



Integra Coal Operations Pty Ltd

ABN: 96 118 030 998

Glennies Creek Open Cut Coal Mine

Groundwater Assessment

Prepared by

**Australasian Groundwater and Environmental
Consultants Pty Ltd**

October, 2007

**Specialist Consultant Studies Compendium:
Part 8**

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Groundwater Assessment

of the

Glennies Creek Open Cut Coal Mine

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EXECUTIVE SUMMARY

Integra Coal Operations Pty Ltd (ICO), is proposing to develop the Glennies Creek Open Cut Coal Mine ("the Project") near its existing operations north of Singleton in the Hunter Valley. The open cut coal mine will be located adjacent to the northern boundary of the now partially infilled Camberwell North Pit.

Approval for the development requires that an Environmental Assessment (EA) describing the potential impacts of the proposed development on the surrounding environment be prepared. An integral part of the EA is an assessment of the impact on the groundwater regime in the area.

The New South Wales Department of Planning (DoP) prepared a list of requirements to be addressed by the EA for the proposed open cut mine. The requirements were outlined in a letter dated 27 April 2006. Review of available data, field investigation and modelling of the impact of the Project on the groundwater regime was conducted in order to satisfy these requirements.

In summary, the results and conclusions of these studies are as follows.

Two distinct aquifers exist in the vicinity of the Project Site. These are an aquifer associated with shallow, unconsolidated Quaternary Alluvium made up of clay, silt, sand and gravel and a relatively deeper consolidated, sedimentary aquifer made up of Permian coal seams, together with interbedded sandstones and shales. The alluvial sediments directly overlie the Permian strata, however, available data suggests that there is no interaction between the two groundwater systems.

The Quaternary Alluvium along the bed of Glennies Creek has been identified to depths of 12m below natural surface and contains fresh groundwater. The standing water level within the alluvial sediments is very similar to the water level within the Glennies Creek. Hydraulic tests on the alluvial sediments of Glennies Creek indicates very high permeability associated with the coarse gravels.

The Permian groundwater system is hydraulically separate from the alluvial system. Standing groundwater levels within the Hebden/Barrett Coal Seams are significantly lower than those measured in the alluvial aquifer and show impact of dewatering by open cut and underground mining. In the area of the proposed Glennies Creek Open Cut Coal Mine the groundwater in the Permian aquifers is currently flowing from the north of the proposed open cut mine to the southwest toward the Camberwell North Pit void, the portal sump and the Glennies Creek Underground mine.

Groundwater quality within the coal seams is brackish to saline with EC values ranging between 7 280 and 10 280 μ S/cm. Hydraulic conductivity of the Hebden and Barrett Coal Seams is very low and was assessed to vary between 1.2×10^{-2} and 6.2×10^{-4} m/day.

A highly permeable and porous zone considered to be associated with the Camberwell Horst was identified within the footprint of the open cut. Yields of up to 50L/s were obtained during drilling through this zone. Test pumping data suggests that the extent of this zone is limited.

An assessment of groundwater use within the area surrounding the Project Site identified one existing well pumping from the Glennies Creek Quaternary Alluvium and three spring fed dams. Two abandoned or partially abandoned wells were located in close proximity to the proposed Glennies Creek Open Cut Coal Mine. The Quaternary Alluvium within the area contains groundwater of suitable quality and yield for stock, domestic and irrigation purposes; however, due to the availability and security of the current surface water supply, many of the older groundwater wells within the alluvium have been abandoned. No bores or wells within the Permian strata were identified which is assumed to relate to the fact that the groundwater quality is not suitable for domestic or irrigation purposes.

Due to the surface nature of the Camberwell Coal Handling and Preparation Plant (CHPP) and haul roads, it was assumed that these activities will have no impact on the groundwater regime of the area, as such the hydrogeological assessment focussed on the potential impacts of the proposed Glennies Creek Open Cut Mine.

Analysis of the available data and numerical simulations of the combined impact of the existing mines on the groundwater in the area concluded the following.

- There is an existing cone of depression developing around the Glennies Creek Underground Coal Mine and the Camberwell Open Cut and Camberwell North Pit as a result of previous and current dewatering at these mines. This cone of depression is very steep and limited to the areas immediately surrounding the mine workings.
- Neither the currently abandoned Ravensworth East open cut nor the Ashton mine have any impact on the groundwater regime in the proposed Glennies Creek open cut area.
- The cone of depression developing around the Mt Owen Mine is currently separated from the cone of depression of the Glennies Creek and Camberwell mines and will remain separated for the life of the proposed Glennies Creek Open Cut Coal Mine.
- The simulated inflows to the proposed Open Cut are expected to vary between about 40m³/day and 260m³/day with the highest inflows expected to be encountered when the mining intersects the Camberwell Horst.
- Dewatering of the Glennies Creek Open Cut Coal Mine will have no impact on the flows in the Glennies Creek, on the alluvial aquifer associated with the creek, or on the bores and wells tapping the alluvial aquifers.

1 INTRODUCTION

Integra Coal Operations Pty Ltd (ICO) is planning to develop the Glennies Creek Open Cut Coal Mine ("the Project") near its existing underground operations north of Singleton in the Hunter Valley (**Drawing No 1**). The open cut coal mine will be located adjacent to the northern boundary of the now partially infilled Camberwell North Pit.

Approval for the development requires that an Environmental Assessment (EA) describing the potential impacts of the proposed development on the surrounding environment be prepared. An integral part of the EA is an assessment of the impact on the groundwater regime in the area.

The proposed mine may impact the groundwater regime through pit dewatering and through interaction with groundwater held within the spoil of the Camberwell North Pit. No groundwater based water supply for the proposed mining operation is forecast.

This report describes the assessed impact of the proposed open cut coal mine on the hydrogeological (groundwater) regime of the Project Site and surrounding area and provides groundwater impact mitigation options where adverse impacts may occur. The report was prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) at the request of R.W. Corkery & Co Pty Ltd (RWC), on behalf of its client, ICO.

2 DIRECTOR GENERAL REQUIREMENTS AND STUDY OBJECTIVES

The New South Wales Department of Planning issued Director-General's Requirements to be addressed by the EA on 27 April 2006. In addition, other government agencies have issued requirements. These were supplied by R.W. Corkery & Co. Pty. Limited on 5 May 2006 in summary form.

ENVIRONMENTAL REQUIREMENTS RAISED BY THE DIRECTOR-GENERAL RELATING TO GROUNDWATER (25.01.07)	
Key Assessment Requirements:	
• <i>Groundwater</i> – Include detailed modelling of potential surface and groundwater impacts, a site water balance, and a detailed description of any proposed creek diversion. – Include a surface and groundwater contingency strategy as part of the mitigation measures which detail the measures proposed to protect the water supply to landowners in the region and the environment.	

ENVIRONMENTAL REQUIREMENTS RAISED BY THE DIRECTOR-GENERAL RELATING TO GROUNDWATER (25.01.07)	
References - The various State Groundwater Policy documents (DNR). <i>Managing Urban Stormwater: Soils and Construction Volume 14th Edition</i> (Landcom). <i>Guidelines for Fresh and Marine Water Quality and Guidelines for Water Quality Monitoring and Reporting</i> (ANZECC). <i>Rehabilitation Manual for Australian Streams</i> (Land and Water Resources Research and Development Corporation). <i>NSW State Rivers and Estuaries Policy – NSW Sand and Gravel Extraction Policy for Non Tidal Rivers</i> (DNR). <i>Approved Methods for the Sampling and Analysis of Water Pollutants in NSW</i> (DECC). <i>Environmental Guidelines: Use of Effluent by Irrigation</i> (DECC).	
ENVIRONMENTAL REQUIREMENTS RAISED BY GOVERNMENT AGENCIES RELATING GROUNDWATER	
Government Agency	Paraphrased Requirement
Department of Natural Resources (10/04/06)	Provide details of any proposed groundwater extraction, including purposes, location and construction details of all proposed bores and expected annual extraction volumes.
	Provide details of any proposed works likely to intercept groundwater.
	Describe different aquifer systems including their extent and inter-relationships (surface water bodies and dependent ecosystems).
	Describe flow directions and rates and the physical and chemical characteristics of the aquifers.

3 LEGISLATION / POLICY

The following section outlines New South Wales State Government statutory requirements that apply to the Project Site and proposed mining operation with respect to groundwater.

3.1 Water Management Act 2000

The object of the Water Management Act 2000 is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The 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 approvals – 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 – authorises the holder to conduct activities that affect the aquifer. This approval is for activities that intersect groundwater, other than water supply bores and may be issued for up to ten years.

For controlled activities and aquifer interference activities, the 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 Act, any work interfering with groundwater is a Licensable Work and requires a licence. There are 3 classes of licences applicable to mining activities.

- Special Purpose Licence – this licence is required by all open cut or underground mines.
- Dewatering Bores Licence – this licence specifies bore yield allocation and requires a fee.
- Piezometers and Monitoring Bores Licence – this licence specifies null yield allocation and does not require a fee.

3.2 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 the environmental, social and economic uses. The policy has three components parts:

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

3.2.1 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.
9. Where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.

3.2.2 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 (GDE), 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.

- GDE 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 ensure that sufficient groundwater is available at all times to identified GDE.
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect GDE.
- 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 systems.

3.2.3 Groundwater Quantity Protection

The objectives of managing groundwater quantity in New South Wales are:

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

3.3 Aquifer Risk

According to DLWC (1998) the Glennies Creek alluvium aquifer falls into category of "Hunter Miscellaneous Tributaries Alluvium" which is classified by DLWC as medium risk aquifer. The coal aquifers fall into the category of "Hunter Coal-Associated Fractured Rocks" classified as Low Risk Aquifers.

4 EXISTING AND PROPOSED MINING IN THE AREA

The first coal mining in the Glennies Creek area commenced as early as the 1860's but was limited to small scale operations. Large scale mining commenced in about 1990. Brief descriptions of the mines closest to the proposed Glennies Creek Open Cut are as follows (refer **Drawing No 1**).

Ashton Open Cut and Underground Mine

Open cut and underground (longwall) operation located near the village of Camberwell, and about 4.5km (Barrett Open Cut) and 5.8km (underground) to the west of the Project Site. Operation commenced in mid 2004. Seams mined are summarised below in **Table 1**.

Table 1
Ashton Mine Coal Seams

Major Coal Seams Present	Working Thickness (m)	Seams Mined
Pikes Gully	2.2	Yes
Liddell Upper	2.15	Yes
Liddell Middle	1.85	No
Liddell Upper Lower	2.20	No
Liddell Lower Lower	0.98	No
Barrett Upper	1.50	No
Barrett Lower	2.30	No

Camberwell Open Cut Mine

Mining in the area of the Camberwell North Pit and Camberwell Open Cut commenced as a number of small collieries worked between 1873 and 1948 down-dip from the outcrops of the Upper Hebden and Lower Barrett Seams. The largest of these mines, the Rosedale Colliery, produced about 600 000t from the Upper Hebden Seam. The other collieries were much smaller.

The Camberwell North Pit is no longer operational and is almost completely filled with an overburden emplacement. The portal to the Glennies Creek Underground Coal Mine is located in the unfilled section of this pit. Mining from Camberwell North Pit commenced in 1991 and was completed in 1998. Mining from the Camberwell Open Cut commenced in 1997 and in 2001 reached the base of the Upper Liddell Seam in the northern part of the pit and the Pikes Gully Seam in the southern part. The pit is mined to the lower Hebden Seam (**Table 2**). Mining from the Camberwell Open Cut is scheduled to be completed by the end of 2010.

Table 2
Camberwell Mine Coal Seams

Major Coal Seams Present	Working Thickness (m)	Seams Mined
Arties	4.1*	Yes
Liddell Upper	1.7*	Yes
Liddell Middle	2.4*	Yes
Liddell Lower Middle	1.3*	No
Liddell Lower	1.2*	No
Barrett Upper	1.4	Yes
Barrett Lower	2.4	Yes
Hebden Upper	2.3	Yes
Hebden Lower	1.1	No
* occurs as a number of splits totalling this thickness		

A sump exists in the northern pit close to the portal of the Glennies Creek Underground Coal Mine. The standing water level in the sump was about 9m AHD in 1999 and rose to about 14m AHD by 2000, and to about 33m AHD by 2001. It is understood that currently (2006) the water level in the sump is maintained at 41m AHD in order to provide a freeboard between the sump and the portal of the Glennies Creek underground.

Glennies Creek Underground Coal Mine

The Glennies Creek Underground Coal Mine is a longwall operation located about 2km northwest of the Project Site.

Work on the access drifts commenced in the middle of 1999, and by September 1999 about 560m of the drift had been completed. Mining of the Liddell Mine Seam (**Table 3**) in the first Long Wall Panel No 1 commenced in August 2002 and by the end of 2003 the first three panels (LW1 to LW3) were mined out. Panels LW4 to LW6 were mined out between January 2004 and March 2006 and Panel LW7 is currently in preparation. Extraction from Panels LW8 to LW9 is planned between 2006 and 2008. In total there are 17 panels to be mined. The mine is expected to be in operation till about 2025.

Table 3
Glennies Creek Underground Coal Seams

Major Coal Seams Present	Working Thickness (m)	Seams Mined
Liddell Middle	2.30	Yes
Liddell Lower	2.20	No
Barrett	3.00	No
Hebden	2.55	No

Mt Owen Open Cut Mine

The Mt Owen Open Cut Mine is located 8km north of Ravensworth and about 8km to the northwest of the Project Site.

Mining commenced in late 1993 and is planned to continue till about 2021 to 2025. The mining will continue within the existing Pit B and will extend southward in Pit C between 500m and 800m south from Pit B. The depth of Pit C will be up to 270m below surface. Mined seams are presented in **Table 4**.

Narama Pit

The pit is located to the east of the Ashton Mine. It is mining the Bayswater Seam. The mining will be completed in 2013.

Table 4
Mt Owen Coal Seams

Major Coal Seams Present	Working Thickness (m)	Seams Mined
Lemington A, B, C and D	unknown	Lemington A and B
Pikes Gully	unknown	Yes
Arties	unknown	Yes
Liddell Upper	unknown	Yes
Liddell Middle	unknown	Yes
Liddell Lower	unknown	Yes
Barrett	unknown	Yes
Hebden Upper	unknown	Yes
Hebden Lower	unknown	No

Ravensworth East, (formerly the Swamp Creek Open Cut)

The open cut mine is located about 6.5km to the northwest of the Project Site. No mining is currently being conducted in this pit. The mine void consists of a north-south trending thin void flanked by overburden dumps to the west. Mining occurred in the Bayswater Seam which is stratigraphically more than 250m above the Middle Liddell Seam. The pit void water level was about 45m AHD in 1999.

Rixs Creek Open Cut Mine

The mine is located 5km northwest of Singleton and about 2km southwest from the Project Site. It is an open cut operation (**Table 5**) that includes some old workings probably as old as the 1860's. Large scale production at the mine began in 1990.

Table 5
Rixs Creek Mine Coal Seams

Major Coal Seams Present	Working Thickness (m)	Seams Mined
Pikes Gully	3.4	Yes
Arties Upper	2.5	Yes
Arties Lower	1.0	Yes
Liddell Upper	1.0	Yes
Liddell Middle	1.6	No
Liddell Lower-Middle	0.7	No
Liddell Lower	1.2	Yes
Barrett Upper	2.3	Yes
Barrett Lower	3.1	Yes
Hebden	2.6	Yes

Glendell Open Cut Mine (Non operational)

The proposed mine is located to the west of Glennies Creek Underground and immediately to the north of the Ashton Mine. Currently it is non operational. Re-opening of the open cut mine has been considered since about 2003. It is understood that there is currently no set date for commencement of mining from this area.

5 PROPOSED GLENNIES CREEK OPEN CUT COAL MINE

The Project would involve the following activities.

- Construction of a site access road off Middle Falbrook Road.
- Construction of the open cut facilities area (including transportable offices, a bathhouse, a crib room, a report room, first aid facilities and stores; as well as a workshop, lay-down areas, parking facilities and associated infrastructure).
- Coal mining by open cut methods within a pit shell covering approximately 90ha (7.7Mt reserve). Within this area, drilling has identified three principal coal seams amenable to mining by open cut methods, namely the:
 - Middle / Lower Liddell;
 - Barrett; and
 - Hebden seams.
- Transportation of run-of-mine (ROM) coal to the Camberwell Coal Handling and Preparation Plant (CHPP) via a combination of internal haul routes A to E.

- When required, stockpiling of ROM coal at a temporary ROM coal stockpile area located at the top of the active open cut ramp (see Part B6.2) or at the existing RL100 Stockpile Area, with subsequent transportation to the Camberwell CHPP.
- Highwall / auger mining. During the course of the open cut mining, there may be opportunities to undertake mining from the northern highwall using either highwall or auger mining methods to extract additional coal. These methods of mining would result in underground extraction for a maximum length of approximately 300m from the base of the highwall. The final distance would depend on the type of mining undertaken. Highwall or auger mining would not occur outside the Project Site boundaries, nor would not result in subsidence of the ground surface. The coal that would be extracted by this method would be in addition to the 7.7Mt to be extracted by open cut mining methods.
- Programmed placement of waste rock materials from the open cut. Initially this would be to an out-of-pit emplacement, with subsequent placement out-of-pit as well as to in-pit in areas where mining has been completed. The proposed out-of-pit emplacement would have a disturbance footprint of approximately 43ha
- Storage and washing of ROM coal and despatch of product coal from the Camberwell CHPP.
- Progressive reshaping and rehabilitation of all areas of mining-related disturbance.
- Implementing and maintaining comprehensive systems to manage noise, vibration, air quality, visibility, surface water, groundwater, flora, fauna and Aboriginal heritage issues.

Mining at the proposed open cut is planned to commence at the eastern end of the pit and would progress to the west. At a maximum production rate of 1.5Mt ROM coal per annum, the proposed open cut coal mine has a life of approximately five to six years. Should the annual production rate be less than the maximum, the life of the proposed open cut mine would be extended. Additionally, the coal mined through either highwall or auger mining campaigns may slightly increase the mine life. No advance dewatering of the coal seams is expected to be required at this time.

6 REGIONAL SETTING

6.1 Project Site

The Project Site is located approximately 12km north of the town of Singleton in the Hunter Valley of New South Wales, as shown on **Drawing No 1**. The proposed open cut would be located immediately to the north of now backfilled Camberwell North Pit, some 2km southeast of the Glennies Creek Underground Coal Mine and 8km southeast of Mt Owen Pit B.

The Project Site covers a total area of approximately 376ha and incorporates all areas of disturbance associated with proposed project-related activities, and includes:

- the Open Cut Project Area (320ha incorporating a 90ha mine area) (see **Drawing No 2**);
- Haul Route Corridor D (100m wide x 1 400m long);
- Haul Route Corridor E (40m wide x 2 700m long) (the existing RL 100 Haul Route); and
- the Camberwell Coal Handling and Preparation Plant (CHPP) (31ha).

At the time of writing the majority of the Open Cut Project Area would occur within Coal Lease 382 (CL382), although some surface works, such as overburden/interburden emplacement construction, transportation of coal to the Camberwell CHPP and preparation of that coal, would be undertaken on the adjacent tenement, CL357. Land within the Project Site is owned by project-related companies.

6.2 Topography and Drainage

The Project Site and the immediate environs are located in a generally undulating area with low to moderate relief. Ground levels within the Project Site slope to the north and range from approximately 110m AHD to 90m AHD. Drainage of the Project Site is northwards to Glennies Creek (also called Fal Brook) via a number of ephemeral creeks. Glennies Creek itself is perennial with flow being maintained by regular releases from Lake St Clair, upstream of the Project Site. Glennies Creek width varies between about 3m and 7m and the depth of water in the creek is up to about 0.3m at its closest point to the Project Site. The confluence of Glennies Creek with the Hunter River is located approximately 7.5km southwest of the Project Site. Other main creeks in the area include Main Creek, Betties Creek and Foy Brook, all located to the northwest and west of the proposed open cut.

The western portion of the Project Site is drained by the ephemeral Stony Creek which in turn drains to Glennies Creek upstream of the Project Site.

The Hunter River flows about 7km to 9km to the west and south of the site. Glennies Creek flows between 800m to about 2km to the north and northwest, and Main Creek about 4.5km further to the west of the proposed pit. The location of the creeks is shown on **Drawing No 3**.

A large dam about 24ha in size (Possum Skin Dam) abuts the northwest corner of the proposed Glennies Open Cut Coal Mine. The dam is a part of the Glennies Creek Underground Coal Mine water management system. The water level in the dam is maintained at an approximately constant elevation of 88.5m AHD. A small sump, about 50m by 50m, exists near the portal to the Glennies Creek Underground Mine. The water level in the sump is maintained at elevation of about 41m AHD in order to avoid flooding of the portal. Few other larger ponds exist, also to the south of the proposed Glennies Creek Open Cut Coal Mine.

6.3 Climate

The climate around the Project Site is typical of temperate areas and is characterised by hot, dry summers dominated by thunderstorms and cool winters with frequent frosts. As part of the EIS studies, PSM Australia Pty Ltd (2006) analysed the rainfall records from thirteen (13) regional rainfall stations located within 60km of the Project Site in order to establish a composite rainfall record applicable to the Glennies Creek area. Long term rainfall data from the Singleton Post Office (BoM Station 061070) (1881 – 1969) was used as the index station in the analysis with a weighting factor applied to the data from the supplementary rainfall stations. The weighting factor was based on establishing a correlation between the stations based on the period of overlapping record. PSM Australia Pty Ltd also evaluated the open water and net evaporation for the Project Site based on Bureau of Meteorology data. The results of this analysis are presented in **Table 6**.

Table 6
Monthly Rainfall and Evaporation Data - Glennies Creek Composite
[after PSM Australia 0792377079 (2006)]

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual
Rainfall (mm)	80	80	76	73	49	52	48	39	45	52	60	72	725
Open Water Evap	216	168	162	108	75	60	60	78	114	168	186	204	1602
Net Evap	136	88	86	35	29	8	12	38	69	116	126	132	877

Source: PSM 2006 (Table 3.5)

6.4 Geology and Structure

The proposed Glennies Creek Open Cut Coal Mine is located with the Hunter Coalfield of the Sydney Basin. The Sydney Basin extends over 35,000km² and stretches from Wollongong in the south, northward on the coast to Newcastle and reaches to the northwest inland past Muswellbrook. The Sydney Basin forms part of the Sydney-Gunnedah-Bowen Basin which is a large structural basin trending north-south over eastern Australia (Beckett, 1988).

The evolution and stratigraphy of the Hunter Coalfield is discussed in detail by Coxhead (1996) as follows.

“The Hunter Coalfield comprises Permian sediments, overlain to the west by Triassic sediments and overthrust to the east by Carboniferous strata. The Permian sediments have been folded into a series of structures with a general north-south trend, formed by compression of the depositional basin by the New England Fold Belt. Some of these structures were synsedimentary and were active into the Triassic but the major stresses were taken up by the Hunter Thrust Fault, a continental scale structure. Deposition was largely controlled by cyclic periods of marine transgression and regression though syndepositional faulting and folding had some influence.

Two major coal measure sequences are present in the Hunter Coalfield, in ascending order the Greta Coal Measures and the Singleton Super Group. These coal measures are separated by a marine sequence comprising the Maitland Group. The Singleton Super Group may be subdivided into the Whittingham Coal Measures and the Wollombi Coal Measures that are separated by marine strata of the Denman Formation. The lower part of the Whittingham Coal Measures is known as the Vane sub-group.

The Vane sub-group is divided into two formations: the coal bearing Foybrook Formation and the overlying Bulga Formation. The Foybrook Formation contains up to six potentially mineable coal seams in ascending order, the Hebden, Barrett, Liddell, Arties, Pikes Gully and Lemington Seams. The seams frequently split and interseam lithologies include siltstone, lithic sandstone and conglomerate. The high energy sediments are characteristic of active channel systems. The overlying Bulga Formation is not present in the area; the highest strata are in the Upper Liddell horizon”.

The stratigraphic column of the area, after Hunter Coalfield Regional Geology Map (1993), is shown below on **Figure 1**.

The proposed open cut would extract coal from three coal seams of the Foybrook Formation, namely the Liddell, Barrett and Hebden Seams. Within the Open Cut Project Area, these seams are split into multiple coal plies as shown on **Figure 2** and in total approximately 9.5m thickness of coal is present within the proposed open cut. The base of mining would be to the floor of the Hebden Seam. The maximum depth of the pit will be up to about 100m below the present ground surface.

The Project Site is located within the Foybrook Formation and the proposed mine will extract coal from coal seams within this formation, that is, the Liddell, Barrett and Hebden Seams. The Foybrook Formation is underlain by the Saltwater Formation consisting of sandstones, siltstones and minor coaly bands. According to the Hunter Coalfield Regional Geology Map, 1:100 000 (Second Edition 1993) the thickness of Foybrook Formation in the area is estimated at about 150m. Underlying the Foybrook Formation is the Mulbring Siltstone. This formation, which consists of siltstones, claystones and minor fine grained sandstones, is up to about 500m thick in the area.

Geological structural features in the Glennies Creek area are shown on **Drawing No 7**.

The most significant structural features in the area are two approximately parallel thrust faults to the north of the Project Site: the continental scale Hunter Thrust Fault and to the south, the Hebden Thrust Fault. A series of approximately parallel, generally north to south trending synclines and anticlines surround the site. The closest such structures to the Project Site are the Darlington and Sedgfield Anticlines and Mundowa Syncline to the east and Rixs Creek Syncline to the west and the Camberwell Anticline further to the west. An unnamed thrust fault (subsequently called in this report the Camberwell Thrust Fault) is orientated approximately parallel to the Camberwell Anticline is another significant structural feature to the west of the site.

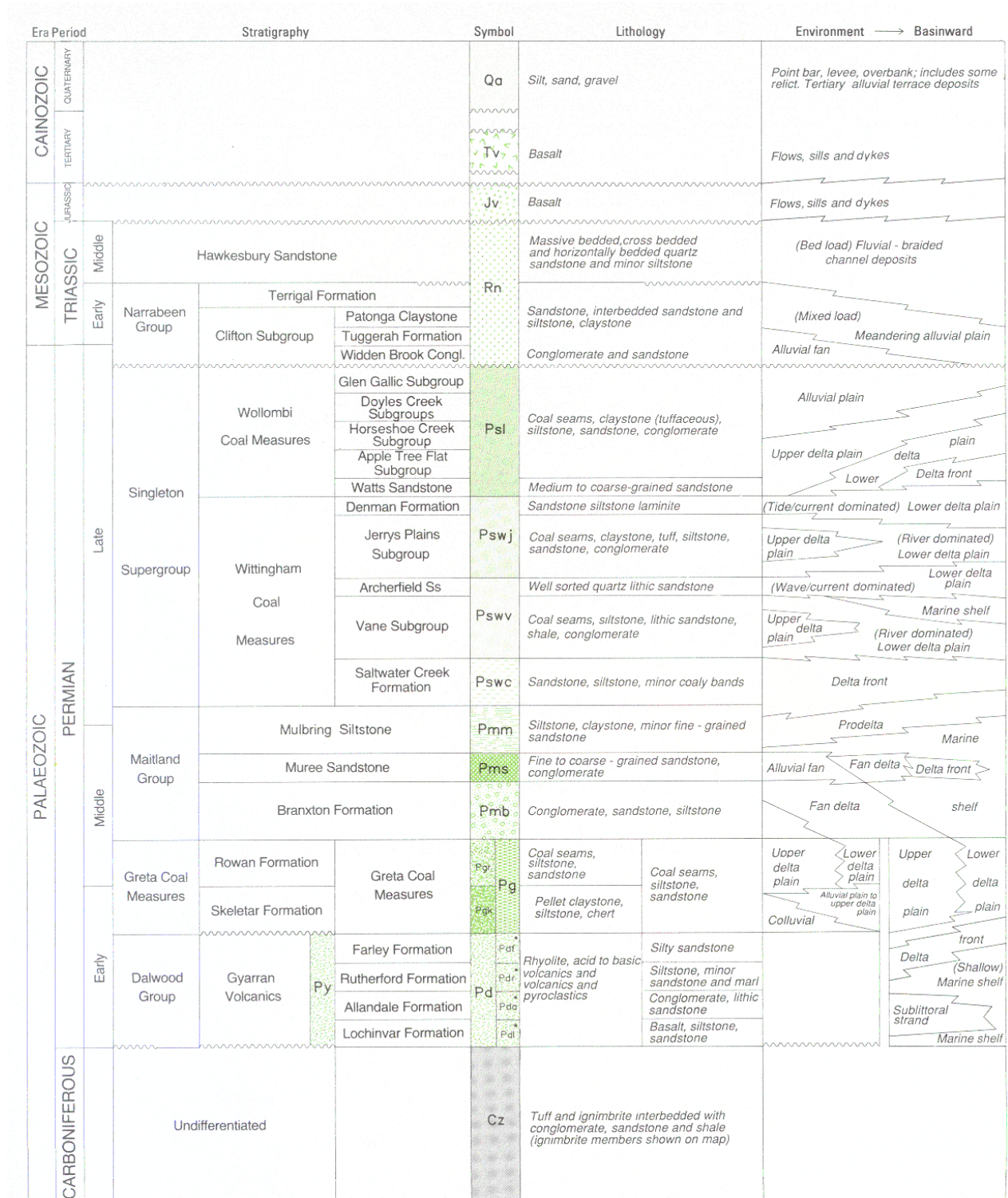


Figure 1 Hunter Coalfield Stratigraphic Column (after Hunter Coalfield Regional Geology Map 1:100 000, Second Edition 1993)

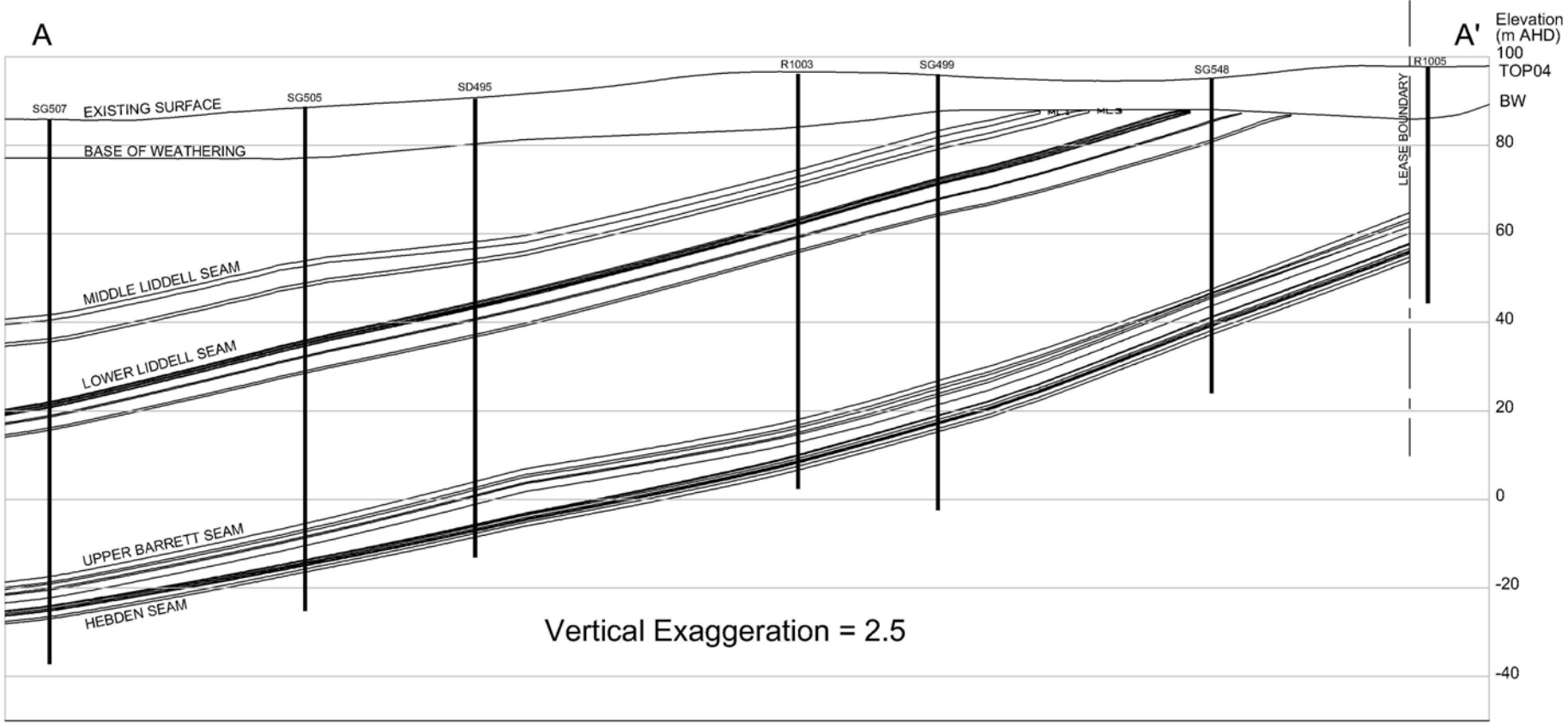


Figure 2 Glennies Creek Open Cut Geological Cross Section

Overlying the Permian strata are unconsolidated sedimentary deposits of Quaternary age associated with the Hunter River and its major tributaries, such as Glennies Creek, Main and Betties Creeks and Foy Brook. The alluvium consists of fine to coarse grained sand, gravel and cobbles within a sandy or loamy matrix.

