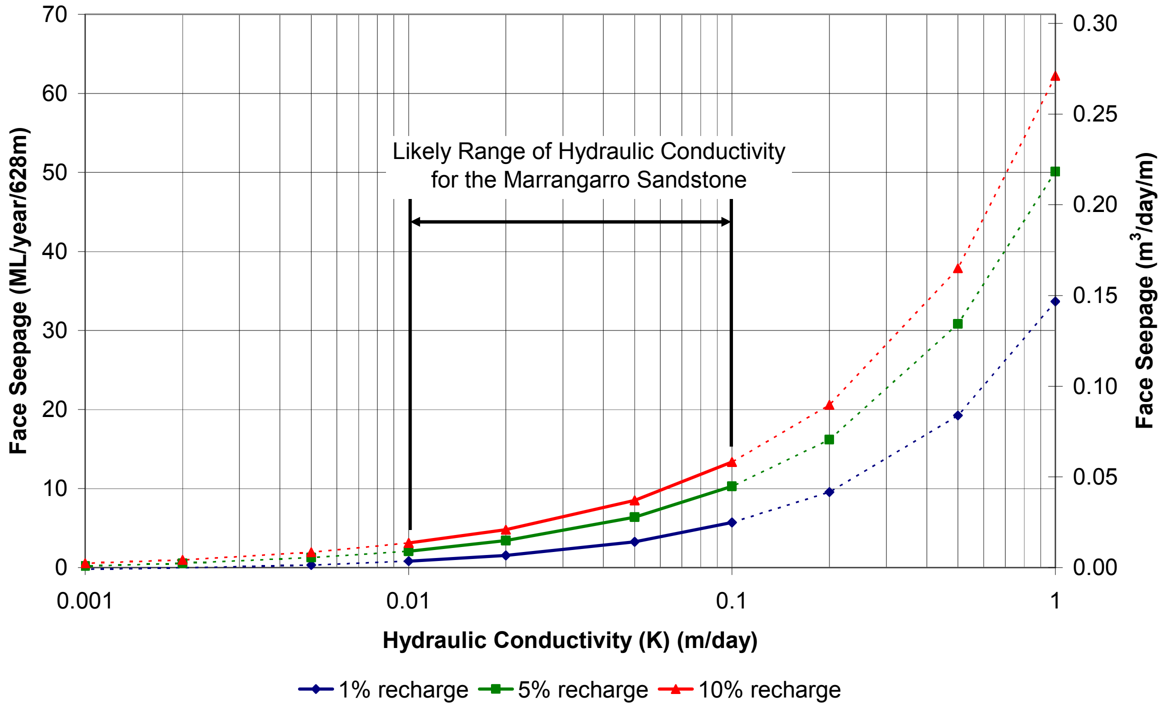

Figure 26: Groundwater Seepage Rates from the Marrangaroo Formation to Quarry Pit

11.0 DISCUSSION ON GROUNDWATER IMPACTS – MINING PHASE

The following sections outline the impact of the Project on the groundwater regime with regard to the potential for:

- a reduction in groundwater levels immediately surrounding the mining areas;
- loss of groundwater yield at existing bores;
- reduction in groundwater levels within flooded workings adjacent to open cut mining areas;
- changes in groundwater quality; and
- reduction in groundwater discharge to GDEs.

11.1 Impact on Groundwater Levels

The impact of the proposed Project on groundwater levels is expected to be localised, and limited largely to the northern area of the Project.

Where mining is proposed within the saturated zone, an analytical assessment of impact on water levels was undertaken. The assessment indicated that drawdown will occur where the rate of groundwater extraction from the mine workings exceeds the rate that the Lithgow Coal Seam and the Marrangaroo Formation is able to recharge. This will lead to drawdown of the potentiometric surface within the immediate vicinity of the Project compared to pre-mining levels.

Pressure reductions from open cut and highwall mining are predicted to have a localised impact surrounding the mining operations. The limited extent of impact is due to the pre-existing shallow hydraulic gradient and the low hydraulic conductivity of the coal seam and sandstone aquifers. Based on the assessments described above, it is anticipated that the radius of groundwater depressurisation would extend up to 500m within the Marrangaroo Formation.

The zone of depressurisation within the Lithgow Coal Seam will be negligible to the east of the Invincible mining areas proposed, owing to the proximity and dewatering at the Baal Bone Colliery. The zone of depressurisation within the Lithgow Coal Seam associated with the Cullen Valley and the East Tyldesley mining areas may result in a zone of depressurisation that could extend from the mining areas and potentially cover small areas of surrounding properties. The resultant drawdowns are expected to be limited as the mining is not extending far into the saturated zone and the zone of depressurisation will be further restricted by areas where the coal seam crops out at the ground surface and by the shallow hydraulic gradient.

The depressurisation within the Lithgow Coal Seam and the Marrangaroo Formation will have no direct impact as the groundwater resource has limited use beyond the mining industry. The study indicated that the Project will generate low volumes of seepage from the coal seams and Marrangaroo sandstones. This seepage rate was estimated to be between 2ML/year and 23ML/year for both aquifers combined. This volume of groundwater removed from the aquifers will have a negligible affect on the water management commitments of the neighbouring Baal Bone Colliery.

Impact on groundwater levels will not occur to the west of the Project Boundary owing to the outcrop of the Permian aquifers along the western Project Boundary. In addition, groundwater levels to the east of the Project Boundary have been noted by other studies to have already been significantly drawn down by the Baal Bone Colliery. The proximity of the Baal Bone Colliery will result in cumulative impacts on groundwater levels; however, owing to the long history of mining within the immediate area, the proposed Project will not produce any further significant impact on the groundwater regime.

11.2 Impacts on Existing Registered Bores

Drawing No. 7 shows the locations of bores registered with NOW with 3km of the Project Boundary. Eight registered bores constructed in the Permian strata are located within 1km of the Project Boundary. Information on these bores is summarised in Table 15.

Table 15: REGISTERED BORES IN ZONE OF POTENTIAL INFLUENCE

Work No.	Date	Licence Status	Drilling Method	Completed Depth (mbgl)	Distance from Project Boundary (m)
Lapsed or Cancelled Licences					
GW801861	2002	Test Bore – cancelled	Rotary	72	240
GW030898	1981	Industrial – lapsed	Rotary	232	360
GW059350	1983	Mining – cancelled	Rotary Air	24.1	800
Active Licences					
GW804393	2000	Mining (Invincible Colliery) – active	Unknown	27	0
GW064530	1987	Domestic/Stock – active	Rotary Air	85.4	300
GW062283	1986	Mining – active	Rotary Air	59.8	390
GW106258	2003	Domestic/Stock – active	Hammer	122	750
GW064531	1987	Domestic/Stock – active	Rotary	48.8	930

Five bores are registered for industrial and mining use of which three of these bores have had the licence cancelled or lapsed, and one of these bores is licensed to the Invincible Colliery. Three bores (GW106258, GW064530 and GW064531) located within 1km of the Project Boundary are registered for stock and domestic purposes. The depth of these registered stock and domestic bores ranges between 48.8mbgl up to 122mbgl. The depth of these bores suggests that they are accessing groundwater within the Permian Coal Measures, possibly within or below the Nile Subgroup, located beneath the Lithgow Coal Seam and beneath the Marrangaroo Formation. The position and depths of GW64530 and GW064531 are illustrated on Figure 6 and the position and depth of GW062283 is illustrated on Figure 8 which shows these bores accessing water at least 30m beneath the Lithgow Coal Seam and the Marrangaroo Formation. This being the case, it is therefore assessed that the Project would not impact on any private groundwater users in the area.

11.3 Impact on Abandoned Flooded Workings

The vast majority of the proposed mine plan for the Invincible Colliery open cut mining areas is located up-gradient of the flooded underground workings of the Old Invincible Colliery as illustrated in Drawing No. 12. However, some small sections of the Invincible Colliery open cut pit will intercept the old underground workings in the far eastern area. Water stored within the underground workings of the Old Invincible Colliery is likely to be utilised to augment surface water supplies to meet the Project’s water requirements, as has been the long term practice at Cullen Valley Mine drawing water from the Old Tyldesley Colliery underground workings. This practice will also dewater the underground workings in the immediate vicinity which will allow safe mining of the proposed Invincible Colliery open cut pit. As such, these open cut mining areas are not likely to receive any groundwater seepage from the flooded workings.

It is anticipated, that the volume of water stored within the flooded workings of the Old Invincible Colliery will remain largely unaffected by the development of open cut pits and highwall mining areas.

The proposed open cut mine plan for the Cullen and the East Tyldesley mining areas are located proximal and down-hydraulic-gradient from the flooded underground Old Tyldesley Colliery. As detailed in Section 10.5, assessment of potential seepage rates indicates that when a coal seam barrier of 50m is incorporated into the mine design, the seepage from the flooded underground workings into open pits may range from 0.025m^3/day/m up to 0.07m^3/day/m. This is about 11.5ML/year over an exposed coal seam face of 1000m for an average coal seam hydraulic conductivity of 0.09m/day. An exposed coal seam face of 1000m during the life of the Project appears to be unlikely.

Seepage of water from the flooded underground workings of the Old Tyldesley Colliery has been assessed (Section 10.5) to be currently between 3ML/year and 8ML/year (over a seepage face of about 1800m) based on a hydraulic gradient towards the north-east (i.e. towards Baal Bone Colliery). The water level within the flooded workings has been shown to be static. This steady state condition suggests a balance exists between recharge inflow and discharge seepage. Based on this simple assessment, an average recharge rate of water into the Old Tyldesley Colliery would be about 5.5ML/year.

The water level within the Old Tyldesley Colliery is therefore likely to decline over time owing to the increased seepage rate that will occur when open cut pits are excavated in close proximity. In this case, an additional volume of about 8.4ML/year may be potentially lost from the flooded workings of the Old Tyldesley Colliery (assuming that 1000m of coal seam is exposed without backfilling).

Based on the calculations and assumptions above, the volume of water stored within the flooded workings will be reduced by about 1.2% each year that seepage from the flooded workings occurs.

The Project open cut areas will be rehabilitated by filling the mining areas with spoil material. Rehabilitation will be developed in accordance with conceptual landform design objectives and guidelines so that disturbed areas are returned to a condition that is compatible with the surrounding landscapes of the Ben Bullen State Forest and is sustainable in the long term.

Seepage from the flooded Old Tyldesley Colliery will continue for a period of time after the emplacement of spoil rehabilitation owing to the unsaturated state of the spoil. The higher permeability of the spoil (compared to the coal seam barrier) is not expected to retard the seepage. In this case, the spoil will continue to receive seepage until a new steady state condition is reached where the spoil is saturated to a level equal to that within the flooded workings. Recharge to the spoil rehabilitation should therefore be encouraged to assist with re-saturation of the spoil (i.e. recovery of water levels) in a shorter timeframe. In a similar process, the flooded underground workings will be recharged via runoff from the rehabilitated slopes of the western (up dip side) at Cullen Valley Mine. A shorter recovery timeframe will therefore reduce the cumulative loss of water from the flooded workings of the Old Tyldesley Colliery.

The rate of groundwater recovery will depend on the recharge and natural discharge rates, and the specific yield of the backfill material, which for this exercise has been assumed to be 10%. Following emplacement of the spoil, groundwater recharge has been calculated at 5% of average rainfall. At this rate it would take about 8 years for the groundwater level within the spoil material to recover about 3m, this being about the top of the Lithgow Coal Seam. Once the groundwater level within the spoil has recovered about 3m it is anticipated that seepage from the flooded workings of the Old Tyldesley Colliery will return to about pre-mining rates. The cumulative loss of water from the flooded workings will therefore be about 10% of the total water stored in the flooded workings (i.e. about 70ML), assuming that the seepage rate remains constant during recovery. This is a particularly conservative assumption considering that seepage would most likely decline exponentially as recovery in the spoil will reduce the hydraulic gradient during recovery. It is also conservatively assumed that the seepage contribution to spoil recharge will be small compared to rainfall recharge, and in this case, the seepage volume has not been included within the recharge calculations.

11.4 Impact on Groundwater Quality

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 (2011). The assessment provided a geochemical characterisation of the overburden, interburden and potential coal reject material and concluded that:

Overburden

- overburden materials at the Project are likely to be non acid forming (NAF) and have a high factor of safety with respect to potential acid generation. Most overburden samples have negligible total sulphur content and a low to moderate acid neutralising capacity;
- the concentration of total metals in overburden solids is well below applied guideline criteria for soils and is unlikely to present any environmental issues associated with revegetation and rehabilitation;
- most overburden materials will generate pH neutral, low-salinity run-off and seepage following surface exposure. The major ion chemistry of initial surface run-off and seepage

from overburden materials is likely to be dominated by sodium and sulphate with lesser amounts of bicarbonate and chloride;

- the concentration of dissolved trace metals in initial and ongoing run-off and seepage from overburden materials is unlikely to present any significant environmental issues associated with surface and ground water quality as a result of the Project; and
- overburden materials below 10m depth are likely to be non-sodic and may be suitable for revegetation and rehabilitation activities (in final surfaces or as a growth medium). Field trials would be required to determine those materials most suitable for these activities.

Coal rejects

- most coal reject materials are likely to be NAF and have an elevated factor of safety with respect to potential acid generation;
- some coal reject materials have uncertain geochemical characteristic or are potential acid forming (PAF). The few PAF coal reject materials appear to be associated with the Lithgow Seam and particularly coarse reject materials. In contrast, tailings materials generated from processing the Lithgow Seam appear to be NAF;
- the concentration of total metals in potential coal reject solids is well below applied guideline criteria for soils and is unlikely to present any environmental issues;
- most NAF potential coal reject materials will generate pH neutral and relatively low-salinity run-off and seepage following surface exposure. However, PAF coarse reject materials from the Lithgow Seam may generate acidic and more saline run-off and seepage if exposed to oxidising conditions;
- the major ion chemistry of initial surface run-off and seepage from NAF coal reject materials is likely to be dominated by sodium and sulphate with lesser amounts of bicarbonate and chloride;
- for PAF coarse reject materials, the initial concentration of soluble sulphate in surface run-off and seepage is expected to be relatively low, although further exposure to oxidising conditions may lead to increased sulphate concentrations; and
- the concentration of dissolved metals in initial run-off and seepage from NAF coal reject materials is unlikely to present any significant environmental issues associated with surface water and groundwater quality as a result of the Project. For PAF coarse reject materials, there is some potential for the concentration of dissolved metals in surface run-off and seepage to increase over time, if not managed appropriately.

Considering the conclusion reached by RGS (2011) following geochemical assessment of the overburden and potential reject materials, it is considered unlikely that leachate generated from these materials will adversely impact regional groundwater quality.

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

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11.5 Impact on Groundwater Dependent Ecosystems

There are no known springs within the Project Boundary that are fed by groundwater around which groundwater dependent ecosystems have developed.

Notwithstanding this, Coxs River Swamp and Jews Creek Swamp are likely to constitute groundwater dependent ecosystems. Due to the hydraulic disconnection between the Triassic aquifers and the Permian Coal Measures, the distance between the Project and the GDEs, and the low volumes of groundwater extracted by the Project, impacts on these GDEs are unlikely.

12.0 POTENTIAL GROUNDWATER IMPACTS – POST MINING

The final landform after mining ceases will consist of rehabilitated areas similar to the existing pre-mining landform. On emplacement of the spoil, groundwater levels will steadily recover and eventually return to equilibrium. During this stage there will no dewatering and therefore no discharge of groundwater.

The Baal Bone Colliery will cease operations early in the Project life and dewatering will cease. The Baal Bone Colliery underground workings will slowly flood with groundwater and eventually an equilibrium water pressure in the coal seam will be reached over time. No post-closure measures for the Baal Bone Colliery were available for review during this assessment.

The rate of groundwater transfer from the Invincible Colliery flooded workings into the flooded Baal Bone workings will likely be reduced by this increased water pressure. The impact on the Project will likely be to increase the availability of groundwater in flooded workings of the Old Invincible Colliery.

Following rehabilitation, the quality of the groundwater recharge is expected to be similar to that determined by RGS (2011), and will have a relatively low salinity.

13.0 WATER LICENCING

The current mining operation operates without the need for a licence to take groundwater owing to the dry mine site conditions. This assessment suggests that dry mining conditions will still mostly prevail for the proposed Project owing to evaporative losses; however, small volumes of seepage are anticipated to occur where flooded workings seep into proposed open cut mining areas or where mining is undertaken below the saturated zone.

The study indicated that the Project will generate low volumes of seepage from the coal seams and Marrangaroo sandstones. This seepage rate was estimated to be between 2ML/year and 23ML/year for both aquifers combined. It is recommended an application for a water licence under Part 5 of the Water Act in accordance with the Water Management Amendment Act 2010 be applied for to account for this seepage once the WSPs relevant to the Project are implemented.

The water in the flooded workings is expected to be largely comprised of surface water runoff that has entered the workings, with a much smaller contribution from groundwater seepage. The water in the flooded workings is relatively fresh compared to the groundwater samples collected from the coal seam and sandstone aquifers which supports this conclusion.

Water stored within the flooded underground workings will continue to be used to augment surface water supply for Project mining operations. The volume of water required to supplement the surface water supply is unknown at this stage. A water licence will most likely be required to permit the extraction of the water from underground workings regardless of the volume required by the operation.

Based on the publicly available information sourced from NOW, the existing Cullen Valley and the Invincible open cut pits are wholly contained within the NSW Murray-Darling Basin Porous Rock Groundwater Sources WSP. However, the boundary between the NSW Murray-Darling Basin Porous Rock Groundwater Sources WSP and the Greater Metropolitan Region Groundwater Sources WSP follows closely (but to the east) of the south-eastern Project boundary. In this case, the Invincible Colliery Drainage Bore (GW30898) and LD001 are located within the Greater Metropolitan Region Groundwater Sources WSP area. Also, a large percentage of the Invincible Colliery Underground Workings are located within the Greater Metropolitan Region Groundwater Sources WSP area.

There will likely be groundwater sourced from both the Greater Metropolitan Region Groundwater Sources WSP and the NSW Murray-Darling Basin Porous Rock Groundwater Sources WSP areas in the area near the south-eastern project boundary. The amount of groundwater sourced from the Invincible operations may need to be split between the Greater Metropolitan Region Groundwater Sources WSP and the NSW Murray-Darling Basin Porous Rock Groundwater Sources WSP. The percent split may be dependent upon the amount of water (if any) that Coalpac sources from the flooded underground workings of the Invincible Colliery.

The current assessment of groundwater inflow into the mining pits has been based on simplistic flow modelling. The current level of assessment is therefore not able to accurately identify the amount of groundwater sourced from individual mine pits nor from individual WSP areas. In this case, it is appropriate to be conservative and apply for a water licence from each of the WSP areas that will entitle both the Invincible and the Cullen Valley operations 23ML/annum each. This provides a contingency of 100% which is appropriate considering the level of modelling sophistication applied to this assessment.

Additional groundwater monitoring bores recommended (outlined in Section 15.1 below), will also require licences prior to installation.

14.0 AQUIFER RISK

The data review described above indicates that the proposed coal mining activities within the Project Boundary pose a low risk to the groundwater regime for the following reasons:

- many of the coal seams are elevated and located within the unsaturated zone, where much of the mining will be undertaken;
- the upper coal seam crops out at the ground surface meaning they do not form a continuous aquifer;
- the hydraulic gradients and hydraulic conductivities of the coal seam and sandstone aquifers are both low;
- west of the Project Boundary the Permian aquifers outcrop; and
- to the east of the Project Boundary groundwater levels have already been significantly drawn down by the Baal Bone Underground Mine.

The mining operation will therefore generate a localised zone of depressurisation in the coal seams, but this is not expected to impact on adjacent landholder bores, nor GDEs. Due to this low risk, limited monitoring of groundwater levels and quality has been undertaken to date. However, a monitoring program is required to confirm the conclusion reached that the risk to the groundwater regime is low. A monitoring program is therefore discussed below.

15.0 GROUNDWATER MONITORING SYSTEM

This section of the report provides a recommended groundwater monitoring program that will provide both an on-going assessment of the impact of the Project and a proactive indicator of any adverse impacts on the groundwater regime.

15.1 Installation of Additional Monitoring Bores

Some of existing monitoring bores are located within the footprint of the proposed mining area and will therefore be removed as mining progresses. Therefore, it is recommended that the remaining sites be augmented with additional monitoring bores that will not be disturbed during the life of the Project. The sites of the existing and proposed additional monitoring bores are shown on Drawing No. 13. The purpose of the proposed bores is to monitor for depressurisation principally in the Lithgow Coal Seam and the Marrangaroo Formation on an on-going basis.

It should be noted that the proposed monitoring bore locations are preliminary only, and access and installation issues have not been assessed. The feasibility of the monitoring program should be addressed during development of the consolidated water management plan to be prepared for the Project.