7 HYDROGEOLOGICAL FIELD WORK

In order to understand the hydrogeological regime and assess the potential impacts of open cut mining on the existing groundwater system, it was necessary to carry out field operations to:

- establish monitoring bores for assessing the piezometric levels and groundwater quality;
- assess the hydraulic permeability of the Hebden Coal Seam by undertaking pumping tests and falling head tests; and
- undertake a bore census of nearby licenced and unlicenced stock and domestic bores.

7.1 Monitoring Bore Construction

On the basis of the existing geological information and proposed open cut layout, eleven groundwater monitoring bores were drilled within and surrounding the proposed open cut coal mine pit shell (**Drawing No 4**). The drilling was carried out by a licenced water bore driller from Ultradrilling Pty Ltd and all work was supervised by a hydrogeologist from AGE.

Drilling was undertaken using a top head drive Pioneer Mole rotary drilling rig. Drilling was carried out using blade and hammer bits and compressed air. On completion of drilling to total depth for each hole, the hole was developed or airlifted with compressed air. This served to clean up the hole and purge any introduced fluid from the hole. The drilling rig was equipped with an onboard 900cfm, 350psi compressor. The boreholes intersecting the coal seams were geophysically logged using gamma, calliper, density sensitivity and conductivity tools.

Materials used to construct the monitoring bores are as follows.

- Casing – Class 9 and 12, 50mm diameter upvc, 6m lengths, bell joints.
- Endcaps – Class 18, 50mm diameter, push on.
- Gravel pack – 3mm to 7mm, washed, gravel.
- Bentonite – Granulated bentonite chips.
- Shroud – 168.3mm diameter steel, lockable cap.

Casing was run to the total depth in each borehole with the lowermost 18m of casing slotted with approximately 12 to 16 slots per 6m length of uPVC casing using a grinder and cutting disc. The gravel pack was emplaced by pouring directly from the surface, with the depth to the gravel pack measured periodically to ensure the target coverage above the screened interval

was attained. A 1m to 2m thick bentonite plug was then placed above the gravel pack to minimise the potential ingress of surface water to the screened zone. Backfilling of the annulus to within 10m of the surface was completed with drill cuttings and the steel protective shroud cemented in place with a 5% bentonite cement mix. Each bore was constructed in accordance with the 'Minimum Construction Standards for Water Bores in Australia'.

During drilling, the cuttings were lithologically logged by AGE. The bore logs for each of the groundwater monitoring bores are presented in **Appendix 1. Table 7** summarises the information for those bores and **Table 8** summarises the water level data.

Table 7
Summary of Monitoring Bores

Bore Name	Coordinates (GDA94)*		Total Hole Depth (mbGL)	Surveyed Elevation (m AHD)		EC (µS/cm)	pH	Temp (°C)
	Easting	Northing		Ground Level	Top of Casing			
GC01	325124	6406664	108	96.013	96.456	10280	8.46	21.3
GC02	325160	6406490	105	105.495	106.243	7610	8.77	19.8
GC05	324337	6406203	108	80.334	80.995	7280	8.47	20.4
GC06	324941	6406784	126	102.931	103.316	9270	8.33	21.1
GC07	325864	6407071	120	93.034	93.352	8250	7.01	31.7
GC08	326332	6407214	120	105.095	105.677	7610	8.29	20.1
GC09	323259	6407315	9	69.885	70.593	500	7.07	21.5
GC10	324414	6408030	11.5	74.891	75.595	540	7.05	19.7
GC13	326169	6406745	66	105.356	105.55	-	-	-
GC14	325774	6407042	123	90.99	91.831	9560	8.28	21.1
GC15	325912	6406961	114	95.035	95.635	8170	8.46	19.8
GC16	326029	6407077	120	98.853	99.741	7760	8.41	20.1
GCTB	325149	6406572	90	102.564	102.809	9930	8.03	17.2

* See Drawing No 4

Table 8
Summary of Water Levels in Monitoring Bores

Bore Name	Coordinates (GDA94)		Water Level	
	Easting	Northing	Below Top of Casing	m AHD
GC01	325124	6406664	47.87	48.59
GC02	325160	6406490	59.01	47.23
GC05	324337	6406203	35.16	45.84
GC06	324941	6406784	50.99	52.33
GC07	325864	6407071	21.51	71.84
GC08	326332	6407214	33.82	71.86
GC09	323259	6407315	5.17	65.42
GC10	324414	6408030	6.96	68.64
GC13	326169	6406745	45.38	60.17
GC14	325774	6407042	23.33	68.50
GC15	325912	6406961	33.31	62.33
GC16	326029	6407077	27.85	71.89
GCTB	325149	6406572	54.30	48.51

Water levels recorded on the 30th May 2005

7.1.1 Quaternary Alluvium Bores

Three locations were selected for the construction of shallow monitoring bores in the alluvium of Glennies Creek. The locations were selected on the basis of the drainage from the Project Site with the ultimate purpose being to establish bores up-gradient and down-gradient of any watersheds in which the proposed pit is located. However, due to the boggy site conditions at the proposed GC11 location, the drilling rig was unable to access the site. An alternative location for this bore is to be negotiated in the future with landholders upstream of the proposed monitoring site.

Two groundwater monitoring bores were drilled and constructed within the Glennies Creek alluvium (GC09 and GC10) [**Drawing No 4**]. These bores were sited to allow for up-gradient and down-gradient groundwater monitoring of the water sheds draining the proposed open cut mine including the catchment encompassing Possum Skin Dam. Both bores intersected shallow groundwater within alluvial sand and gravel deposits and were drilled until consolidated Permian strata was identified. The nature of the material within the Glennies Creek alluvium consisted of very coarse gravel and cobbles within a sandy or loamy matrix and required a casing advance hammer drilling technique (ODEX) to complete the bores to the desired depths. The strata logs for these bores are provided in **Appendix 1**.

The Quaternary alluvium is overlying the Permian Foybrook Formation which contains the coal seams proposed to be mined within the open cut. The unconsolidated alluvial material was drilled until a positive identification of the underlying Permian material was made. Within both alluvial boreholes, the Permian material consisted of very fine grained, light grey, sandstone.

Monitoring bore GC09 was located down-gradient of an unnamed minor creek that drains into Glennies Creek from below Possum Skin Dam. This bore was drilled to a depth of 9mbGL (metres below ground level) with the base of alluvium recorded at 8mbGL. The electrical conductivity (EC) of groundwater measured from this bore was 500 μ S/cm, with pH of 7.07. The standing water level (SWL) within GC09 was regularly measured at approximately 5.1mbTOC (below top of casing) or 65.4mRL. This SWL is considered very similar to the water level maintained within Glennies Creek.

Monitoring bore GC10 was drilled in a location that is up-gradient of the Possum Skin Dam catchment and down-gradient of the Stony Creek catchment. This bore was drilled to a depth of 12mbGL with the base of alluvium recorded at 11.2m. Groundwater EC was measured at 540 μ S/cm and pH of 7.05. The SWL for GC10 remained steady at approximately 6.9mbTOC or 68.6mRL.

The drilling of the Quaternary alluvium associated with Glennies Creek indicates that the groundwater quality is fresh with an EC between 500 μ S/cm and 540 μ S/cm. The SWL of the alluvium is at a similar elevation to the water level within Glennies Creek. The groundwater flow direction is as expected being downstream and is likely to closely mimic the surface water levels within the creek and will rise and fall in direct response to creek levels.

7.1.2 Permian Bores

The Permian Foybrook Formation contains the Hebden, Barrett and Liddell Coal Seams which are proposed to be exploited by the Glennies Creek Open Cut Coal Mine. A total of six monitoring bores were originally proposed to target the Hebden Coal Seam. However, drilling conditions required an additional four monitoring bores to be drilled and one of the original monitoring bores (GC07) to be converted into a production bore. All bores were located so as to provide information on the groundwater levels, flow direction and quality within the coal seams to be mined. Monitoring bores GC05, GC06, GC08, GC14 and GC16 were located outside of the proposed open cut pit shell with the intention of providing long term monitoring rates for the mine. Monitoring bores GC01, GC02, GC13 and GC15 were located within the proposed open cut pit shell. The open holes were geophysically logged prior to bore construction and were screened adjacent the Hebden and Barrett Coal Seams. The strata logs for these bores are provided in **Appendix 1**.

The bores were drilled with rotary air circulation using a standard hammer bit for penetration. Three of the proposed monitoring bores (GC03, GC04 and GC12) were not drilled due to logistical problems.

Typically, groundwater was intersected within the various coal seams including the Liddell, Barrett and Hebden Seams. Groundwater flow was occasionally observed within sandstone between the various coal seams. The majority of the groundwater bores were constructed so as to target the Hebden and Barrett Coal Seams.

Airlift yields were generally recorded between 0.02 – 0.69L/s from the coal seam boreholes at total depth (TD). The exception to this was GC07 which airlifted an estimated 20L/s. The majority of this groundwater was intersected within a fracture at 62m. The high yielding nature of this bore is discussed in the following sections.

7.1.2.1 Groundwater Levels

On completion of drilling and development, the groundwater monitoring bores were surveyed and water levels were measured on a daily basis during the drilling and pumping test program. The depth to SWL in the monitoring bores (**Table 8**) ranged between 21–59mbTOC that is elevation of between 47–72m AHD. The hydrographs of measured SWLs of the coal seam and alluvium monitoring bores are shown in **Figure 3** and set of groundwater contours prepared based on observed coal seam water levels shown on **Drawing No 5**.

The contours indicate that the groundwater within the Hebden/Barrett Coal Seams is flowing from north of the proposed pit area to the southwest toward the Glennies Creek Colliery portal sump. During the drilling program, the portal sump had an estimated water level of approximately 46m AHD. The contours also suggest that the groundwater movement is to the south toward the Camberwell North Pit void. The Glennies Creek underground longwall coal mine extends from the portal sump to the northwest. Whilst the groundwater contours do not indicate flow to this feature, it is expected that groundwater flow occurs to the longwall mine.

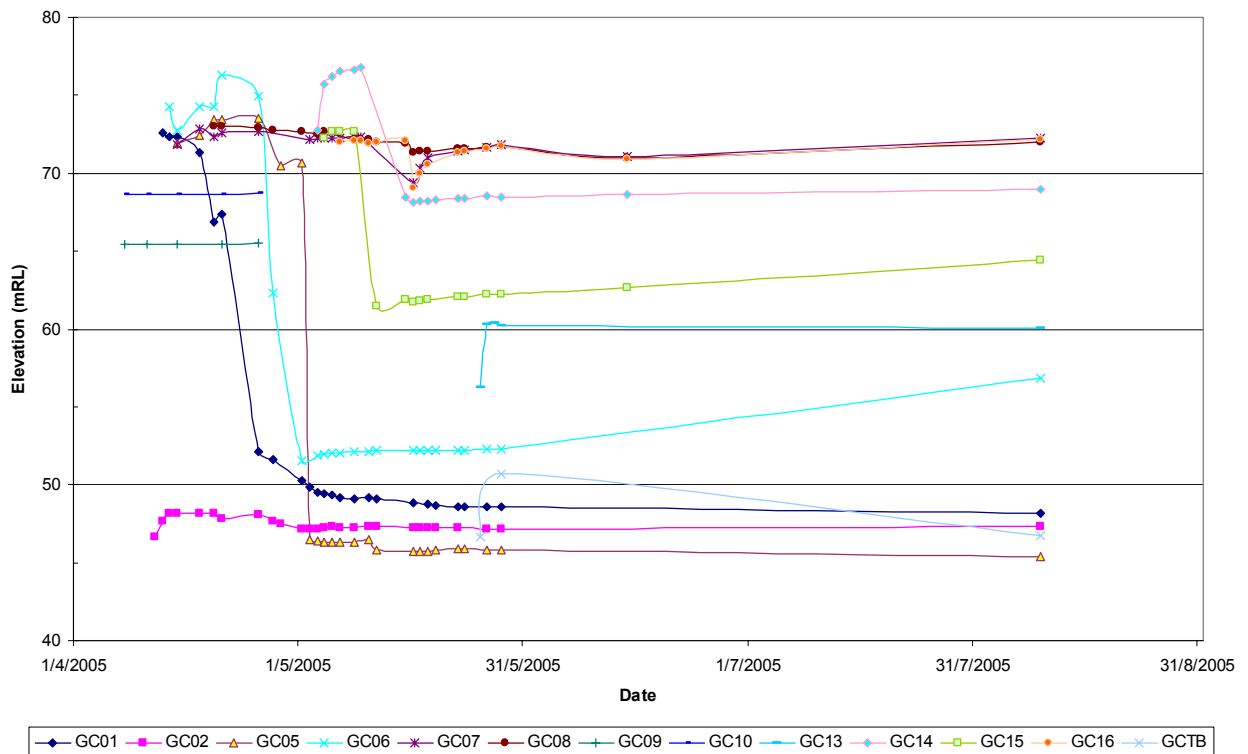


Figure 3 Monitoring Bores Hydrographs

A 1996 structure contour plan showing the base of the Barrett Coal Seam for the Camberwell Coal Mine (**Drawing No 6**) also shows the location of a normal fault/dyke system called the Camberwell Horst. The Camberwell Horst extends from the existing highwall of the Camberwell North Pit to the northeast toward GC07. This normal fault / dyke system is discussed in detail by Coxhead (1996). *“A dyke system associated with faulting has been encountered in the Camberwell North Pit and shown by a ground magnetic survey to continue into CL382. Generally two vertical dykes are present either side of a zone of intense shearing and deformation. In the northern highwall in November 1992 the western dyke showed vent or plug like characteristics, thickening to 11m and containing conglomerate boulders in a soft matrix. The total width of the zone was 20 to 25m. In the highwall in January 1996 the eastern dyke was observed (from a distance) to be much thinner and tapered out in the Lower Liddell seam. Disturbance between the dykes seemed less, although intense jointing could be seen to the east of the east dyke.”*

Further to this, notes and sketches provided by ICO indicates ‘water make’ from the normal fault/dyke system. From this description of the dyke and associated faulting and alteration, it is likely that this structure is the source of groundwater within GC07. Compartmentalization through faulting or further intrusives may be the reason the limited but highly permeable zone has not drained into the Camberwell North Pit void.

Groundwater quality within the Permian Coal Seams at Glennies Creek is highly brackish with EC measured between 7280–10280 μ S/cm with pH of 8.28–8.77. The SWL of the Hebden Coal Seam is measured between 46m AHD (GC02) and 73m AHD (GC08).

7.1.3 Hydraulic Tests

The transmissivity (m^2/day) and hydraulic conductivity (m/day) of the Hebden/Barrett Coal Seam interval was measured and analysed from a 10-hour pumping test of GCTB, a 48-hour pumping test of GC07, and from five falling head tests on GC02, GC05, GC06, GC08 and GC13 (**Tables 4, 5, and 6**). The analyses of these permeability tests are shown in **Appendices 2 and 3** and summarised in the following subsections.

7.1.3.1 Pumping Tests

A test production bore (GCTB) was selected on the basis of seam structure data, open cut geometry and proximity to the monitoring boreholes discussed above. The purpose of the test production bore was to assess:

- the permeability of the combined Hebden/Barrett coal seam interval;
- the degree of hydraulic connection between the proposed open cut area and the Camberwell North Pit void; and
- the ability of the coal to reduce the suspended solids contents of the void water.

As for each of the monitoring bores, the test production bore (GCTB) was drilled to the base of the Hebden Coal Seam. The bore was screened with machine slotted 6" uPVC casing and constructed with blank 6" uPVC casing to full depth. Upon completion of construction, the test bore was test pumped with water levels in the bore and surrounding standpipe monitoring bores measured. During the test pumping the bore ran dry under a low flow rate and the test was concluded after 9½ hours pumping, compared with the proposed 48 hours. The results of the GCTB pumping test are shown in **Table 9**.

Table 9
Summary of Analysis of Pumping Test Data – GCTB

Bore	Pumping Rate 'Q' (m^3/day)	Static Pressure Head (mbTOC)	Depth of Slotted Casing (mbGL)	Maximum Drawdown* (m)	Transmissivity 'T' (m^2/day)	Method of Analysis
GCTB	3.93	54.81	72 – 84	24.43	7.67×10^{-2}	Cooper & Jacob ^a
					9.82×10^{-2}	Theis & Jacob Recovery ^a

a – Kruseaman G.P. and de Rider N.A. (1990)

The 10-hour pumping test on GCTB was carried out at a pumping rate of 0.045L/s. At this pumping rate, the water level within the bore decreased to 79 metres below the top of the bore casing (mbTOC) at which point the water began cascading into the bore. The pump was shut down and the water level within the bore was allowed to recover. Monitoring bores GC01, GC02 and GC06 were all monitored regularly during the pumping test, however, no noticeable drawdown was recorded in the bores in response to pumping. The analysis of this pumping test provides transmissivity values of $7.67\text{--}9.82 \times 10^{-2} \text{m}^2/\text{day}$, a coal seam thickness of 8m provides hydraulic conductivity values of 9.6×10^{-3} to $1.2 \times 10^{-2} \text{m}/\text{day}$.

Analysis of the GCTB pumping test is shown in **Appendix 2** and the interpretation of the Hebden Coal Seam permeability is discussed below.

As discussed above, the proposed groundwater monitoring bore GC07 was converted into a test production bore. This was carried out due to the considerable quantity of groundwater intersected within a fractured sandstone unit associated with the Camberwell Horst during drilling and airlifting (up to 20L/s). On reaming of the 5¾" diameter borehole to 9½" diameter, the airlift was visually estimated at 50L/s. The bore was cased with 6⅝" (168.3mm) steel and test pumped at 10L/s for 48 hours. Groundwater monitoring was concentrated on bores GC08, GC14, GC15 and GC16. The purpose of this test pumping was to:

- ascertain the source of the groundwater;
- assess the permeability of the fracture zone; and
- assess the degree of hydraulic connection between the fracture zone and the Hebden Coal Seam.

The results of the GC07 pumping test are shown in **Table 10**. The analysis of the pumping test is detailed in **Appendix 2**. The interpretation of the pumping test, including discussion on the hydraulic connection between the fracture zone associated with the Camberwell Horst (**Drawing No 6**) and the Hebden Coal Seam is discussed in detail below.

Table 10
Summary of Analysis of Pumping Test Data – GC07

Bore	Pumping Rate 'Q' (m ³ /day)	Static Pressure Head (mbTOC)	Depth of Slotted Casing (mbns)	Maximum Drawdown (m)	Transmissivity 'T' (m ² /day)	Storage Coefficient	Method of Analysis
GC07	864	21.42	60 – 72 96 – 102	13.35	22.9	-	Cooper & Jacob
					569	-	Theis & Jacob Recovery
GC08	-	33.77		1.20	87	3.55 x 10 ⁻⁴	Cooper & Jacob
					845	-	Theis & Jacob Recovery
GC14	-	23.26		0.59	173	1.84 x 10 ⁻²	Cooper & Jacob
					294	-	Theis & Jacob Recovery
GC15	-	33.25		0.10	404	6.24 x 10 ⁻²	Cooper & Jacob
					357	-	Theis & Jacob Recovery
GC16	-	27.76		6.55	21.2	4.72 x 10 ⁻⁴	Cooper & Jacob
					256	-	Theis & Jacob Recovery

7.1.3.2 Falling Head Tests

Due to the results obtained from the GCTB pumping test, it was decided to conduct falling head tests on six of the groundwater monitoring bores at Glennies Creek (GC02, GC05, GC06, GC08, GC10 and GC13). The rationale behind carrying out these tests was to assess:

- the permeability of the Hebden Coal Seam adjacent to the Camberwell void;
- the distribution of permeability of the Hebden Coal Seam; and
- the permeability of the Glennies Creek alluvium.

The results of these falling head tests are summarised in **Table 11** and the analyses shown in **Appendix 3**. The results and interpretation of the tests are discussed below. The falling head test undertaken on GC10 was not able to be recorded or analysed due to the high permeability of the alluvial sediments.

Table 11
Summary of Falling Head Tests

Bore Name	Hydraulic Conductivity	
	cm/sec	m/day
GC02	7.1×10^{-7}	6.17×10^{-4}
GC05	1.5×10^{-6}	1.27×10^{-3}
GC06	2.5×10^{-6}	2.17×10^{-3}
GC08	1.1×10^{-5}	9.30×10^{-3}
GC13	1.1×10^{-6}	9.32×10^{-4}

7.1.3.3 Hydraulic Test Interpretation

From the falling head tests carried out on the groundwater monitoring bores, the interpreted hydraulic conductivity of the Hebden/Barrett Coal Seam interval is between 9.3×10^{-3} m/day and 6.17×10^{-4} m/day.

As discussed above, during the drilling of GC07, significant airlift yields were observed (20L/s). This large inflow of water was associated with a fracture at ~62m which is clearly identified on the downhole calliper log (**Appendix 1**). This fracture was intersected within very fine to coarse grained, light grey sandstone. Further water was intersected at ~100m, however, poor drill cutting returns could not establish the origin of this water. Geophysics over this interval indicated a very minor sandstone lens within a siltstone and mudstone bed. The borehole was completed to a depth of 120m.

Given the large volume of groundwater being developed from the borehole, it was considered crucial to construct a production bore at the site. The 6" (152.4mm) borehole was reamed to 102m with a 9½" (241.3mm) hammer, during which airlift yield was estimated at 50L/s. The bore was constructed with 6⅝" (168.3mm) steel casing to a depth of 102m, 5m above the main coal seam at 107m, and a pumping test was performed on the bore. A pumping rate of 10L/s was achieved over 48 hours with maximum drawdown of 13.35m. Groundwater bores GC08, GC13, GC14, GC15 and GC16 were regularly monitored during the pumping test and recovery. Drawdown was most pronounced to the east of the pumping bore (GC07) within GC16 (6.55m) and GC08 (1.20m). Bores GC14 (0.59m), GC15 (0.10m) and GC13 (0.02m).

The transmissivity of the fractured zone associated with the Camberwell Horst was analysed at 22.9m²/day from the pumping test drawdown data recorded at the test bore, GC07. Analysis of the recovery data for GC07 gives a figure of 569m²/day, however, this transmissivity value derived from recovery data is considered excessive and is likely to be a product of poor groundwater recovery within a finite storage. Given the pattern of drawdown and recovery for GC07, it would appear that the groundwater is stored within a void or fracture system. Sudden drops within the water level during pumping are typical of fractured groundwater systems, whilst poor initial recovery indicates a depletion of the groundwater in storage. The slow recovery may indicate that the water level within the fracture system is recovering with groundwater from lower permeability zones.

Water levels measured 12 days after completion of the pumping test on GC07 further suggest dewatering of a finite storage. The water level within GC07 was some 0.82m lower than the initial starting water level prior to pumping, as was GC08 (0.78m) and GC16 (0.97m). Monitoring bores GC14 and 15 both fully recovered.

The storage coefficient of the Hebden/Barrett Coal Seam interval was calculated from the pumping test data at $1.84 - 6.24 \times 10^{-2}$ for bores GC14 and GC15, and $3.55 - 4.72 \times 10^{-4}$ for bores GC08 and GC16.

A web based search was performed on the Department of Primary Industries (DPI) Geological Survey of NSW DIGS Database to gather any information on possible historical mining within the area. It was suggested that given the large volume of groundwater under airlift, that GC07 may have intersected old underground workings. The only historical underground workings referred to in the area related to the 'Rosedale/Nundah' Coal Mine which operated during the 1920's. This mine operated within the area of the Camberwell Mine yet records do not suggest that it extended as far north as GC07.

7.2 Groundwater Quality

Groundwater samples were collected from the monitoring bores installed in 2005. The summary of chemical analyses of these samples is presented on **Table 12**.

7.3 Bore Census/Existing Groundwater Users

DNR groundwater records indicate a number of registered groundwater facilities within the 15km radius from the proposed open cut area. A distance of 15km was selected as it was considered to encompass the maximum possible area of impact on the groundwater resources that may result from the Project. The data provides an indication of existing and abandoned groundwater facilities in the district, and includes varying information on location, casing details, strata logs, water level and quality. The data is by no means comprehensive for each groundwater facility. A summary showing details of DNR registered bores within 15km radius from the site is presented in **Table 13**. The location of these facilities is shown on **Drawing No 4**. The borecards for each facility are provided in **Appendix 4**.

Table 12
Bore Water Quality

Parameters	Units	GCTB 21 Jun 05	GC02 30 Jun 05	GC07 21 Jun 05	GC07 30 Jun 05
Conductivity	μS/cm	12250	10900	11200	11140
TDS	mg/L	8208	7303	7504	7464
pH	-	8.2	8.51	7.32	8.05
Temperature (field)	°C	-	-	-	-
TSS	mg/L	19	8	3	11
Turbidity	NTU	24	1.1	12	2.3
Colour	HU	-	2	-	8
TOC	mg/L	<1	<1	<1	<1
DOC	mg/L	-	-	-	-
Total Alkalinity	mg/L CaCO ₃	935	1090	1040	874
Total Hardness	mg/L CaCO ₃	253	115	1440	1490
Ca ²⁺	mg/L	37	14	122	115
Mg ²⁺	mg/L	39	19	275	291
Na ⁺	mg/L	3250	2910	2280	2300
K ⁺	mg/L	14	13	15	16
NH ₄ ⁺ (as N)	mg/L	2.27	1.59	1.59	1.56
Sr ²⁺	mg/L	7.76	3.38	21.6	18
Ba ²⁺	mg/L	0.897	0.577	0.026	0.017
Fe ²⁺	mg/L	-	<0.05	-	0.07
Fe (total)	mg/L	1.02	<0.1	1.38	0.2
Mn ²⁺	mg/L	0.24	<0.001	0.021	0.02
OH ⁻	mg/L CaCO ₃	-	-	-	-
CO ₃ ²⁻	mg/L CaCO ₃	30	156	<1	<1
HCO ₃ ⁻	mg/L CaCO ₃	905	934	1040	874
SO ₄ ²⁻	mg/L	176	7	703	775
Cl ⁻	mg/L	4380	3910	3390	3560
NO ₃ ⁻ (as N)	mg/L	.076	0.798	0.026	<0.01
F ⁻	mg/L	0.8	1	0.2	0.2
SiO ₂ (reactive)	mg/L	13.2	11.9	<0.1	16
SiO ₂ (total)	mg/L	-	-	-	-
CO ₂	mg/L	-	-	-	-
Total Coliforms	counts/ml	-	-	-	-
Colony Plate Counts	counts/ml	-	-	-	-
PO ₄ ⁻	mg/L	0.023	0.118	<0.01	<0.01
S ⁻	mg/L	58	2	234	258
Al	mg/L	0.064	0.03	<0.01	<0.01
Cu	mg/L	0.004	0.002	0.002	0.007
As	mg/L	0.004	0.004	0.005	0.003
Cd	mg/L	<0.001	0.011	<0.0001	<0.001
Cr	mg/L	0.003	<0.001	0.003	<0.001
Pb	mg/L	<0.001	<0.001	<0.001	<0.001
Hg	mg/L	<0.001	<0.0001	<0.0001	<0.0001
Ni	mg/L	0.004	0.002	0.001	0.001
Zn	mg/L	0.025	<0.005	0.018	0.007
CN	mg/L	-	<0.005	-	0.0066

Table 13
Registered Groundwater Bores Within 15km Radius the Project Site

Page 1 of 2

Bore Number	Easting	Northing	Type	Status	Purpose	Total Depth (m)	Aquifer Type	Date Drilled	Water Quality	SWL Depth (m)	Date
GW011543	324313	6407613	hand dug well (timber shoring)	unknown	unknown	5.5	alluvium	1925	good	4.6 (69.9 m AHD)	Jul-56
GW013603	323257	6405315	hand dug well	unknown	irrigation	12.8	unknown	1938	fair	7.9	
GW018328	318251	6407751	well (timber shoring)	unknown	unknown	5.8	alluvium	1959	1 001 to 3 000ppm		
GW018329	318304	6407691	well (timber shoring)	collapsed	unknown	4.9	unknown	1959	1 001 to 3 000ppm		
GW018949	328542	6413909	well	unknown	Irrigation /stock	3.7	unknown	1960	unknown		
GW019565	323348	6406056	well	unknown	Domestic /stock	7.3	unknown	1962	good	6.1 (63.9m AHD)	
GW024385	317665	6409805	well	unknown	Irrigation /stock	4.6	unknown	1926	unknown		
GW035474	317724	6412302	bore	abandoned	groundwater assessment	3.9	unknown	unknown	poor		
GW045084	322029	6406833	bore	unknown	domestic	18.9	quartz (sandstone?)	1976	unknown	-	-
GW046786	317260	6409089	well	unknown	domestic	6.9	alluvium	1972	unknown		
GW046787	317205	6409242	well	unknown	domestic	6.2	alluvium	unknown	unknown		
GW046788	317314	6408967	well	unknown	domestic	6.1	alluvium	unknown	unknown		
GW046789	317341	6408906	well	unknown	domestic	6.9	alluvium	unknown	unknown		
GW047999	330401	6398260	well	unknown	Domestic /irrigation/ stock	12.5	alluvium	1981	unknown		
GW049285	324873	6408486	well	unknown	Farming	9.1	unknown	1979	unknown	6.7 (69.3m AHD)	1979
GW052121	327387	6400519	bore	unknown	domestic/ stock	30.5	shale	1981	unknown		
GW052859	323159	6404943	well	unknown	domestic/stock	9.1	unknown	unknown	hard	3.7	

Table 13 (Cont'd)
Registered Groundwater Bores within 15km Radius of the Project Site

Page 2 of 2

Bore Number	Easting	Northing	Type	Status	Purpose	Total Depth (m)	Aquifer Type	Date Drilled	Water Quality	SWL Depth (m)	Date
GW052917	327382	6414506	bore	abandoned	domestic/stock	15.2	basalt	1981	3 001 to 7 000ppm		
GW054627	330183	6409563	bore	abandoned	stock	35	conglomerate	1981	fair		
GW056703	325310	6413361	bore	abandoned	stock	22.9	basalt/coal	1981	1 001 to 3 000ppm		
GW063740	327405	6414660	bore	unknown	domestic/stock	39.6	basalt/shale	1986	unknown		
GW064515	320397	6406065	hand dug well	unknown	domestic	5.5	unknown	1919	unknown		
GW067291	326263	6408140	well	unknown	domestic/farming/stock	27.4	unknown	unknown	unknown		
GW078054	317122	6409487	bore	unknown	industrial	16.2	sandstone	unknown	fair		
GW079793	317782	6411964	hand dug well (timber shoring)	abandoned	unknown	2.82	unknown	unknown	unknown		
GW080177	319778	6413633	bore	unknown	unknown	unknown	unknown	2002	unknown		
GW080178	319920	6413371	bore	unknown	unknown	unknown	unknown	2002	unknown		
GW080179	320595	6411994	bore	unknown	unknown	unknown	unknown	2002	unknown		

A bore census was carried out to verify the DNR records, determine the number of and location of any groundwater bores wells or springs within a 4km radius of the mine. All information obtained during the bore census (including a contact log of landholders) was recorded and is included in **Appendix 5**.

A total of 33 landholders were contacted by phone or in person during the field program. The bore census identified; one existing well extracting from the Glennies Creek alluvium that is used for domestic and dairy, three waterholes excavated into the alluvial plain of the Main Creek, north of Glennies Creek, that intersect a shallow water table and are used for stock purposes, and three disused and abandoned, backfilled wells on the Glennies Creek alluvium.

The majority of landholders within the area either pump from Glennies Creek, have a network of dams receiving rainfall runoff, or a combination of both.

Anecdotal evidence from a number of landholders indicates that with the exception of the alluvial sediments of Glennies Creek, the water within the area is typically brackish to saline. This evidence complements other data reported at the proposed open cut coal mine and indicates that the groundwater from the Permian coal seams is of poor quality and that use and extraction is limited to dewatering by the coal mining industry. The groundwater at the mines is used mainly for dust suppression and coal washing. The Glennies Creek Underground Coal Mine is reporting groundwater inflows of between 0.8ML/day and 1.1ML/day¹.

No groundwater dependent ecosystems were identified within or in close proximity of the Project Site.

8 HYDROGEOLOGICAL REGIME

8.1 Hydrogeology

The broad hydrogeology of the Upper Hunter Valley has been discussed in detail by Australian Groundwater Consultants (1984). That report focused upon the identified impacts of the coal mining industry on the existing groundwater resources and concludes:

"In general good quality and high yields of groundwater occur in the unconsolidated alluvial sediments of Recent age in the Upper Hunter Valley. These sediments consist mainly of gravel, sand and clay deposits associated with the Hunter River and Wollombi Brook.

Groundwater resources in the consolidated sedimentary rocks of Permian age which form the bulk of bedrock in the Upper Hunter Valley region are generally of higher salinity and lower yield. The coal seams are the main aquifers within the Permian strata, and show a semi-confined hydraulic behaviour with leakage from adjacent interburden rocks. Weathered zones of the Permian strata near surface also form aquifers.

¹ Ken Barry, Environmental Advisor for Integra Coal Operations Pty Ltd, e-mail dated 2 May 2006.

The permeabilities of the coal seams are in the range 0.001 and 12m/day with a log mean value of 0.11m/day. The permeabilities of the coal seams decrease exponentially with depth.

The sedimentary rocks which comprise the interburden strata have permeabilities in the range 0.426 and 0.0013m/day and a log mean of 0.0018m/day.

The permeabilities of the unconsolidated sediments are generally 10 to 100 times greater than the coal seams.

The regional composite potentiometric surface is a subdued replica of the topography. The potentiometric surface is located at a greater depth beneath the elevated areas. Groundwater flows from elevated areas to lower lying areas. Superimposed on the regional flow pattern are local flow systems which are controlled by the shape of the local rather than regional topography. In the valleys the potentiometric surface is often at ground level, and these areas constitute groundwater discharge points which are brackish or saline.

The total dissolved salt content of the groundwater is also closely related to the groundwater flow system. A higher residence time generally yields water with higher salinity. The residence time is related to the length of the flow path and the permeability of the strata. Low permeability and longer flow paths yield water which has a higher salinity.

Mine groundwater inflow rates are not commonly recorded and is only recorded where inflows are appreciable. Troublesome pit inflows generally range between 0.5 – 3.4ML/day. In other pits, inflows are generally less than 200m³/day, and evaporation generally removes the major proportion of this water before it reaches the base of the pit.”

A typical stratigraphic profile in the Glennies Creek area is shown on **Figure 4**.

8.1.1 Aquifer Systems

The principal aquifers² in the Project Site are associated with the Permian coal seams and with the Quaternary alluvium. The distribution and hydraulic properties of these aquifers are discussed below.

8.1.1.1 Alluvial Aquifers

The geological map of the Hunter Region indicates that the Quaternary deposits in the area are associated mainly with the bed of Hunter River and its main tributaries, of which the closest to the Project Site are Glennies Creek, Main and Betties Creeks and Foy Brook. Distribution of the Quaternary alluvium is shown on **Drawing No 8**.

² An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in useable quantities.

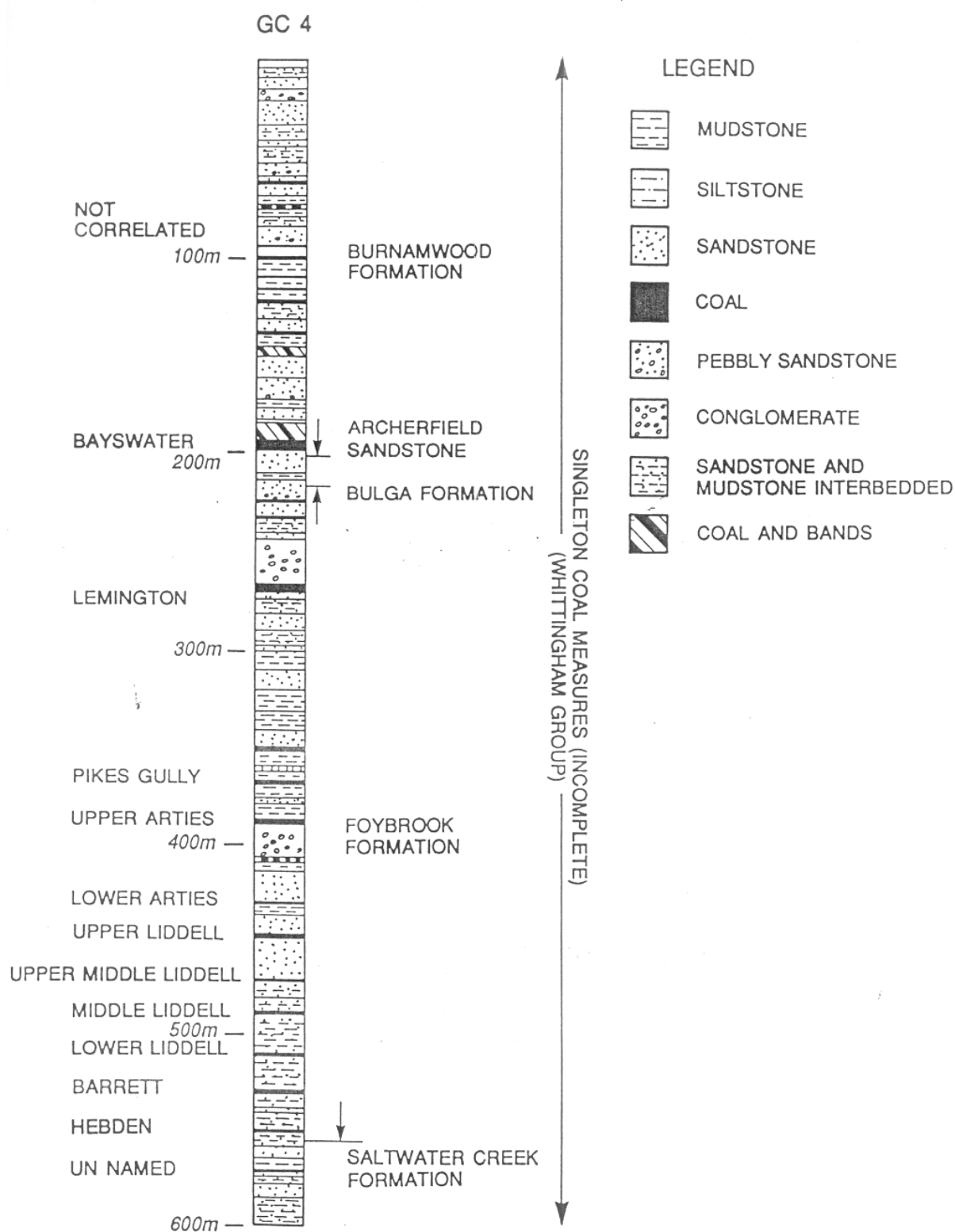


Figure 4 Typical Stratigraphic Column (after Dames and Moore 1990)

The alluvial aquifers are unconfined and comprise fine to coarse grained sand and gravel overlain by very fine to medium grained loamy sand, silty sand and clay. Only the basal part of the sandy and gravelly deposits is saturated in vicinity of the Glennies Creek. The saturated zone in two monitoring bores (GC09 and GC10) was between 3m and 4m thick. The base of the sand and gravel unit is marked by very fine grained, light grey sandstone of Permian age. The thickness of the surficial fine grained deposits overlying the alluvial aquifer was about 2m.

Two monitoring bores installed by GeoTerra (2005) in Betties Creek alluvium show a predominantly clayey profile.

A summary of the above alluvial monitoring bores is presented in **Table 14**.

As discussed earlier the standing water level (SWL) within GC09 was regularly measured in April 2005 at approximately 5.1mbTOC or 65.4m AHD. This SWL is considered very similar to the water level maintained within Glennies Creek. The SWL in GC10 remained during the same period steady at approximately 6.9mbTOC or 68.6m AHD. The groundwater flow direction is downstream and is likely to closely mimic the surface water levels within the creek and will rise and fall in direct response to creek levels.

The quality of groundwater in the Quaternary Alluvium associated with Glennies Creek is classified as fresh. However, considering that the flow in the creek is maintained by releases of water from Lake St Clair upstream from the proposed open cut, as discussed in Section 6.2, and the apparently good hydraulic connection between the creek and the alluvial aquifer, the quality of the water in the Glennies Creek alluvium is more likely to reflect the quality of water in Lake St Clair than the quality of groundwater in pristine conditions.

8.1.1.1.1 Hydraulic Parameters

With exception of the falling head test in GC10, no other hydraulic testing was conducted within the alluvial aquifer in the Glennies Creek area. As discussed in Section 7, the test results could not be interpreted due to the high hydraulic conductivity of the Glennies Creek alluvial deposits.

Additional testing of alluvial deposits was conducted in the alluvium of Bowmans Creek in the Ashton and Glendell areas. Hydraulic conductivity of these deposits as reported by HLA Envirosciences Pty Ltd in 2001 and varied between 0.38m/day and 0.94m/day. A comparison of lithological description of the alluvial deposits along Glennies Creek (sand and gravel) and Bowmans Creek indicate that Glennies Creek alluvial aquifers have a higher hydraulic conductivity than those associated with Bowmans Creek.

Table 14
Summary of Alluvial Groundwater Monitoring Bores

Bore Name	Coordinates (GDA94)		Surveyed Ground Elevation (m AHD)	Total Borehole Depth (mbGL)	Strata Depth (mbGL)	Lithological Description	Water Level (mbGL)	Water Quality EC (µS/cm) pH	Strata
	Easting	Northing							
GC09	323259	6407315	69.89	9.0	0.0 to 2.0	Sand, very fine grained and loamy	4.46 (65.42m AHD)	EC 500 pH=7.07	Glennies Creek alluvium
					2.0 to 8.0	Sand and gravel, fine to coarse			Permian deposits
					8.0 to 9.0	Sandstone, very fine grained			
GC10	324414	6408030	74.89	12.0	0.0 to 1.0	Clay	6.26 (68.64m AHD)	EC=540 pH=7.05	Glennies Creek alluvium
					1.0 to 2.0	Silty Sand			
					2.0 to 4.0	Sand medium to fine grained			
					4.0 to 11.2	Sand and gravel, fine to coarse with some boulders at the base			
					11.2 to 12.0	Sandstone, very fine grained			Permian deposits
GCP1	322080 ^a	6406090 ^a	97 ^c	NA	NA	"Alluvium"	4.0 → 8.91 ^b (93m AHD → 88m AHD)	EC=3110 to 3720	Glennies Creek
GCP2	323447	6409344	83 ^c	2.7	0.0 to 2.7	Sand, coarse and gravelly	2.45 (80.5m AHD)	EC=340 pH=6.8	Main Creek alluvium
GCP3 (alluvium)	320945	6408387	80 ^c	5.5	0.0 to 1.8	Clay	2.95 (74.5m AHD)	EC=14800 pH=7.28	Betties Creek alluvium
					1.8 to 2.5	Silty Clay			
					2.5 to 5.0	Clay, sandy and gravelly			
					5.0 to 5.5	Sandstone, fine grained			Permian deposits
GCP4 (alluvium)	320838	6409804	89 ^c	6.0	0.0 to 2.5	Clay	3.36 (85.5m AHD)	EC=8610 pH=6.68	Betties Creek alluvium
					2.5 to 5.4	Clay, gravelly			
					5.4 to 6.0	Sandstone, fine grained			Permian deposits

a – coordinates estimated contours

b – water level declining from about 4m depth in January 02 to 8.91m depth in April 05
NA – not available

c – elevation estimated from the topographic

8.1.1.2 Permian Aquifers

8.1.1.2.1 Distribution

The coal seams are confined aquifers which generally exhibit relatively low hydraulic conductivities and recharge rates. Groundwater storage and movement occurs within the coal seam cleats and fissures, and within fractures associated with faults intersecting the seams. Other sediments in the coal overburden and interburden sequence are usually relatively impermeable and form aquitards. Some Permian sandstones yield minor groundwater although in the section of the coal measures to be mined, these are rare.

The Permian strata may therefore be categorised into the following hydrogeological units.

- Hydrogeologically “tight” and hence very low yielding to essentially dry sandstone and siltstone that comprise the majority of the Permian interburden and overburden.
- Low to moderately permeable coal seams which are the prime water-bearing strata within the Permian sequence.

Typically, during drilling, groundwater was intersected within the various coal seams including the Liddell, Barrett and Hebden Seams, however, groundwater flow was also occasionally observed within sandstone between the various coal seams. Airlift yields within the Glennies Creek area were generally recorded between 0.02 – 0.69L/s (from the coal seam) from boreholes at their total depth. As discussed in Section 7, a notable exception was bore GC07 which airlifted an estimated 20L/s. The majority of this groundwater was intersected within a fracture at 62m. The fracture appears to be associated with the Camberwell Horst. A summary of all Permian monitoring bores is shown in **Table 15**.

Table 15
Summary of Permian Groundwater Monitoring Bores

Bore Name	Coordinates (GDA94)		Surveyed Ground Elevation (m AHD)	Total Hole Depth (mbGL)	Water Level		EC (µS/cm)	pH	Temp (°C)
	Easting	Northing			Below Top of Casing	m AHD			
GC01	325124	6406664	96.013	108	47.87	48.59	10 280	8.46	21.3
GC02	325160	6406490	105.495	105	59.01	47.23	7 610	8.77	19.8
GC05	324337	6406203	80.334	108	35.16	45.84	7 280	8.47	20.4
GC06	324941	6406784	102.931	126	50.99	52.33	9 270	8.33	21.1
GC07	325864	6407071	93.034	120	21.51	71.84	8 250	7.01	22.3
GC08	326332	6407214	105.095	120	33.82	71.86	7 610	8.29	20.1
GC13	326169	6406745	105.356	66	45.38	60.17		-	-
GC14	325774	6407042	90.99	123	23.33	68.50	9 560	8.28	21.1
GC15	325912	6406961	95.035	114	33.31	62.33	8 170	8.46	19.8
GC16	326029	6407077	98.853	120	27.85	71.89	7 760	8.41	20.1
GCTB	325149	6406572	102.564	90	54.81	48.55	9 930	8.03	17.2
GCP3	230924	6408389	NA	49.2	3.45	NA	12 840	7.54	NA
GCP4	320838	6409600	NA	36.0	13.55	NA	20 900	7.24	NA

8.1.1.2.2 Hydraulic Parameters

Results of hydraulic testing of the Permian strata were discussed in Section 7.1.3. In summary, the pumping test results from the test bore GCTB yielded a transmissivity of the Hebden Coal Seam of between $7.67 \times 10^{-2} \text{ m}^2/\text{day}$ and $9.82 \times 10^{-2} \text{ m}^2/\text{day}$ which for an 8m thick coal seam converts to the hydraulic conductivity of between $9.6 \times 10^{-3} \text{ m/day}$ and $1.3 \times 10^{-2} \text{ m/day}$. Falling head tests yielded a hydraulic conductivity of the Hebden/Barrett Coal Seams of between $9.3 \times 10^{-3} \text{ m/day}$ and $6.17 \times 10^{-4} \text{ m/day}$.

Hydraulic testing of the GC07 bore yielded a transmissivity of the Permian strata of $22.9 \text{ m}^2/\text{day}$ based on the data from the pumping stage of the test. It was concluded that the groundwater in this bore is stored within a void or fracture system probably associated with the Camberwell Horst. The Camberwell Horst extends from the existing highwall of the Camberwell North Pit to the northeast toward GC07. Compartmentalization through faulting or further intrusives may be the reason the limited but highly permeable zone has not drained into the Camberwell North Pit void.

The storage coefficient of the Hebden/Barrett Coal Seams was estimated from the pumping test data at $1.84\text{--}6.24 \times 10^{-2}$ for bores GC14 and GC15, and $3.55\text{--}4.72 \times 10^{-4}$ for bores GC08 and GC16.

Over 150 packer test have been conducted in nearby mines in order to assess the hydraulic conductivity of the various coal seams being mined. The data was collated and reported by HLA Envirosciences Pty Ltd (2001). A plot of the hydraulic conductivity assessments versus depth from the above tests is shown on **Figure 5**. As shown on the plot the hydraulic conductivity results obtained during 2005 hydraulic testing in the Glennies Creek area fit well with the packer test data, although on average appear to exhibit somewhat lower (up to an order of magnitude) hydraulic conductivity.

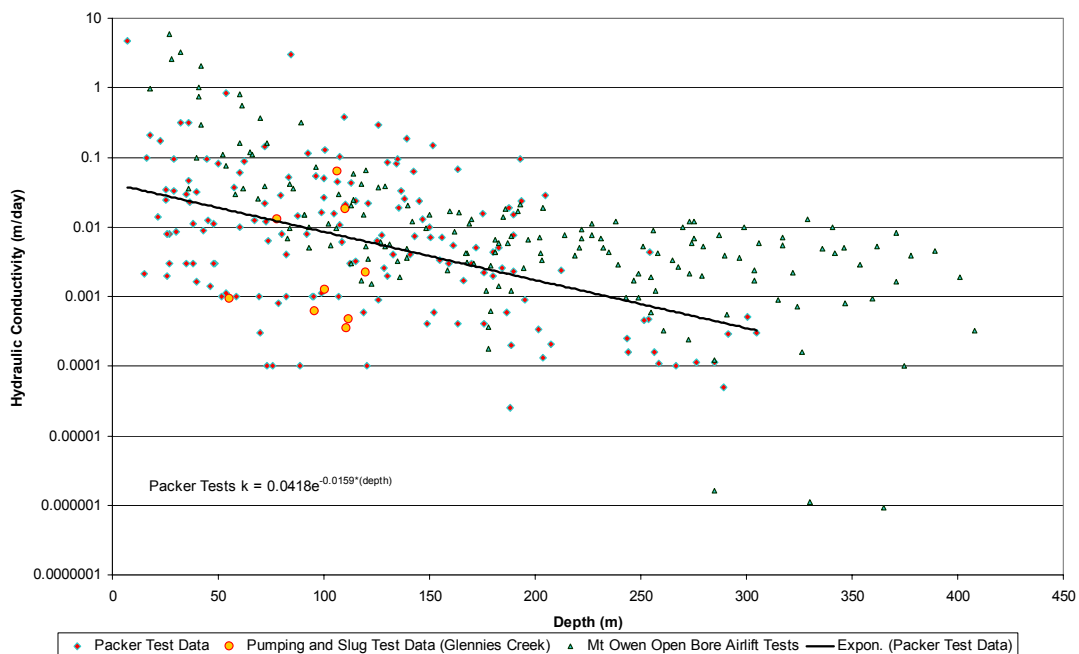


Figure 5 Coal Seams Hydraulic Conductivity vs Depth, Glennies Creek Area

It is apparent that there is an exponential decline in hydraulic conductivity with depth of the coal seams. The equation for the decline in the hydraulic conductivity with depth is in a form of:

$$k=0.0418* \exp^{(-0.0159 \times z)}$$

Where: 0.0418 = base hydraulic conductivity near surface (m/day), and
 z = depth of the coal seam (m)

The above equation is similar to the one developed by Australian Groundwater Consultants Pty Ltd (AGC) (1984) who also observed a reduction in hydraulic conductivity of the coal seams with depth in the Hunter Valley region. However, the coal seams in the Glennies Creek area appear to be about an order of magnitude less permeable than the average of the all Hunter Valley coal seams reported by AGC.

Figure 5 shows a decline in average coal hydraulic conductivity of about two orders of magnitude with depth; from about (0.03m/day) at 25m depth to about 3.0×10^{-4} m/day at a depth of 300m.

In 2003, Mackie Environmental Research (Mackie), conducted a detailed investigation of the hydraulic permeability of the Permian strata in the Mt Owen area. Mackie reported (Mackie 2003) estimates of hydraulic conductivity of the Permian strata from about 160 airlift tests in open bores in the Mt Owen area. The results of these tests shown as a plot of estimated hydraulic conductivity versus depth are presented on **Figure 5**. The above estimates, while fitting well within the envelope of the estimates obtained from the packer, pump and slug tests conducted primarily within the coal seams, also show that the hydraulic conductivity from the airlift tests below the depth of about 250m remains approximately constant in the range of between about 0.01m/day and 0.0001m/day. It should be noted that when there is a large contrast in hydraulic conductivity between the coal seams and interburden and overburden rocks the estimates of the hydraulic conductivity obtained from the airlift tests in open bores are indicative of the coal seam conductivity and not the surrounding rocks. Furthermore, if there is a decline in hydraulic conductivity with depth, the estimates may be also biased towards the shallower, more permeable coal seams. It is therefore likely that the hydraulic conductivity of the deep, below about 350m depth, coal seams will be somewhat smaller than the hydraulic conductivity estimated from the airlift tests in deep open bores.

Laboratory determinations of the hydraulic conductivity conducted by Mackie on mainly sandstone samples collected from different depths indicate horizontal hydraulic conductivity of between about 3.85×10^{-6} and 1.35×10^{-5} m/day to the depth of about 170m declining to between 2.70×10^{-7} and 5.97×10^{-7} m/day between about 200m and 350m depth (Mackie 2003) as shown on **Figure 6**. For comparison, **Figure 6** also shows estimates of hydraulic conductivity obtained from the airlift tests. It should be noted that laboratory determinations of hydraulic conductivity provide the lowest values and are most representative of strata where fracturing and jointing is limited or where fractures and joints are relatively disconnected. Based on the above data and after analysis of fracturing and jointing of the Permian strata in the Mt Owen area, Mackie concluded that the bulk hydraulic conductivity of the Permian strata (coal and inter- and over-burden) below elevation of -250m AHD was about 1×10^{-4} m/day in the horizontal direction and 1×10^{-5} m/day in the vertical direction.

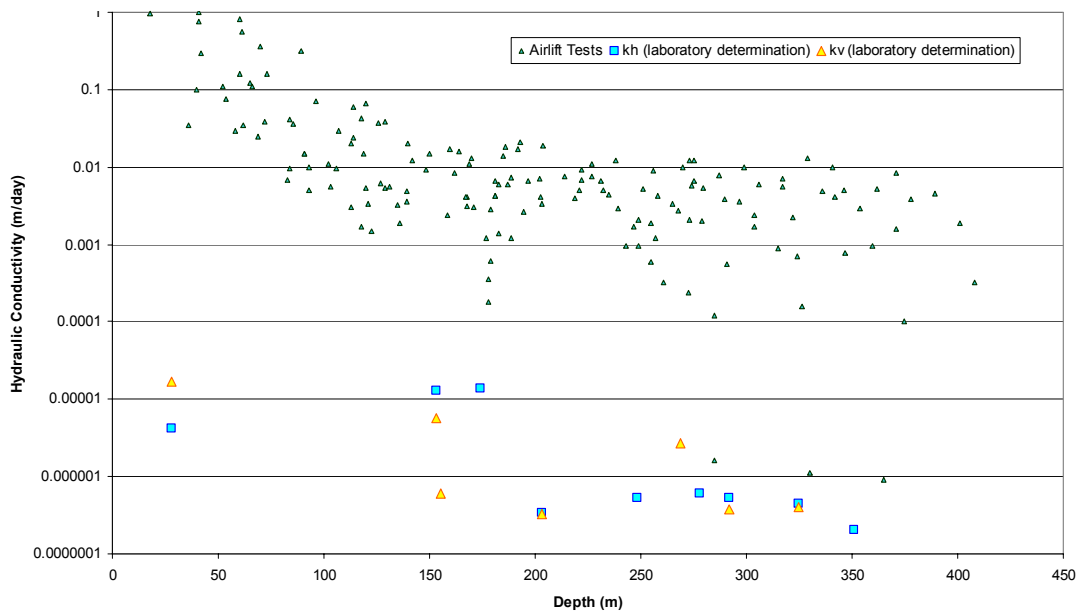


Figure 6 Comparison of Hydraulic Conductivity Determinations with Depth (After Mackie 2003)

8.1.1.2.3 Piezometric Elevations and Discharge

Water level information in the Glennies Creek area is limited to data collected in monitoring bores installed by AGE in 2005 (11 monitoring bores), five water level depths recorded on the DNR database and four monitoring bores installed by GeoTerra in the vicinity of the adjacent Glennies Creek Underground Coal Mine.

A summary of these water level data is presented in **Table 16**.

After completion of the drilling of monitoring bores GC01 to GC16 and the GCTB test bore, regular monitoring of the water levels in these bores was undertaken. A plot of recorded water levels is shown on **Figure 3**.

The plot shows a distinct decline in water levels in monitoring bores GC01, GC05, GC06, GC14 and GC15. It should be noted that the water levels prior to the decline were measured in open boreholes while the water levels at later stage were measured in completed monitoring bores by which time the overlying shallow strata were sealed off from the target aquifer (Barrett/Hebden Seam). The plot indicates that the measured water levels, particularly in the most westerly monitoring bores are affected by dewatering of the Camberwell North Pit and probably by the Glennies Creek Underground Coal Mine. The observed slow rate of recovery in monitoring bores GC06, GC14 and GC15 is indicative of very low hydraulic conductivity of the aquifer. It should be noted that a number of monitoring bores were installed in the vicinity of Possum Skin Dam. The water level in the dam is maintained at about 88.5m AHD, however, monitored water levels even in the closest to the dam monitoring bore, GC14, about 130m to the east from the dam, was no higher than 76.8m AHD when the bore was not cased and open along its whole length. The above would indicate that the base of the dam is well sealed from the underlying formation and there is very little, if any, hydraulic connection between the dam and the underlying aquifers.

Table 16
Summary of Water Level Data

Page 1 of 2

Monitoring Bore	Easting (m)	Northing (m)	Ground Level Elevation (m AHD)	Water Level Depth (m)	Water Level Elevation (m AHD)	Date of Measurement	Strata	Comment
GC01	325124	6406664	96.013	48.23	48.23	10 August 2005	Permian	Collected after completion of bore construction, affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GC02	325160	6406490	105.495	58.82	47.42	10 August 2005	Permian	Affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GC05	324337	6406203	80.334	35.52	45.48	10 August 2005	Permian	Affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GC06	324941	6406784	102.931	46.39	56.93	10 August 2005	Permian	Not fully recovered. Affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GC07	325864	6407071	93.034	21.08	72.27	10 August 2005	Permian	
GC08	326332	6407214	105.095	33.51	72.17	10 August 2005	Permian	Not fully recovered
GC09	323259	6407314	70.593	5.17	65.42	30 May 2005	Glennies Creek alluvium	
GC10	324413	6408029	75.595	6.96	68.64	30 May 2005	Glennies Creek alluvium	
GC13	326169	6406745	105.356	45.55	60.00	10 August 2005	Permian	Affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GC14	325774	6407042	90.99	22.90	68.93	10 August 2005	Permian	Affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GC15	325912	6406961	95.035	31.09	64.55	10 August 2005	Permian	Not fully recovered. Affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GC16	326029	6407077	98.853	27.44	72.30	10 August 2005	Permian	Not fully recovered
GCTB	325149	6406572	102.564	56.10	46.71	10 August 2005	Permian	Affected by dewatering of Camberwell Pits and Glennies Creek Underground.

Table 16 (Cont'd)
Summary of Water Level Data

Page 2 of 2

Monitoring Bore	Easting (m)	Northing (m)	Ground Level Elevation (m AHD)	Water Level Depth (m)	Water Level Elevation (m AHD)	Date of Measurement	Strata	Comment
GCP1	322080 ^a	6406090 ^a	97 ^c	4.0 → 8.91 ^b	93 → 88	Jan 2002 to April 2005	Glennies Creek alluvium	Affected by dewatering of Camberwell Pits and Glennies Creek Underground.
GCP2	323447	6409344	83 ^c	2.45	80.5	7 April 2005	Main Creek alluvium	
GCP3	320945	6408387	80 ^c	2.95	77.0	7 April 2005	Betties Creek alluvium	
				3.45	76.5	7 April 2005	Permian	
GCP4	320838	6409804	89 ^c	3.36	85.5	7 April 2005	Betties Creek alluvium	
				13.55	75.5	7 April 2005	Permian	Affected by dewatering of Glennies Underground.
GW011543	324313	6407613	74.5 ^c	4.60	69.9	July 1956	Probably Glennies Creek alluvium	
GW013603	323257	6405315	70 ^c	7.90	62.1	NA	Probably Glennies Creek alluvium	
GW019565	323348	6406056	70 ^c	6.10	63.9	NA	Glennies Creek alluvium	
GW049285	324873	6408486	76 ^c	6.70	69.3	1979	Glennies Creek alluvium	
GW052859	323159	6404943	NA	3.70	NA	NA	Probably Glennies Creek alluvium	

a – coordinates estimated

b – water level declining from about 4m depth in January 02 to 8.91m depth in April 05

c – elevation estimated from the topographic contours

NA – not available

The water level data available within the Project Site does not indicate any obvious compartmentalization of the coal seam, but this may in part be due to the level of accuracy of the measurements and distribution of monitoring bores.