It should be noted that MB3 does not need to be installed in the near future as CP115 is currently providing adequate monitoring. However, CP115 is schedule to be destroyed by mining in 2016. As such, it would be prudent to establish monitoring in MB3 prior to the destruction of CP115.

A bore licence must be obtained from NOW prior to installation of any new monitoring bores. All monitoring bores should be constructed according to the Australian guidelines (Land and Water Biodiversity Committee (2003) by an appropriately qualified water bore driller. The recommended sites for additional monitoring bores are summarised in Table 16.

Regular monitoring of GW804393 should also be reinstated. However, if this bore is utilised as a future water supply bore, an additional monitoring bore should be constructed proximal to the production bore.

In addition, consideration should also be given to Coalpac providing the option of monitoring private landholder bores proximal to the Project Boundary. The feasibility of this option could be addressed during the development of a water management plan for the site. The landholder bores could be equipped with automatic water level pressure transducers which could be set to capture long-term data. In the event of a water level decline within these bores, the data collected over time may provide information on the likely cause. Equipping the four most proximal private bores registered with NOW (GW106258, GW064530, GW064531, and GW062283) with data loggers could be undertaken, should the landholder wish this to occur.

Any groundwater level data collected from private bores would be assessed during annual assessments. Where monitoring indicates the occurrence of abnormal conditions, an additional assessment of the impacts will be undertaken. The additional assessment in conjunction with field inspections may indicate that remedial action is required. Appropriate stakeholder consultation will be part of determining and implementing any necessary remedial and/or mitigating actions.

Table 16: SUMMARY OF RECOMMENDED MONITORING

Bore ID	Easting (MGA94, z56)	Northing (MGA94, z56)	Aquifer	Comment
Existing Monitoring Bores				
CP114	223718.4	6316033.9	Marrangaroo Formation	Standing Water Level = 6 hourly (automatic), or monthly with manual measurement Water Quality = Annually
CP115	223329.9	6313644.1	Lithgow Coal Seam	
CP116	222675.5	6314782.7	Lithgow Coal Seam	
CP119*	225710.0	6313323.6	Lithgow Coal Seam	
CP123	224969.4	6308929.7	Marrangaroo Formation	
LD001	229413	6310733	Invincible Colliery Void	
To Be Installed				
MB1	222470	6315045	Marrangaroo Formation	Long term replacement of CP116
MB2	223799	6313677	Lithgow Coal Seam	Additional bore
MB3	225695	6313283	Lithgow Coal Seam	Long term replacement of CP115
MB4	226715	6311142	Lithgow Coal Seam	Replacement of damaged bore CP119
MB5	226715	6311142	A = Moolarben B = Irondale C = Lithgow	Additional bore
MB6	226920	6310868	Old Invincible Colliery Void	Replacement of damaged GW030898
To Be Reinstated				
GW804393	223965	6312955	Tyldesley Colliery Void	Monitoring to be Recommenced
Optional Groundwater Level Logger Installation				
GW106258	222719	6317347	Permian Sandstone	Owners Consent Required
GW064530	224148	6316244	Permian Sandstone	
GW064531	224820	6316294	Permian Shale	
GW062283	225466	6314523	Permian Shale	

15.2 Water Level Monitoring Plan

Groundwater levels have until recently been manually measured. However, more recently automatic water level pressure transducers have been installed within the monitoring bores. The water levels are now recorded on a four-hour interval. The automatic loggers will enable water level fluctuations due to rainfall recharge and pumping to be distinguished from potential water level declines due to depressurisation as a result of the Project. Manual monitoring is suitable for identification of long term trends in groundwater levels but does not provide data on short term events such as rainfall recharge.

Registered bores identified as being within the simulated zone of depressurisation should also be inspected to determine if the bores are still operational and in-use. Monitoring should be undertaken in four proximal registered bores as detailed above in Table 16 if the owners consent is granted.

The monitoring bores installed near Coxs River Swamp are the property of Xstrata. These monitoring bores are currently monitored in accordance with the environmental conditions imposed on Xstrata for the Baal Bone Colliery. Coalpac will attempt to seek a data sharing agreement with Xstrata to access monitoring data from the monitoring bores located along the Cox River Swamp.

15.3 Water Quality Monitoring Plan

Water samples should be collected from the monitoring bores on a twelve monthly basis (or as otherwise agreed with NOW) and the samples analysed for:

- physico-chemical parameters;
- major cations and anions;
- nutrients - ammonia, nitrate, nitrite; and
- dissolved metals - iron, lead, chromium, cadmium, zinc, arsenic, copper and nickel.

It is recommended the water quality monitoring regime continue for the life of the Project. It is also recommended that groundwater water quality trigger values be derived for each monitoring bore. However, in the absence of long-term historical groundwater quality data, the use of ANZECC guideline trigger values for stock watering be utilised until site specific trigger values are available.

15.4 Mine Water Seepage Monitoring

It is recommended that monitoring of any unexpected mine water seepage (i.e. greater than that predicted in this report) be undertaken, particularly to identify seepage rates. This will likely occur where the first mining strip is taken adjacent to up-dip flooded underground workings (“Seepage Areas”). The seepage monitoring program should include:

- recording of the time, location and volume of any unexpected increased groundwater outflow from the highwall and endwall in the Seepage Area.

15.5 Data Management and Reporting

It is recommended data management and reporting include:

1. annual assessment of departures from identified monitoring data trends. If consecutive monitoring data over a period of 6 months exhibit an increasing divergence in an adverse impact sense from anticipated trends, then such departures should initiate further actions. These may include a need to conduct more intensive monitoring or to invoke impact re-assessment and/or mitigative measures.
2. if more intensive monitoring is initiated (under Point 1 above) then normal review of depressurisation of coal measures should be undertaken by a suitably qualified hydrogeologist. The reporting will include consideration of all relevant water level and water quality data.

AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD

Reviewed by:

Tim Armstrong

TIMOTHY J. ARMSTRONG
Senior Hydrogeologist

JAMES S. TOMLIN
Principal Hydrogeologist

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17.0 GLOSSARY

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

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

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

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

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

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

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

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

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.

Head - sum of datum level, elevation head and pressure head which in unconfined aquifers is equal to the groundwater elevation.

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.

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

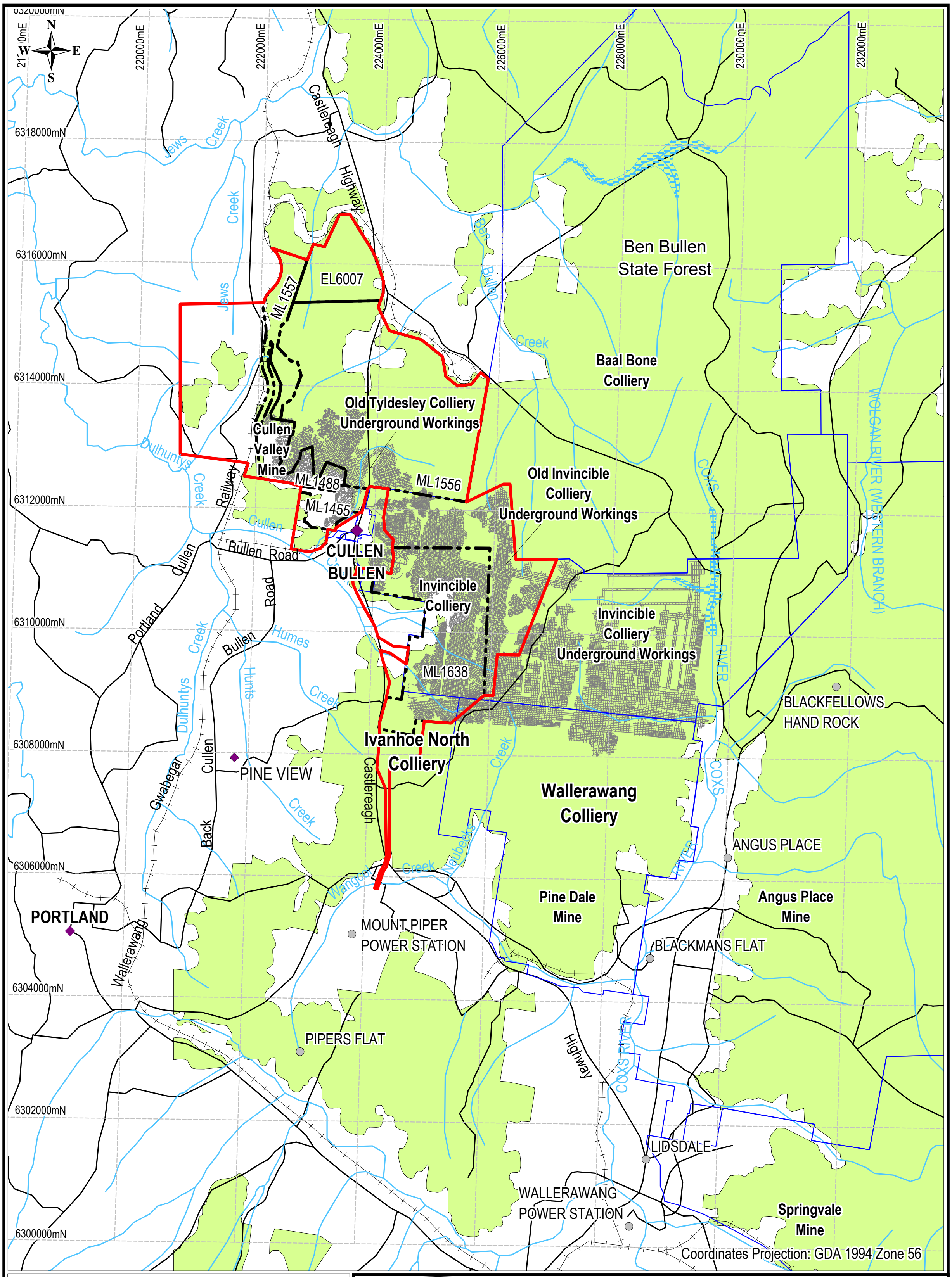
Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil. Gravity drainage may take many months to occur.

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

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

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

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



- LEGEND -

▬	EL Boundary
▬ · ▬	ML Boundary
🟥	Project Boundary
▨	Swamp Area

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL
CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
SITE LOCATION

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 90,000 (A4)
PROJECT No: G1515
DRAWING No: 1
APPROVED BY:
DATE: May 2011

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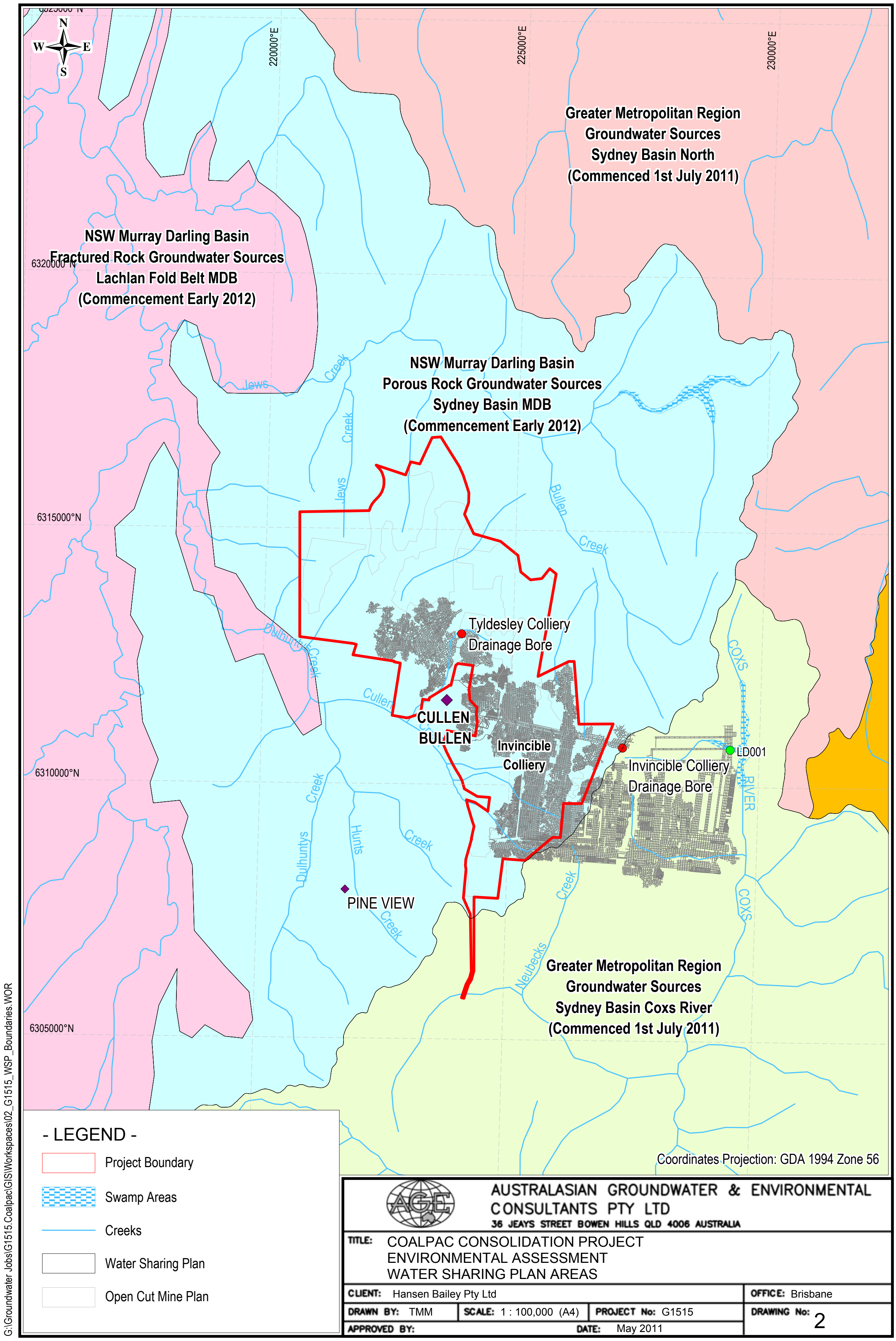

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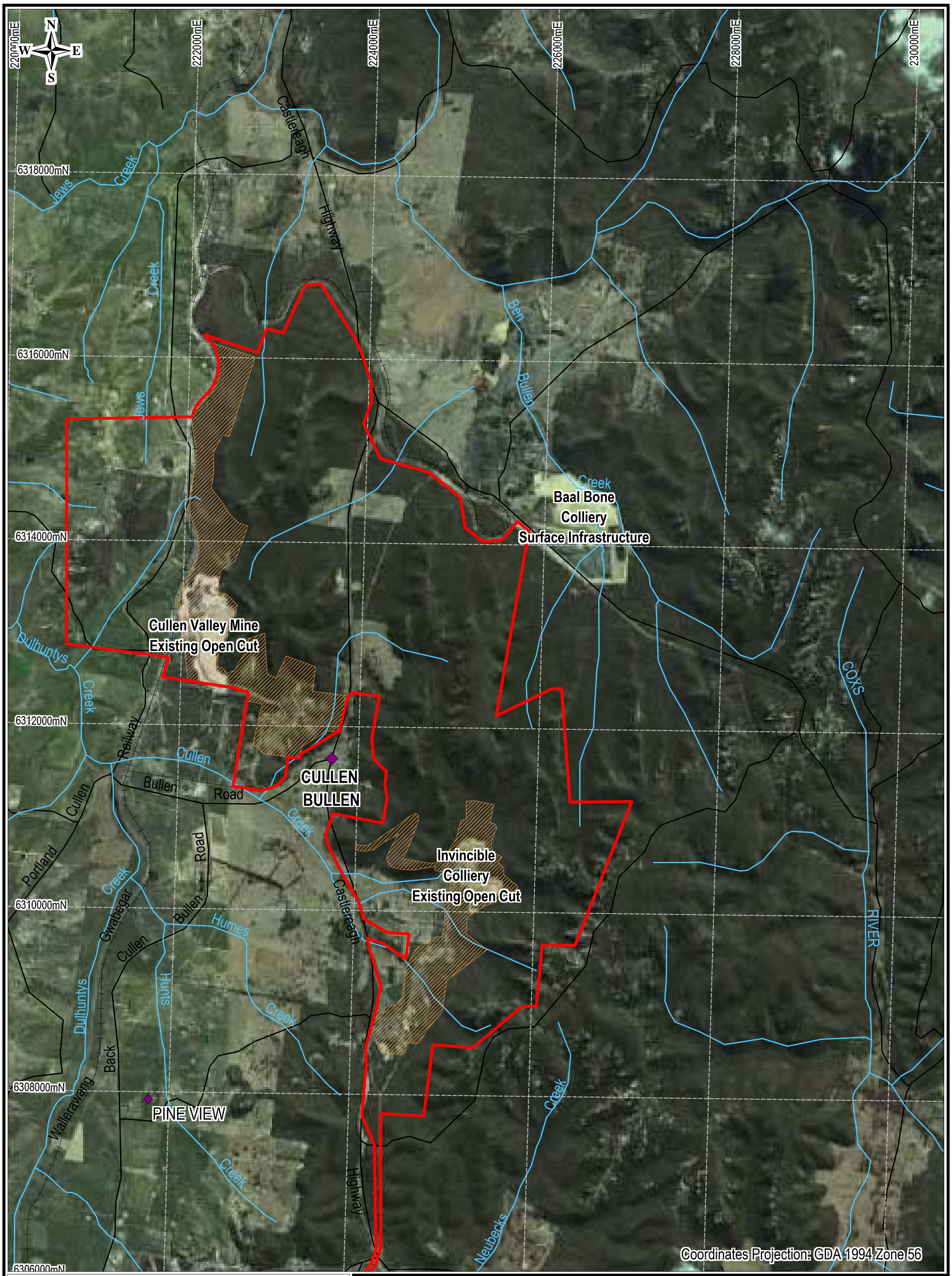

- LEGEND -

◆	Town
—	Road
▭	Project Boundary
▨	Existing Mining Operations

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36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
SITE LAYOUT

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 60,000 (A4)
PROJECT No: G1515
DRAWING No: 3
APPROVED BY:
DATE: May 2011

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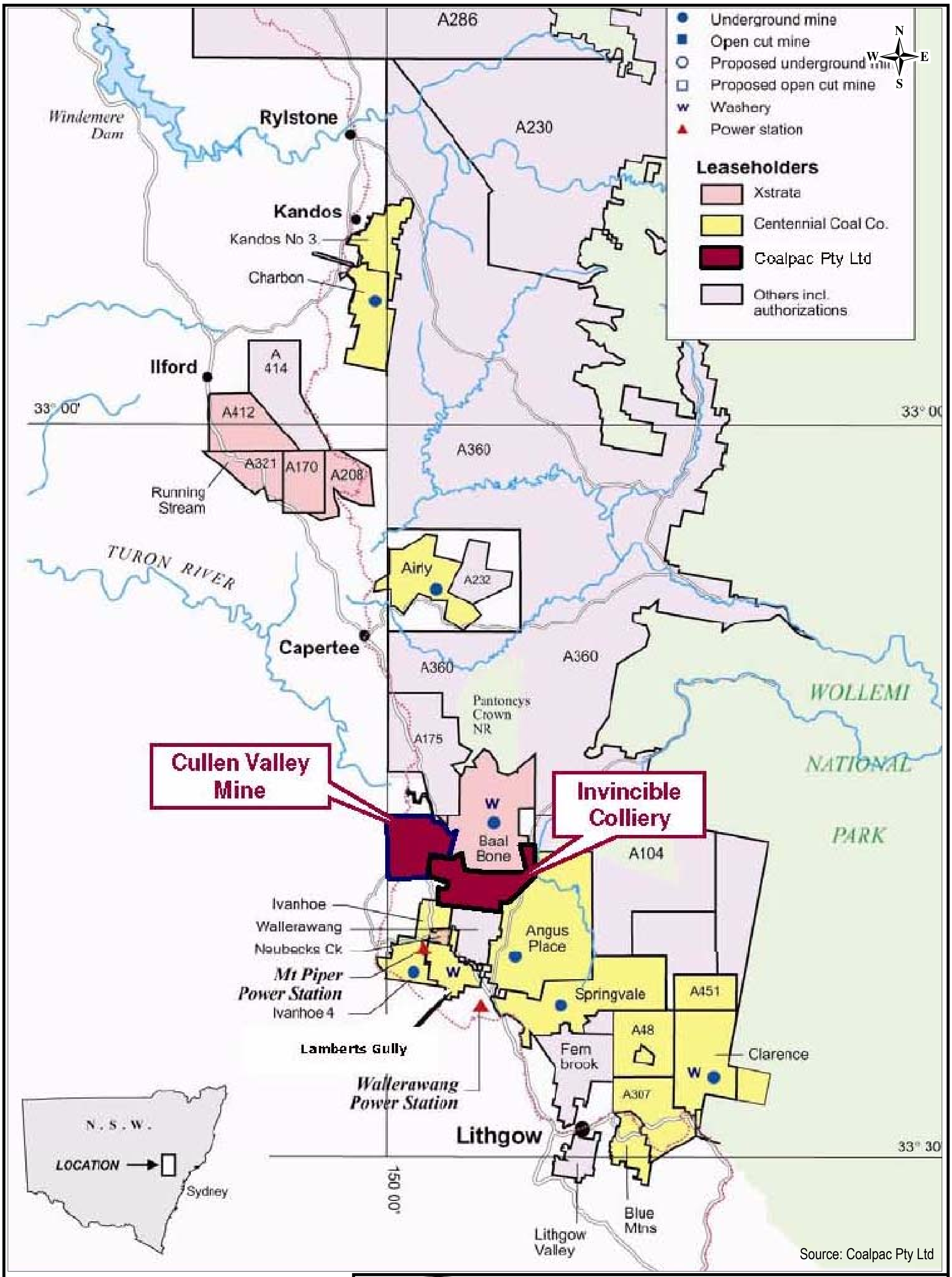