In pristine conditions, the groundwater discharge in the Glennies Creek area was most likely towards Glennies Creek. However, dewatering by Camberwell and Glennies Creek Underground has locally modified the direction of the groundwater flow towards the mines. A plot of interpreted groundwater contours based on water level measurements collected on 10 August 2005 is shown on **Drawing No 5**.

The low salinity of groundwater in the Glennies Creek alluvium (see **Table 17**) does not appear to support the assumption of Glennies Creek being a discharge zone from the Permian aquifers, however, it should be noted that regular releases of water from Lake St Clair, up-gradient from the Project Site, have most likely improved the quality of groundwater in the

Glennies Creek alluvium. In contrast, the groundwater quality in the Betties Creek alluvium, which is not affected by releases from the dam, indicates discharge of saline water from the Permian aquifers into the alluvial aquifer. This is confirmed by results of surface water sampling conducted by GeoTerra (2005) in small, isolated pools along the bed of Betties Creek, which showed extremely variable water EC between 117µS/cm and 1270µS/cm.

Mining in the area and associated dewatering has changed the groundwater flow pattern and created new discharge zones. The main groundwater dewatering in vicinity of the proposed Glennies Creek Open Cut Coal Mine is associated with the Camberwell North Pit and Camberwell Open Cut and dewatering of the Glennies Creek Underground Coal Mine. Inflows to Glennies Creek Underground Coal Mine during development of the mine were around 2 000m³/day (PSM 2006), and declined to between about 800m³/day and 1 100m³/day in 2005 to 2006 (Ken Barry, ICO, personal communication).

8.1.2 Groundwater Quality

A summary of the water quality indices in the alluvial and Permian aquifers is shown in **Table 17**.

Table 17
Summary of Water Quality Data

Bore Name	Coordinates (GDA94)		Total Hole Depth (mbGL)	EC (µS/cm)	pH	Temp (°C)	Aquifer
	Easting	Northing					
GC01	325124	6406664	108	10 280	8.46	21.3	Permian Coal Seam
GC02	325160	6406490	105	7 610	8.77	19.8	Permian Coal Seam
GC05	324337	6406203	108	7 280	8.47	20.4	Permian Coal Seam
GC06	324941	6406784	126	9 270	8.33	21.1	Permian Coal Seam
GC07	325864	6407071	120	8 250	7.01	22.3	Permian Interburden and Coal Seam
GC08	326332	6407214	120	7 610	8.29	20.1	Permian Coal Seam
GC09	323259	6407315	9	500	7.07	21.5	Quaternary alluvium
GC10	324414	6408030	11.5	540	7.05	19.7	Quaternary alluvium
GC13	326169	6406745	66	-	-	-	Permian Coal Seam
GC14	325774	6407042	123	9 560	8.28	21.1	Permian Coal Seam
GC15	325912	6406961	114	8 170	8.46	19.8	Permian Coal Seam
GC16	326029	6407077	120	7 760	8.41	20.1	Permian Coal Seam
GCTB	325149	6406572	90	9 930	8.03	17.2	Permian Coal Seam
GCP1	322080 ^a	6406090 ^a	NA	3 110 to 3 720	NA	NA	Glennies Creek alluvium
GCP2	323447	6409344	2.7	340 to 578	6.3 to 6.8	NA	Main Creek alluvium
GCP3 (alluvium)	320945	6408387	5.5	14 800	7.28	NA	Betties Creek alluvium
GCP3 (Permian)	230924	6408389	49.2	12 840	7.54	NA	Permian Sandstone
GCP4 (alluvium)	320838	6409804	6.0	8 610	6.68	NA	Betties Creek alluvium
GCP4 (Permian)	320838	6409600	36.0	20 900	7.24	NA	Permian Sandstone
NA – not available a – coordinates estimated							

In summary, the groundwater quality within the Permian Age strata is brackish with EC measured between 7 280µS/cm and 20 900µS/cm. The pH of the groundwater ranges between 7.0 and 8.8. The quality of the groundwater is considered typical for coal seams.

The quality of water in the alluvial aquifers is highly variable with EC measured between 340µS/cm and 14 800µS/cm. The pH of the groundwater ranges between 6.3 and 7.3. The quality of water in Glennies Creek alluvium appears to be influenced by releases of fresh water from Lake St Clair up-gradient from the Project Site and is unlikely to be representative of the quality of water in pristine conditions.

Surface water sampling conducted by GeoTerra (2005) in small isolated pools along Betties Creek bed showed extremely variable water EC between 117µS/cm and 12 270µS/cm.

9 NUMERICAL GROUNDWATER MODEL

9.1 General

The United States Geological Survey three-dimensional, finite-difference, modular, groundwater flow model MODFLOW (McDonald and Harbaugh, 1984), with the PMWIN (Chaing and Kinzelbach, 1996), pre- and post-processing package, was used to simulate the impact of open cut and longwall mining operations on the groundwater regime. The MODFLOW code is the most widely used code for groundwater modelling and is presently considered an industry standard.

The numerical groundwater model was developed in order to assess groundwater inflows to the proposed open cut mine and to the underground workings, to simulate the extent of the cone of depression induced by mine dewatering and the recovery of groundwater levels after mine closure.

9.2 Modelling Objectives

The objectives of the predictive modelling were as follows.

- Assess potential cumulative impact of the Project and other existing and approved mines (including the Camberwell, Rixs Creek, Ashton, Glendell, Ravensworth East and Mt Owen coal mines) on groundwater.
- Delineate the boundary of the depressurisation trough associated with advance dewatering and mining.
- Assess the expected inflow of groundwater to the open cut mine.
- Assess the impacts of any final landform on the groundwater regime.
- Assess the highest groundwater table at the Project Site.

9.3 Conceptual Model

Every numerical groundwater model has as its foundation a conceptual model. The conceptual model is the basic idea of how the groundwater system operates and is an idealised and simplified representation of the natural system. It includes all essential features of the system, that is, the hydrogeological regime as described in Section 8, to an appropriate level of detail. Extensive information on the natural system is typically required to develop an equivalent and simplified conceptual groundwater model representative of the system. Development of the conceptual groundwater model is a crucial step in groundwater modelling and often highlights gaps in data or deficiencies in understanding of the groundwater system.

“A conceptual model contains numerous qualitative and subjective interpretations. The appropriateness of the conceptual model can not be tested until a numerical model is built and comparisons between field observations and model simulation results are made” (Zheng and Bennett 1995).

The conceptual groundwater model of the Project Site was developed based on geological and topographical data of the area, geological information from coal exploration bores, results from hydrogeological investigations conducted within the area, as well as from other nearby mines, and relevant data from the DNR groundwater database.

The conceptual model of the region encompasses the area between the subcrops of the base of the Saltwater Creek Formation to the south, east, southwest and west of the proposed open cut, the crest of the Sedgefield Anticline to the east, the Hunter Thrust Fault to the north and northwest and the crest of the Camberwell Anticline to the west. The extent of the conceptual model is shown on **Drawing No 9**.

The area of the conceptual model is assumed to be surrounded by “no flow” boundaries and therefore there is no groundwater exchange between the conceptual model domain area and areas outside. The base of the conceptual model coincides with the base of the Saltwater Creek Formation which is assumed to be 150m below the base of the Hebden Seam.

The base of the model domain is underlain by a thick sequence of siltstones and claystones of Mulbring Siltstone. The lithology of this formation indicates a very low hydraulic conductivity which is expected to be at least two orders of magnitude lower than the hydraulic conductivity of the coal seams. According to Anderson and Woessner (1992), two orders of magnitude contrast in hydraulic conductivity values is sufficient to justify placement of an impermeable boundary in the groundwater flow model. Therefore, the assumption of a “no flow” boundary both at the base and along the Mulbring Siltstone outcrops is considered to be justifiable.

The geological formations to the north of the Hunter Thrust Fault consist predominantly of tuff and ignimbrite both of which are hydraulically tight and of very low hydraulic conductivity. The crest of the Camberwell Anticline is assumed to be a “no flow” boundary because of its distance from the proposed Glennies Creek open cut mine, separation from the open cut by a zone of decreasing hydraulic conductivity associated with deepening of the coal seams along the axis of the Rixs Creek Syncline and assumption that the cone of depression developing around the Glennies Creek open cut will not reach this boundary during the life time of the open pit. The “no flow” boundary assumption for this section of the conceptual model domain results also in the model being conservative.

Two thrust faults within the model domain area, the Hebden and Camberwell Thrust Faults, to the north and west of the Project Site respectively are assumed to have no significant impact on the geometry and boundary conditions of the conceptual domain. Geological maps supplied by ICO (**Drawing No 10**) show a zone of significant steepening of the coal seams in the vicinity of the Camberwell Thrust Fault but not a zone of discontinuity. Therefore the Camberwell Thrust fault is not included as a distinct hydraulic element in the conceptual groundwater model of the area. However, should there be a dislocation of the coal seams by the Camberwell Thrust Fault then the area of the conceptual hydrogeological model should be probably limited to this fault. However, considering the small distance of about 1km between the fault and the western limits of the model, this is not considered to have a major impact on the limits of the conceptual model.

A similar situation exists along the part of the Hebden Thrust Fault. The geological maps supplied by ICO show continuity of the coal seams along the eastern end of the Hebden Thrust Fault, that is to the north of the Project Site. However, further to the west, approximately between the Glennies Creek Underground and the Mt Owen Coal Mine there is a significant difference in elevations between the coal seams on both sides of the fault. Neither ICO geological maps or Mt Owen data (Mackie 2003) show any discontinuity across the Hebden Thrust Fault, even though the difference in coal seam elevations across the fault appear to be up to 250m, therefore the fault was not included in the conceptual groundwater model of the area. However, should in fact the fault dislocate the seams then it would be possible that the section of the model to the north of the Hebden Thrust Fault would be within a different hydraulic system and separated from the Project Site.

As discussed in Section 8, the coal seams are the main aquifers in the area with the interburden and overburden being significantly less permeable than the coal seams. The cross section shown on **Figure 1** indicates that the coal seams and their splits are clustered into two distinct groups as follows.

- Middle and Lower Liddell Seams.
- Barrett and Hebden Seams.

In order to simplify the geometry of the groundwater domain, the seams in each of these two groupings were combined and are represented by two different aquifers in the conceptual model. Therefore the conceptual model includes three aquifers separated by two aquitards and underlain by another aquitard as follows.

- Unconfined alluvial aquifer associated with alluvial deposits of the Glennies, Mains and Betties Creeks.
- Aquitard associated with overburden rocks overlying the Liddell Seam.
- Confined Permian aquifer associated with the Liddell Seam.
- Aquitard associated with interburden rocks between the Liddell and Barrett Seams.
- Confined Permian aquifer associated with the Barrett and Hebden Seams.
- Aquitard associated with sandstones and siltstones of the Saltwater Creek Formation underlying the Hebden Seam.

The conceptual model of the groundwater regime is shown on **Figure 7**.

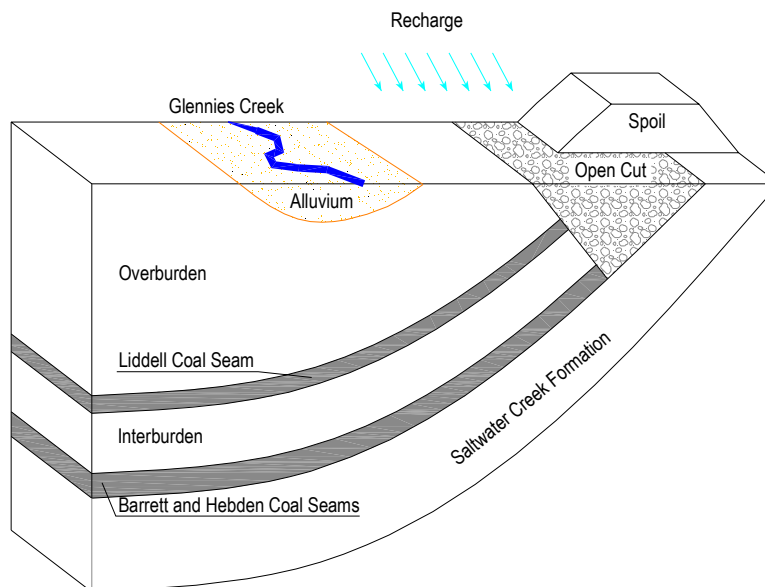


Figure 7 Conceptual Model of Groundwater Regime

The Saltwater Creek Formation is likely to have hydraulic conductivity decreasing with depth. At the shallow depths where weathering and erosion reduce the compressive forces, the hydraulic conductivity of this formation is likely to be higher than at greater depths.

Considering the tight nature of the over- and inter-burden rocks, recharge to the coal seams is expected to occur mainly along the sub-crop of the coal seams, primarily as a result of rainfall, but possibly also during periods of surface water flow in Glennies Creek in the areas where the creek bed intersects the coal seam subcrop or is nearby.

In pristine conditions, discharge from the Permian aquifers occurs only to the creeks in the area, as indicated by an elevated and variable salinity of the groundwater in the alluvium and in the small isolated pools along the Betties Creek bed. However, once large scale mining commenced in the early 1990's, dewatering of the mine workings created new groundwater discharge areas. The artificial dams in the area including the large Possum Skin Dam do not appear to be hydraulically connected to the Permian aquifers in the area as discussed in Section 8.1.1.2.

As discussed in Sections 7.1 and 8.1, groundwater only occurs in the very basal section of the alluvium and recharge to the alluvial aquifer appears to be minimal. With exception of the Glennies Creek alluvial aquifer, a significant proportion of recharge to the alluvial aquifers in many places may occur from upward seepage along faults and fractures from the deeper Permian aquifers. However, in some areas recharge may also occur from rainfall or occasional flooding. Surface water sampling conducted by GeoTerra (2005) along the bed of Betties Creek is indicative of such variable recharge processes.

In the case of the Glennies Creek alluvium, recharge appears to be primarily from releases of surface water from Lake St Clair.

Discharge from the alluvial aquifer occurs to the different creeks down-gradient from the Project Site. Some discharge from the aquifer may also occur through evapotranspiration along the creeks where deep rooted remnants of the native vegetation remain.

The hydraulic conductivity of the various aquifers varies significantly. The hydraulic conductivity of the basal section of the alluvial aquifer in the Glennies Creek alluvium is considered to be relatively high as indicated by hydraulic testing and the lithological description of this aquifer. Hydraulic conductivity of other alluvial aquifers was estimated to vary between about 0.38m/day and 0.94m/day as discussed in Section 8.1.1.1.1.

The hydraulic conductivity of the Permian aquifers (coal seams) is much lower and is considered to decline with increasing depth of the seams. The hydraulic conductivity of the coal seams is considered to be of the order of about 0.1m/day near the surface, declining to less than about 0.001m/day at a depth of 300m. The decline in the hydraulic conductivity of the seam was assumed to follow the exponential decline described in Section 8.2.1.2.2.

The hydraulic conductivity of the inter- and over-burden appears to be significantly smaller than that of the coal seam. However, at shallow depths where erosion and weathering have altered the structure of these strata the contrast in hydraulic conductivity between the inter- and over-burden rocks and the coal seams is likely to be smaller than at greater depths. The geological cross section (**Figure 1**) indicates that the depth of coal oxidation in the area is between about 30m and 70m. It is considered that this depth is also indicative of the depth of rock weathering and alteration of hydraulic properties.

Hydraulic testing and field observations discussed in Section 7, indicate that there is a zone of increased hydraulic conductivity along the Camberwell Horst.

9.4 Model Development

9.4.1 Model Geometry

In agreement with the conceptual groundwater model of the area, the numerical model consists of three aquifers separated and underlain by a low permeability inter- and over-burden and is represented by six model layers. The upper model layer (Layer 1) represents the shallow alluvial aquifer where the alluvial deposits exist, and overburden rocks beyond the extent of these deposits. The extent of the alluvial aquifer is shown on **Drawing No 8**. The base of this aquifer was interpreted from elevations of the base of the sand/gravel layer from available borehole data.

The interburden between the aquifers is represented in the model by intermediate layers (Layer 2 and 4).

The upper coal aquifer (Layer 3) represents the combined Middle and Lower Liddell Seams. The extent of this layer is limited by the interpreted subcrop of the base of the Liddell Seam and the limits of the conceptual model domain as described in Section 9.3. The lower coal aquifer (Layer 5) represents the combined Barrett and Hebden Seams. The extent of this layer is limited by the subcrop of the base of the Hebden Seam and the limits of the conceptual model domain as described in Section 9.3.

The elevation of the base of the coal aquifers was adopted from the elevations of the base of the Liddell and Hebden Coal Seams supplied by ICO. In the areas outside the extent of the ICO data, these elevations were based on the data published in various reports for the surrounding mines or were arbitrarily set at the elevations considered to be consistent with other elevation data.

The thickness of the coal seam aquifers (Layers 3 and 5) was based on data supplied by ICO. Outside the extent of the ICO data the thicknesses of the coal seams were adopted from the published coal thicknesses in various areas as discussed in Section 4.

The Saltwater Creek Formation is represented in the model by Layer 6.

The model domain was discretised into 58806 rectangular cells arranged into 6 layers, 101 columns and 99 rows. 42000 of these cells were active during simulation. The dimensions of the model cell size vary from 75m by 75m within the proposed Glennies Creek open cut area and up to 750m by 387m at the extremities of the model as shown on **Drawing No 11**. The model extent from west to east is approximately 20.3km and 24.4km from south to north.

The northwest corner of the grid is located at 312925mE and 6414309mN, and the grid was rotated 30° to the west in order to align it with the subcrop of the seams.

The cells located outside the extent of the conceptual model domain were excluded from the simulation.

9.4.2 Hydraulic Parameters

The hydraulic parameters of the model domain were assumed as shown in **Table 18** and were adopted after calibration of the model.

Table 18
Hydraulic Parameters

Page 1 of 2

Layer	Parameter	Value
Layer 1 (alluvium aquifer)	Horizontal Hydraulic Conductivity k_h (m/day)	5 – Glennies Creek Alluvium 1 – Other Creeks Alluvium 10 – Hunter Valley Alluvium
	Vertical Hydraulic Conductivity k_v (m/day)	2.5 – Glennies Creek Alluvium 0.5 – Other Creeks Alluvium 5 – Hunter Valley Alluvium
	Specific Yield S_y (1/m)	0.25
	Specific Storage S_s (1/m)	0.001
Layer 2 (interburden)	Horizontal Hydraulic Conductivity k_h (m/day)	5 – Camberwell Horst zone 0.005 – within 60m thick weathered zone 0.0005 – below 60m weathered zone
	Vertical Hydraulic Conductivity k_v (m/day)	5 – Camberwell Horst zone 0.0005 – within 60m thick weathered zone 0.00005 – below 60m weathered zone
	Specific Yield S_y (1/m)	0.01
	Specific Storage S_s (1/m)	1×10^{-5}

Table 18 (Cont'd)
Hydraulic Parameters

Page 2 of 2

Layer	Parameter	Value
Layer 3 (Middle and Lower Liddell Seams)	Horizontal Hydraulic Conductivity k_h (m/day)	5 - Camberwell Horst zone 0.16 to 0.0018 at depth of over 300m
	Vertical Hydraulic Conductivity k_v (m/day)	5 - Camberwell Horst zone 0.16 to 0.00018 at depth of over 300m.
	Specific Yield S_y (1/m)	0.05
	Specific Storage S_s (1/m)	5×10^{-5}
Layer 4 (interburden)	Horizontal Hydraulic Conductivity k_h (m/day)	5 – Camberwell Horst zone 0.005 – within 60m thick weathered zone 0.0005 – below 60m weathered zone
	Vertical Hydraulic Conductivity k_v (m/day)	5 – Camberwell Horst zone 0.0005 – within 60m thick weathered zone 0.00005 – below 60m weathered zone
	Specific Yield S_y (1/m)	0.01
	Specific Storage S_s (1/m)	1×10^{-5}
Layer 5 (Barrett and Hebden Seams)	Horizontal Hydraulic Conductivity k_h (m/day)	5 – Camberwell Horst zone 0.09 to 0.0018 at depth of over 300m.
	Vertical Hydraulic Conductivity k_v (m/day)	5 – Camberwell Horst zone 0.01 to 0.00018 at depth of over 300m
	Specific Yield S_y (1/m)	0.05
	Specific Storage S_s (1/m)	5×10^{-5}
Layer 6 (Saltwater Creek Formation)	Horizontal Hydraulic Conductivity k_h (m/day)	0.001
	Vertical Hydraulic Conductivity k_v (m/day)	5×10^{-6}
	Specific Yield S_y (1/m)	0.01
	Specific Storage S_s (1/m)	1×10^{-5}

9.4.3 Boundary Conditions

The groundwater model domain is surrounded by “no flow” boundaries. The base of the model was also assumed to be a “no flow” boundary. A “no flow” boundary does not allow any exchange of water between the model domain and the surrounding areas. Groundwater outflow from the model domain is allowed through MODFLOW “drain” and “river” cells. The drain cells were set along the creek beds intersecting the model domain area and the river cells were set along Glennies Creek.

Drain cells remove the water from the aquifer when the simulated groundwater level in the model cell is above the elevation of the drain. River cells allow drainage of the aquifer to the river when the simulated groundwater levels in the aquifer around the river are higher than the river stage. When the groundwater level in the surrounding aquifer is lower than the river stage, the river can supply water to the aquifer or act as a recharge zone, with the rate of recharge dependent on the difference in elevation between the groundwater in the aquifer and the river stage, and the hydraulic conductivity of the river bed. As discussed in Section 7, the water levels in the Glennies Creek appears to be at the same elevation as the water level in shallow monitoring bores installed along the creek bed which indicates good hydraulic connection between the alluvium aquifer and the creek.

On commencement of mining in the Project Site, dewatering of the mine workings created new boundary conditions which are represented in the model by MODFLOW “drain” cells.

9.4.4 Recharge and Discharge

Recharge to the model domain was assumed to occur along the coal seam subcrops and the alluvium areas. The rate of recharge is unknown and was therefore obtained during model calibration. It was assumed that the recharge to the coal seams could occur only over the areas where the seam subcrops were shallower than 60m that is where the coal seams were overlain by weathered overburden. The calibrated rates of recharge adopted in the model were 7.3mm/year to the coal seams, and 8.1mm/year to the alluvium.

As discussed, discharge from the model domain was assumed to occur to the main creeks intersecting the model area. The creeks, with exception of Glennies Creek, were simulated using MODFLOW “drain” cells. Glennies Creek was simulated using MODFLOW “river” cells. The elevation of the “drains” and “river” stage, along Glennies Creek, was set at the elevation of the creek beds.

On commencement of mining in the Project Site, additional discharge zones were created by dewatering of the mine workings. These discharge zones were simulated using MODFLOW “drain” cells. The elevation of the “drains” representing the mine workings was set near the elevation of the base of the mined coal seams.

9.5 Model Calibration

“Calibration of a groundwater flow model refers to a demonstration that the model is capable of producing field measured heads and flows which are the calibration values. Calibration is accomplished by finding a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes that match field measured values within an acceptable range of error” (Anderson and Woessner [1992]).

The objective of model calibration is to reproduce the estimated groundwater levels that existed in the Project Site in pre-mining conditions and reproduce inflows to the Glennies Creek Underground. The accuracy of the model calibration depends on the quality of calibration parameters, and the data defining the model domain such as aquifer geometry, boundaries, hydraulic properties and stresses imposed on the aquifer. It is considered that the horizontal and vertical extent of the model and model boundaries are sufficiently well defined to construct and calibrate the Glennies Creek groundwater model. However, the quality of calibration targets such as water levels are of variable quality as discussed in Section 9.5.1.

9.5.1 Calibration Targets

The calibration targets are groundwater levels in the alluvial aquifers, the coal seams and inflows to the Glennies Creek Underground Mine. The groundwater levels in the coal seams were obtained from the dedicated monitoring bores installed within the proposed Glennies Creek open cut area as well as those reported by GeoTerra (2005) for the Glennies Creek Underground Mine. Groundwater levels in alluvial aquifers were obtained from dedicated monitoring bores installed for Glennies Creek open cut and Glennies Creek underground as well as those measured in DNR registered monitoring bores. In addition, it was assumed that the water levels measured in monitoring bores GC01 to GC10, when the bores were open along their whole length, and prior to the construction of the monitoring bores, were representative of shallow aquifers not yet affected by dewatering in surrounding mines. As discussed in Section 7 and shown on **Figure 3**, water levels measured in some of these open bores were markedly higher before the installation of casing. The early water level data are interpreted as being representative of the shallow, weathered sections of the Permian strata and not of the deeper coal seam aquifers. Most of the water level data measured in Permian monitoring bores in the Glennies Creek Open Cut and underground area are already affected by dewatering of Camberwell Pits and Glennies Creek Underground, as shown on **Figure 3** and **Drawing No 5** and are therefore of limited value to steady state model calibration.

The accuracy of the water level data in the calibration data set was estimated to vary between about 0.5m and 4m depending on the bore location, accuracy of the bore collar elevation, frequency and date of measurements and expected impact by mine dewatering. For instance, the accuracy of the water level elevation estimates in the DNR registered bores was estimated at $\pm 2\text{m}$ as the collar elevation of these bores had to be estimated from the topographic map and there was only one measurement of the water level depth per bore, with measurements taken between 1956 (GW011543) and 1979 (GW049285), and with the unknown date of measurement in the remaining bores.

Due to a lack of long term monitoring data, it was assumed that the water levels in bores selected for steady state calibration were representative of the long term average (steady state) groundwater levels. However, fluctuations in groundwater level in the area are expected. The location of the bores selected for calibration is shown on **Drawing No 4**. The confidence interval of calibration targets was estimated to vary between 0.5m and 4m with the majority of the intervals of about 2m. The estimate of this interval was based primarily on the consistency of the water level data, however, it can not take into account the unknown impact of dewatering by the Camberwell Open Cut and the Glennies Creek Underground Coal Mine on observed groundwater levels. It is likely that the confidence interval in monitoring bores located close to these mines should be biased towards higher than the observed water levels.

A total of 21 water level data points were used for calibration. A summary of the bores used as calibration targets is presented in **Table 19**.

Table 19
Steady State Calibration Targets and Calibration Results

Bore Name	Calibration Target SWL (m AHD)	Confidence Interval (m)	Confidence Range (m AHD)		Calibrated Elevation (m AHD)	Difference (m)
			from	to		
GC01(open bore)	72.6	1	71.6	73.6	73.8	-1.3
GC05 (open bore)	73.6	3	70.6	76.6	70.5	3.0
GC06 (open bore)	75.0	3	72.0	78.0	73.3	1.7
GC07	72.3	2	70.3	74.3	75.5	-3.2
GC07 (open bore)	72.6	1	71.6	73.6	75.5	-2.9
GC08	72.0	2	70.0	74.0	77.5	-5.5
GC08 (open bore)	73.1	1	72.1	74.1	76.1	-3.1
GC09	65.5	0.5	65.0	66.0	66.4	-0.9
GC10	68.7	0.5	68.2	69.2	68.7	0.0
GC14 (open bore)	76.7	4	72.7	80.7	75.5	1.2
GC15 (open bore)	72.6	1	71.6	73.6	75.5	-2.9
GC16	72.2	2	70.2	74.2	76.1	-3.9
GCP1	71.0	2	69.0	73.0	68.4	2.6
GCP2	80.5	2	78.5	82.5	81.5	-1.0
GCP3 (alluvium)	77.0	2	75.0	79.0	77.3	-0.3
GCP3 (Permian)	76.5	2	74.5	78.5	77.1	-0.6
GCP4 (alluvium)	85.5	2	83.5	87.5	84.1	1.4
GW011543	69.9	2	67.9	71.9	70.0	-0.1
GW013603	63.1	2	61.1	65.1	65.7	-2.6
GW019565	63.9	2	61.9	65.9	66.4	-2.5
GW049285	69.3	2	67.3	71.3	69.7	-0.4

The second calibration target was inflow to the Glennies Creek Underground Mine. As discussed in Section 7.3, the groundwater inflows to the mine are estimated by the mine personnel to be between 0.8ML/day and 1.1ML/day (800m³/day and 1100m³/day).

9.5.2 Calibration Results

Comparison of observed and simulated groundwater levels in the Glennies Creek open cut model area are shown on **Figure 8**.

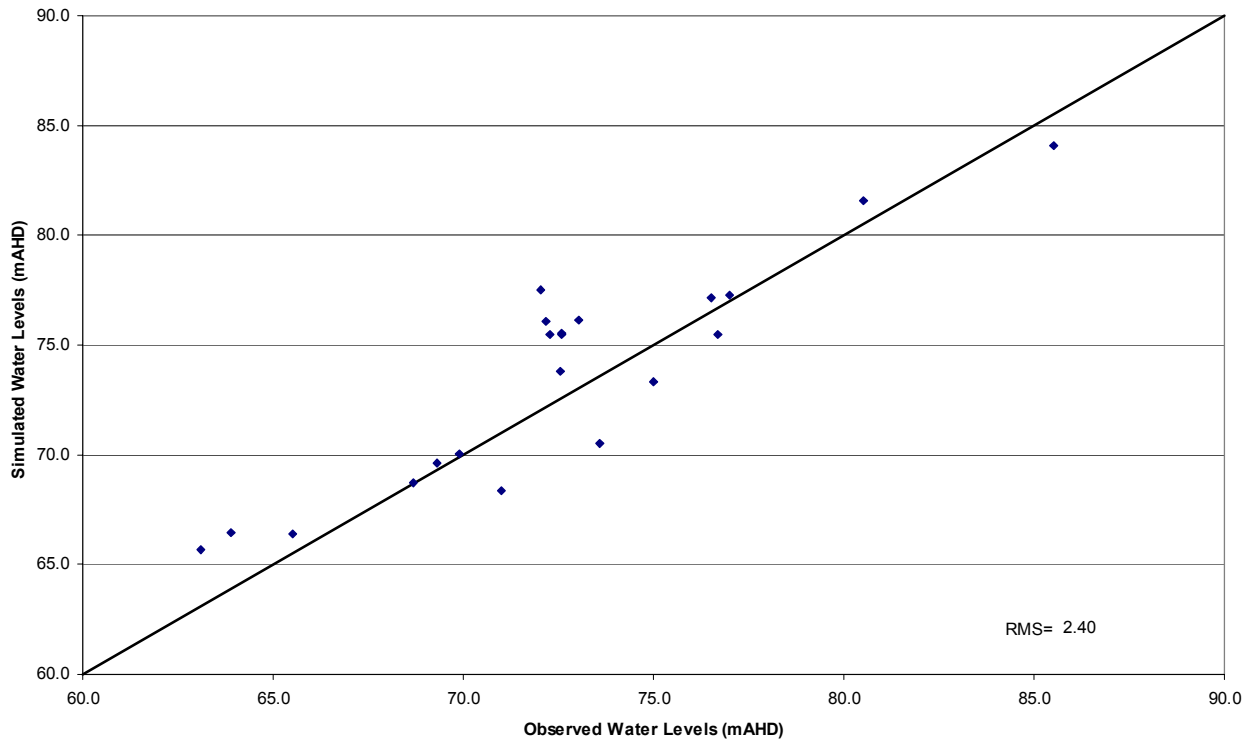


Figure 8 Observed versus Calibrated Groundwater Levels

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

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

where:

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

is considered to be the best measure of error, if errors are normally distributed.

The RMS error calculated for the calibrated model is 2.40m. The maximum acceptable value for the calibration criterion depends on the magnitude of the change in heads over the model domain. If the ratio of the RMS error to the total head loss in the system is small, the errors are

only a small part of the overall model response, (Anderson and Woessner (1992)). The total observed head loss within the model domain is 82m, therefore the ratio of RMS to the total head loss is 2.9%. Taking into account level of uncertainty in the accuracy of the calibration targets this calibration error is considered to be very good.

The mass balance error, that is the difference between calculated inflows and outflows to the model, at the completion of the calibration run, expressed as percent of discrepancy, was 0.00%, indicating good accuracy of the numerical solution and overall stability of the model.

A comparison of observed and simulated inflows to the Glennies Creek Underground Coal Mine is shown in **Table 20**.

Table 20
Observed and Simulated Inflows to Glennies Creek Underground (2005 to 2006)

Observed Inflow (m ³ /day)	Simulated Inflow (m ³ /day)
800 to 1100	860 to 978

The simulated steady state elevation of the groundwater table is shown on **Drawing No 12**.

9.5.3 Model Budget

The steady state and 2006 water balance of the calibrated model is shown in **Table 21**. Year 2006 simulation results were used as initial conditions for the predictive simulations.

Table 21
Model Water Budget

	Steady State	Year 2006
Inflow		
Storage (m ³ /day)	0.0	19219.3
Drains (m ³ /day)	0.0	0.0
Recharge (m ³ /day)	368.0	369.7
Glennies Creek Leakage (m ³ /day)	155.4	157.1
Total Inflow (m ³ /day)	523.4	19746.1
Outflow		
Storage (m ³ /day)	0.0	155.8
Drains(m ³ /day)	150.0	19226.7
Recharge (m ³ /day)	0.0	0.0
Glennies Creek Leakage (m ³ /day)	373.4	365.3
Total Outflow (m ³ /day)	523.4	19747.9
Discrepancy (%)	0.00	-0.01

10 PREDICTIVE SIMULATIONS

As the CHPP and associated haul roads are essentially surface works, it was assumed that these activities will have no impact on the groundwater regime of the area, as such numerical groundwater flow modelling undertaken for the hydrogeological impact assessment focussed on the potential impacts of the proposed Glennies Creek Open Cut Mine.

10.1 Development of Mining

As discussed in Sections 4 and 5, mining in the area of the proposed Glennies Creek Open Cut Coal Mine commenced as early as the 1860's but was limited to small scale operations and at this early stage was unlikely to have any major impact on the groundwater conditions in the area. Large scale mining, likely to affect groundwater conditions in the vicinity of the proposed open cut, commenced in 1991, with development of the Camberwell North Pit immediately south of the Project Site. In 1999, development work commenced on the Glennies Creek Underground Coal Mine west of the proposed Glennies Creek Open Cut Coal Mine. Mining from the first Long Wall Panel, LW1 commenced in August 2002. Further away from the Project Site, large scale mining at Mt Owen commenced in 1993.

The proposed open cut is about 1.8km long in an approximate east-west direction and up to 600m wide in a north-south direction. The base of mining will be to the floor of the Hebden Seam. The maximum depth of the pit will be up to about 100m below the present ground surface.

Mining at the proposed Glennies Creek open cut is proposed to commence at the eastern end of the pit and progress to the west. The spoil will be progressively placed in the mined out areas behind the mining front. The mine has a life of approximately five to six years. No advance dewatering of the coal seams is expected to be required at this time.

10.2 Modelling Strategy

The future response of the groundwater system to the proposed mine schedule and the rate of groundwater inflow to the open cut has been assessed by running the model in predictive mode for a total period of 6 years, assuming commencement of mining at the beginning of 2007. Simulated 2006 groundwater elevations have been used as initial conditions.

The open cut mining strips and the underground workings were simulated using MODFLOW "drain" cells. "Drain" cells allow water to be removed from the model domain if the hydraulic head in the cell is above a nominated drainage level. The drainage level specified was near the base of all model layers intersected by the proposed Glennies Creek Open Cut Coal Mine, as well as by the other open cut mines within the model domain, that is Layers 1 to 5. Dewatering of the Glennies Creek Underground Coal Mine was simulated using "drain" cells located only within the Layer 3, which is the layer representing the Liddell Seam mined by the Glennies Creek Underground.

“Drain” cells were moved in three-monthly intervals across the mine area in accordance with the mine plan. Once the mining strip was backfilled with interburden and overburden, the “drain” cell within the backfilled strip was removed from the model. In the case of the Glennies Creek Underground Coal Mine, the “drain” cells were progressively added to the model in agreement with the mine plan supplied. Once the “drain” cells were activated in the Glennies Creek Underground Coal Mine area, they remained active until the end of the simulation.

As discussed, Glennies Creek was simulated using MODFLOW “river” cells which allow for losing or gaining river reaches to be modelled, depending upon the prevailing hydraulic head in the cell relative to the nominated river stage. This was done in order to allow simulation of the recharge to the alluvial aquifer by the waters released from Lake St Clair.

The surface water elevation along Glennies Creek was assessed on the basis of topographic maps of the area. Where the model extended beyond the limits of the available topographic maps the elevations were assigned from publicly available digital elevation maps (DEM) of the area.

Prior to simulating the impact of the proposed Glennies Creek open cut on the groundwater regime, the current impact of the existing mines had to be assessed. The impact of these mines was simulated by running the calibrated model from the steady state conditions until early 2006. The existing mines were simulated using MODFLOW “drain” cells as discussed.

Time wise, the period prior to commencement of mining from the proposed Glennies Creek Open Cut Coal Mine was discretised into 20, approximately year long stress periods. The simulation of this period was necessary in order to obtain the distribution of the groundwater levels at the proposed commencement of mining at the proposed Glennies Creek Open Cut Coal Mine. The 6 year long Glennies Creek Open Cut Coal Mine mining period was discretised into 24 stress periods with four stress periods per year. A stress period is a period of time during which there is no change to stresses, such as pumping rates, recharge or dewatering, imposed on the model.

It was assumed that dewatering of the final void in Camberwell North Pit, where mining was completed in April 1999, will continue and will maintain the elevation of the water level in the pit at about 41m AHD in order to prevent flooding of the portal to the underground mine. It was also assumed that dewatering of the surrounding mines will not only continue but will be expanded according to the known development plans. It should be noted that dewatering of the surrounding mines will continue after closure of the Glennies Creek open cut. According to the current plans, the last mine to close in the vicinity of the Glennies Creek open cut will be the Glennies Creek Underground Coal Mine which is planned to close in about 2026.

10.3 Simulation Results

10.3.1 Current Modelled Impact of Existing Mines

Simulation of the impact of the existing mines on the groundwater regime in the Glennies Creek open cut area indicates that a deep and steep cone of depression has already developed around the Glennies Creek Underground Coal Mine, Mt Owen and Camberwell Open Cut Mines. The simulated cone of depression around the Glennies Creek Underground Coal Mine has coalesced with the cone of depression developing around the Camberwell Pits.

However, the simulated cone of depression around the Mt Owen open cut is not connected with the other areas of groundwater drawdown.

The simulated drawdown in 2006, in the Barrett/Hebden Seam, within the Project Site varies from about 20m in the south western corner of the proposed open cut to about 5m at the eastern end. The simulated extent of the cone of depression in the combined seams is shown on **Drawing No 13**.

The cone of depression in the Liddell Seam as well as in the interburden between the seams is deeper but at the same time less extensive than that in the Hebden Seam. The simulated cone of depression in the overburden above the Liddell Seam is both less extensive and smaller than in the coal seams and in the interburden. The deepest depression of about 20m was simulated above the Glennies Creek Underground Coal Mine Panel LW1. In the Glennies Creek Open Cut Coal Mine area, a drawdown of 11m was simulated in the northwest corner of the proposed mine.

10.3.2 Impact at the End of Mining

The response of the groundwater system to the proposed mining and inflow to the open cut has been assessed by running the model from January 2007 to December 2012. Simulated 2006 heads have been used as initial conditions.

10.3.2.1 Water Table/Piezometric Surface

Dewatering undertaken as part of mining operations will create a cone of depression in the piezometric surface around open cut pit. Simulation results indicate that by the end of mining from the Glennies Creek open cut, that the cone of depression will be quite limited. This is due to the generally low permeability of the coal measures.

In Year 2012, that is by the end of mining, the simulated cone of depression in the Barrett/Hebden Seam, defined by the 1m drawdown contour, extended between 1km to the east and 2.4km to the north of the open cut. The simulated cone of depression is shown on **Drawing No 14**. The drawing also shows that the Glennies Creek Underground Coal Mine will have a major impact on the groundwater levels in the area. The proposed Glennies Creek Open Cut Coal Mine will have significantly less impact than the underground mine. The cones of depression developed around both Glennies Creek mines as well as the Camberwell open cuts will remain coalesced and continue slow development consistent with the mine development. However, the areal extent of this combined cone of depression will remain limited. At the time of the proposed Glennies Creek Open Cut Coal Mine closure, the cone of depression around Mt Owen will remain separate from the cone of depression developing around the Glennies Creek and the Camberwell Mines.

Simulations also indicate that the cone of depression developing in the overburden of the Liddell Seam will be of similar areal extent but significantly shallower. The largest simulated groundwater drawdown was about 40m was above the Glennies Creek Underground Coal Mine. The depth of the cone of depression under Glennies Creek was simulated to vary between about 1m and 5m at the north of the Project Site, with no drawdown to the northeast of the Project Site. The simulated drawdown in the overburden is shown on **Drawing No 15**.

10.3.3 Mine Inflows

Simulated inflows to the proposed Glennies Creek Open cut varied between 40m³/day and 260m³/day as shown on **Table 22**.

Table 22
Simulated Groundwater Inflows to Glennies Creek Open Cut

Date	Simulated Inflows (m ³ /day)
Jan 2008	44
Jan 2009	61
Jan 2010	176
Jan 2011	261
Jan 2012	113
Jan 2013	44

The direction and sequence of mining has impact on the simulated inflows. Generally mining in the open pits progresses down-dip and during those times the simulated inflows to the pits are steadily increasing. However, at times when mining is conducted at shallow depths the simulated inflows stabilise or even slightly decline.

The largest simulated inflow to the open pit of about 260m³/day was at the end of Year 4 of mining. At that time, the simulated mining was conducted across the Camberwell Horst. As discussed earlier, the field data indicate that the Horst is the prominent water-bearing structure in the Glennies Creek Open Cut Coal Mine area, and therefore it was represented in the model as a zone of increased hydraulic conductivity, significantly higher than that of the surrounding coal measures. The simulated inflows gradually declined after 2011 and by the end of mining reached value of about 36m³/day.

10.3.4 Impact on Glennies Creek

The modelling indicates that the cumulative impact of mine dewatering in the area on Glennies Creek will be negligible. The summary of the simulated water balance for the creek, along its whole length, is presented on **Table 23**. The simulated increase in seepage of 2m³/day from the creek to the aquifers, as well as a decrease of 8m³/day in groundwater discharge to the creek between beginning and completion of mining from the open cut (between 2007 and 2013) is within the accuracy of the simulation. Furthermore, the simulated impact on Glennies Creek is mainly due to dewatering of the Glennies Creek Underground Coal Mine and not the proposed Glennies Creek Open Cut Coal Mine. The simulation shows that the Project will have essentially no impact on the flows in Glennies Creek.

Table 23
Simulated Groundwater Inflows and Outflows From Glennies Creek

Date	Seepage from Glennies Creek (m ³ /day)	Groundwater Discharge to Glennies Creek (m ³ /day)	Balance (m ³ /day)
Jan-2007	157	364	-207
Apr-2007	157	364	-207
Jan-2008	157	363	-206
Jan-2009	157	362	-205
Jan-2010	157	361	-204
Jan-2011	158	359	-201
Jan-2012	158	357	-199
Jan-2013	159	356	-197

10.4 Groundwater Balance

The components of the model-derived groundwater balance at the end of the 6 years of mining operation are shown in **Table 24**.

Table 24
Groundwater Balance - End Of Mining

Flow Term	In (m ³ /day)	Out (m ³ /day)	Gain (+) or Loss (-) (m ³ /day)
Storage	2355.1	239.4	+2115.7
Constant Head	0.0	0.0	0.0
Drains	0.0	2281.8	-2281.8
River Leakage	158.6	355.9	-197.3
Recharge	369.2	0.0	369.2
			0.0
Sum	2882.8	2877.0	+5.8
Discrepancy [%]			+0.20

The cumulative discrepancy between inflows and outflows for the whole mining period between 2007 and 2012 was -5.8m³, a discrepancy 0.20%, which is considered to be a very good result.

10.5 Post Mining Impact

10.5.1 Groundwater Recovery – Aquifer and Final Void

On completion of mining, a small final void (only temporary until it is backfilled) will remain open at the western end of the Project Site. The areal extent of the void will be about 12.3 ha at the surface and 3.7ha at the base of the pit. The elevation of the void floor will vary between 5m AHD and 25m AHD. In the remainder of the open cut area, the coal seams and coal measures will be replaced by interburden or overburden, which will be a mixture of broken sandstone, siltstone, shale and minor coal material. Post mining dewatering of the open cut will discontinue and the spoil of the backfilled open cut mine will gradually fill with water until an equilibrium water table level establishes within the spoil material and in the final void. The sources of water that will initially fill the void are:

- seepage from the coal measures; and
- runoff and rainfall infiltration through the overburden emplacements.

Dewatering of the Glennies Creek Underground Coal Mine will, however, continue for about 14 years after the open cut closure. The cone of depression around the underground mine will continue to deepen and expand during that time to include the area of the Glennies Creek Open Cut Coal Mine. Within the open cut area, the expanding cone of depression around the Glennies Creek Underground Coal Mine and filling of the open cut by groundwater inflow and spoil recharge, will compensate each other. However, on the regional scale the continuing dewatering of the Glennies Creek Underground Coal Mine will result in expansion of the cone of depression.

The final void will initially be a sink to groundwater seepage and will collect direct rainfall, seepage through the in-pit waste rock emplacement and limited runoff. Prior to backfilling of the void water would be lost to evaporation. Detailed predictions of the water balance within the backfilled void are presented in PSM (2006).

10.6 Model Limitations

Development, calibration and the results of predictive simulations from any groundwater model is based on data characterizing the groundwater system under investigation. The data is typically collected from sparsely distributed locations and over a limited period of time. It is neither feasible nor possible to collect all the data characterizing the whole aquifer system in detail and therefore various assumptions have to be made during development of the groundwater model. A number of assumptions were made during development of the groundwater model described in this report and these assumptions together with their impact on the simulation results are discussed below.

It was assumed that aquifers simulated within the model domain area, are hydraulically continuous and without internal boundaries. The impact of such an assumption on the simulation results is such that there are no impediments to the development of the cone of depression around the mine. If there were low permeability (barrier) faults or dykes which have the effect of compartmentalising the aquifer into a number of hydraulically distinctive zones then the simulated drawdown would be different. The extent and the shape of the cone of depression would be determined by the geometry and hydraulic parameters of such faults but would in general be smaller and deeper in the extraction area zones. The inflows to the mine would also be most likely reduced in such case.

Should there be any hydraulically conductive faults, similar to the Camberwell Horst, intersecting the pit area, a cone of depression around the mine would develop primarily along the faults traces. In these circumstances the depth of the cone of depression would be smaller than simulated. The presence of such faults would also result in higher localised inflows to the mine.

An assumption was made regarding the hydraulic parameters of the coal seams and the overburden which governs the rate of transfer of groundwater between the coal seam and the alluvial aquifer. Any increase in the hydraulic conductivity of the coal seams or the inter- and over-burden rocks would be to decrease the depth of the cone of depression around the mine in the coal seams and increase it in the inter- and over-burden rocks, increase the extent of the cone of depression, and to decrease the post mining elevation of groundwater levels.

An assumption was also made regarding the continuity of the coal seams across the Hebden and Camberwell Thrust Faults. If in fact these thrust faults displaced the coal seams and acted as hydraulic barriers the domain of the groundwater model would be smaller. In this case, the Mt Owen Mine would be located in a separate groundwater system and there will be no impact of this mine dewatering on the Glennies Creek area. The impact of Camberwell Thrust Fault being a boundary to the Glennies Creek groundwater domain would be negligible since this fault is located in close vicinity of the boundary adopted in the model.

11 POTENTIAL IMPACT OF THE PROJECT ON GROUNDWATER REGIME AND MITIGATION OPTIONS

This section of the report discusses the impact of the mine and where adverse impacts are identified, mitigation measures. In particular, the potential impacts identified by DGRs are addressed. As discussed above the impact assessment has been focussed on the potential hydrogeological impacts of the proposed open cut mine rather than those associated with the surface works of the CHPP and haul roads.

11.1 Impacts on Existing Bores and Wells

Extraction of groundwater by mine dewatering will lower the elevation of the piezometric surface of the coal seam aquifers, and inter- and over-burden rocks, that is, it will create a “cone of depression” around the mine. However, it will have no impact on the water levels in the alluvial aquifer of Glennies Creek. The numerical model simulated the development and extent of the “cone of depression” in the coal seams and it was found that the radius of impact of the mine, as determined by the 1m drawdown contour on the piezometric surface is between about 1km and 2.4km to the north and east of the proposed open cut. The simulation also indicated that development of the cone of depression to the west of the proposed open cut will be depend entirely on the dewatering of the Glennies Creek Underground Coal Mine and the Camberwell Pits. The extent and size of the cone of depression will be influenced by the development of the mine and the cone of depression will be centred over the underground mine area. However, the simulations also indicated that the cone of depression will be very steep and confined to the areas immediately surrounding the underground workings and will not extend further than about 1.5km from the limits of the underground workings. In the area of the Camberwell Pits, the extent of the cone of depression will be somewhat larger but it will not extent further than about 1.8km from the pit limits.

Therefore only those bores that are either above the Glennies Creek Underground mine workings or within the combined cone of depression of the Glennies Creek and Camberwell Mines will be impacted by mine dewatering. As shown in Section 7, **Table 13** and on **Drawing No 4, Drawing No 14** and **Drawing No 15**, privately owned bores within a 15km radius are completed mainly in alluvial aquifers and most of the bores are beyond the extent of the cone of depression. The bores within the cone of depression are owned by the mine and are not in use. It is therefore assessed that the mine will not impact on any groundwater users in the area.

Simulations indicate that the bores located in alluvium even within the cone of depression will not be impacted by mine dewatering. Therefore it is also assessed that the mine will not impact any users of alluvial groundwater.

11.2 Impact on Glennies Creek

As discussed in Section 10.3.4 simulation indicates that there will be essentially no impact of the mine dewatering in the Glennies Creek area on Glennies Creek. The simulated small increase in the seepage from the creek as well as decrease in groundwater discharge to the creek of 2m³/day and 8m³/day respectively, between beginning and completion of mining from the open cut is within the accuracy of the simulation. Furthermore, even this small impact on the creek is mainly due to dewatering of the Glennies Creek Underground Coal Mine and not the proposed Glennies Creek Open Cut Coal Mine.

11.3 Groundwater Inflow to Mine and Control Strategies

Groundwater inflow to the open cut primarily occurs from the coal seams as there is little water in the over- and inter-burden rocks of the coal measures and the alluvium is over 750m from the open cut footprint. Predictive numerical modelling has indicated that groundwater inflow to the pit will be small and therefore groundwater inflow control strategies, such as advance dewatering, should not be required. The predicted groundwater inflows of up to about 260m³/day can be controlled by strategically located sump pumps.

12 ENVIRONMENTAL MONITORING AND MANAGEMENT

The recommended groundwater monitoring program is as summarised in **Table 25**. It is recommended that all groundwater monitoring, water level measurements and sample collection, storage and transportation be undertaken in accordance with the procedures outlined by the Murray Darling Basin Commission (1997).

It is recommended that the above groundwater monitoring program be coordinated with the monitoring program of the Glennies Creek Underground and Camberwell Open Cut Coal Mines.

A bore licence should be obtained from DNR prior to the installation of any new monitoring bores. All monitoring bores should be constructed according to the Australian guidelines (Land and Water Diversity Committee, 2003) by an appropriately qualified water bore driller.

Table 25
Recommended Groundwater Monitoring Program

Location	Parameters	Frequency
Glennies Creek Open Cut 2 No. alluvium bores (GC09 and GC10). 11 No. Coal Measures bores (GC1 to GC16 and GCTB).	water level	monthly
	pH, EC	monthly
	pH, EC, Na, Mg, Ca, Cl, HCO ₃ , SO ₄ , Total Fe	biannually
DNR registered bores along Glennies Creek 3 No. alluvium bores/wells. (GW067291, GW049285, GW011543)	water level	monthly
	pH, EC	monthly
	pH, EC, Na, Mg, Ca, Cl, HCO ₃ , SO ₄ , Total Fe	biannually
	pH, EC	quarterly
	pH, EC, Na, Mg, Ca, Cl, HCO ₃ , SO ₂ , Total Fe	biannually

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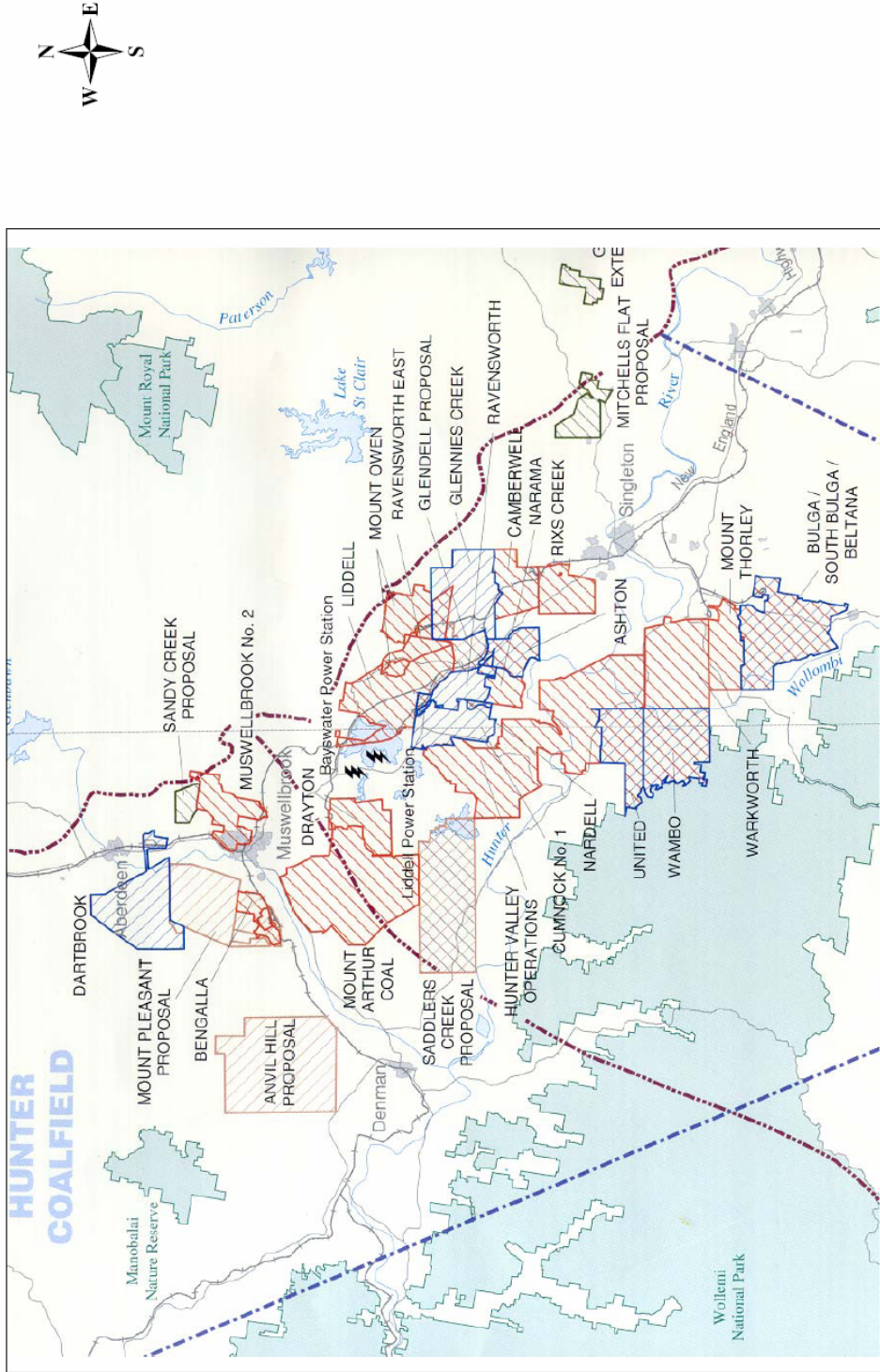
R.W Corkery & Co. Pty. Limited, (October 2004), *"Conceptual Project Development Plan for the Glennies Creek Open Cut Coal Mine Proposal"*.

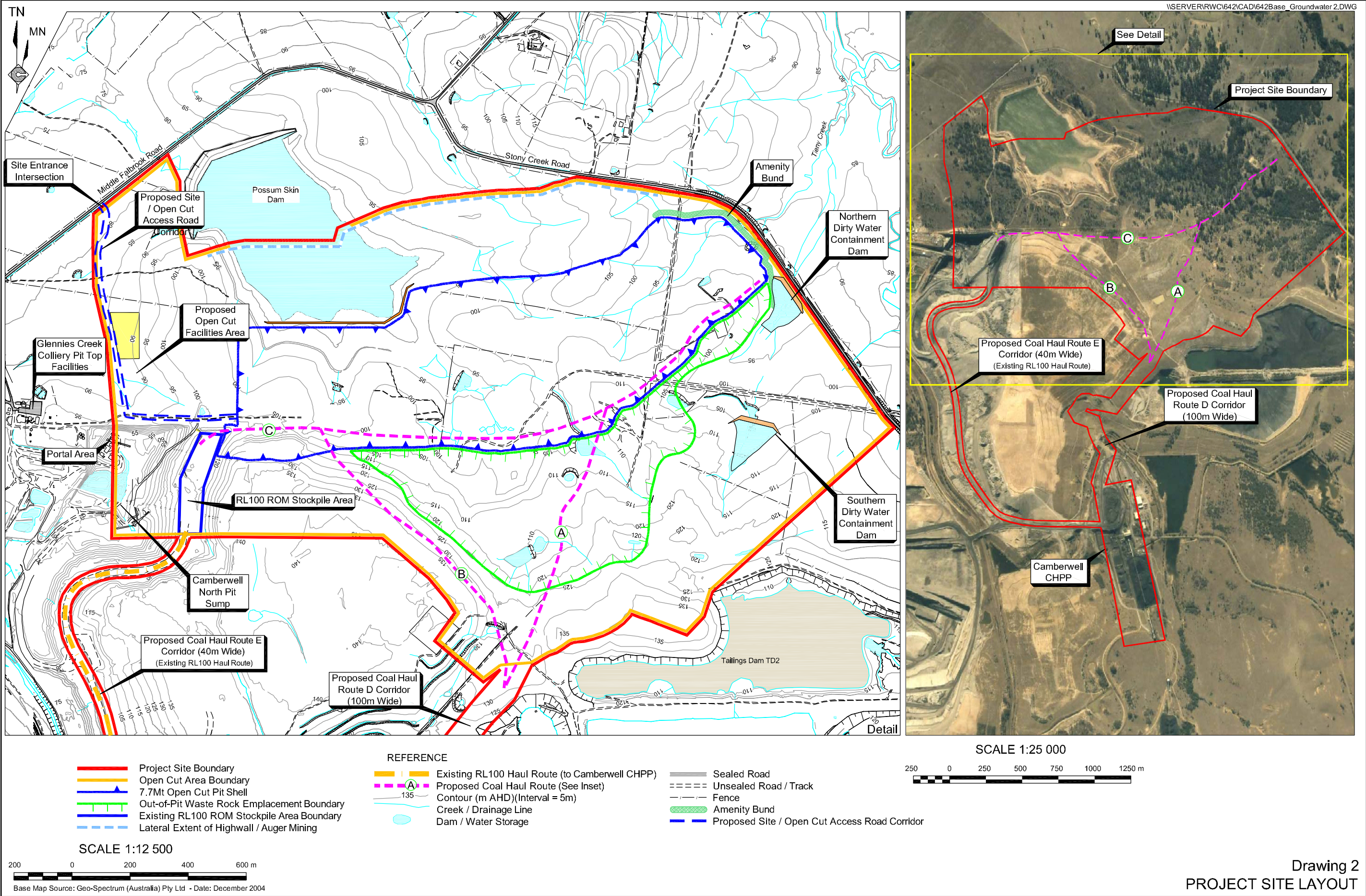
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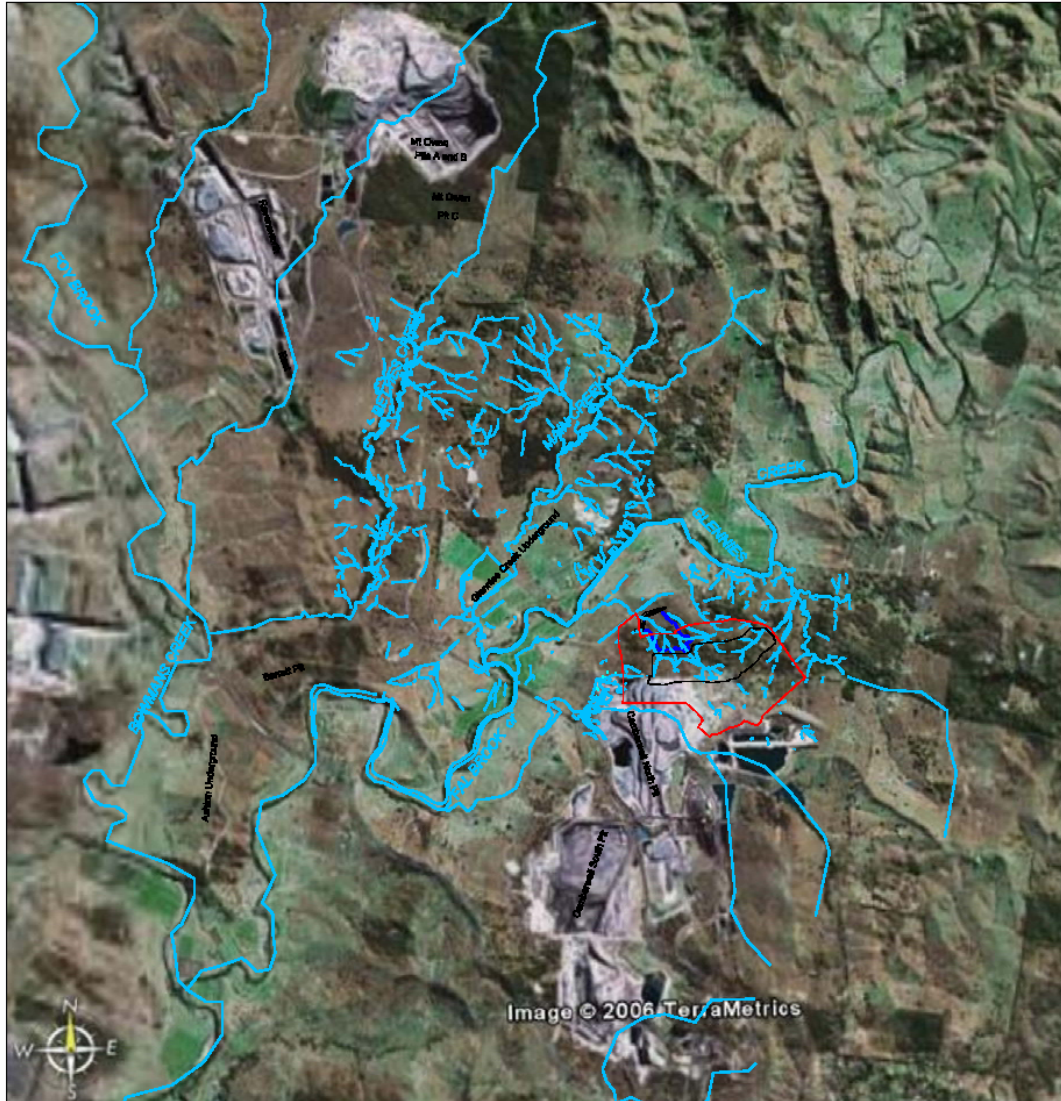
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DRAWINGS

(Colour Versions of these Drawings are available on the Project CD)







LEGEND

-  Creek/Drainage
-  Proposed Glennies Creek Open Cut
-  Open Cut Project Area



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

**TITLE: PROPOSED GLENNIES CREEK OPEN CUT COAL MINE PROJECT
GROUNDWATER ASSESSMENT
SURFACE DRAINAGE**

CLIENT: Integra Coal Operations Pty Ltd

OFFICE: Brisbane

DRAWN BY: B.S.