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36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
ADJACENT MINING TENEMENTS

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
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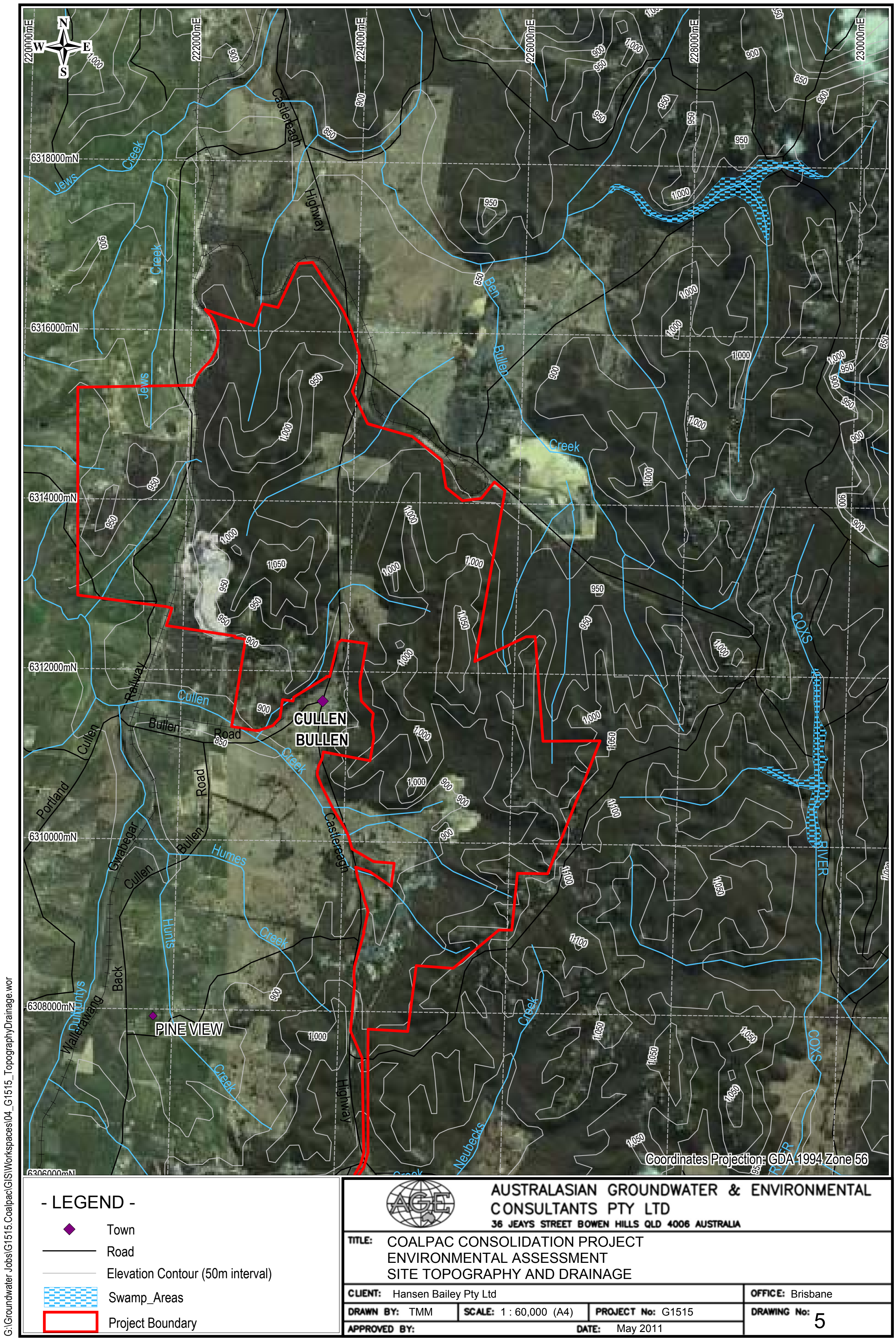
PROJECT No: Project G1515
DRAWING No: 4
APPROVED BY:
DATE: May 2011

(Project No. G1515)



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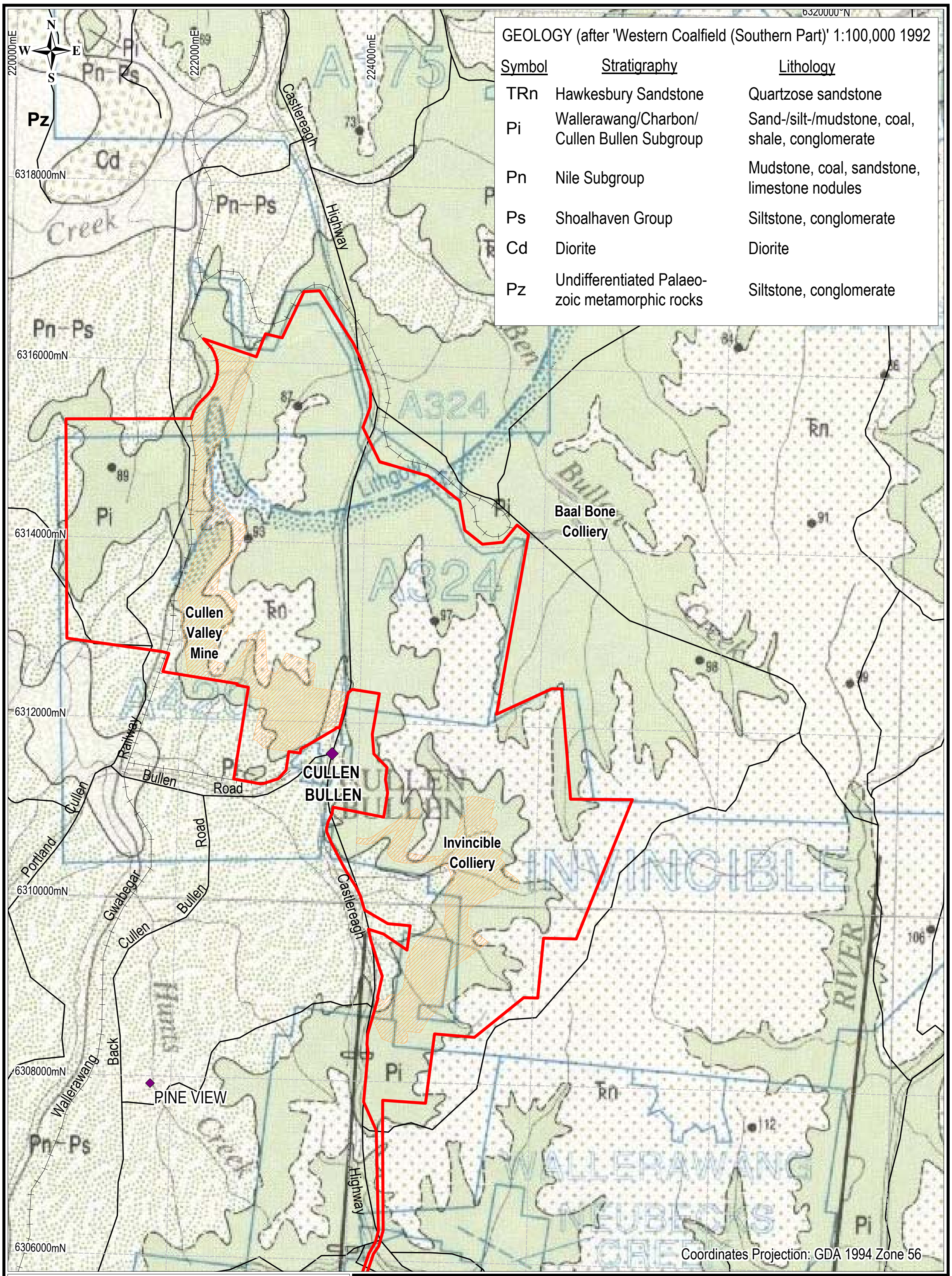

GEOLOGY (after 'Western Coalfield (Southern Part)' 1:100,000 1992

Symbol	Stratigraphy	Lithology
TRn	Hawkesbury Sandstone	Quartzose sandstone
Pi	Wallerawang/Charbon/ Cullen Bullen Subgroup	Sand-/silt-/mudstone, coal, shale, conglomerate
Pn	Nile Subgroup	Mudstone, coal, sandstone, limestone nodules
Ps	Shoalhaven Group	Siltstone, conglomerate
Cd	Diorite	Diorite
Pz	Undifferentiated Palaeozoic metamorphic rocks	Siltstone, conglomerate

- LEGEND -

◆	Town
—	Road
▭	Project Boundary
▨	Existing Mining Operations

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36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
GEOLOGY

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
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PROJECT No: G1515
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APPROVED BY:
DATE: May 2011

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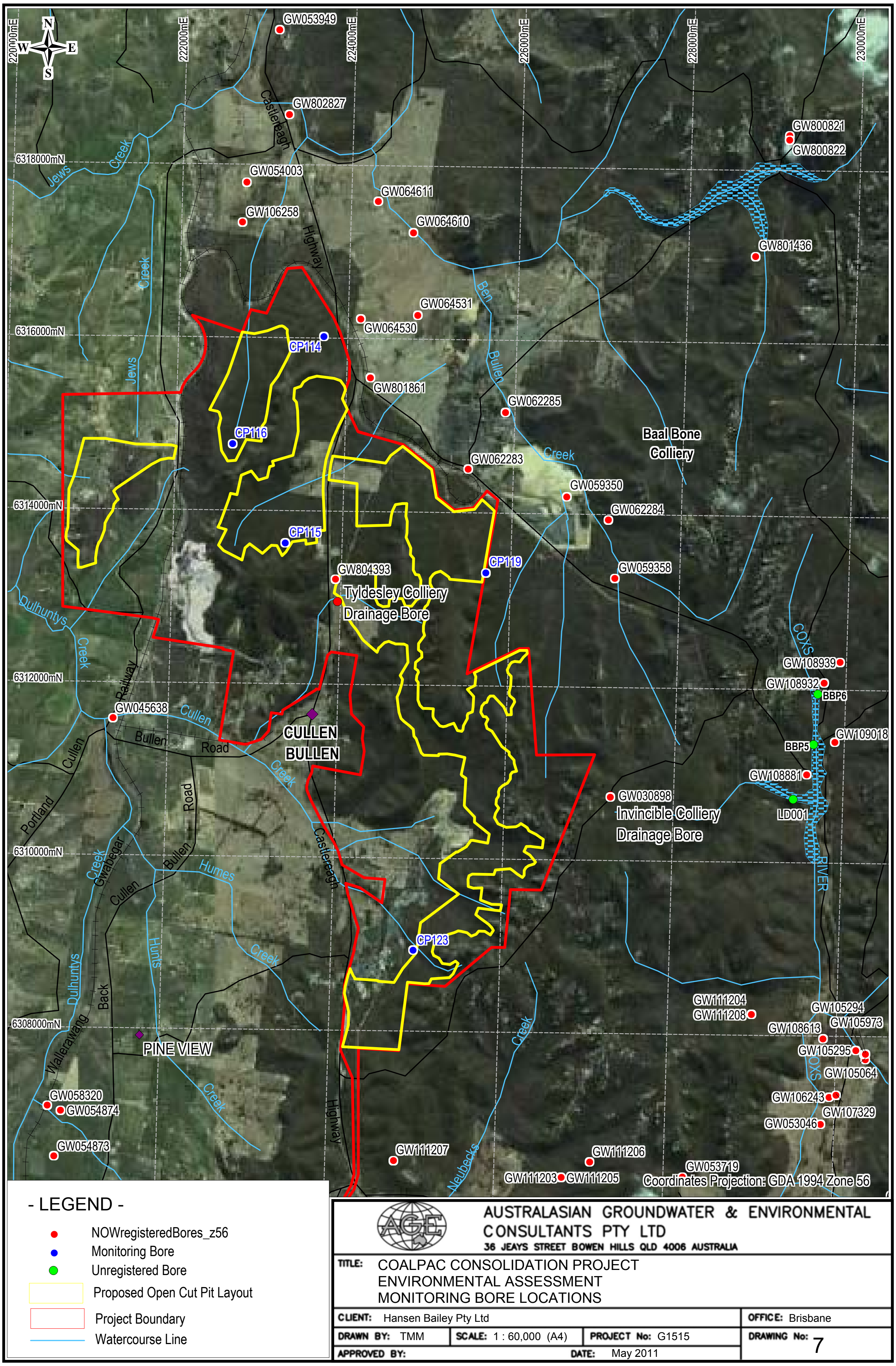

- LEGEND -

●	NOWregisteredBores_z56
●	Monitoring Bore
●	Unregistered Bore
☐	Proposed Open Cut Pit Layout
☐	Project Boundary
—	Watercourse Line

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TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
MONITORING BORE LOCATIONS

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 60,000 (A4)
PROJECT No: G1515
DRAWING No: 7
APPROVED BY:
DATE: May 2011

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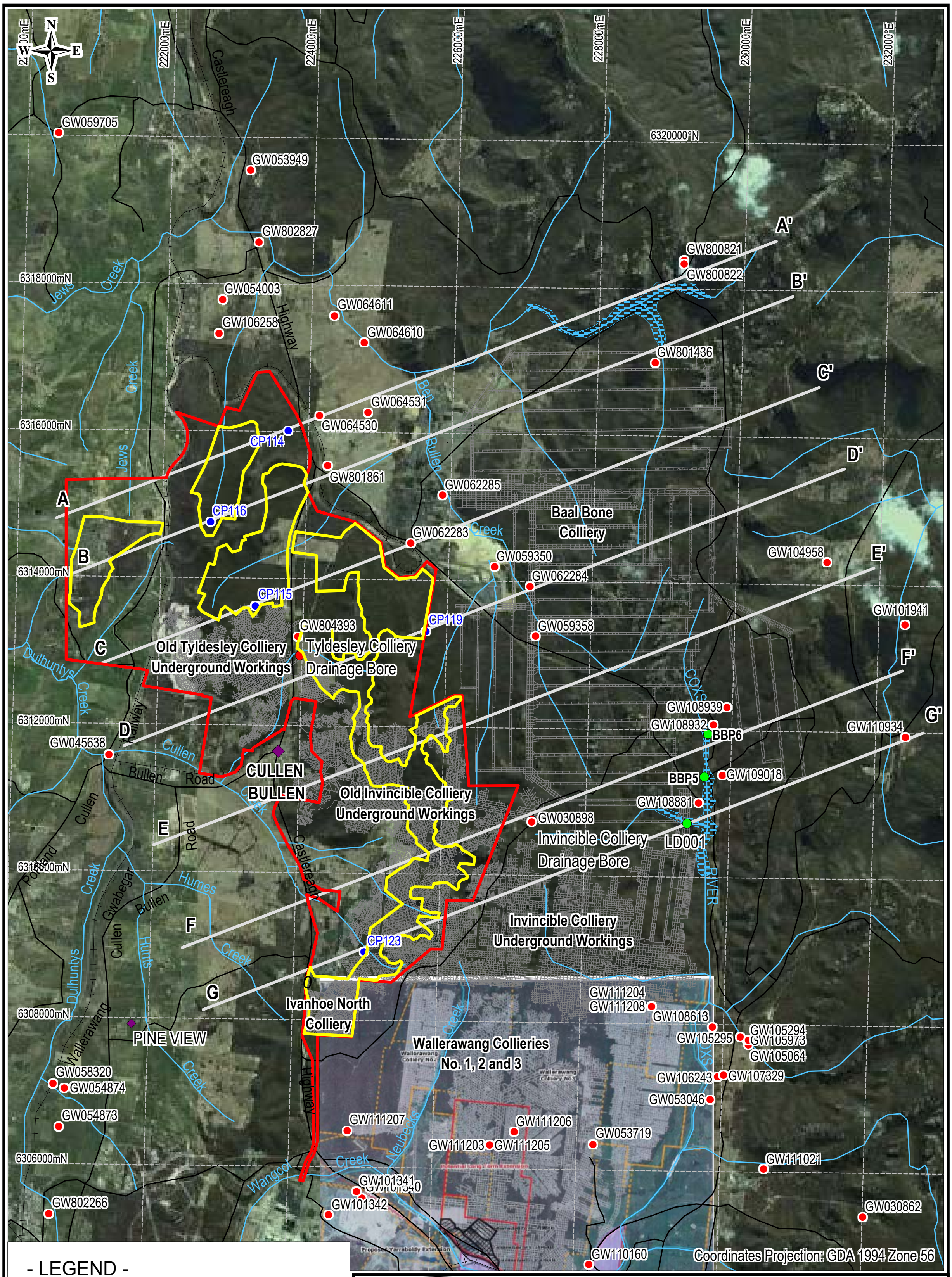

- LEGEND -

🔴	NOW Registered Bore
🔵	Monitoring Bore
🟢	Unregistered Bore
—	A - A' Cross-section Position
—	Underground Mine Workings
🟨	Proposed Open Cut Pit Layout
🟥	Project Boundary

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36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
CROSS-SECTION POSITIONS

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 60,000 (A4)
PROJECT No: G1515
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APPROVED BY:
DATE: May 2011

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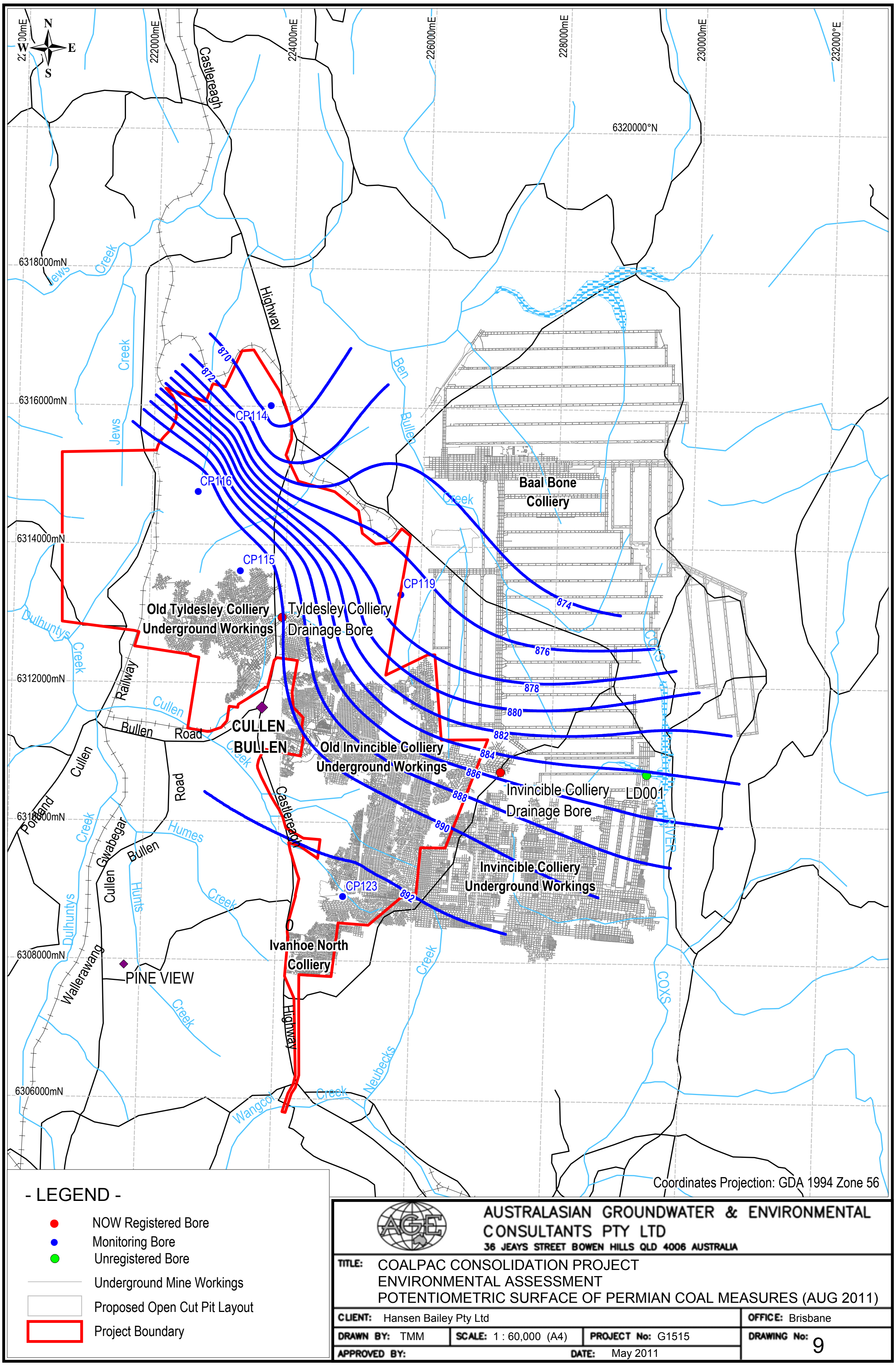

- LEGEND -

● NOW Registered Bore
● Monitoring Bore
● Unregistered Bore
Underground Mine Workings
Proposed Open Cut Pit Layout
Project Boundary

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36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
POTENTIOMETRIC SURFACE OF PERMIAN COAL MEASURES (AUG 2011)

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 60,000 (A4)
PROJECT No: G1515
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DATE: May 2011

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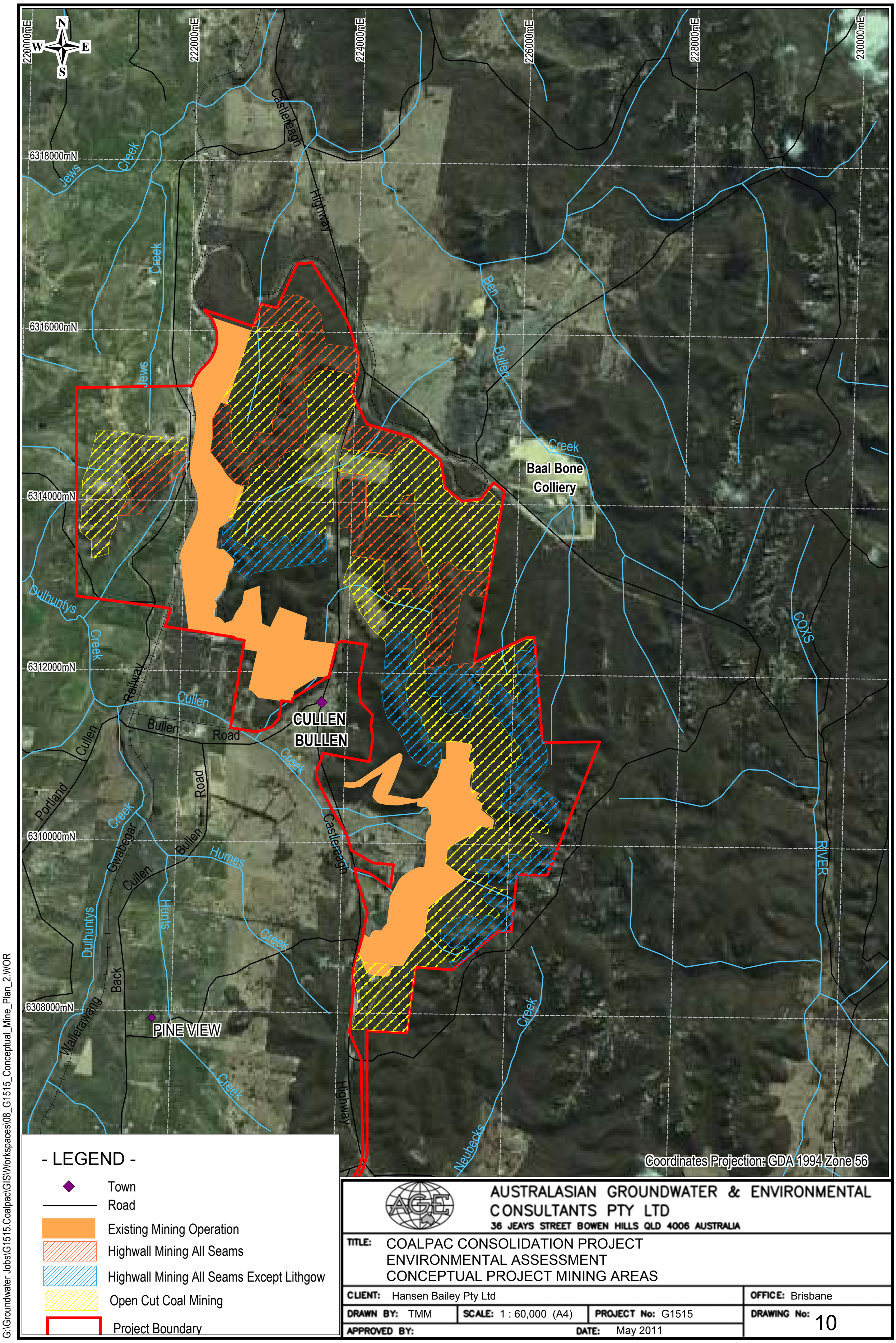


- LEGEND -

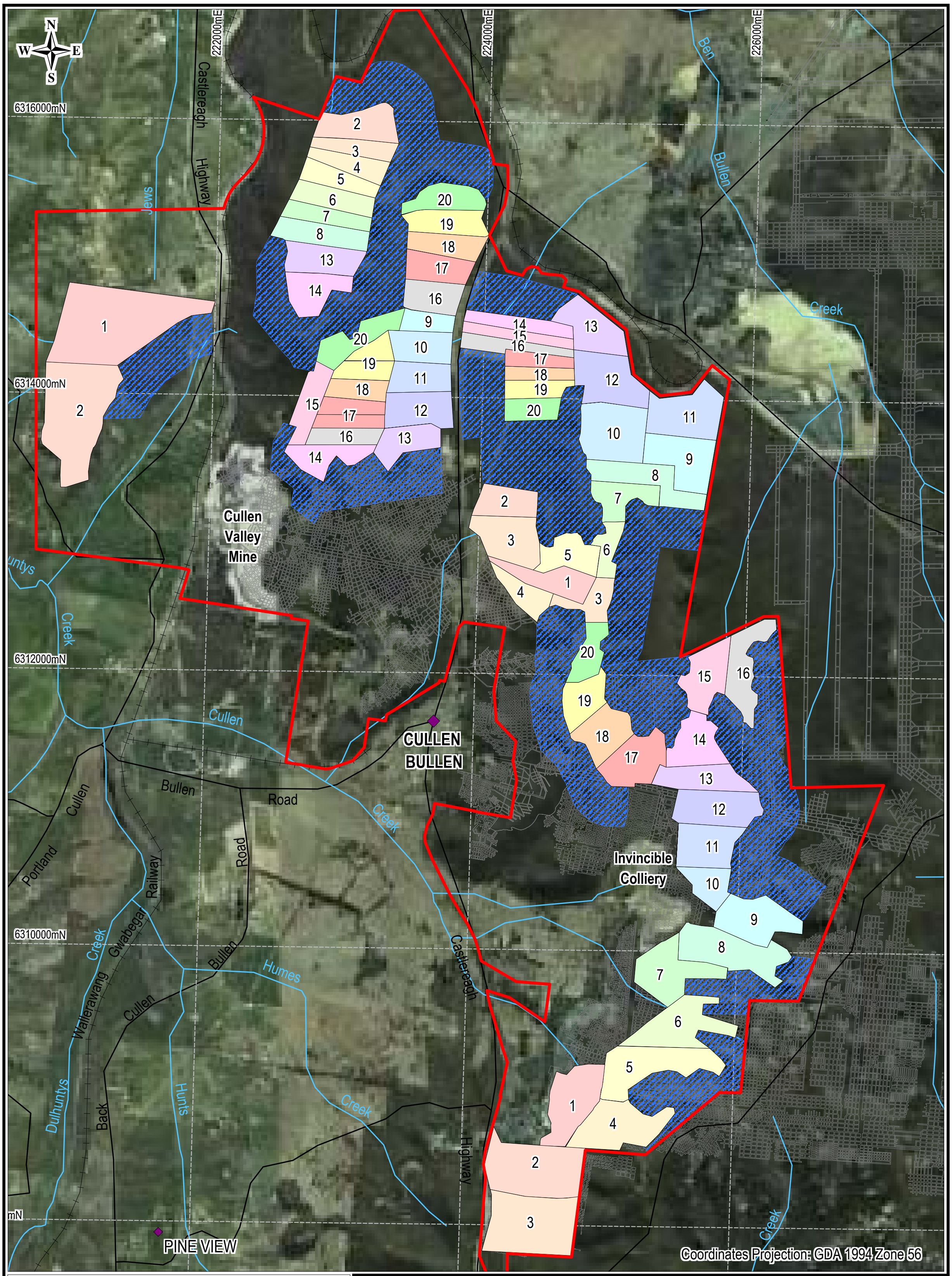
◆	Town
—	Road
🟧	Existing Mining Operation
▨	Highwall Mining All Seams
▨	Highwall Mining All Seams Except Lithgow
▨	Open Cut Coal Mining
☐	Project Boundary

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
CONCEPTUAL PROJECT MINING AREAS

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 60,000 (A4)
PROJECT No: G1515
DRAWING No: 10
APPROVED BY:
DATE: May 2011

(Project No. G1515)



G:\Groundwater Jobs\G1515.Coalpac\GIS\Workspaces\11_G1515_MinePlan.wor

- LEGEND -

☐ Proposed Open Cut Pit Schedule (year)

▨ Proposed Highwall Mining Area

🟥 Project Boundary

— Underground Mine Workings

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
CONCEPTUAL PROJECT MINING SEQUENCE 2011-2031

CLIENT: Hansen Bailey Pty Ltd

OFFICE: Brisbane

DRAWN BY: TMM

SCALE: 1 : 40,000 (A4)

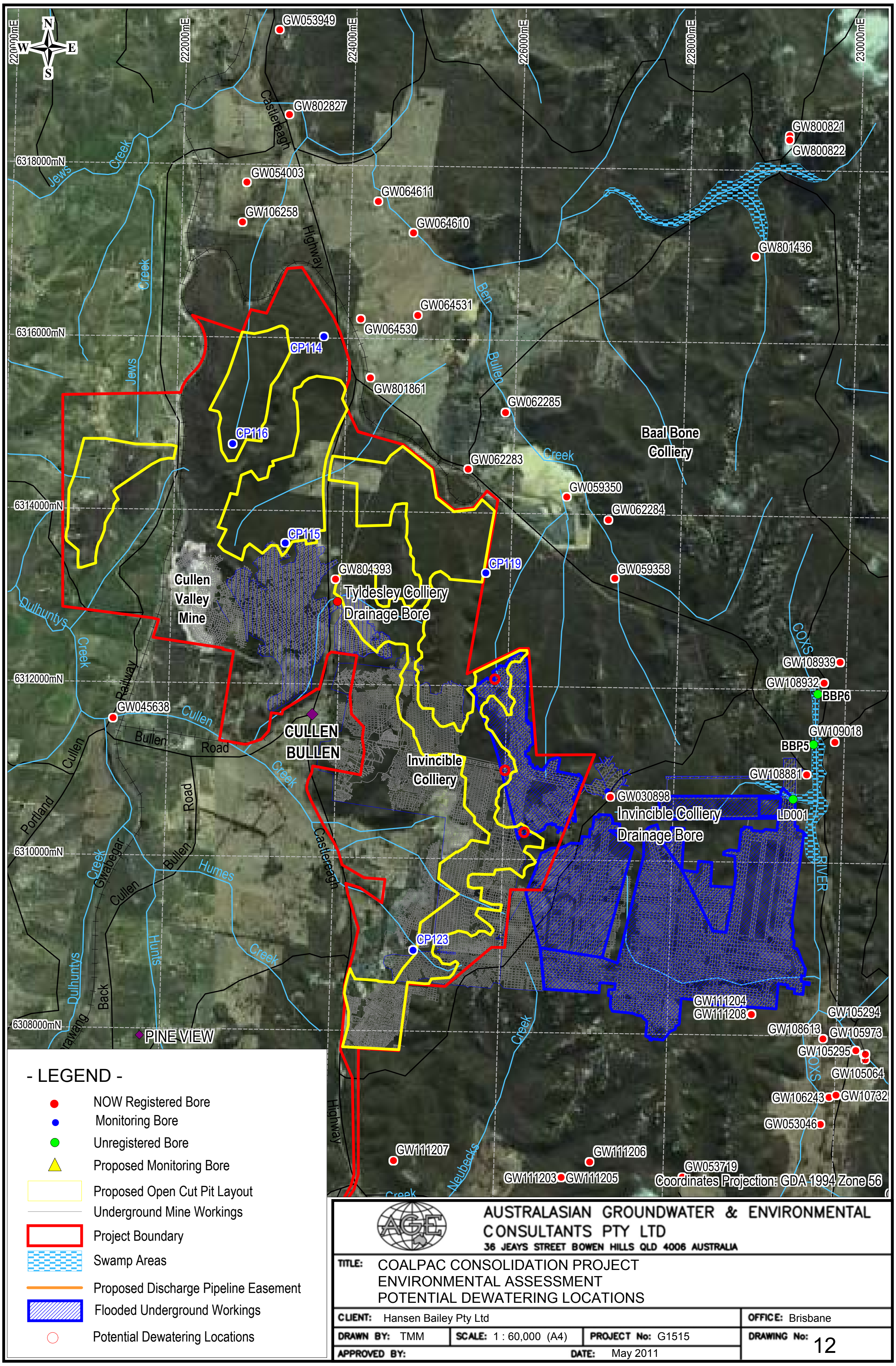
PROJECT No: G1515

DRAWING No: 11

APPROVED BY:

DATE: January 2012

(Project No. G1515)



- LEGEND -

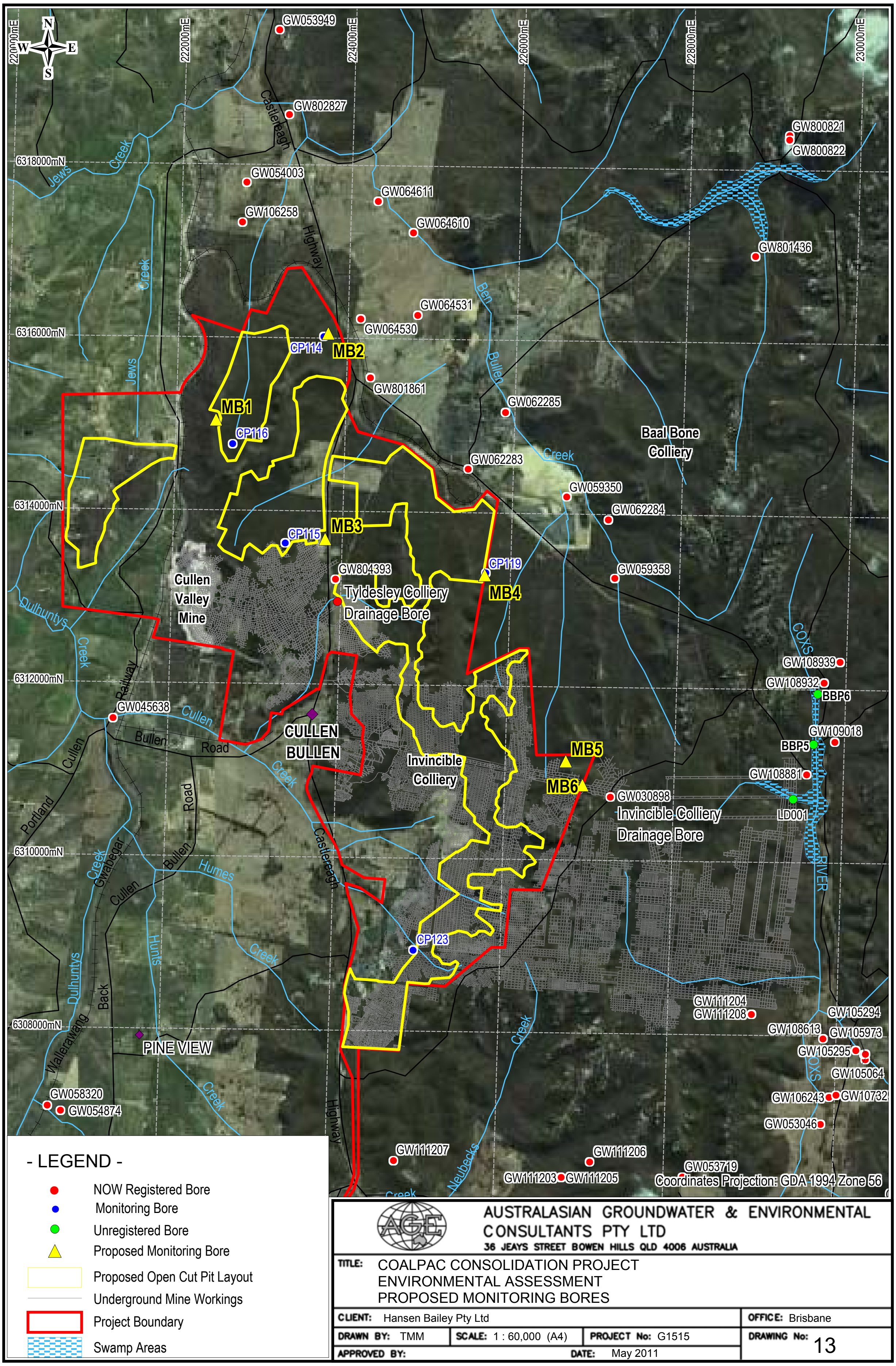
🔴	NOW Registered Bore
🔵	Monitoring Bore
🟢	Unregistered Bore
△	Proposed Monitoring Bore
▭	Proposed Open Cut Pit Layout
▭	Underground Mine Workings
🟥	Project Boundary
▨	Swamp Areas
—	Proposed Discharge Pipeline Easement
▨	Flooded Underground Workings
○	Potential Dewatering Locations

AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
POTENTIAL DEWATERING LOCATIONS

CLIENT: Hansen Bailey Pty Ltd
OFFICE: Brisbane
DRAWN BY: TMM
SCALE: 1 : 60,000 (A4)
PROJECT No: G1515
DRAWING No: 12
APPROVED BY:
DATE: May 2011

(Project No. G1515)



AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD
36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA

TITLE: COALPAC CONSOLIDATION PROJECT
ENVIRONMENTAL ASSESSMENT
PROPOSED MONITORING BORES

CLIENT: Hansen Bailey Pty Ltd			OFFICE: Brisbane
DRAWN BY: TMM	SCALE: 1 : 60,000 (A4)	PROJECT No: G1515	DRAWING No: 13
APPROVED BY:		DATE: May 2011	

(Project No. G1515)

APPENDIX 1

Monitoring Bore Photographs

(Project No. G1515)

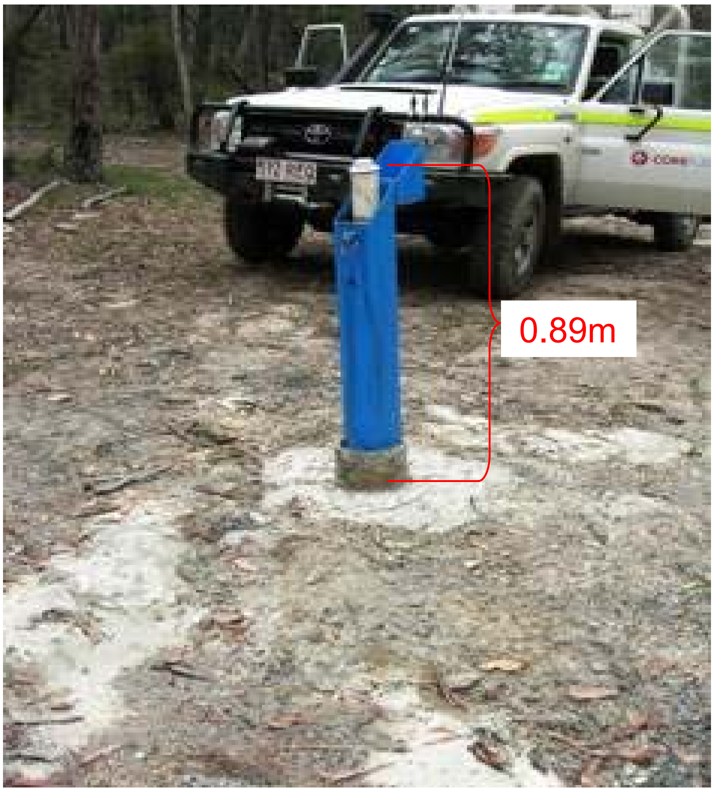


Plate 1: Monitoring Bore CP114

Plate 2: Monitoring Bore CP115

(Project No. G1515)