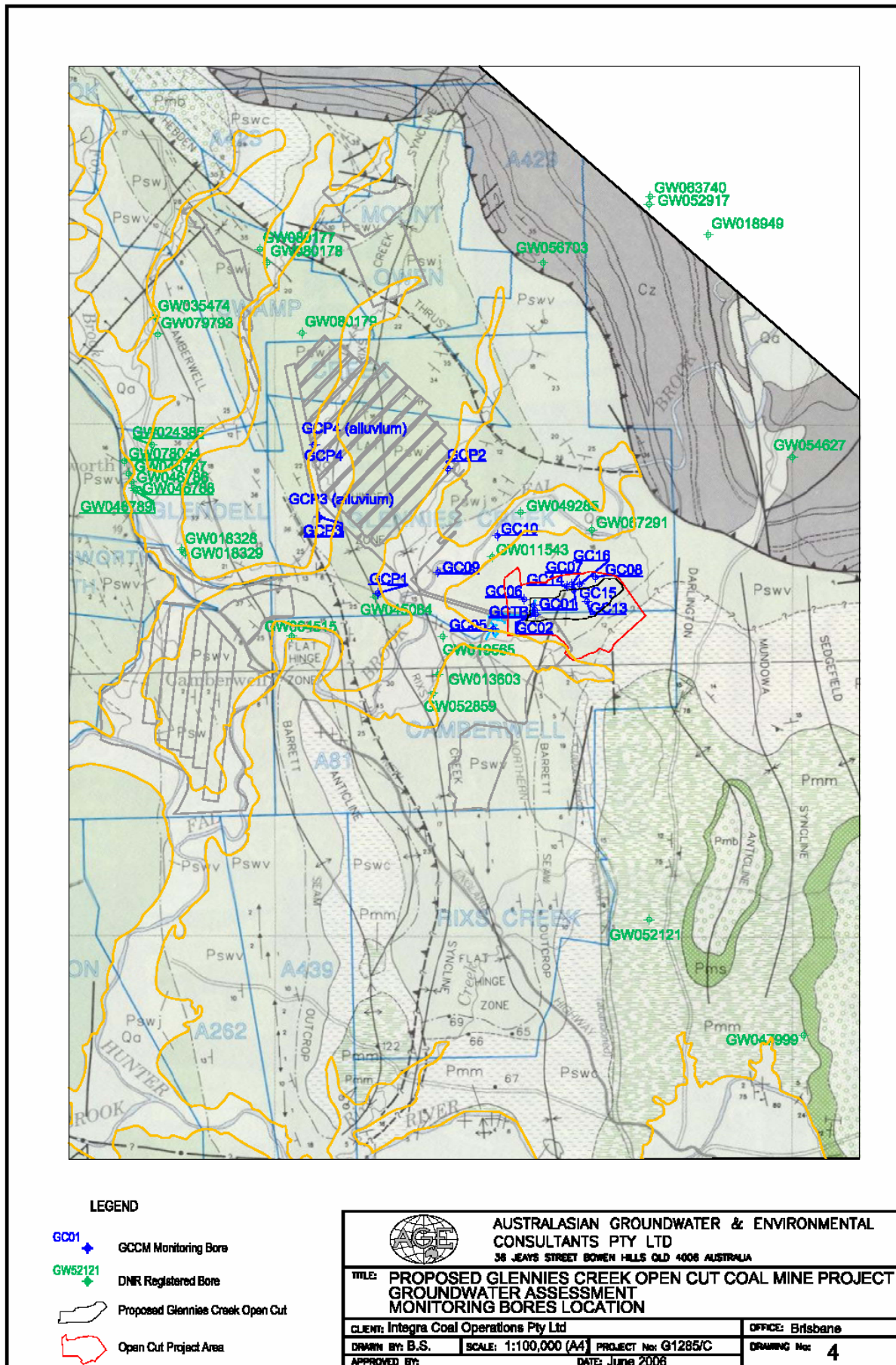
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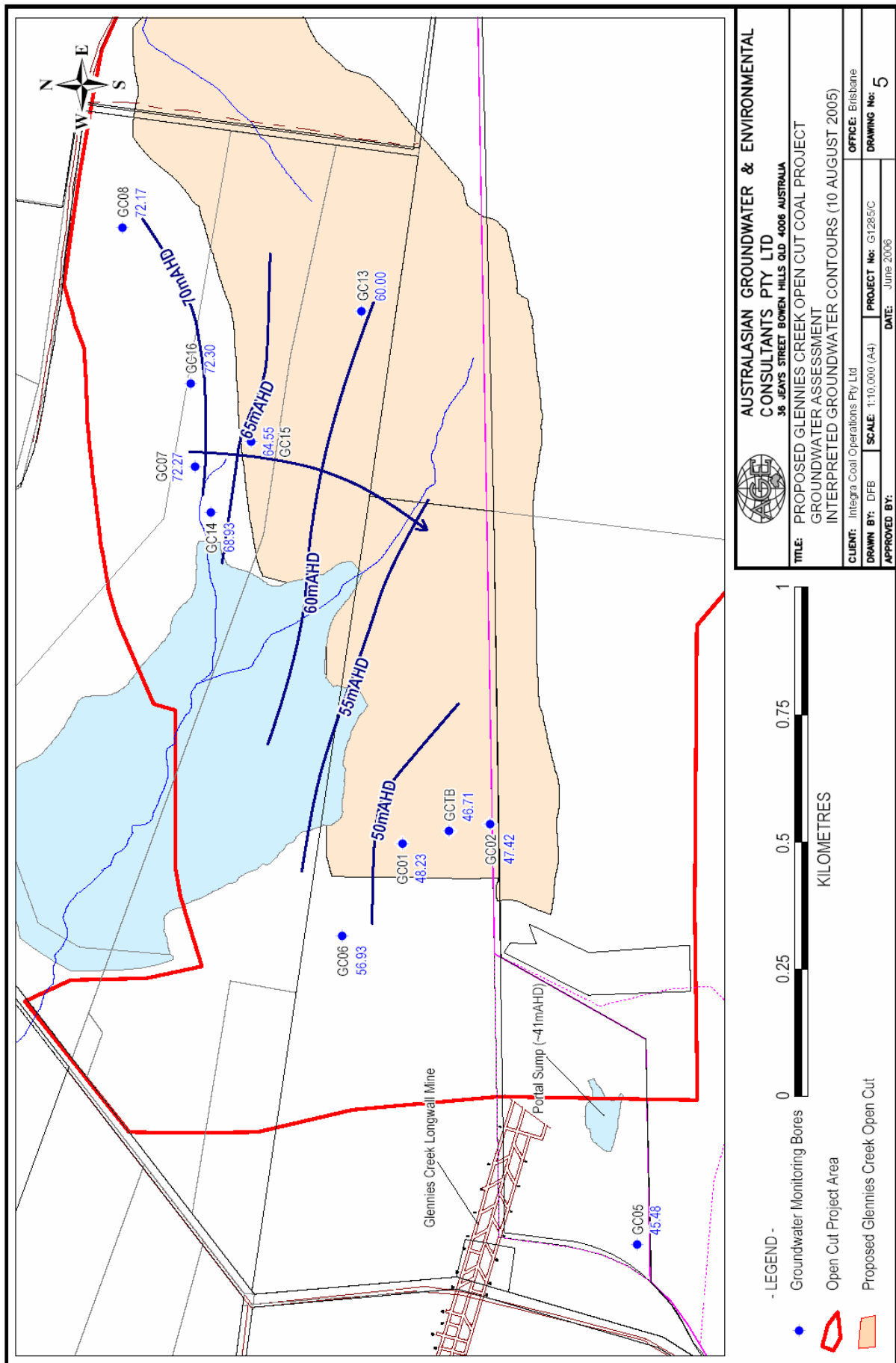
PROJECT No: G1285/C

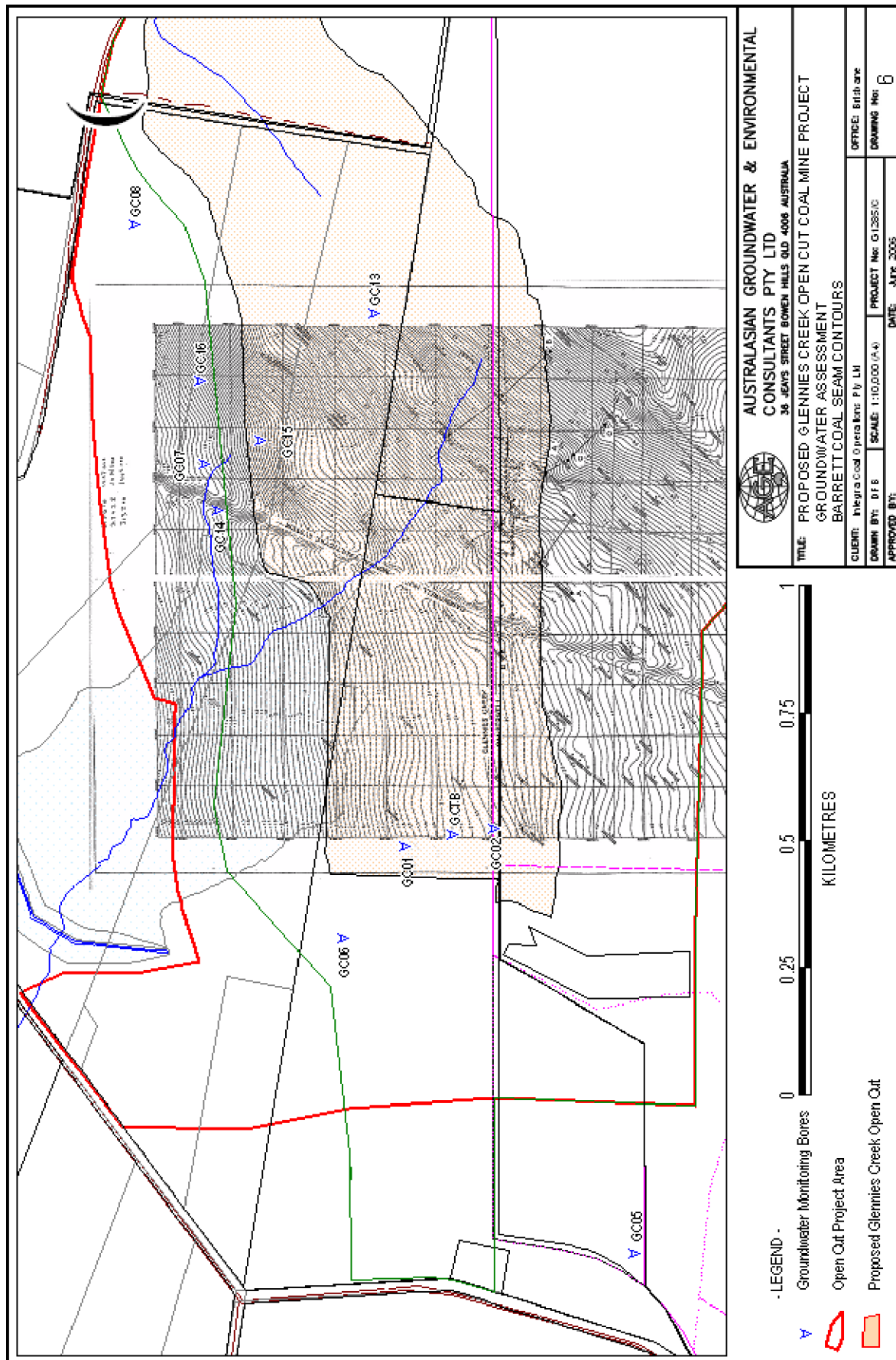
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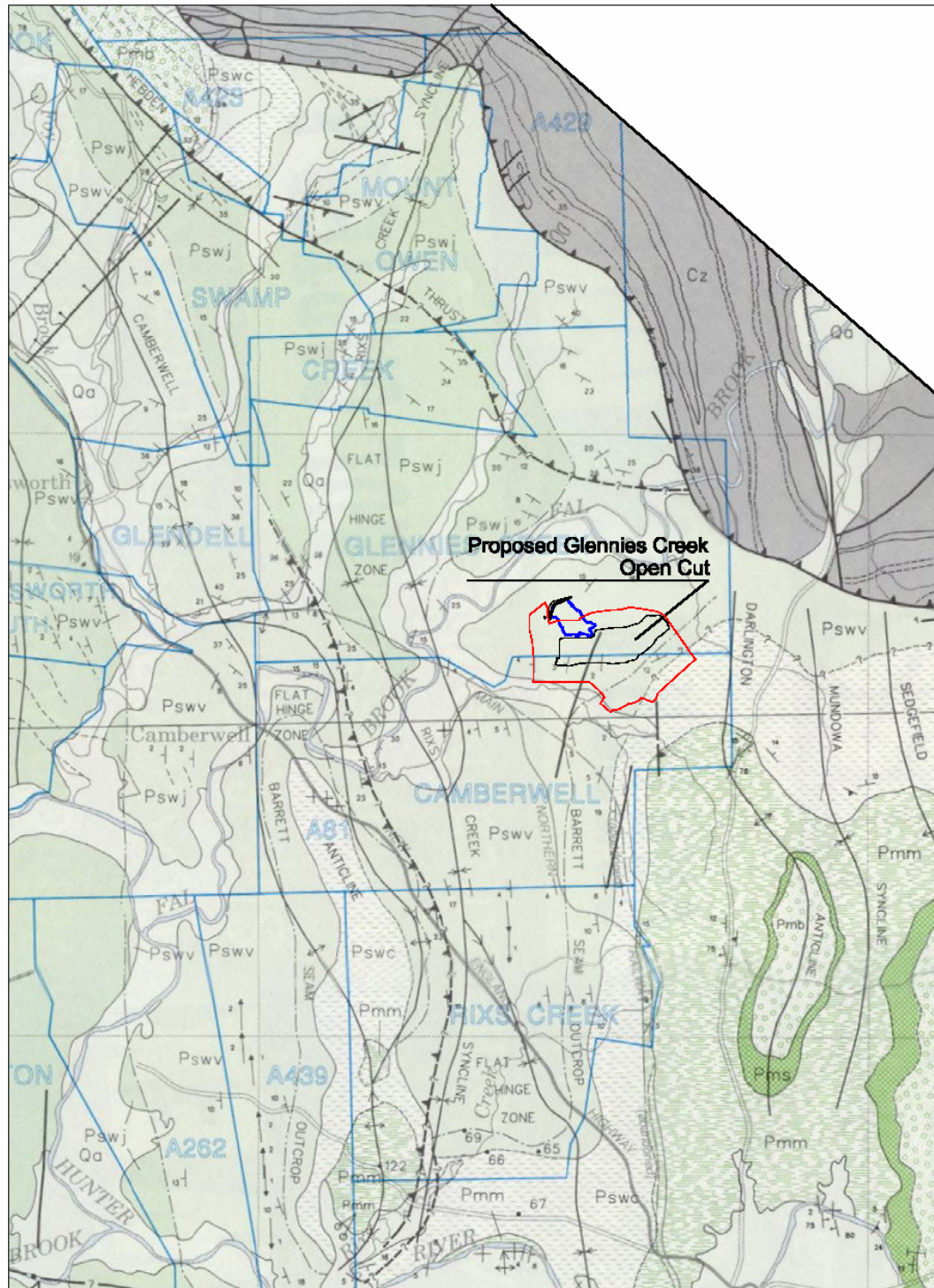
APPROVED BY:

DATE: June 2006









LEGEND

-  Proposed Glennies Creek Open Cut
-  Possum Skin Dam
-  Open Cut Project Area



**AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL
CONSULTANTS PTY LTD**
38 JEAYS STREET BOWEN HILLS QLD 4008 AUSTRALIA

**TITLE: PROPOSED GLENNIES CREEK OPEN CUT COAL MINE PROJECT
GROUNDWATER ASSESSMENT
REGIONAL GEOLOGY OF GLENNIES CREEK AREA**

CLIENT: Integra Coal Operations Pty Ltd

OFFICE: Brisbane

DRAWN BY: B.S.

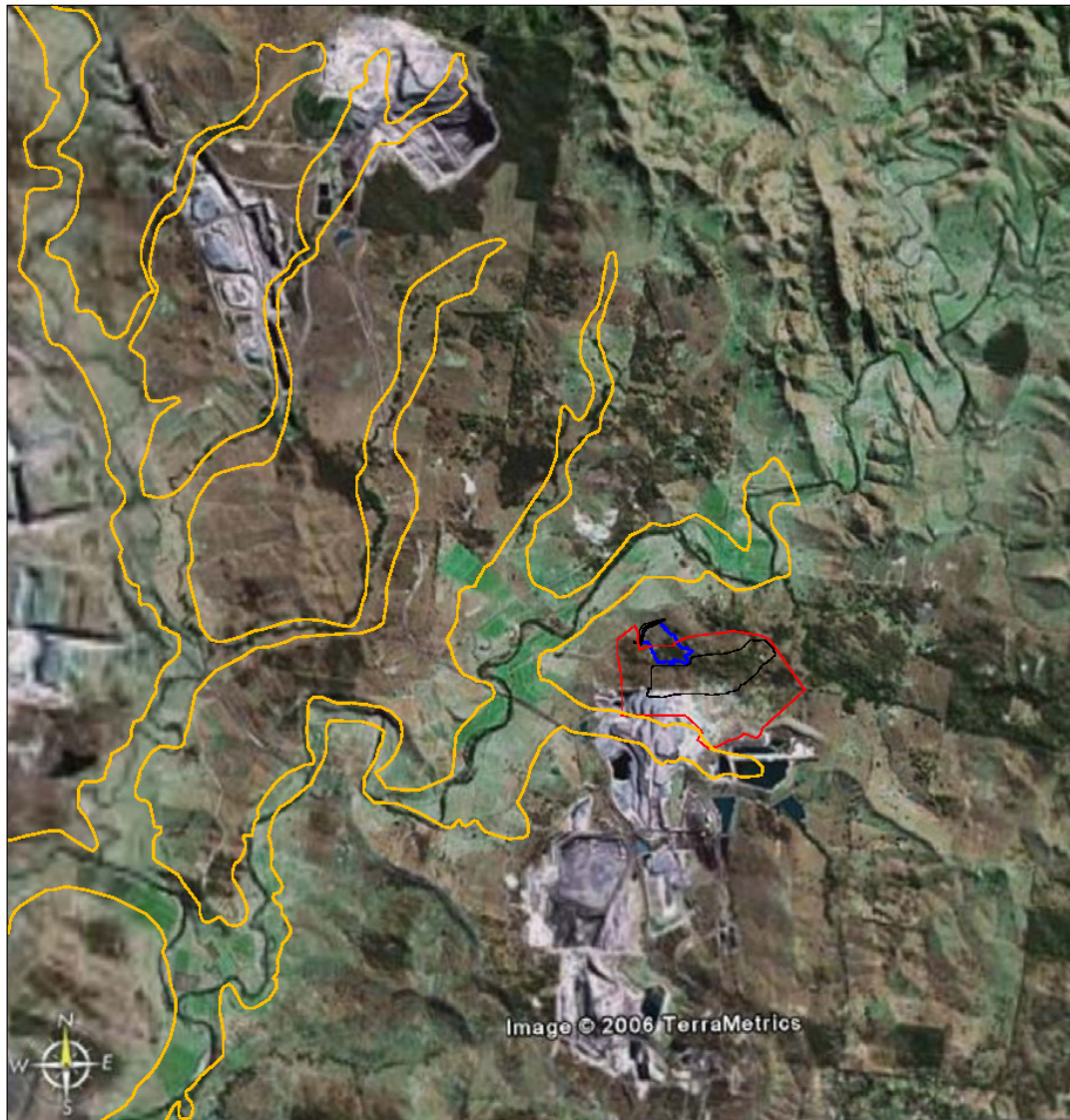
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APPROVED BY:

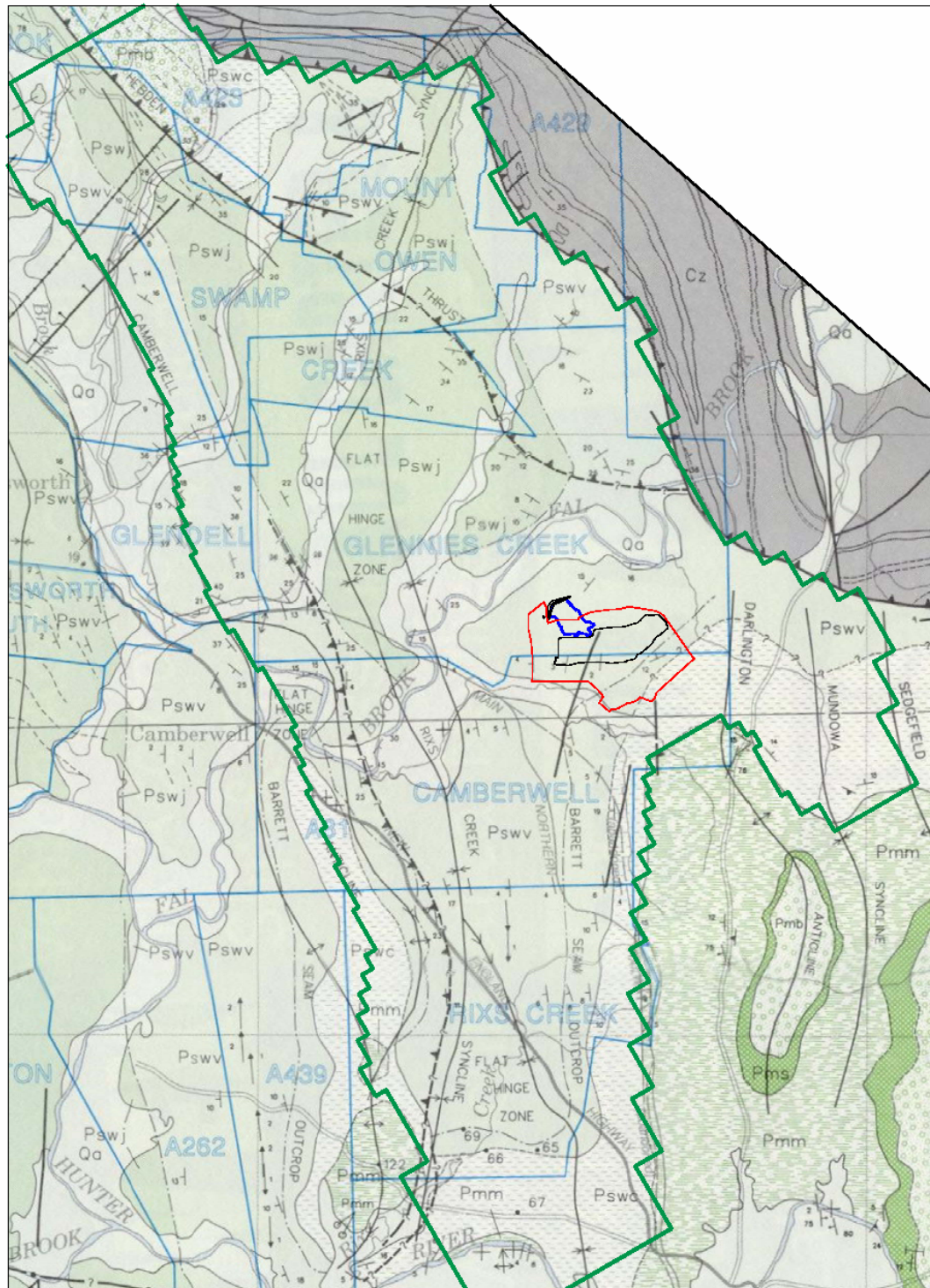
DATE: JUNE 2008



LEGEND

- Limits of Alluvial Deposits
- Proposed Glennies Creek Open Cut
- Possum Skin Dam
- Open Cut Project Area

		AUSTRALASIAN GROUNDWATER & ENVIRONMENTAL CONSULTANTS PTY LTD 36 JEAYS STREET BOWEN HILLS QLD 4006 AUSTRALIA	
		TITLE: PROPOSED GLENNIES CREEK OPEN CUT COAL MINE PROJECT GROUNDWATER ASSESSMENT DISTRIBUTION OF ALLUVIAL DEPOSITS	
CLIENT: Integra Coal Operations Pty Ltd		OFFICE: Brisbane	
DRAWN BY: B.S.	SCALE: 1:100,000 (A4)	PROJECT No: G1285/C	DRAWING No: 8
APPROVED BY:		DATE: June 2006	



LEGEND

-  Proposed Glennies Creek Open Cut
-  Possum Skin Dam
-  Open Cut Project Area
-  Model Limits



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

**TITLE: PROPOSED GLENNIES CREEK OPEN CUT COAL MINE PROJECT
GROUNDWATER ASSESSMENT
EXTENT OF GROUNDWATER MODEL**

CLIENT: Integra Coal Operations Pty Ltd

OFFICE: Brisbane

DRAWN BY: B.S.