Plate 3: Monitoring Bore CP116

Plate 3: Monitoring Bore CP123

(Project No. G1515)

APPENDIX 2

Monitoring Bore Logs

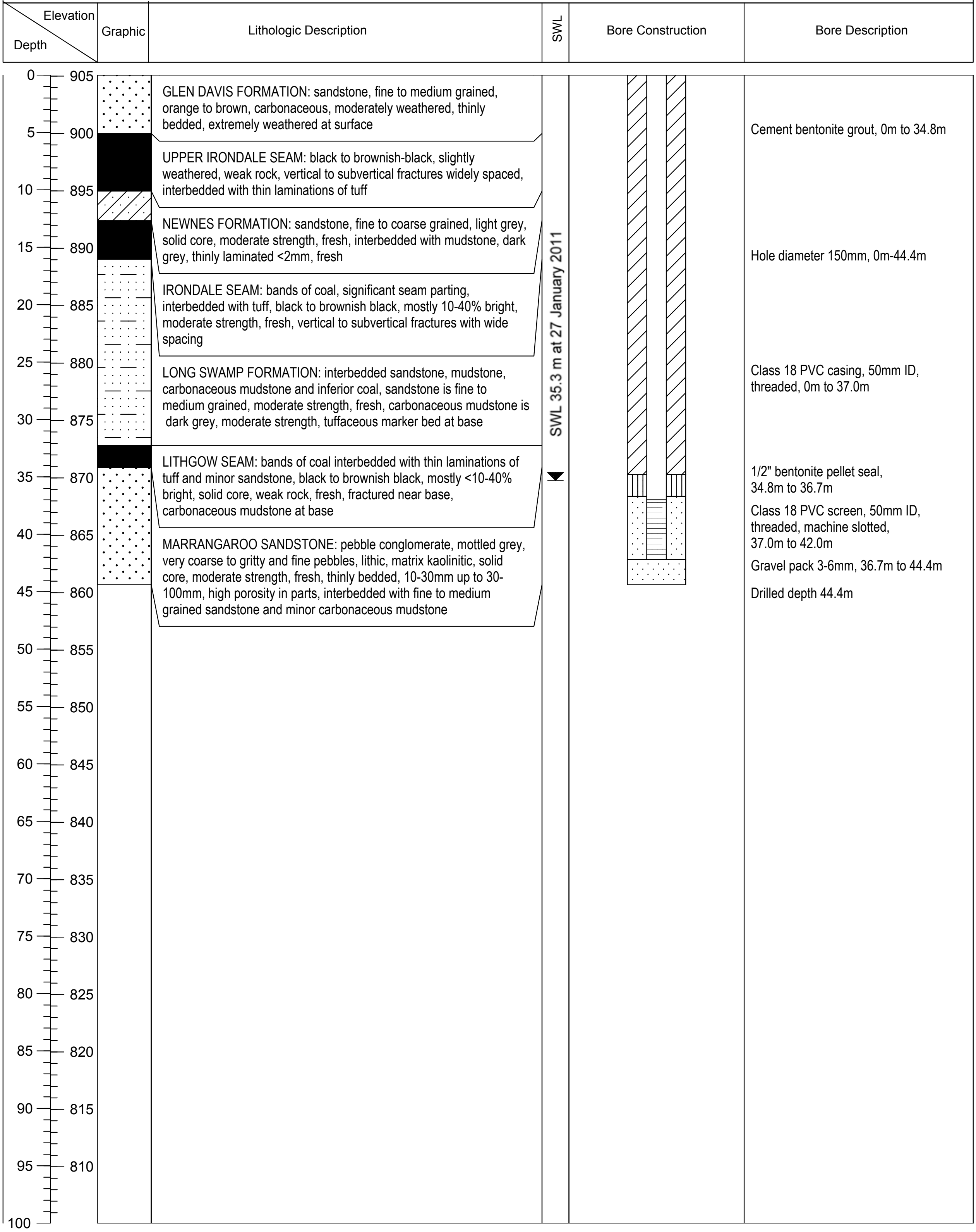
Australasian Groundwater & Environmental Consultants Pty Ltd

36 Jeays St, Bowen Hills, Queensland 4006

BOREHOLE LOG

BOREHOLE ID: **CP114** Page 1 of 1

PROJECT NO.	**G1515**	DRILLER:		DATUM:	**MGA 1994 Z.56**
PROJECT NAME:	**Coalpac**	DRILLING METHOD:		GROUND LEVEL:	**905.09 mAHD**
DATE:	**10 December 2010**	DRILL RIG:		TOP OF CASING LEVEL:	**+0.89 m**
CONTRACTOR:		COORDINATES:	**223718.4mE / 6316033.89mN**	LOGGED BY:	**AC**



GLEN DAVIS FORMATION: sandstone, fine to medium grained, orange to brown, carbonaceous, moderately weathered, thinly bedded, extremely weathered at surface

UPPER IRONDALE SEAM: black to brownish-black, slightly weathered, weak rock, vertical to subvertical fractures widely spaced, interbedded with thin laminations of tuff

NEWNES FORMATION: sandstone, fine to coarse grained, light grey, solid core, moderate strength, fresh, interbedded with mudstone, dark grey, thinly laminated <2mm, fresh

IRONDALE SEAM: bands of coal, significant seam parting, interbedded with tuff, black to brownish black, mostly 10-40% bright, moderate strength, fresh, vertical to subvertical fractures with wide spacing

LONG SWAMP FORMATION: interbedded sandstone, mudstone, carbonaceous mudstone and inferior coal, sandstone is fine to medium grained, moderate strength, fresh, carbonaceous mudstone is dark grey, moderate strength, tuffaceous marker bed at base

LITHGOW SEAM: bands of coal interbedded with thin laminations of tuff and minor sandstone, black to brownish black, mostly <10-40% bright, solid core, weak rock, fresh, fractured near base, carbonaceous mudstone at base

MARRANGAROO SANDSTONE: pebble conglomerate, mottled grey, very coarse to gritty and fine pebbles, lithic, matrix kaolinitic, solid core, moderate strength, fresh, thinly bedded, 10-30mm up to 30-100mm, high porosity in parts, interbedded with fine to medium grained sandstone and minor carbonaceous mudstone

Cement bentonite grout, 0m to 34.8m

Hole diameter 150mm, 0m-44.4m

Class 18 PVC casing, 50mm ID, threaded, 0m to 37.0m

1/2" bentonite pellet seal, 34.8m to 36.7m

Class 18 PVC screen, 50mm ID, threaded, machine slotted, 37.0m to 42.0m

Gravel pack 3-6mm, 36.7m to 44.4m

Drilled depth 44.4m

(Project No. G1515)

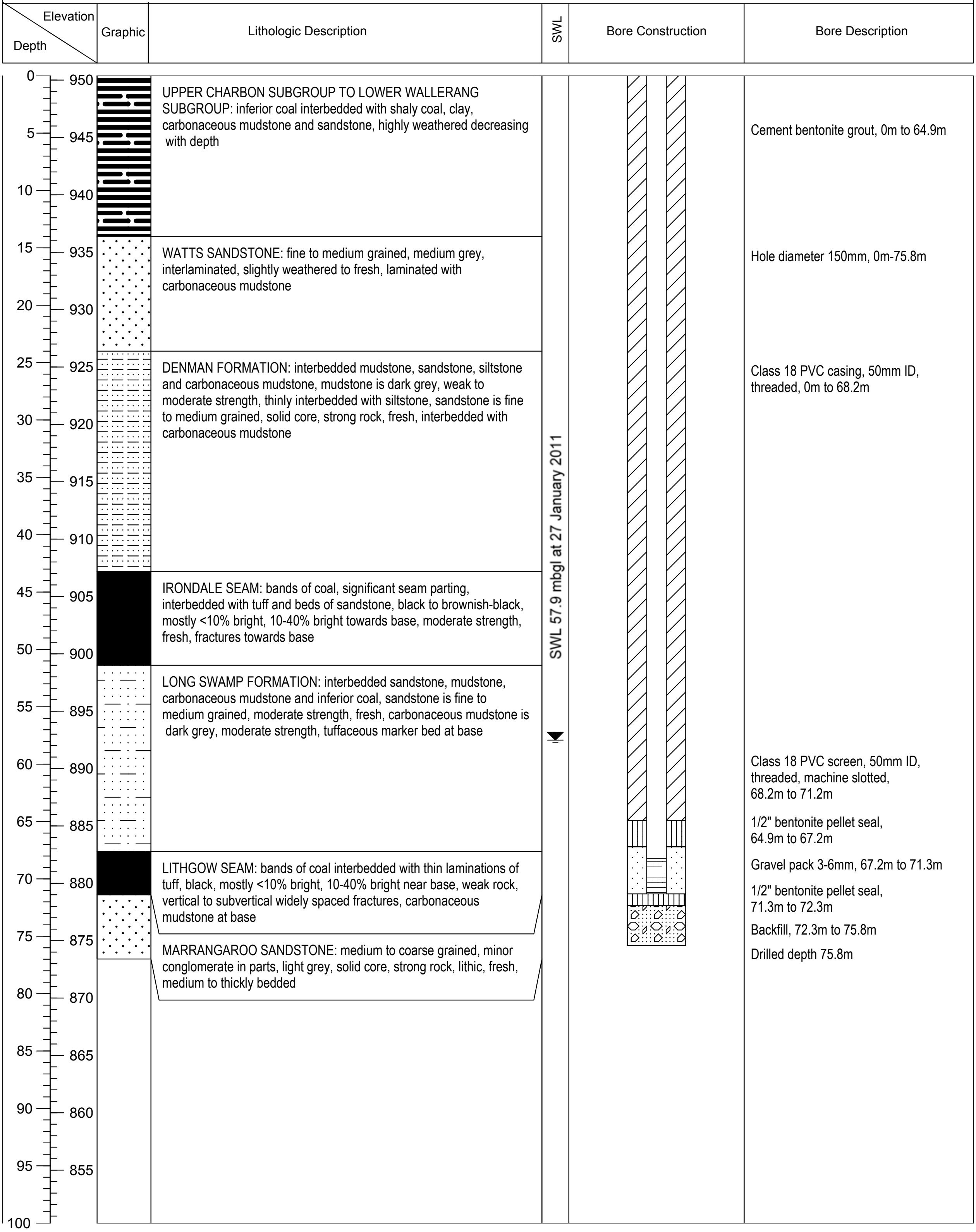
Australasian Groundwater & Environmental Consultants Pty Ltd

36 Jeays St, Bowen Hills, Queensland 4006

BOREHOLE LOG

BOREHOLE ID: **CP115** Page 1 of 1

PROJECT NO.	**G1515**	DRILLER:		DATUM:	**MGA 1994 Z.56**
PROJECT NAME:	**Coalpac**	DRILLING METHOD:		GROUND LEVEL:	**950.38 mAHD**
DATE:	**10 December 2010**	DRILL RIG:		TOP OF CASING LEVEL:	**+0.9 m**
CONTRACTOR:		COORDINATES:	**223329.88mE / 6313644.11mN**	LOGGED BY:	**AC**



UPPER CHARBON SUBGROUP TO LOWER WALLERANG SUBGROUP: inferior coal interbedded with shaly coal, clay, carbonaceous mudstone and sandstone, highly weathered decreasing with depth

WATTS SANDSTONE: fine to medium grained, medium grey, interlaminated, slightly weathered to fresh, laminated with carbonaceous mudstone

DENMAN FORMATION: interbedded mudstone, sandstone, siltstone and carbonaceous mudstone, mudstone is dark grey, weak to moderate strength, thinly interbedded with siltstone, sandstone is fine to medium grained, solid core, strong rock, fresh, interbedded with carbonaceous mudstone

IRONDALE SEAM: bands of coal, significant seam parting, interbedded with tuff and beds of sandstone, black to brownish-black, mostly <10% bright, 10-40% bright towards base, moderate strength, fresh, fractures towards base

LONG SWAMP FORMATION: interbedded sandstone, mudstone, carbonaceous mudstone and inferior coal, sandstone is fine to medium grained, moderate strength, fresh, carbonaceous mudstone is dark grey, moderate strength, tuffaceous marker bed at base

LITHGOW SEAM: bands of coal interbedded with thin laminations of tuff, black, mostly <10% bright, 10-40% bright near base, weak rock, vertical to subvertical widely spaced fractures, carbonaceous mudstone at base

MARRANGAROO SANDSTONE: medium to coarse grained, minor conglomerate in parts, light grey, solid core, strong rock, lithic, fresh, medium to thickly bedded

Cement bentonite grout, 0m to 64.9m

Hole diameter 150mm, 0m-75.8m

Class 18 PVC casing, 50mm ID, threaded, 0m to 68.2m

Class 18 PVC screen, 50mm ID, threaded, machine slotted, 68.2m to 71.2m

1/2" bentonite pellet seal, 64.9m to 67.2m

Gravel pack 3-6mm, 67.2m to 71.3m

1/2" bentonite pellet seal, 71.3m to 72.3m

Backfill, 72.3m to 75.8m

Drilled depth 75.8m

(Project No. G1515)

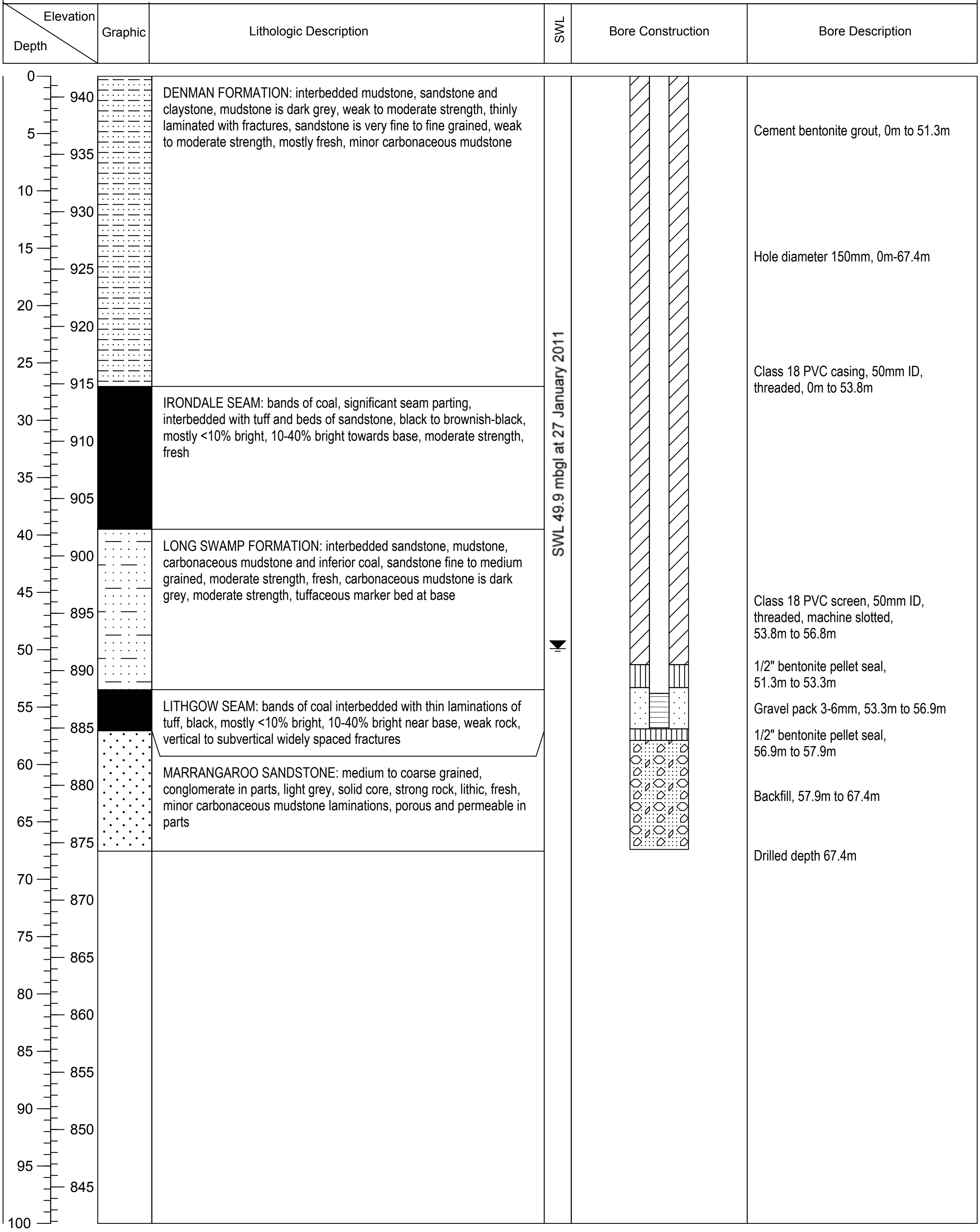
Australasian Groundwater & Environmental Consultants Pty Ltd

36 Jeays St, Bowen Hills, Queensland 4006

BOREHOLE LOG

BOREHOLE ID: **CP116** Page 1 of 1

PROJECT NO.	**G1515**	DRILLER:		DATUM:	**MGA 1994 Z.56**
PROJECT NAME:	**Coalpac**	DRILLING METHOD:		GROUND LEVEL:	**941.82 mAHD**
DATE:	**13 December 2010**	DRILL RIG:		TOP OF CASING LEVEL:	**+0.83 m**
CONTRACTOR:		COORDINATES:	**222675.53mE / 6314782.66mN**	LOGGED BY:	**AC**



DENMAN FORMATION: interbedded mudstone, sandstone and claystone, mudstone is dark grey, weak to moderate strength, thinly laminated with fractures, sandstone is very fine to fine grained, weak to moderate strength, mostly fresh, minor carbonaceous mudstone

IRONDALE SEAM: bands of coal, significant seam parting, interbedded with tuff and beds of sandstone, black to brownish-black, mostly <10% bright, 10-40% bright towards base, moderate strength, fresh

LONG SWAMP FORMATION: interbedded sandstone, mudstone, carbonaceous mudstone and inferior coal, sandstone fine to medium grained, moderate strength, fresh, carbonaceous mudstone is dark grey, moderate strength, tuffaceous marker bed at base

LITHGOW SEAM: bands of coal interbedded with thin laminations of tuff, black, mostly <10% bright, 10-40% bright near base, weak rock, vertical to subvertical widely spaced fractures

MARRANGAROO SANDSTONE: medium to coarse grained, conglomerate in parts, light grey, solid core, strong rock, lithic, fresh, minor carbonaceous mudstone laminations, porous and permeable in parts

Cement bentonite grout, 0m to 51.3m

Hole diameter 150mm, 0m-67.4m

Class 18 PVC casing, 50mm ID, threaded, 0m to 53.8m

Class 18 PVC screen, 50mm ID, threaded, machine slotted, 53.8m to 56.8m

1/2" bentonite pellet seal, 51.3m to 53.3m

Gravel pack 3-6mm, 53.3m to 56.9m

1/2" bentonite pellet seal, 56.9m to 57.9m

Backfill, 57.9m to 67.4m

Drilled depth 67.4m

(Project No. G1515)

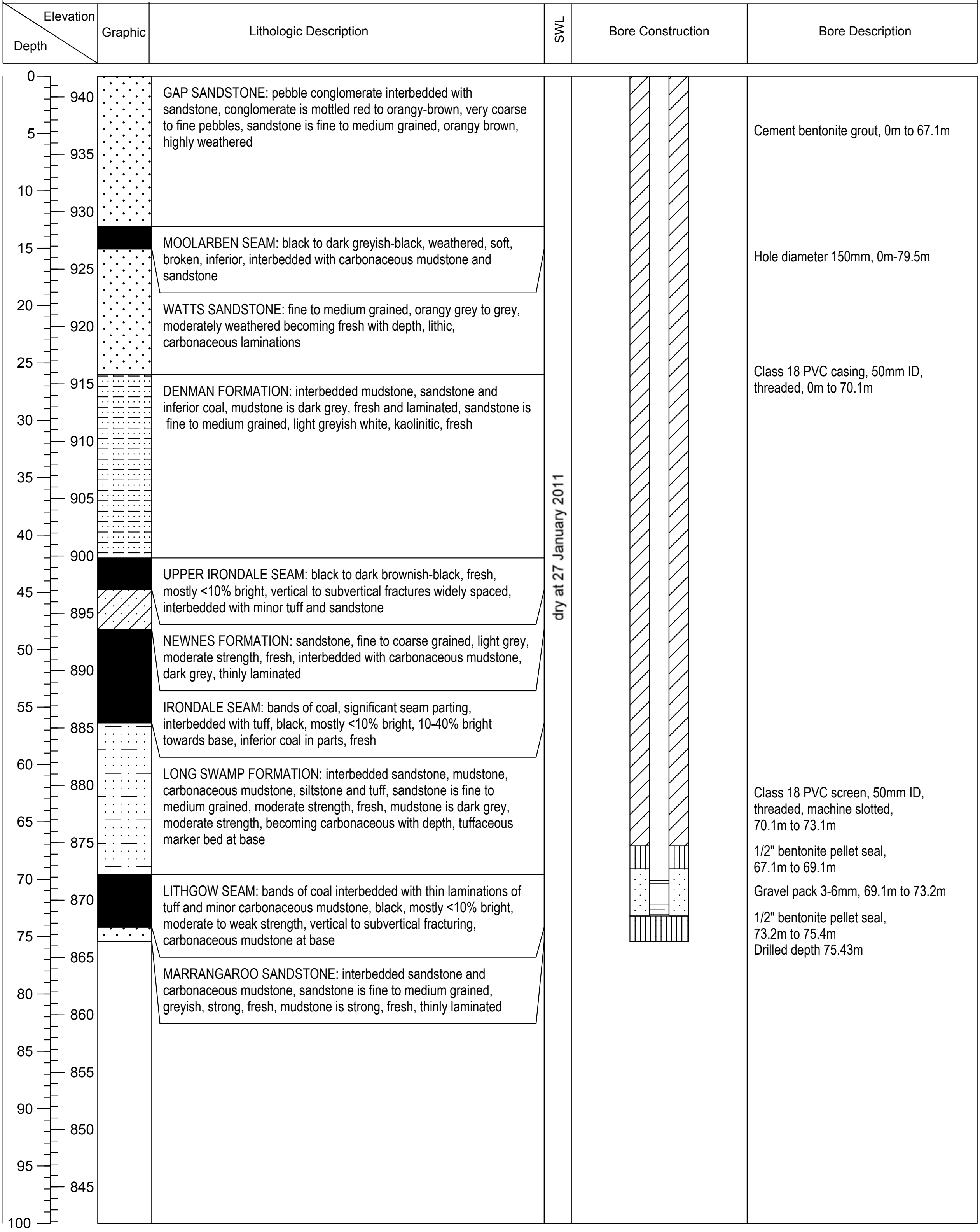
Australasian Groundwater & Environmental Consultants Pty Ltd

36 Jeays St, Bowen Hills, Queensland 4006

BOREHOLE LOG

BOREHOLE ID: **CP119** Page 1 of 1

PROJECT NO.	**G1515**	DRILLER:		DATUM:	**MGA 1994 Z.56**
PROJECT NAME:	**Coalpac**	DRILLING METHOD:		GROUND LEVEL:	**943.75 mAHD**
DATE:	**21 January 2011**	DRILL RIG:		TOP OF CASING LEVEL:	**+0.02 m**
CONTRACTOR:		COORDINATES:	**225709.99mE / 6313323.58mN**	LOGGED BY:	**AC**



GAP SANDSTONE: pebble conglomerate interbedded with sandstone, conglomerate is mottled red to orangy-brown, very coarse to fine pebbles, sandstone is fine to medium grained, orangy brown, highly weathered

MOOLARBEN SEAM: black to dark greyish-black, weathered, soft, broken, inferior, interbedded with carbonaceous mudstone and sandstone

WATTS SANDSTONE: fine to medium grained, orangy grey to grey, moderately weathered becoming fresh with depth, lithic, carbonaceous laminations

DENMAN FORMATION: interbedded mudstone, sandstone and inferior coal, mudstone is dark grey, fresh and laminated, sandstone is fine to medium grained, light greyish white, kaolinitic, fresh

UPPER IRONDALE SEAM: black to dark brownish-black, fresh, mostly <10% bright, vertical to subvertical fractures widely spaced, interbedded with minor tuff and sandstone

NEWNES FORMATION: sandstone, fine to coarse grained, light grey, moderate strength, fresh, interbedded with carbonaceous mudstone, dark grey, thinly laminated

IRONDALE SEAM: bands of coal, significant seam parting, interbedded with tuff, black, mostly <10% bright, 10-40% bright towards base, inferior coal in parts, fresh

LONG SWAMP FORMATION: interbedded sandstone, mudstone, carbonaceous mudstone, siltstone and tuff, sandstone is fine to medium grained, moderate strength, fresh, mudstone is dark grey, moderate strength, becoming carbonaceous with depth, tuffaceous marker bed at base

LITHGOW SEAM: bands of coal interbedded with thin laminations of tuff and minor carbonaceous mudstone, black, mostly <10% bright, moderate to weak strength, vertical to subvertical fracturing, carbonaceous mudstone at base

MARRANGAROO SANDSTONE: interbedded sandstone and carbonaceous mudstone, sandstone is fine to medium grained, greyish, strong, fresh, mudstone is strong, fresh, thinly laminated

Cement bentonite grout, 0m to 67.1m

Hole diameter 150mm, 0m-79.5m

Class 18 PVC casing, 50mm ID, threaded, 0m to 70.1m

Class 18 PVC screen, 50mm ID, threaded, machine slotted, 70.1m to 73.1m

1/2" bentonite pellet seal, 67.1m to 69.1m

Gravel pack 3-6mm, 69.1m to 73.2m

1/2" bentonite pellet seal, 73.2m to 75.4m

Drilled depth 75.43m

(Project No. G1515)

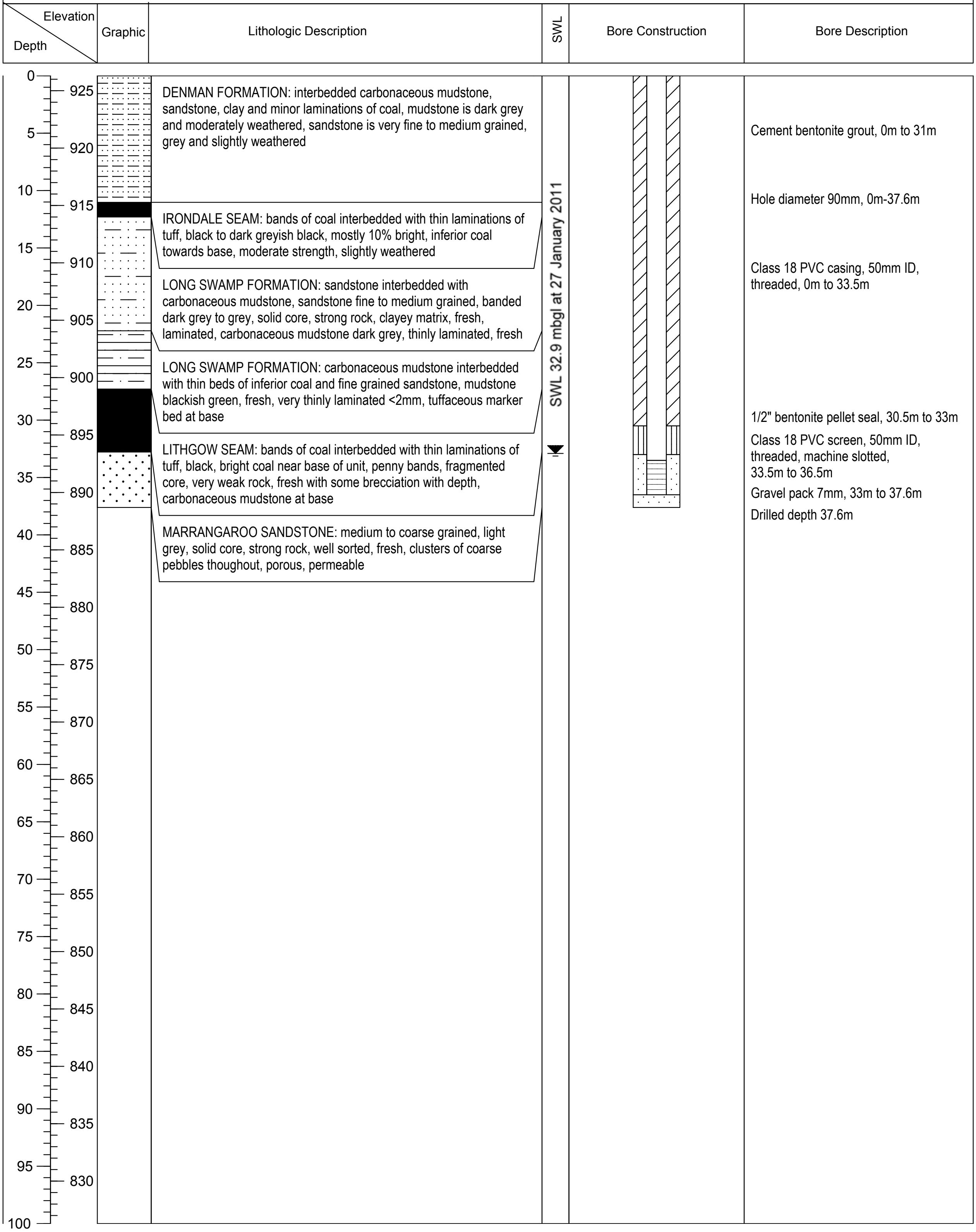
Australasian Groundwater & Environmental Consultants Pty Ltd

36 Jeays St, Bowen Hills, Queensland 4006

BOREHOLE LOG

BOREHOLE ID: **CP123** Page 1 of 1

PROJECT NO. **G1515**
PROJECT NAME: **Coalpac**
DATE: **10 December 2010**
CONTRACTOR:
DRILLER:
DRILLING METHOD:
DRILL RIG:
COORDINATES: **224969.40mE / 6308929.69mN**
DATUM: **MGA 1994 Z.56**
GROUND LEVEL: **926.3 mAHD**
TOP OF CASING LEVEL: **+0.xx m**
LOGGED BY: **AC**



DENMAN FORMATION: interbedded carbonaceous mudstone, sandstone, clay and minor laminations of coal, mudstone is dark grey and moderately weathered, sandstone is very fine to medium grained, grey and slightly weathered

IRONDALE SEAM: bands of coal interbedded with thin laminations of tuff, black to dark greyish black, mostly 10% bright, inferior coal towards base, moderate strength, slightly weathered

LONG SWAMP FORMATION: sandstone interbedded with carbonaceous mudstone, sandstone fine to medium grained, banded dark grey to grey, solid core, strong rock, clayey matrix, fresh, laminated, carbonaceous mudstone dark grey, thinly laminated, fresh

LONG SWAMP FORMATION: carbonaceous mudstone interbedded with thin beds of inferior coal and fine grained sandstone, mudstone blackish green, fresh, very thinly laminated <2mm, tuffaceous marker bed at base

LITHGOW SEAM: bands of coal interbedded with thin laminations of tuff, black, bright coal near base of unit, penny bands, fragmented core, very weak rock, fresh with some brecciation with depth, carbonaceous mudstone at base

MARRANGAROO SANDSTONE: medium to coarse grained, light grey, solid core, strong rock, well sorted, fresh, clusters of coarse pebbles thoughout, porous, permeable

Cement bentonite grout, 0m to 31m

Hole diameter 90mm, 0m-37.6m

Class 18 PVC casing, 50mm ID, threaded, 0m to 33.5m

1/2" bentonite pellet seal, 30.5m to 33m

Class 18 PVC screen, 50mm ID, threaded, machine slotted, 33.5m to 36.5m

Gravel pack 7mm, 33m to 37.6m

Drilled depth 37.6m

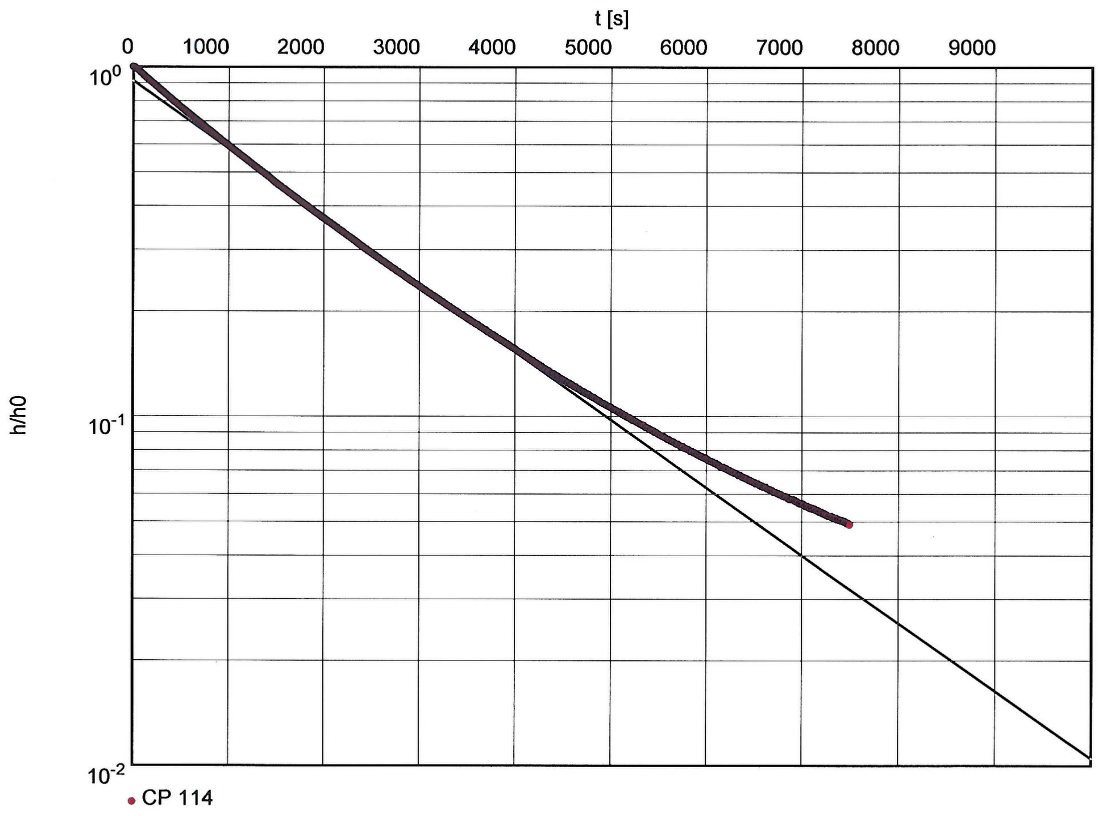
(Project No. G1515)

APPENDIX 3

Falling Head Test Analysis

AGE Consultants 36 Jeays St, Bowen Hills Brisbane, Queensland Australia	slug/bail test analysis BOUWER-RICE's method	Date: 24.02.2011	Page 1
		Project: Coalpac Consolidation	
		Evaluated by: TMM	

Slug Test No.	Test conducted on: 16.02.2011
CP 114	



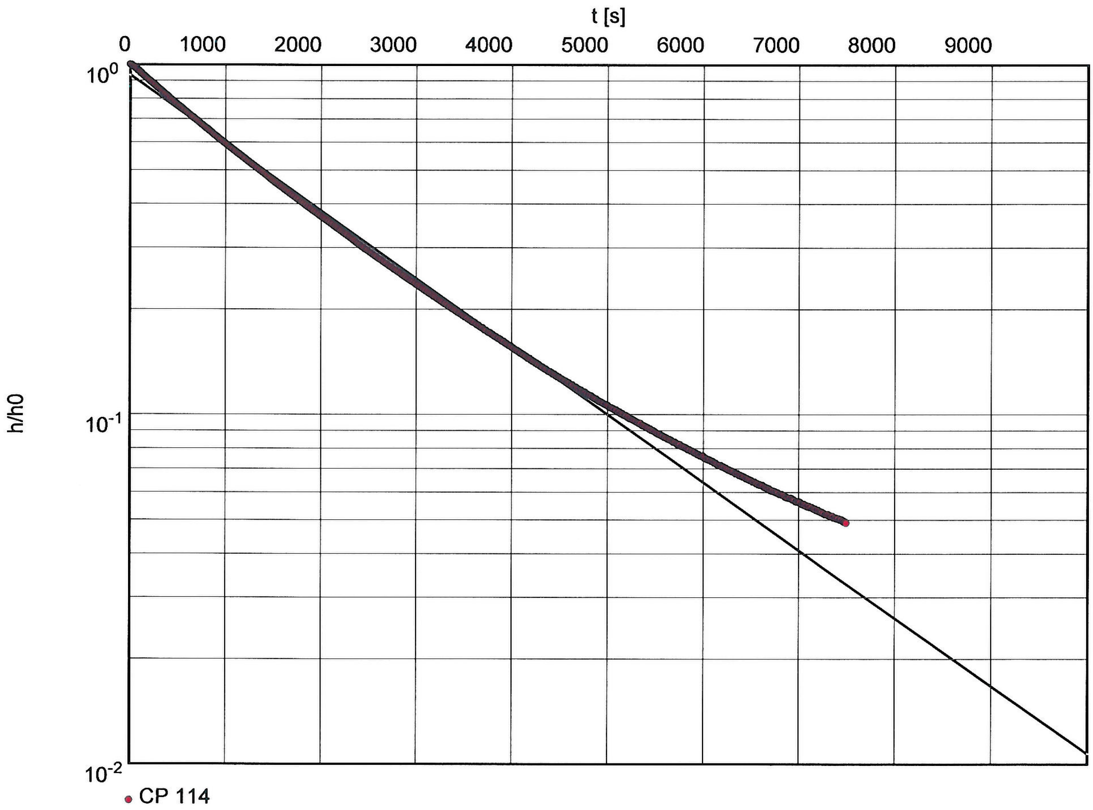
Hydraulic conductivity [m/s]: 7.97 x 10^{-8}

- Falling head test
- Water level recorded with electronic data logger at 10 sec intervals

(Project No. G1515)

AGE Consultants 36 Jeays St, Bowen Hills Brisbane, Queensland Australia	slug/bail test analysis HVORSLEV's method	Date: 24.02.2011	Page 1
		Project: Coalpac Consolidation	
		Evaluated by: TMM	

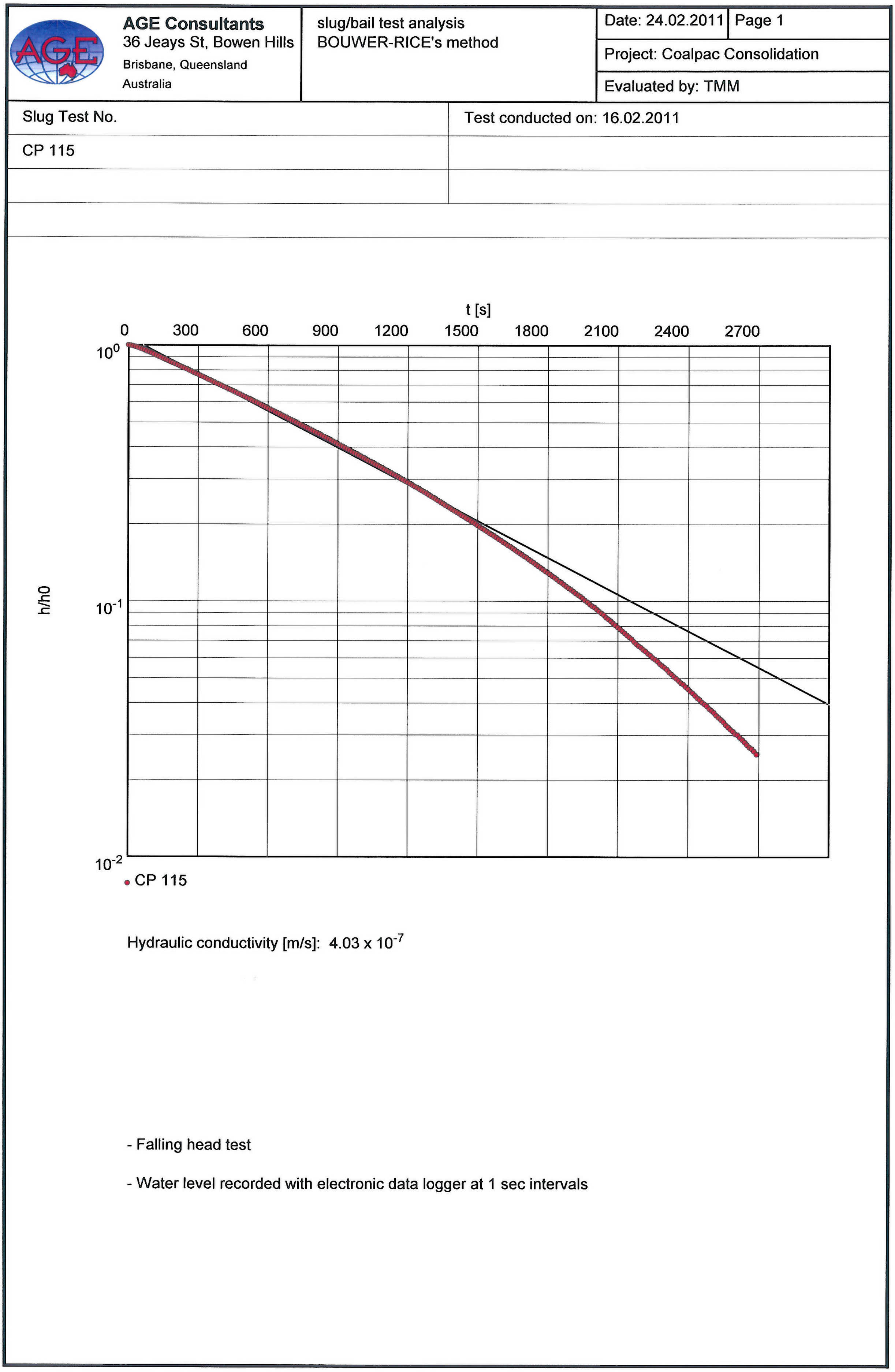
Slug Test No.	Test conducted on: 16.02.2011
CP 114	