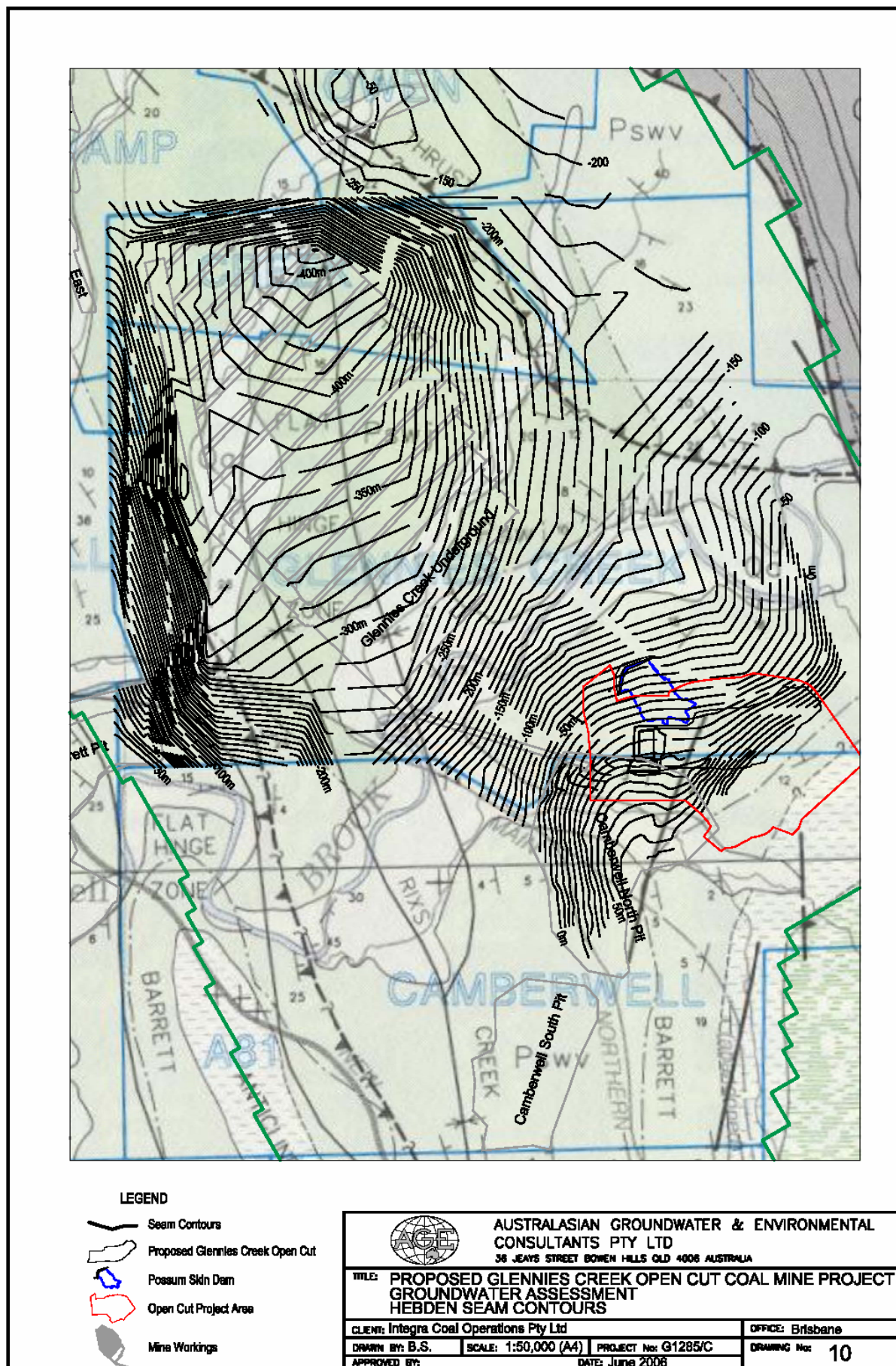
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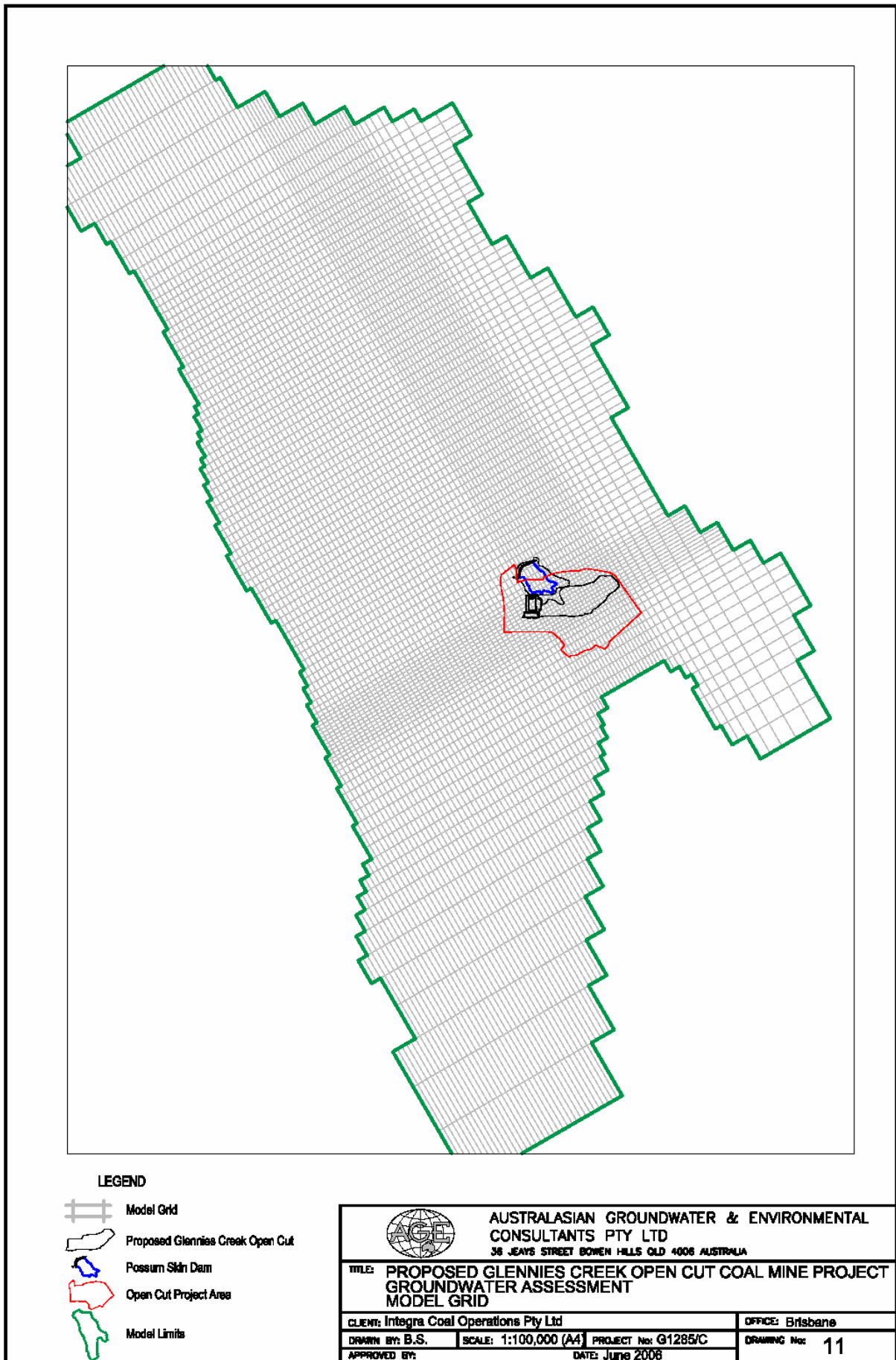
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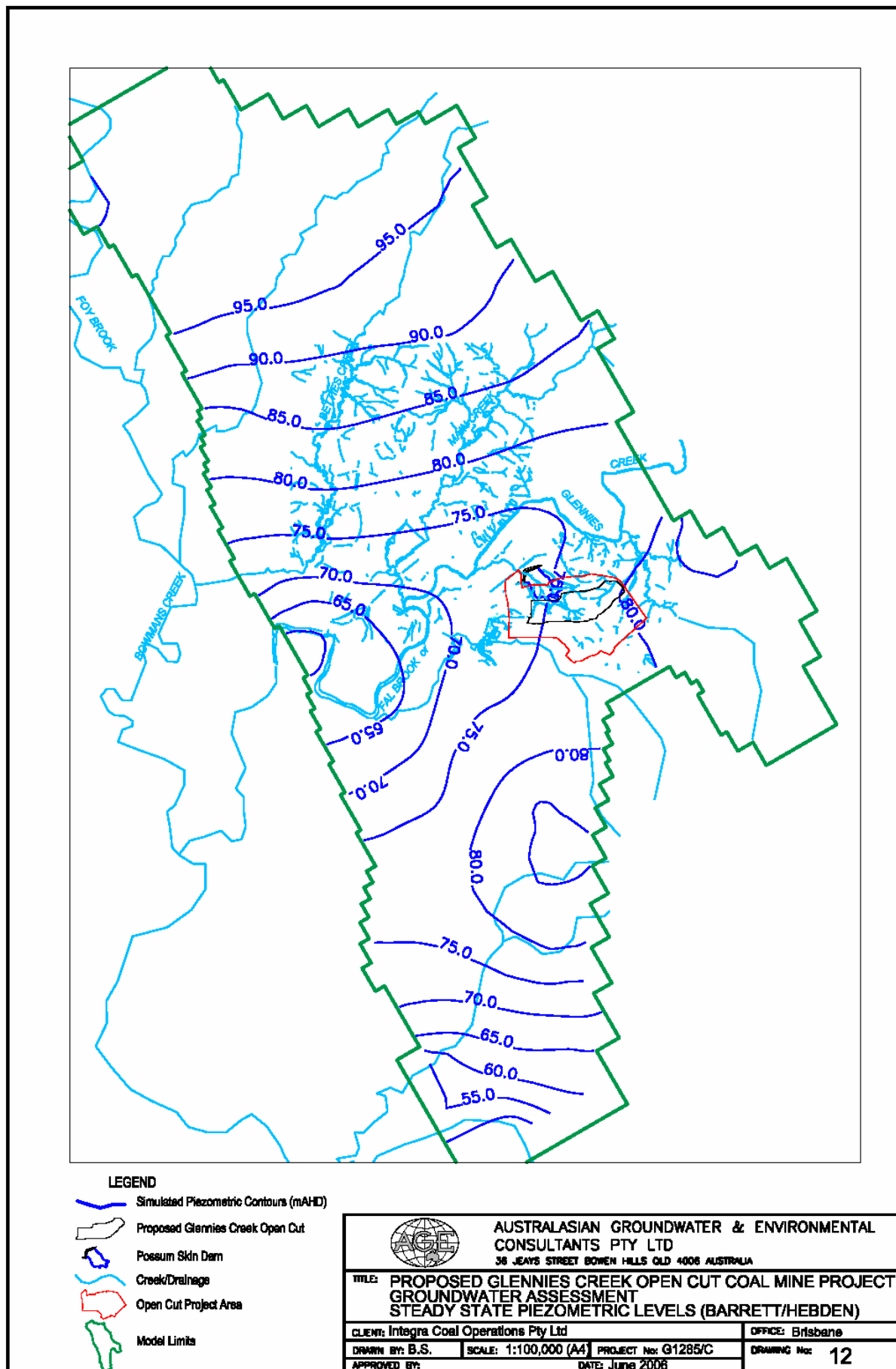
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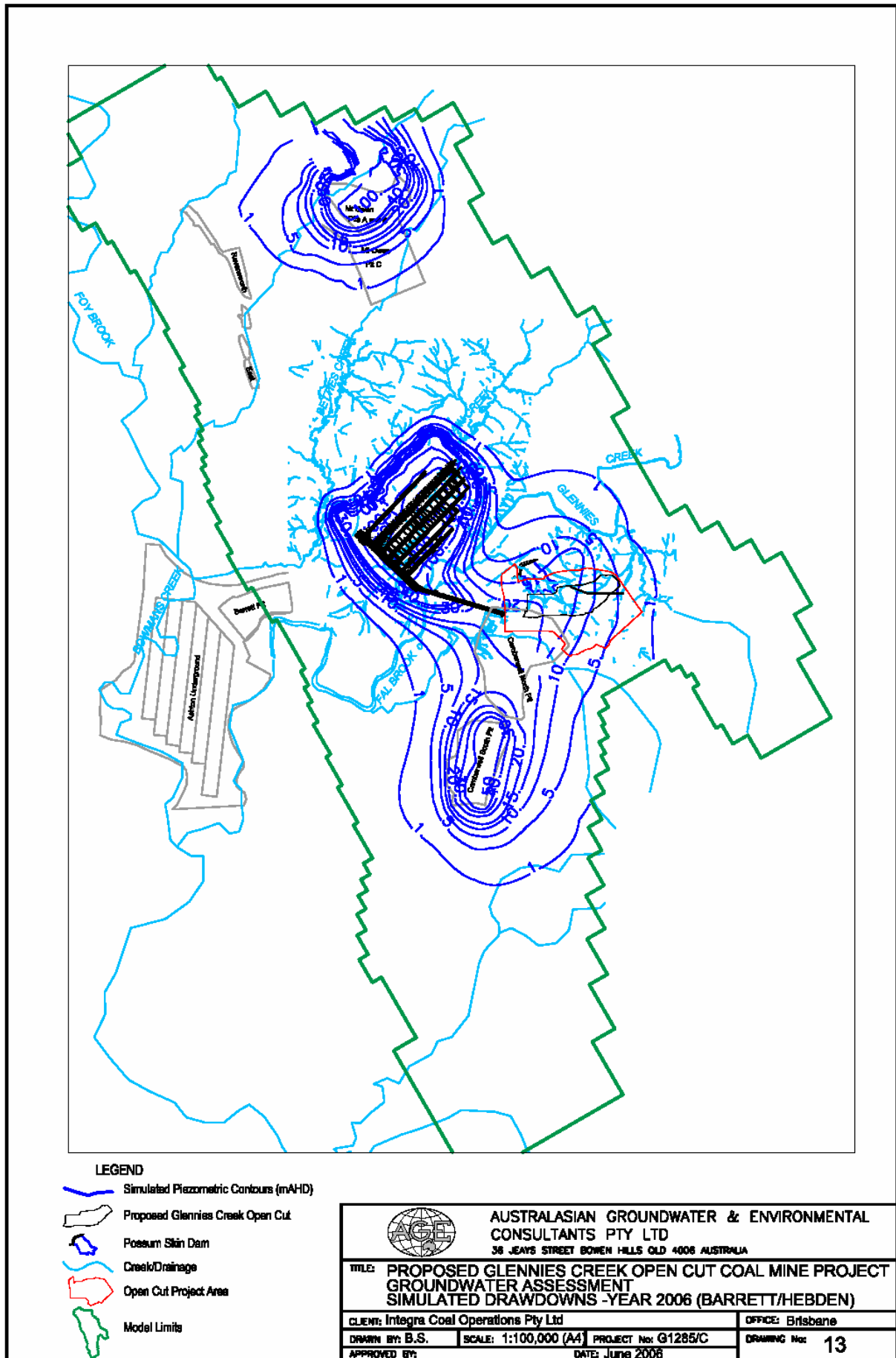
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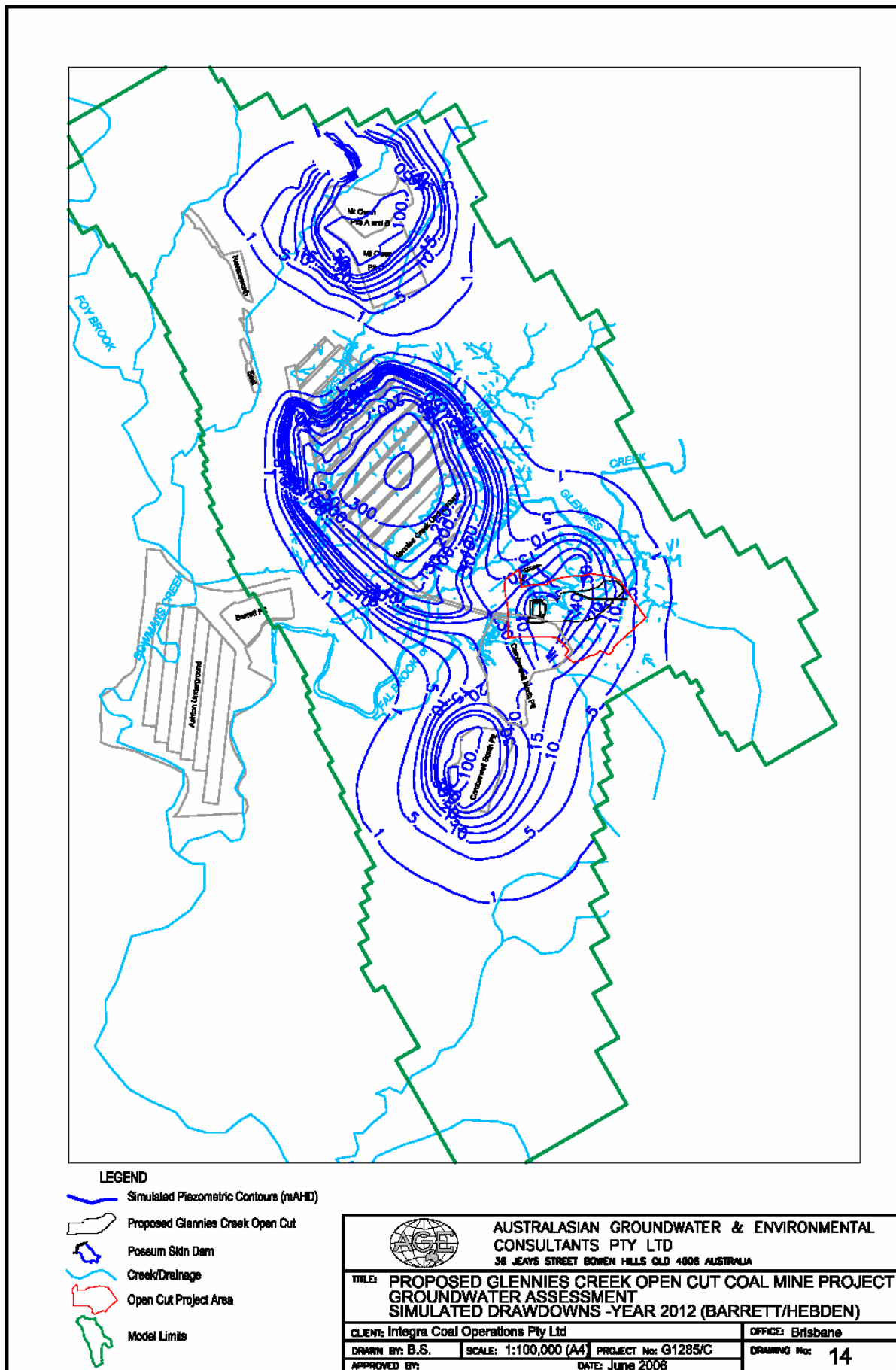
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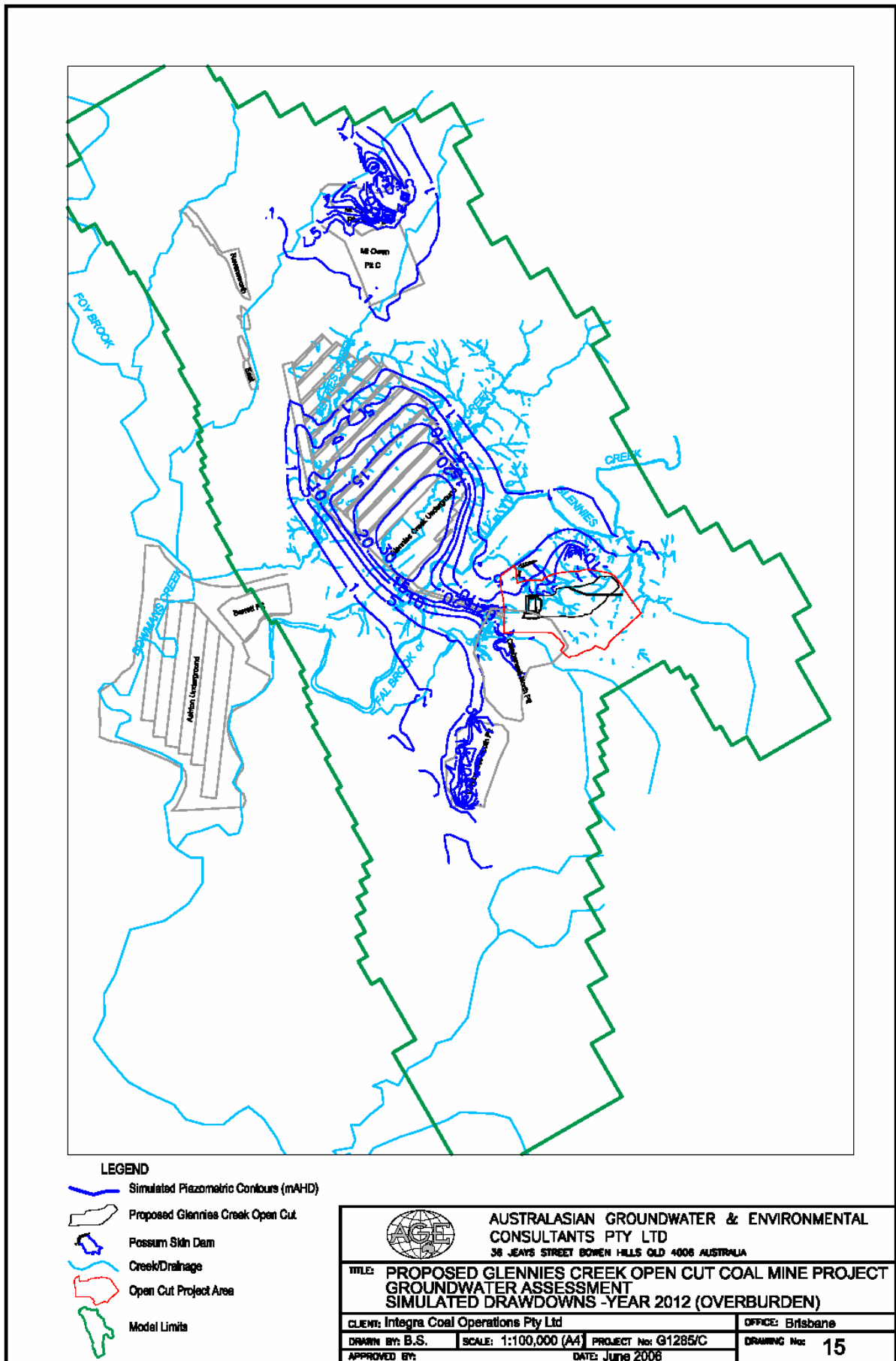












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APPENDICES

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Appendix 1	Groundwater Bore Logs and Geophysics*
Appendix 2	Pumping Test Analyses 10 hour (GCTB) and 48 hour (GC07) Tests*
Appendix 3	Falling Head Test Analyses 10 hour (GCTB) and 48 hour (GC07) Tests*
Appendix 4	DIPNR Registered Groundwater Facilities*
Appendix 5	Bore Census Data
Appendix 6	Glossary of Hydrogeological Terms

*** Included on CD Only**

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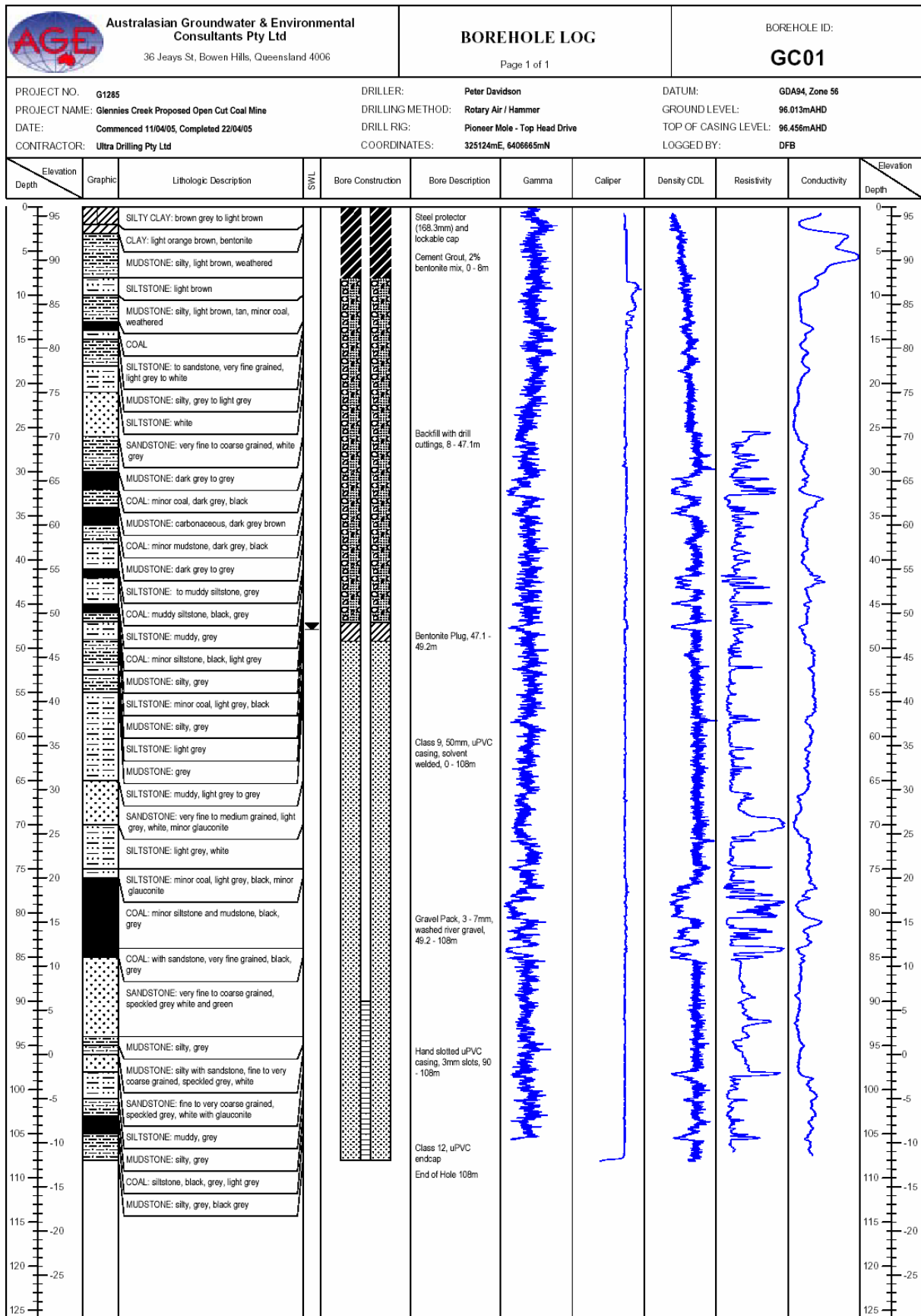
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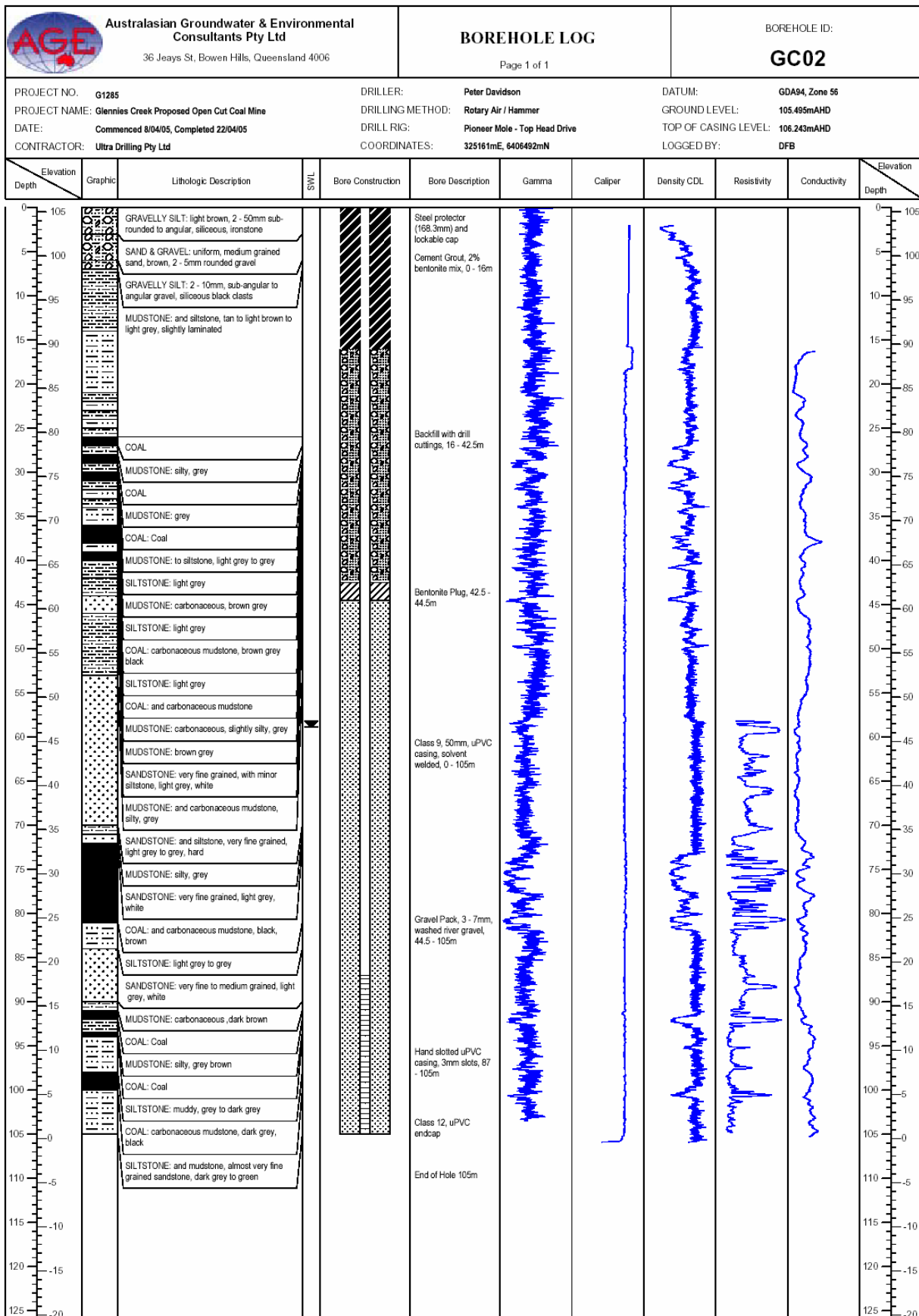
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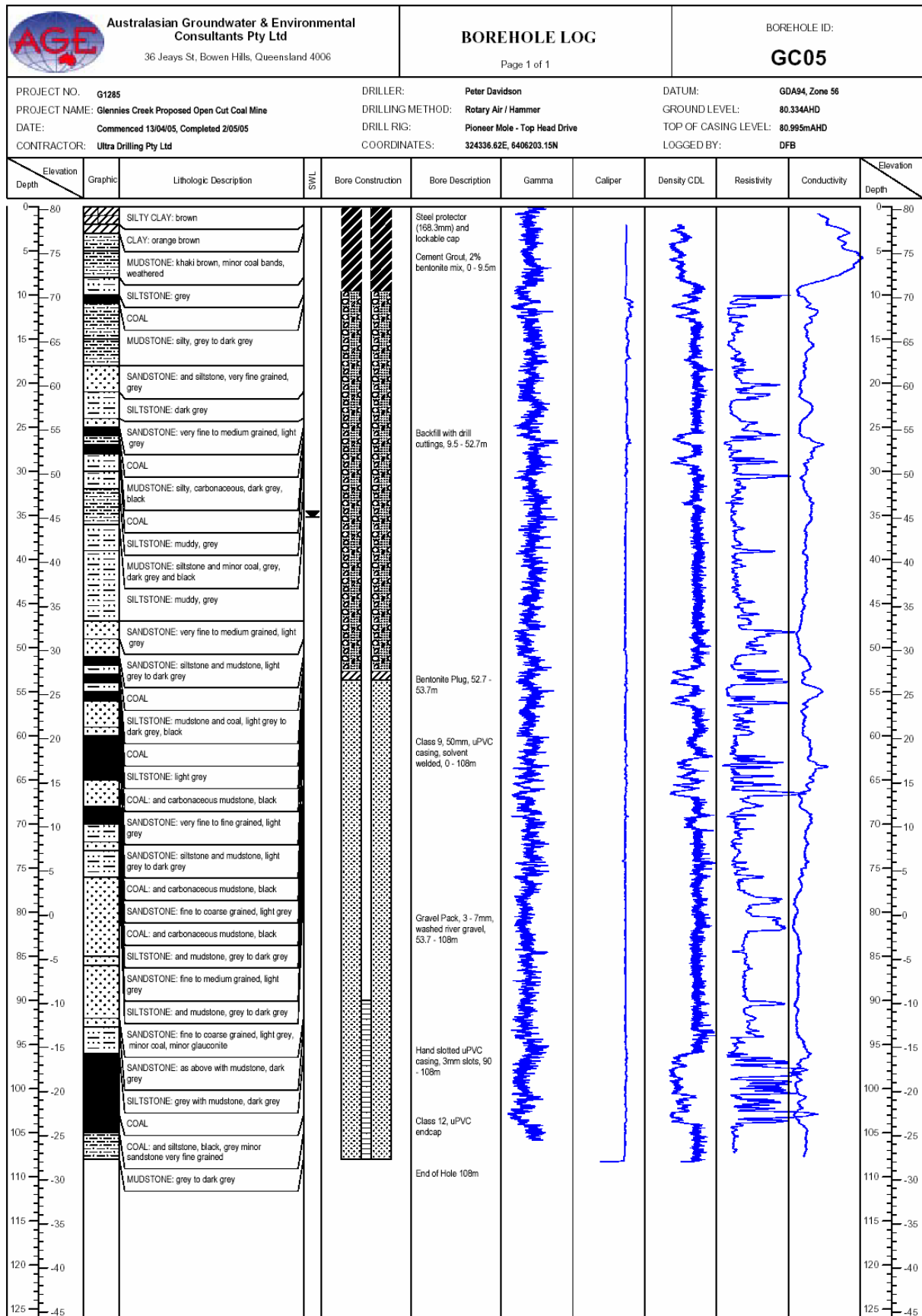
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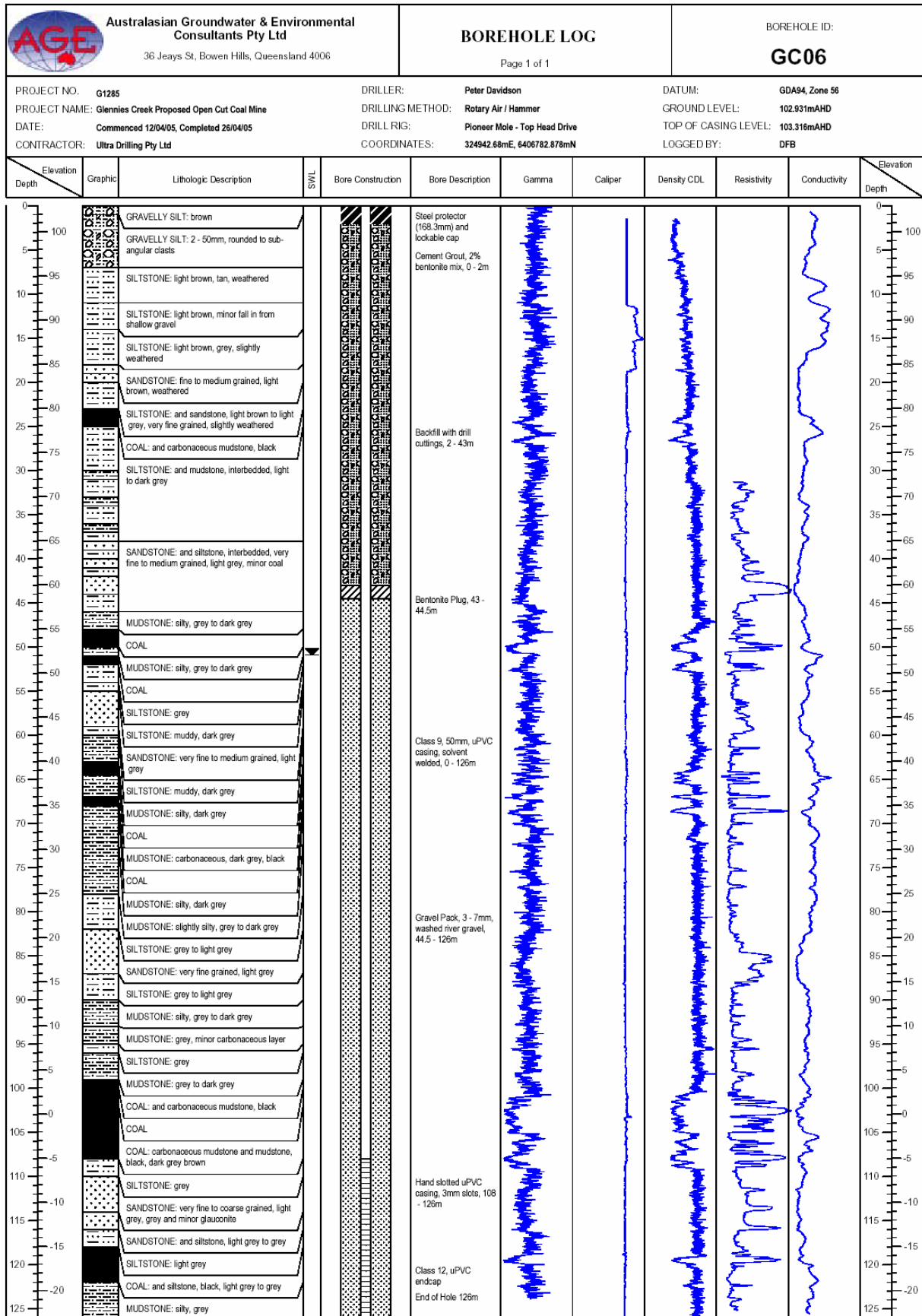
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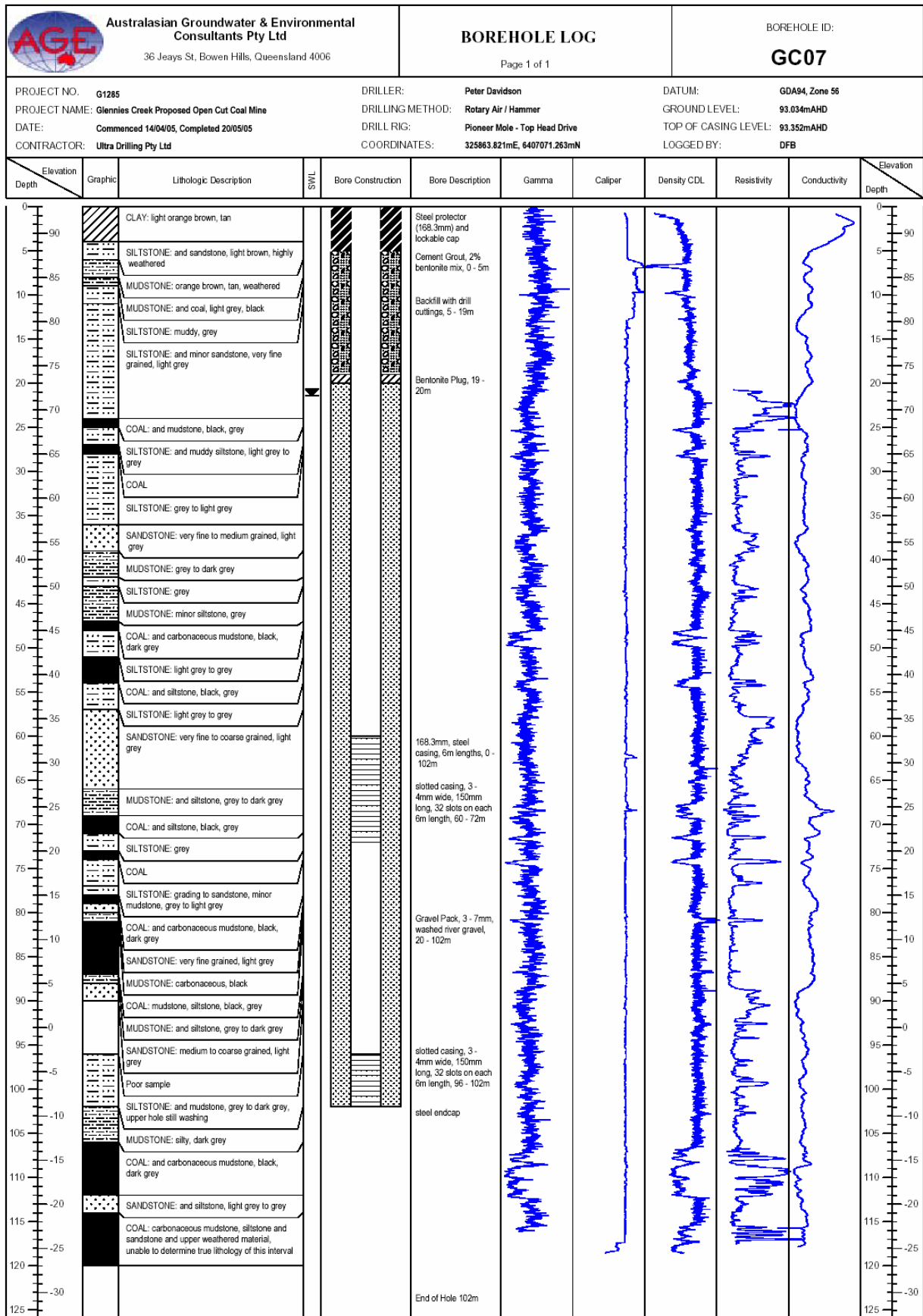
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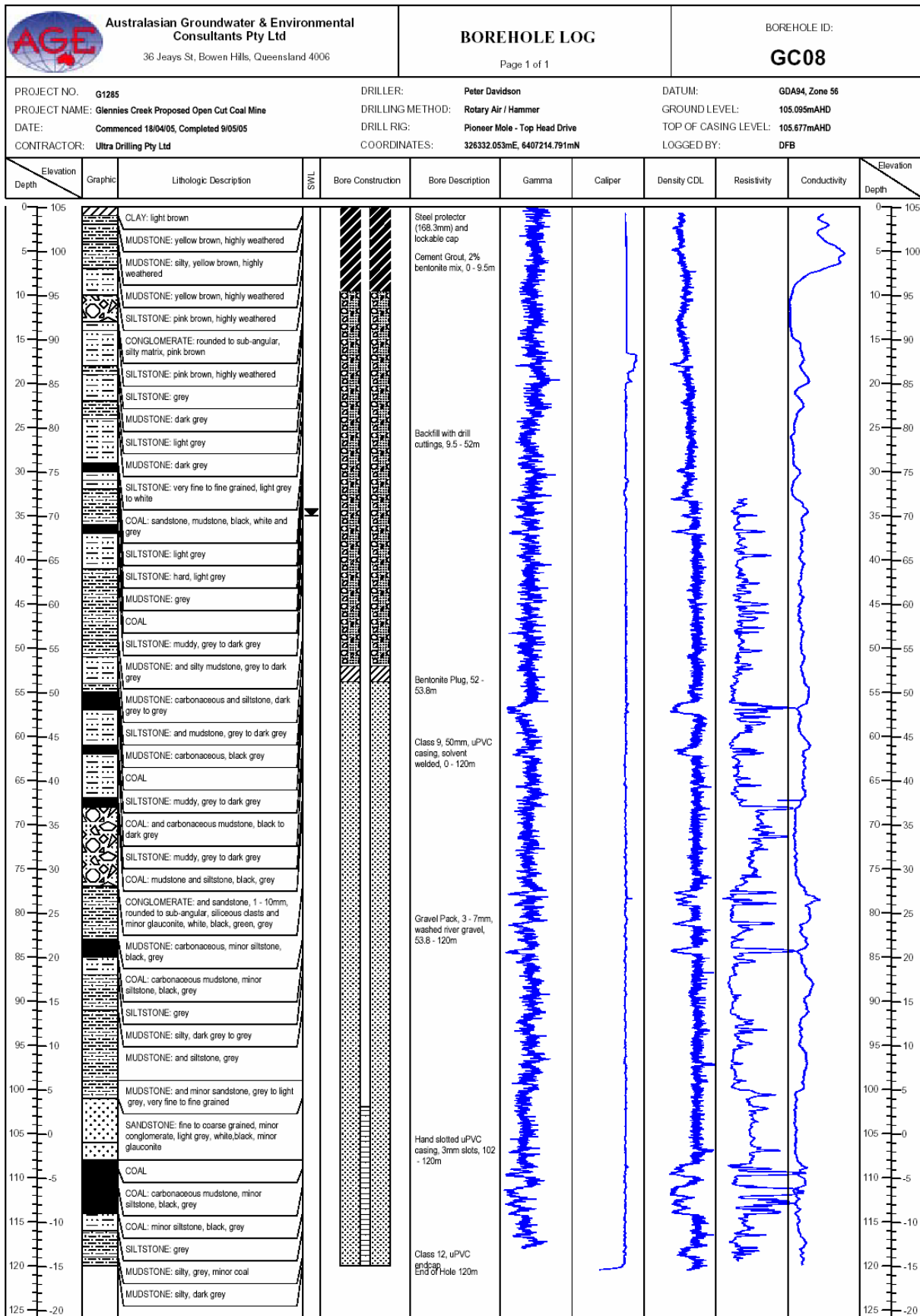