Hydraulic conductivity [m/s]: 8.44×10^{-8}

- Falling head test
- Water level recorded with electronic data logger at 10 sec intervals

(Project No. G1515)



AGE Consultants
36 Jeays St, Bowen Hills
Brisbane, Queensland
Australia

slug/bail test analysis
BOUWER-RICE's method

Date: 24.02.2011	Page 1
Project: Coalpac Consolidation	
Evaluated by: TMM	

Slug Test No.	Test conducted on: 16.02.2011
CP 115	

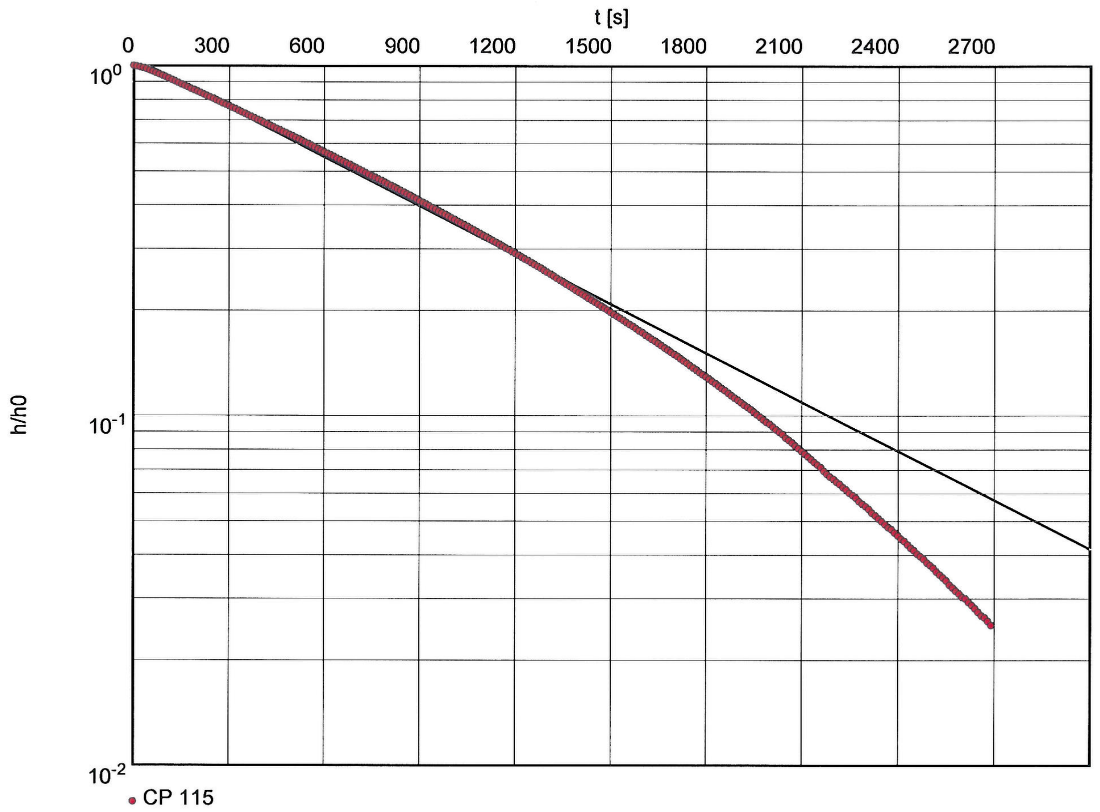
Hydraulic conductivity [m/s]: 4.03×10^{-7}

- Falling head test
- Water level recorded with electronic data logger at 1 sec intervals

(Project No. G1515)

AGE Consultants 36 Jeays St, Bowen Hills Brisbane, Queensland Australia	slug/bail test analysis HVORSLEV's method	Date: 24.02.2011 Page 1 Project: Coalpac Consolidation Evaluated by: TMM

Slug Test No.	Test conducted on: 16.02.2011
CP 115	



Hydraulic conductivity [m/s]: 3.30×10^{-7}

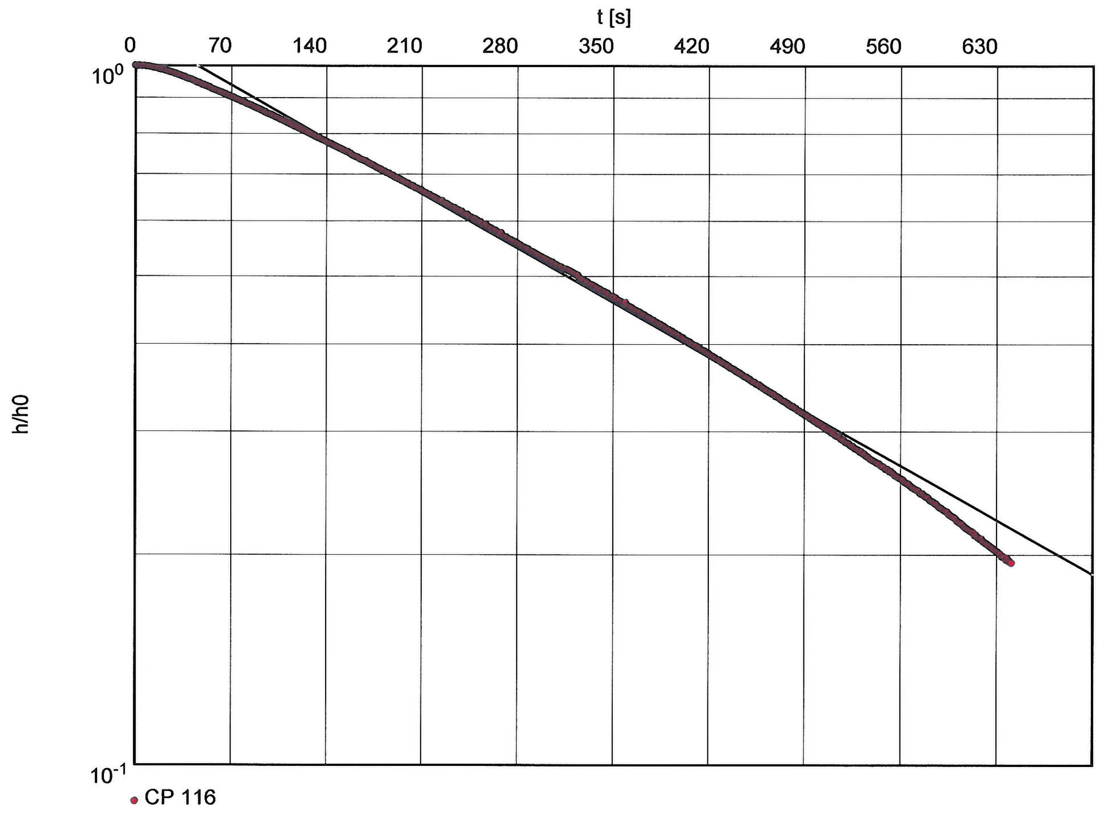
- Falling head test
- Water level recorded with electronic data logger at 1 sec intervals

AGE Consultants
36 Jeays St, Bowen Hills
Brisbane, Queensland
Australia

slug/bail test analysis
BOUWER-RICE's method

Date: 15.02.2011	Page 1
Project: Coalpac Consolidation	
Evaluated by: TJA	

Slug Test No.	Test conducted on: 15.02.2011
CP116	



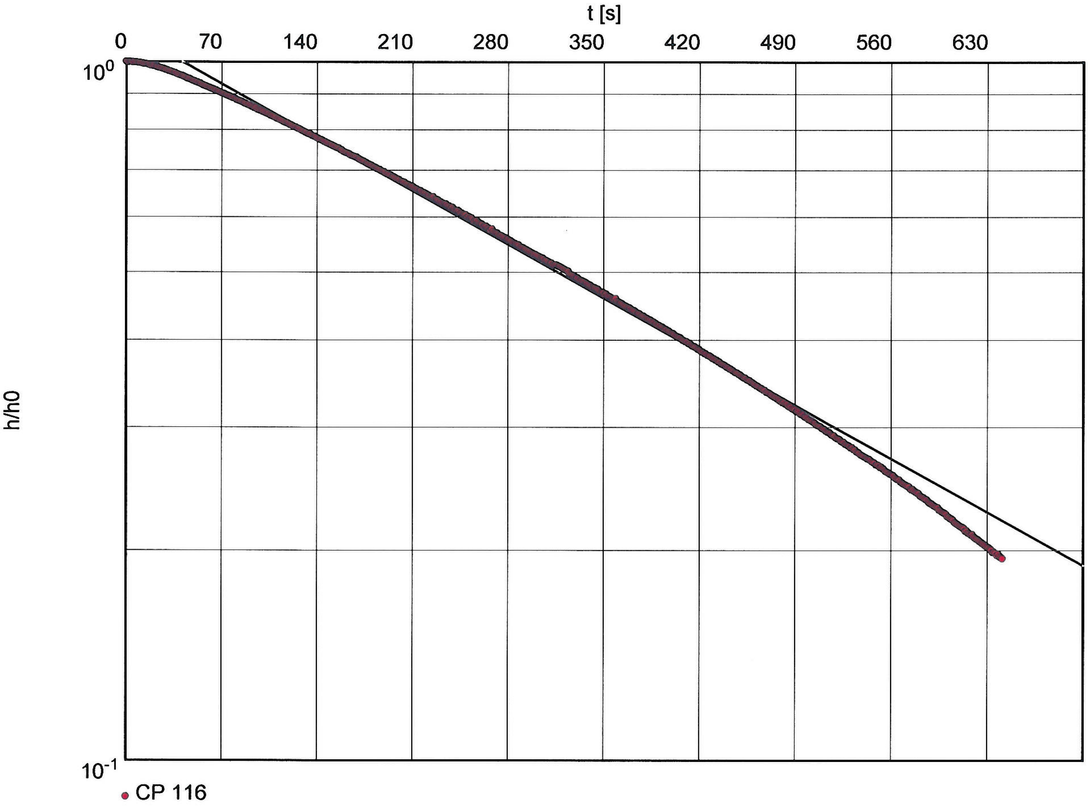
Hydraulic conductivity [m/s]: 7.97×10^{-7}

- Falling head test
- Water level recorded with electronic data logger at 1 sec intervals

(Project No. G1515)

AGE Consultants 36 Jeays St, Bowen Hills Brisbane, Queensland Australia	slug/bail test analysis HVORSLEV's method	Date: 15.02.2011	Page 1
		Project: Coalpac Consolidation	
		Evaluated by: TJA	

Slug Test No.	Test conducted on: 15.02.2011
CP116	



Hydraulic conductivity [m/s]: 8.51 x 10^{-7}

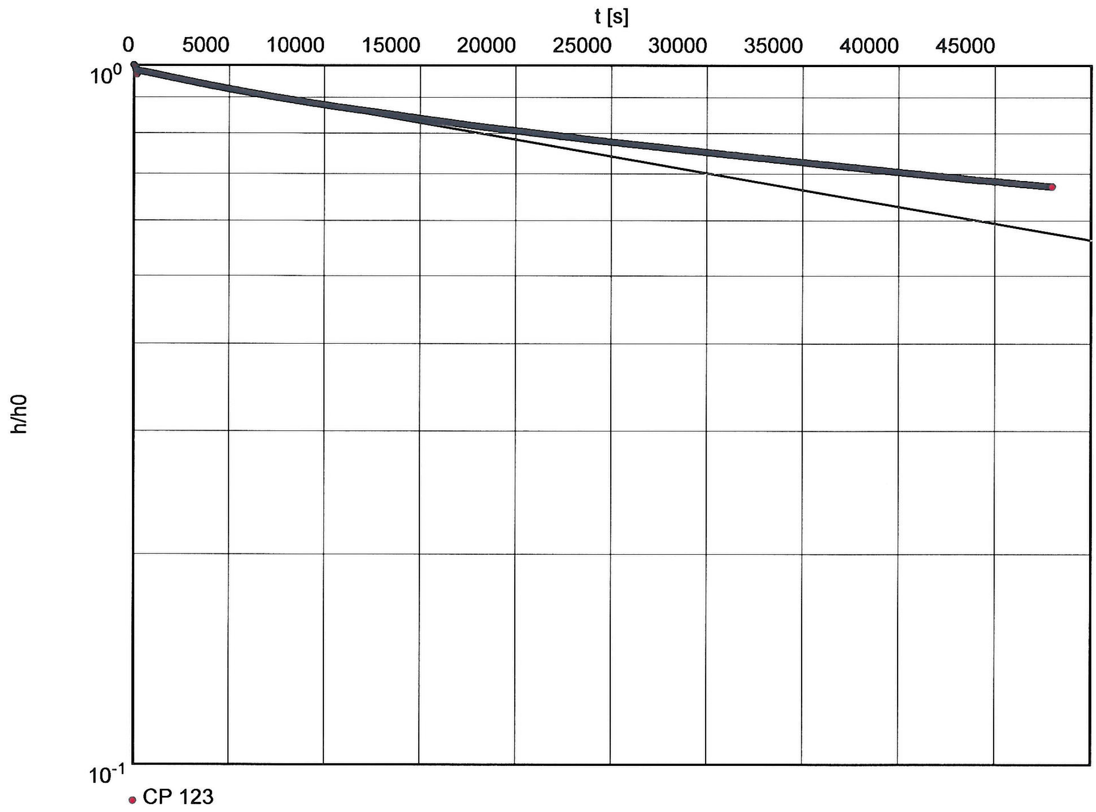
- Falling head test

- Water level recorded with electronic data logger at 1 sec intervals

(Project No. G1515)

AGE Consultants 36 Jeays St, Bowen Hills Brisbane, Queensland Australia	slug/bail test analysis BOUWER-RICE's method	Date: 24.02.2011	Page 1
		Project: Coalpac Consolidation	
		Evaluated by: TMM	

Slug Test No.	Test conducted on: 16.02.2011
CP 123	



Hydraulic conductivity [m/s]: 4.38×10^{-9}

- Falling head test
- Water level recorded with electronic data logger at 10 sec intervals

(Project No. G1515)

AGE Consultants
36 Jeays St, Bowen Hills
Brisbane, Queensland
Australia

slug/bail test analysis
HVORSLEV's method

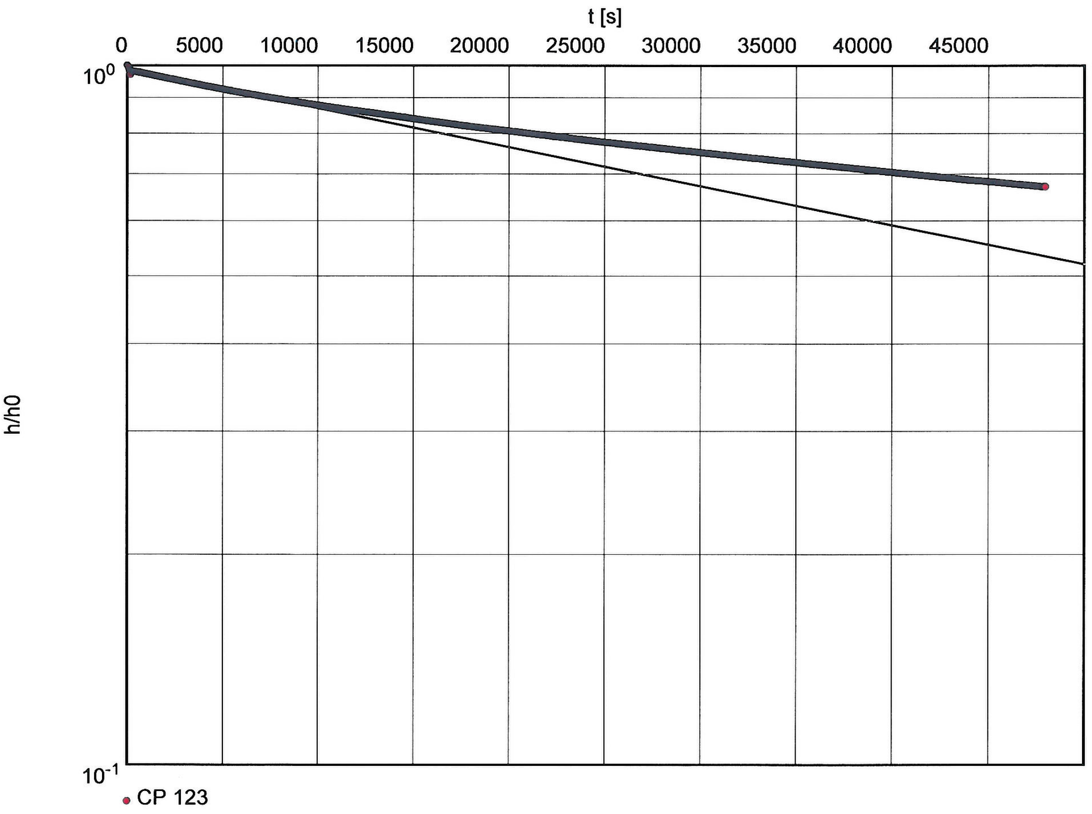
Date: 24.02.2011

Page 1

Project: Coalpac Consolidation

Evaluated by: TMM

Slug Test No.	Test conducted on: 16.02.2011
CP 123	



Hydraulic conductivity [m/s]: 4.97 x 10^{-9}

(Project No. G1515)

APPENDIX 4

Groundwater Chemistry Laboratory Report

(Project No. G1515)

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200 fax 02 9910 6201
enquiries@envirolabservices.com.au
www.envirolabservices.com.au

CERTIFICATE OF ANALYSIS 52050

Client:
Hydroilex
38 Gibbs St
Miranda
NSW 2228

Attention: Rohan Last

Sample log in details:

Your Reference:	**Coalpac-Invincible Colliery, Feb 2011**
No. of samples:	5 Waters
Date samples received / completed instructions received	21/02/11 / 21/02/11

Analysis Details:

Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	28/02/11 / 28/02/11
Date of Preliminary Report:	Not issued

NATA accreditation number 2901. This document shall not be reproduced except in full.
This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025. **Tests not covered by NATA are denoted with *.**

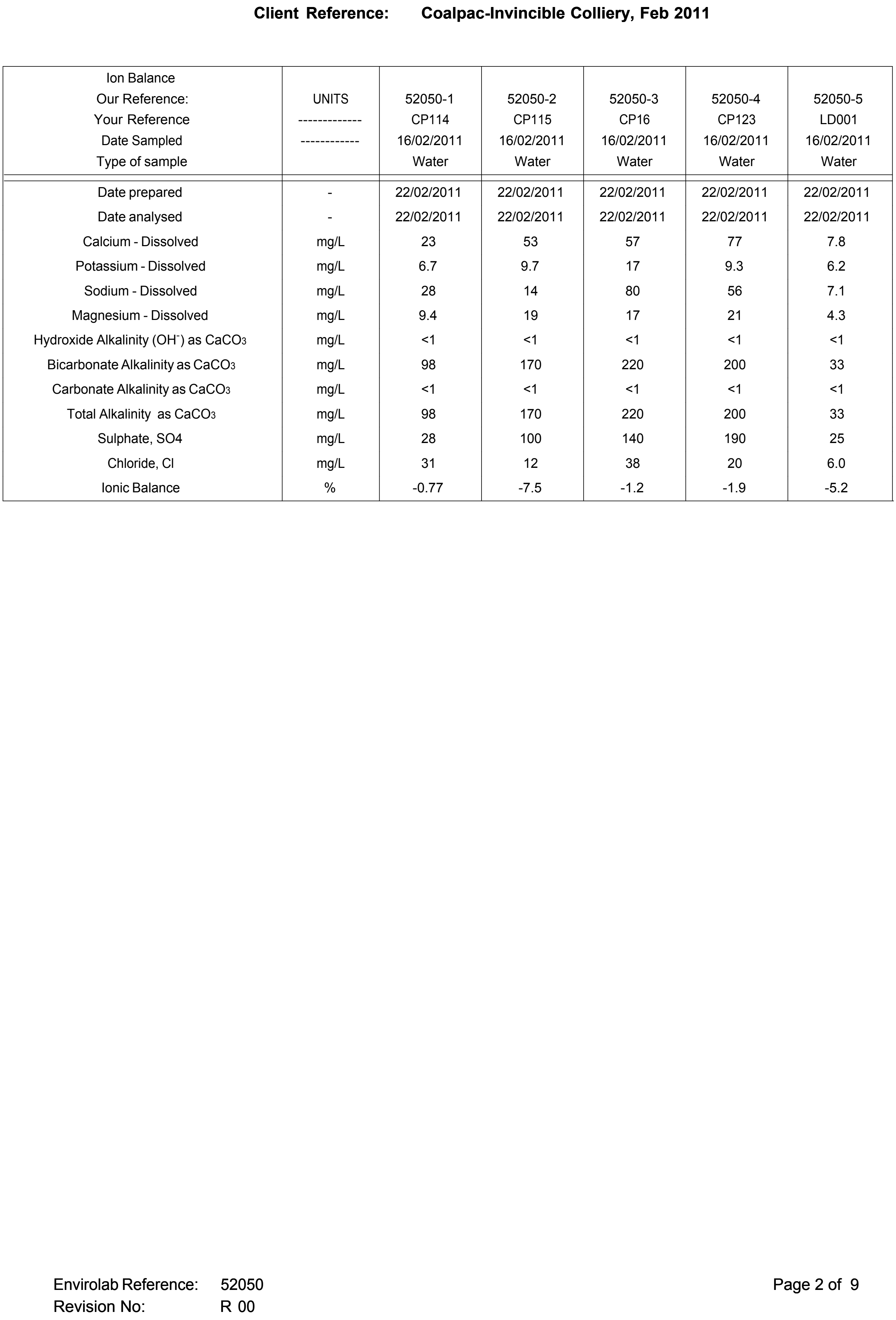
Results Approved By:

Nick Sarlamis
Inorganics Supervisor

Paciuszkiewicz.
Kasjan Paciuszkiewicz
Chemist

ACCREDITED FOR TECHNICAL COMPETENCE

(Project No. G1515)



Client Reference: Coalpac-Invincible Colliery, Feb 2011

Ion Balance Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------- ------------	52050-1 CP114 16/02/2011 Water	52050-2 CP115 16/02/2011 Water	52050-3 CP16 16/02/2011 Water	52050-4 CP123 16/02/2011 Water	52050-5 LD001 16/02/2011 Water
Date prepared	-	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011
Date analysed	-	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011
Calcium - Dissolved	mg/L	23	53	57	77	7.8
Potassium - Dissolved	mg/L	6.7	9.7	17	9.3	6.2
Sodium - Dissolved	mg/L	28	14	80	56	7.1
Magnesium - Dissolved	mg/L	9.4	19	17	21	4.3
Hydroxide Alkalinity (OH^-) as $CaCO_3$	mg/L	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	98	170	220	200	33
Carbonate Alkalinity as $CaCO_3$	mg/L	<1	<1	<1	<1	<1
Total Alkalinity as $CaCO_3$	mg/L	98	170	220	200	33
Sulphate, SO4	mg/L	28	100	140	190	25
Chloride, Cl	mg/L	31	12	38	20	6.0
Ionic Balance	%	-0.77	-7.5	-1.2	-1.9	-5.2

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Miscellaneous Inorganics Our Reference: Your Reference Date Sampled Type of sample	UNITS ------------- ------------	52050-1 CP114 16/02/2011 Water	52050-2 CP115 16/02/2011 Water	52050-3 CP16 16/02/2011 Water	52050-4 CP123 16/02/2011 Water	52050-5 LD001 16/02/2011 Water
Date prepared	-	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011
Date analysed	-	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011
Sulphide	mg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrite as N in water	mg/L	<0.005	<0.005	0.008	<0.005	<0.005
Nitrate as N in water	mg/L	<0.005	0.01	0.06	<0.005	0.01
Fluoride, F	mg/L	0.13	0.19	0.38	0.35	<0.1
Phosphate as P in water	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005
pH	pH Units	6.3	6.6	7.2	7.3	5.9
Electrical Conductivity	µS/cm	350	550	840	780	150
Hardness	mg$CaCO_3$/L	97	210	210	280	37
Total Dissolved Solids (grav)	mg/L	230	370	510	590	76

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All metals in water-dissolved						
Our Reference:	UNITS	52050-1	52050-2	52050-3	52050-4	52050-5
Your Reference	-------------	CP114	CP115	CP16	CP123	LD001
Date Sampled	------------	16/02/2011	16/02/2011	16/02/2011	16/02/2011	16/02/2011
Type of sample		Water	Water	Water	Water	Water
Date prepared	-	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011
Date analysed	-	22/02/2011	22/02/2011	22/02/2011	22/02/2011	22/02/2011
Aluminium-Dissolved	µg/L	<10	<10	<10	160	<10
Antimony-Dissolved	µg/L	<1	<1	<1	<1	<1
Arsenic-Dissolved	µg/L	<1	<1	<1	6	<1
Barium-Dissolved	µg/L	170	200	99	140	73
Beryllium-Dissolved	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Boron-Dissolved	µg/L	11	11	25	27	7
Cadmium-Dissolved	µg/L	<0.1	<0.1	0.2	<0.1	<0.1
Chromium-Dissolved	µg/L	<1	<1	<1	5	<1
Cobalt-Dissolved	µg/L	6	5	2	10	4
Copper-Dissolved	µg/L	<1	<1	5	5	2
Iron-Dissolved	µg/L	790	9,000	<10	1,200	56
Lead-Dissolved	µg/L	<1	<1	<1	13	<1
Lithium-Dissolved*	µg/L	25	45	100	39	29
Manganese-Dissolved	µg/L	650	860	1,000	1,700	500
Molybdenum-Dissolved	µg/L	<1	1	5	13	1
Nickel-Dissolved	µg/L	18	15	21	19	21
Selenium-Dissolved	µg/L	<1	<1	<1	<1	<1
Silver-Dissolved	µg/L	<1	<1	<1	<1	<1
Thallium-Dissolved	µg/L	<1	<1	<1	<1	<1
Thorium-Dissolved*	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5
Tin-Dissolved	µg/L	<1	<1	<1	<1	<1
Uranium-Dissolved	µg/L	<0.5	0.7	14	1.1	<0.5
Vanadium-Dissolved	µg/L	<1	<1	<1	5	<1
Zinc-Dissolved	µg/L	21	44	59	19	66
Bromine-Dissolved*	µg/L	70	40	140	70	30

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Method ID	Methodology Summary
Metals.20 ICP-AES	Determination of various metals by ICP-AES.
LAB.6	Alkalinity - determined titrimetrically in accordance with APHA 20th ED, 2320-B.
LAB.81	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA 21st ED, 4110-B.
LAB.41	Gravimetric determination of the total solids content of water.
LAB.51	Sulphide determined titrimetrically based on APHA.
LAB.56	Nitrite - determined colourimetrically based on EPA353.2. Soils are analysed following a water extraction.
LAB.55	Nitrate - determined colourimetrically based on EPA353.2. Soils are analysed following a water extraction.
LAB.26	Fluoride determined by ion selective electrode (ISE) in accordance with APHA 20th ED, 4500-F-C.
LAB.60	Phosphate water extractable - determined colourimetrically based on EPA365.1
LAB.1	pH - Measured using pH meter and electrode in accordance with APHA 20th ED, 4500-H+.
LAB.2	Conductivity and Salinity - measured using a conductivity cell and dedicated meter, in accordance with APHA2510 20th ED and Rayment & Higginson.
LAB.18	Total Dissolved Solids - determined gravimetrically by drying the sample, in accordance with APHA 20th ED, 2540-C.
Metals.22 ICP-MS	Determination of various metals by ICP-MS.

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QUALITY CONTROL Ion Balance	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			22/02/2011	52050-1	22/02/2011 || 22/02/2011	LCS-W2	22/02/2011
Date analysed	-			22/02/2011	52050-1	22/02/2011 || 22/02/2011	LCS-W2	22/02/2011
Calcium - Dissolved	mg/L	0.5	Metals.20 ICP-AES	<0.5	52050-1	23 || [N/T]	LCS-W2	104%
Potassium - Dissolved	mg/L	0.5	Metals.20 ICP-AES	<0.5	52050-1	6.7 || [N/T]	LCS-W2	99%
Sodium - Dissolved	mg/L	0.5	Metals.20 ICP-AES	<0.5	52050-1	28 || [N/T]	LCS-W2	105%
Magnesium - Dissolved	mg/L	0.5	Metals.20 ICP-AES	<0.5	52050-1	9.4 || [N/T]	LCS-W2	98%
Bicarbonate Alkalinity as $CaCO_3$	mg/L	1	LAB.6	<1	52050-1	98 || 99 || RPD: 1	LCS-W2	99%
Carbonate Alkalinity as $CaCO_3$	mg/L	1	LAB.6	<1	52050-1	<1 || <1	[NR]	[NR]
Total Alkalinity as $CaCO_3$	mg/L	1	LAB.6	<1	52050-1	98 || 99 || RPD: 1	LCS-W2	99%
Sulphate, SO4	mg/L	1	LAB.81	<1.0	52050-1	28 || [N/T]	LCS-W2	104%
Chloride, Cl	mg/L	1	LAB.81	<1.0	52050-1	31 || [N/T]	LCS-W2	100%
Ionic Balance	%		LAB.41	[NT]	52050-1	-0.77 || [N/T]	[NR]	[NR]

QUALITY CONTROL Miscellaneous Inorganics	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			22/02/2011	52050-1	22/02/2011 || 22/02/2011	LCS-W1	22/02/2011
Date analysed	-			22/02/2011	52050-1	22/02/2011 || 22/02/2011	LCS-W1	22/02/2011
Sulphide	mg/L	0.5	LAB.51	<0.5	52050-1	<0.5 || <0.5	LCS-W1	89%
Nitrite as N in water	mg/L	0.005	LAB.56	<0.005	52050-1	<0.005 || [N/T]	LCS-W1	91%
Nitrate as N in water	mg/L	0.005	LAB.55	<0.005	52050-1	<0.005 || [N/T]	LCS-W1	94%
Fluoride, F	mg/L	0.1	LAB.26	<0.1	52050-1	0.13 || 0.12 || RPD: 8	LCS-W1	100%
Phosphate as P in water	mg/L	0.005	LAB.60	<0.005	52050-1	<0.005 || [N/T]	LCS-W1	104%
pH	pH Units		LAB.1	[NT]	52050-1	6.3 || 6.3 || RPD: 0	LCS-W1	100%
Electrical Conductivity	µS/cm	1	LAB.2	<1.0	52050-1	350 || 350 || RPD: 0	LCS-W1	106%
Hardness	$mgCaCO_3/L$	3	Metals.20 ICP-AES	[NT]	52050-1	97 || [N/T]	[NR]	[NR]
Total Dissolved Solids (grav)	mg/L	5	LAB.18	<5	52050-1	230 || 240 || RPD: 4	LCS-W1	96%

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QUALITY CONTROL All metals in water-dissolved	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			22/02/2011	[NT]	[NT]	LCS-W1	22/02/2011
Date analysed	-			22/02/2011	[NT]	[NT]	LCS-W1	22/02/2011
Aluminium-Dissolved	µg/L	10	Metals.22 ICP-MS	<10	[NT]	[NT]	LCS-W1	107%
Antimony-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	94%
Arsenic-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	100%
Barium-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	100%
Beryllium-Dissolved	µg/L	0.5	Metals.22 ICP-MS	<0.5	[NT]	[NT]	LCS-W1	88%
Boron-Dissolved	µg/L	5	Metals.22 ICP-MS	<5	[NT]	[NT]	LCS-W1	91%
Cadmium-Dissolved	µg/L	0.1	Metals.22 ICP-MS	<0.1	[NT]	[NT]	LCS-W1	99%
Chromium-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	100%
Cobalt-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	101%
Copper-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	99%
Iron-Dissolved	µg/L	10	Metals.22 ICP-MS	<10	[NT]	[NT]	LCS-W1	110%
Lead-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	100%
Lithium-Dissolved*	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	92%
Manganese-Dissolved	µg/L	5	Metals.22 ICP-MS	<5	[NT]	[NT]	LCS-W1	101%
Molybdenum-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	98%
Nickel-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	99%
Selenium-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	117%
Silver-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	108%
Thallium-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	101%
Thorium-Dissolved*	µg/L	0.5	Metals.22 ICP-MS	<0.5	[NT]	[NT]	LCS-W1	104%
Tin-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	97%
Uranium-Dissolved	µg/L	0.5	Metals.22 ICP-MS	<0.5	[NT]	[NT]	LCS-W1	99%
Vanadium-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	100%
Zinc-Dissolved	µg/L	1	Metals.22 ICP-MS	<1	[NT]	[NT]	LCS-W1	99%

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QUALITY CONTROL All metals in water-dissolved	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Bromine-Dissolved*	µg/L	10	Metals.22 ICP-MS	<10	[NT]	[NT]	LCS-W1	94%

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Report Comments:

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NA: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike: A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample): This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batched of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes and LCS: Generally 70-130% for inorganics/metals; 60-140% for organics and 10-140% for SVOC and speciated phenols is acceptable.

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APPENDIX 5

Analytical Assessment Assumptions

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Groundwater Discharge into Adjacent Mines

The following assumptions were utilised during the assessment of groundwater seepage into adjacent mines from flooded underground workings:

- an average potentiometric surface of RL892m (h1) is located to the east of the seepage area at Old Tyldesley Colliery;
- an average potentiometric surface of RL883m (h1) is located to the south of the seepage area at the Old Invincible Colliery and the Invincible Colliery;
- all groundwater seepage from the Old Tyldesley Colliery, the Old Invincible Colliery and the Invincible Colliery reports to the Baal Bone Colliery;
- the goafed area of the Baal Bone Colliery is fully drained and does not allow water to back up;
- groundwater seepage will occur through the full face of the Lithgow Coal Seam aquifer;
- the potentiometric surface at the discharge point varies in height and is dependent upon geology however it ranges between RL875m and RL836m (h2);
- steady state conditions have been reached with respect to groundwater seepage;
- hydraulic conductivity of the separating coal seam pillar (Lithgow Coal Seam) will have spatial variability and may be enhanced (i.e. fractured) due to the presence of proximal mining;
- the hydraulic gradient of the steady state seepage condition that has developed between the flooded underground workings and the dry underground workings is based on the distance between the edge of the flooded workings and edge of the Baal Bone Colliery Longwall panel layout; and
- although some vertical groundwater seepage may enter the separating coal seam pillar, the predominant flow of groundwater will be horizontal.

Groundwater Inflow to Proposed Open Cut Mines

The following assumptions were utilised during the assessment of groundwater seepage from the Lithgow Coal Seam aquifer into the proposed open cut pits:

- apart from potentially minor seepage, groundwater inflows are not expected from the upper coal seams, these being the Upper Irondale and Irondale Coal Seams, the Moolarben Coal Seam, the Middle River Coal Seam and the Katoomba Coal Seam;
- the Lithgow Coal Seam is unsaturated above the elevation of the flooded underground mine workings, this being an area covered mostly by the Invincible Colliery mining areas;
- groundwater inflow to the Invincible Open Cut from the Lithgow Coal Seam is therefore expected to be negligible;
- all other mining areas are located down gradient of flooded underground mine workings;
- the Lithgow Coal Seam has a potentiometric surface of about RL892m (h1) to the east of the proposed Cullen Valley and East Tyldesley mining areas;
- steady state conditions have been reached with respect to groundwater flow;
- groundwater seepage will occur through a seepage face that has a height less than the full thickness of the coal seam, in this case the seepage face is about 2.5m thick;

- the potentiometric surface at the discharge point (i.e. seepage face) varies in elevation and is dependent upon geology; however in this case, it has been estimated to be approximately RL871m (h2), this being about the lowest elevation of the Cullen Valley and East Tyldesley mining areas;
- the hydraulic gradient of the steady state drawdown surface ("zone of depressurisation") that develops to the east of the highwall is approximately 250m (~0.84); and
- an evaporation rate of about 5mm/m^2 is applied to the area of the seepage face, which results in a percentage loss of groundwater seepage to the atmosphere, thus reducing the rate of groundwater seepage which reports to the open cut pit.

Groundwater Inflow to Open Pits Near Flooded Workings

Owing to the similarity of conditions, a number of assumptions utilised during the assessment of groundwater inflow into the proposed open pits were also utilised during this assessment. In addition, assumptions specific to the assessment of groundwater inflow to open pits from flooded underground workings were:

- the Cullen Valley and the East Tyldesley mining areas will be located down-gradient of flooded underground mine workings of the Old Tyldesley Colliery;
- the flooded underground mine has a potentiometric surface of about RL892m (h1) to the west of the proposed Cullen Valley and East Tyldesley mining areas;
- the potentiometric surface at the discharge point (i.e. seepage face) varies in elevation and is dependent upon geology; however in this case, it has been estimated to be approximately RL885m (h2), this being about the lowest elevation of the Cullen Valley and East Tyldesley mining areas proximal to the flooded underground workings; and
- the hydraulic gradient between the flooded underground mine workings and the open cut pits will be governed by the width of the separating coal seam barrier – three scenarios with varying widths have been assessed.

Groundwater Inflow to Highwall Mining Areas

A number of assumptions were utilised to develop the conceptual groundwater model relating to highwall mining seepage inflow, these being:

- the coal seam has low porosity and low permeability such that highwall mining is not affected by groundwater ingress;
- groundwater within the coal is removed as coal moisture as the coal is mined;
- no seepage from the over, or underlying formations occurs;
- each highwall mine drive is dry as cessation of mining;
- each highwall mine drive is sealed with backfill and/or grout at the cessation of mining;
- each drive has an approximate width of 3m and has a maximum length of 300m. Each drive is separated by a 3m pillar of coal;
- each drive will take approximately 1-2 days to complete;
- the deepest highwall mine drive will be located within the Lithgow Coal Seam (approx RL880m);
- the radius of impact will be about 250m resulting in a hydraulic gradient of about 0.04.

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- groundwater will seep predominantly through the drive end-face. Open cut mining will remove the coal seam aquifers along the length of the outermost drives;
- interference/dewatering impacts will occur as a result of progressive highwall mine drive development; and
- analytical groundwater inflow calculations assume steady state conditions.

Groundwater Inflow to the Sand Quarry Operation

The following assumptions were utilised during the assessment of groundwater seepage from the Marrangaroo Formation aquifer into the proposed quarry pits:

- there is no seepage through the floor of the pit due to the sharp erosive basal contact with the underlying low permeability silty and coaly sedimentary rocks of the Nile Subgroup represented by Zone 2 of the model shown on Figure 24;
- for Zone 1 the analytical solution considers steady-state, unconfined, horizontal, radial flow, with uniformly disturbed recharge at the water table - although this is not strictly correct for the Marrangaroo Formation, it is considered acceptable as the purpose of was to provide indicative estimates of the radius of influence and inflow.
- the pit walls are approximated as a right circular cylinder;
- groundwater flow is horizontal. The Dupuit-Forchheimer approximation (McWhorter and Sunada, 1977) is used to account for changes in saturated thickness due to depression of the water table;
- the static groundwater level in the Marrangaroo Formation is approximately horizontal;
- uniform distributed recharge to the sandstone/conglomerate sub crop as a result of surface infiltration of rainfall; and
- groundwater flow toward the pit is axially symmetric.

In arriving at the radius of influence and the inflow rate, it was further assumed that:

- the hydraulic conductivity (k_{hi}) of the Marrangaroo Formation ranges between 0.001m/day and 0.1m/day (as discussed in Section 7.6), note that this will result in a conservative overestimate as field permeability results indicate a hydraulic conductivity in the lower range;
- the pre-mining water table (potentiometric level) of the Marrangaroo Formation is at RL 869m (measured in CP114), this being immediately beneath the top of the formation;
- the maximum thickness of Marrangaroo Formation is about 10m, and hence the saturated thickness (h_o), of the coal measures is also about 10m;
- there is minimal rainfall recharge (W) to the Marrangaroo Formation. A range of rainfall recharge values including 1%, 5% and 10% annual average rainfall have been adopted;
- the height of the seepage face in the pit wall (h_p) is about 0.5m;
- the radius (r_p) of the open area (non rehabilitated area) of the quarry pit is 200m; giving a perimeter of about 1257m; and
- an evaporation rate of about 5mm/m^2 is applied to the area of the seepage face, which results in a percentage loss of groundwater seepage to the atmosphere, thus reducing the rate of groundwater seepage which reports to the open cut pit.