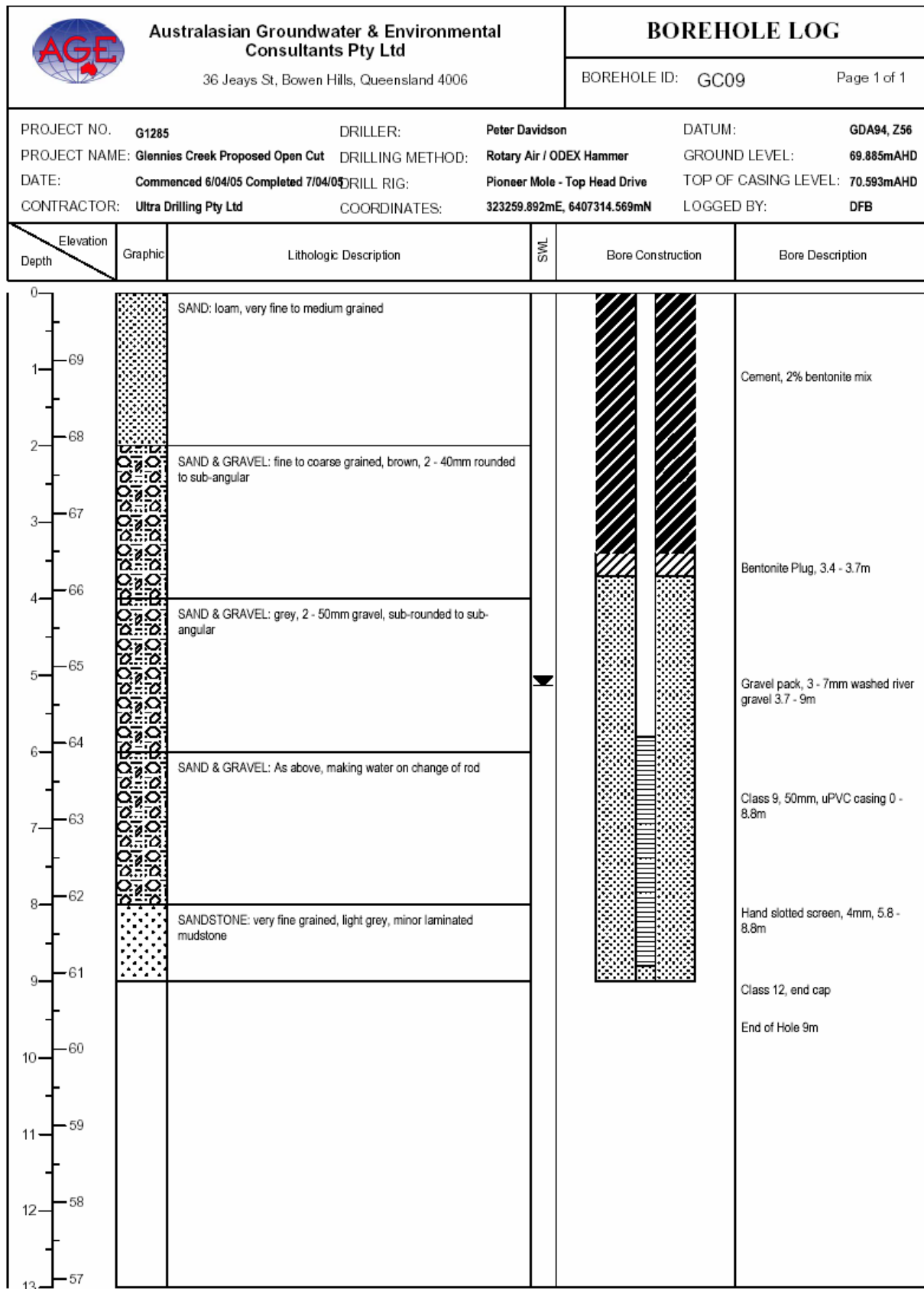


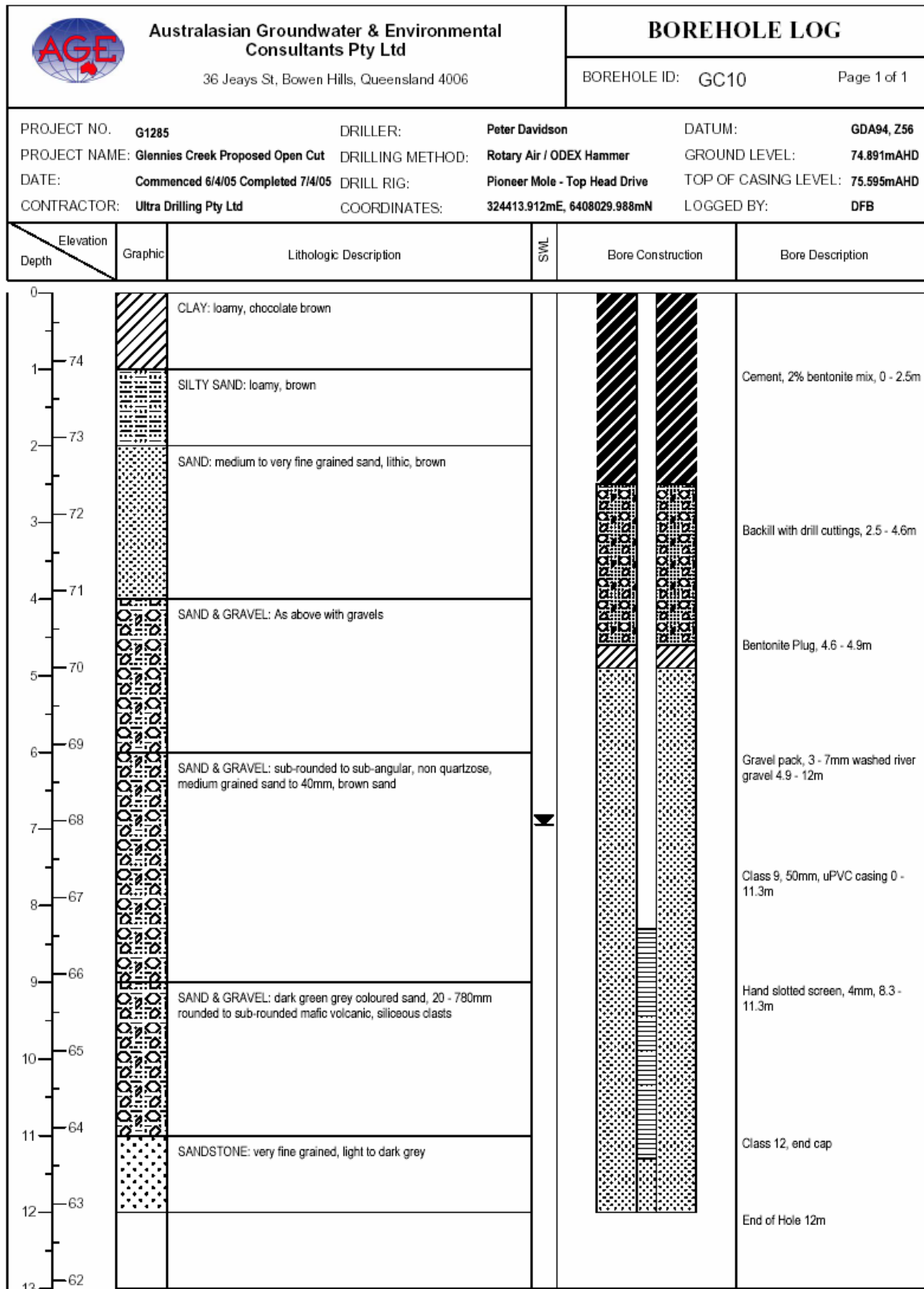


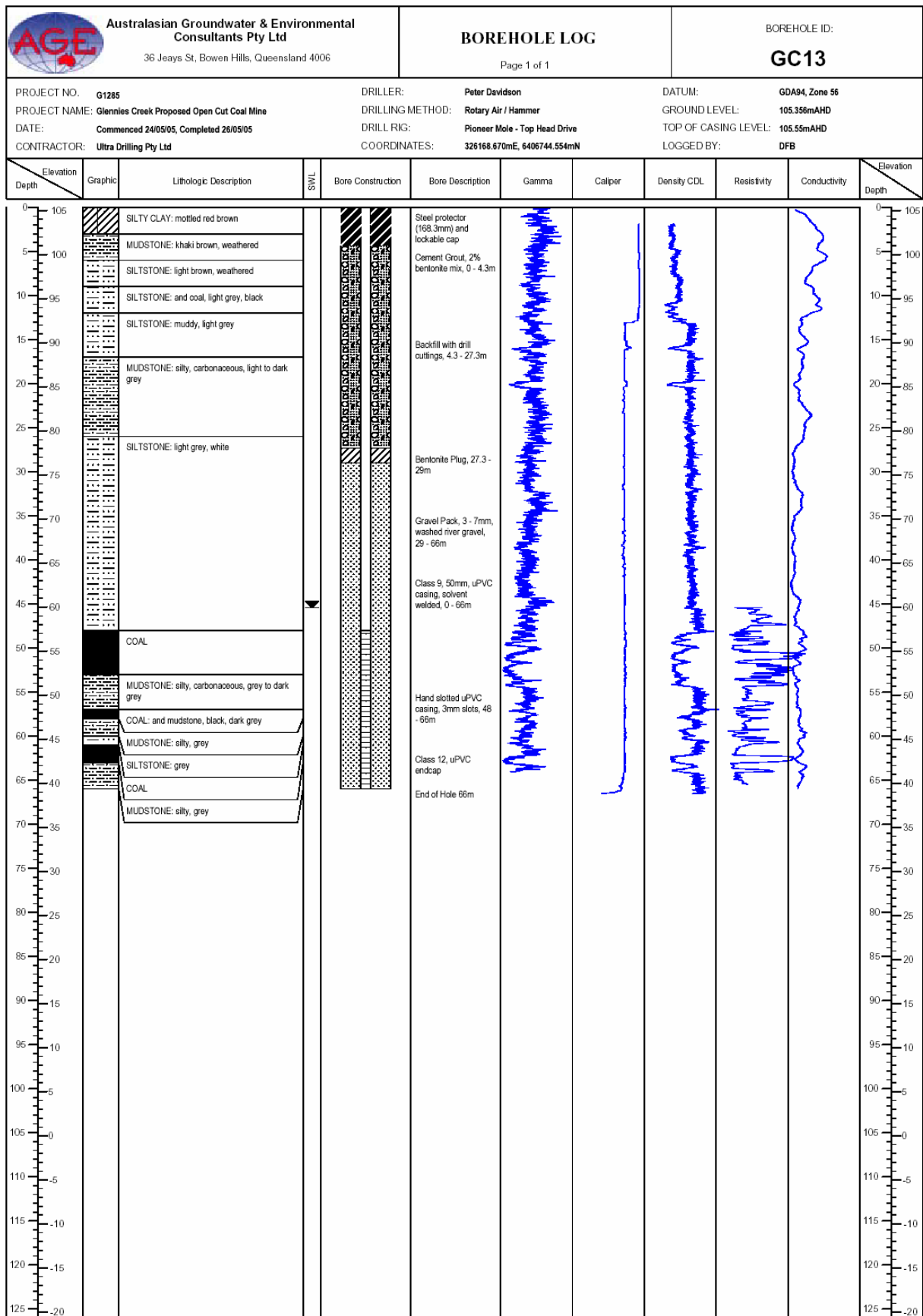


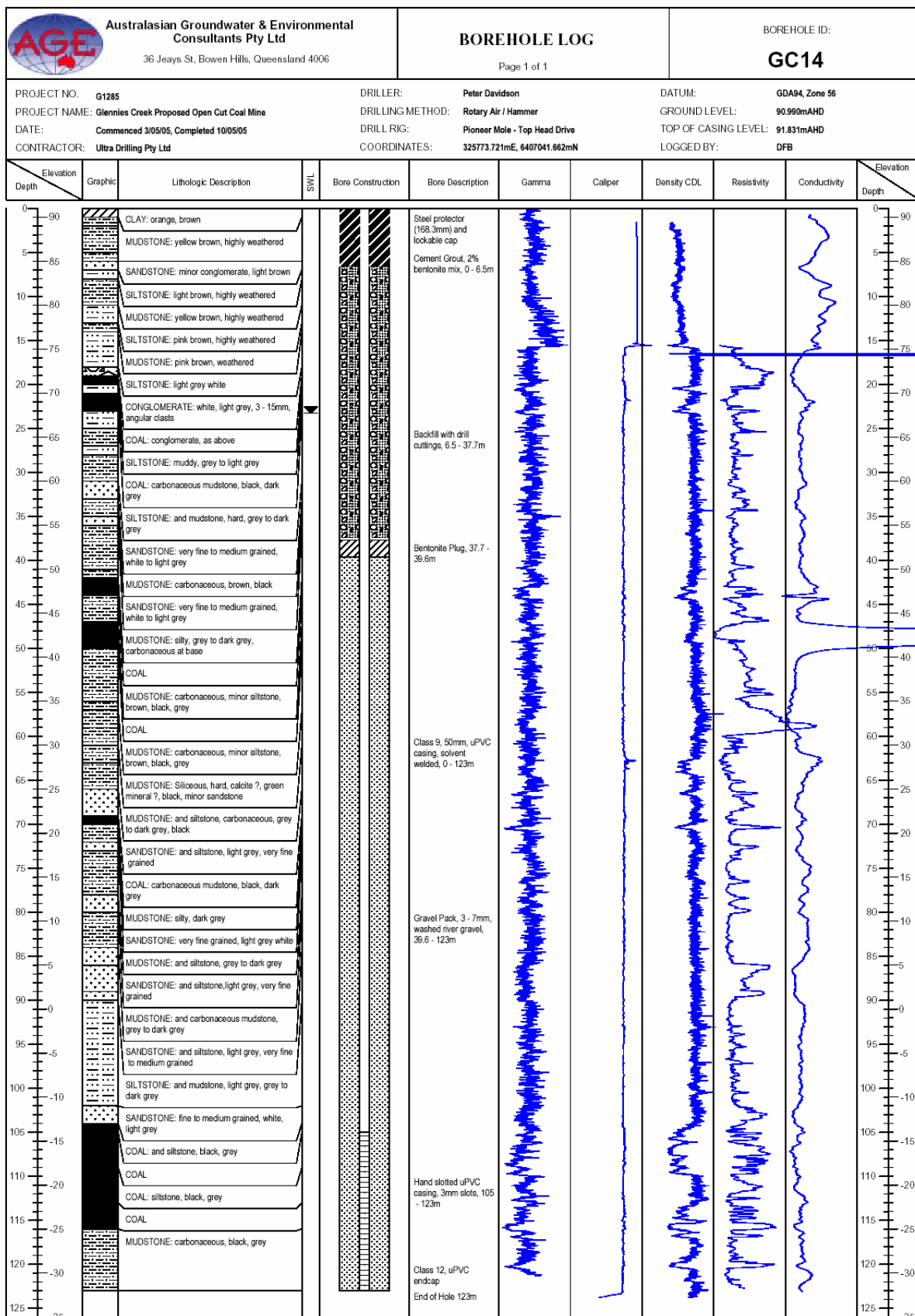


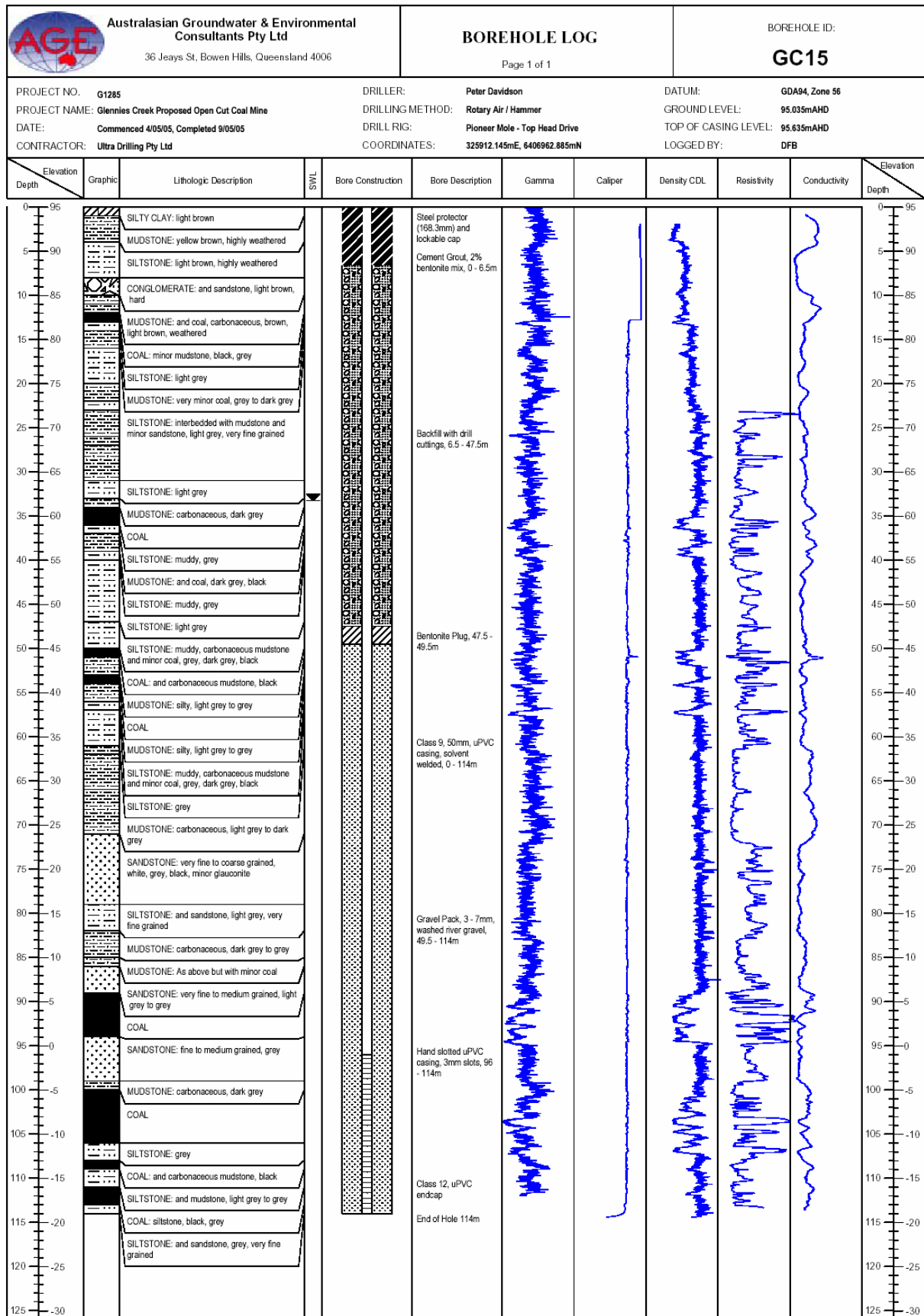


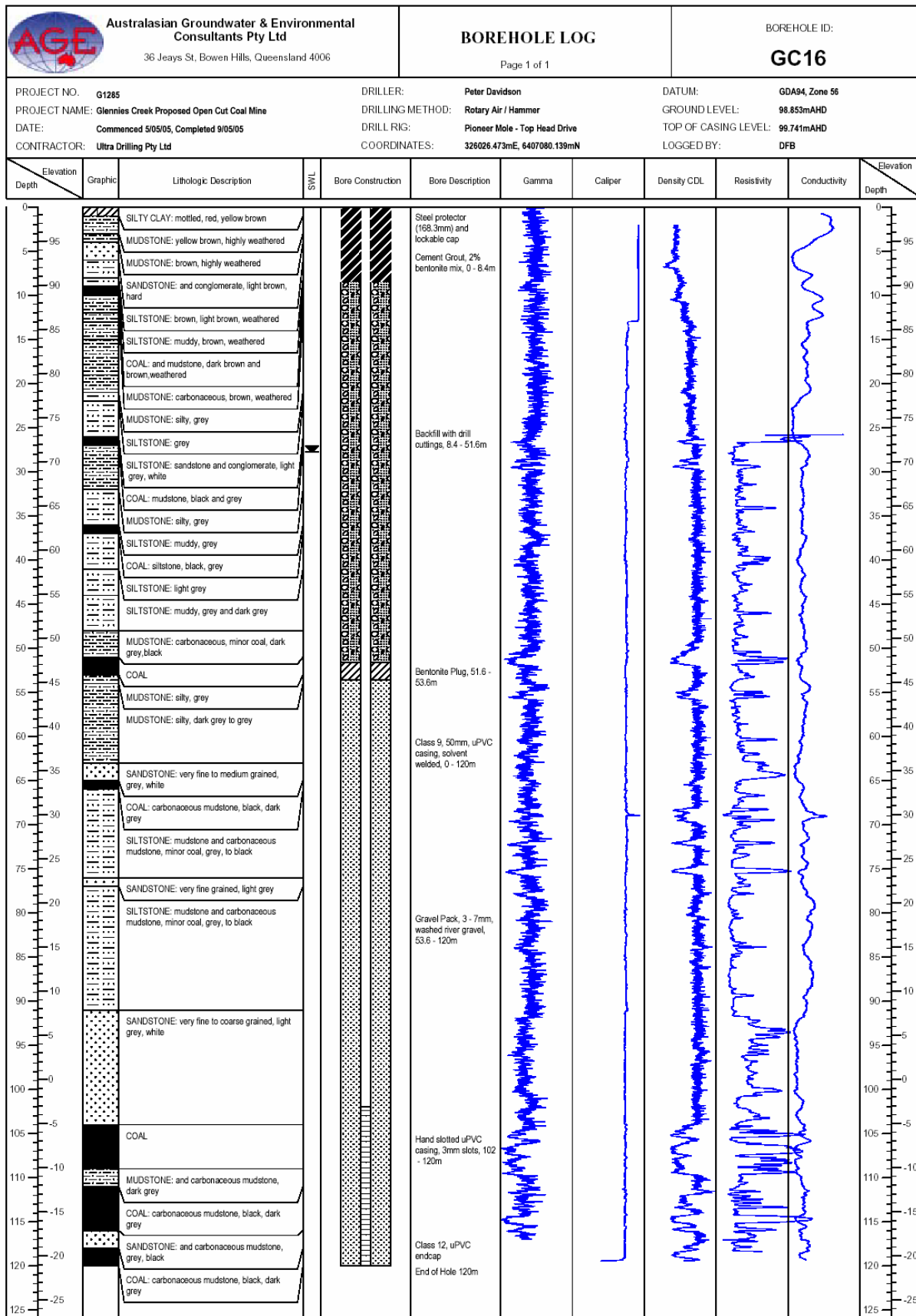


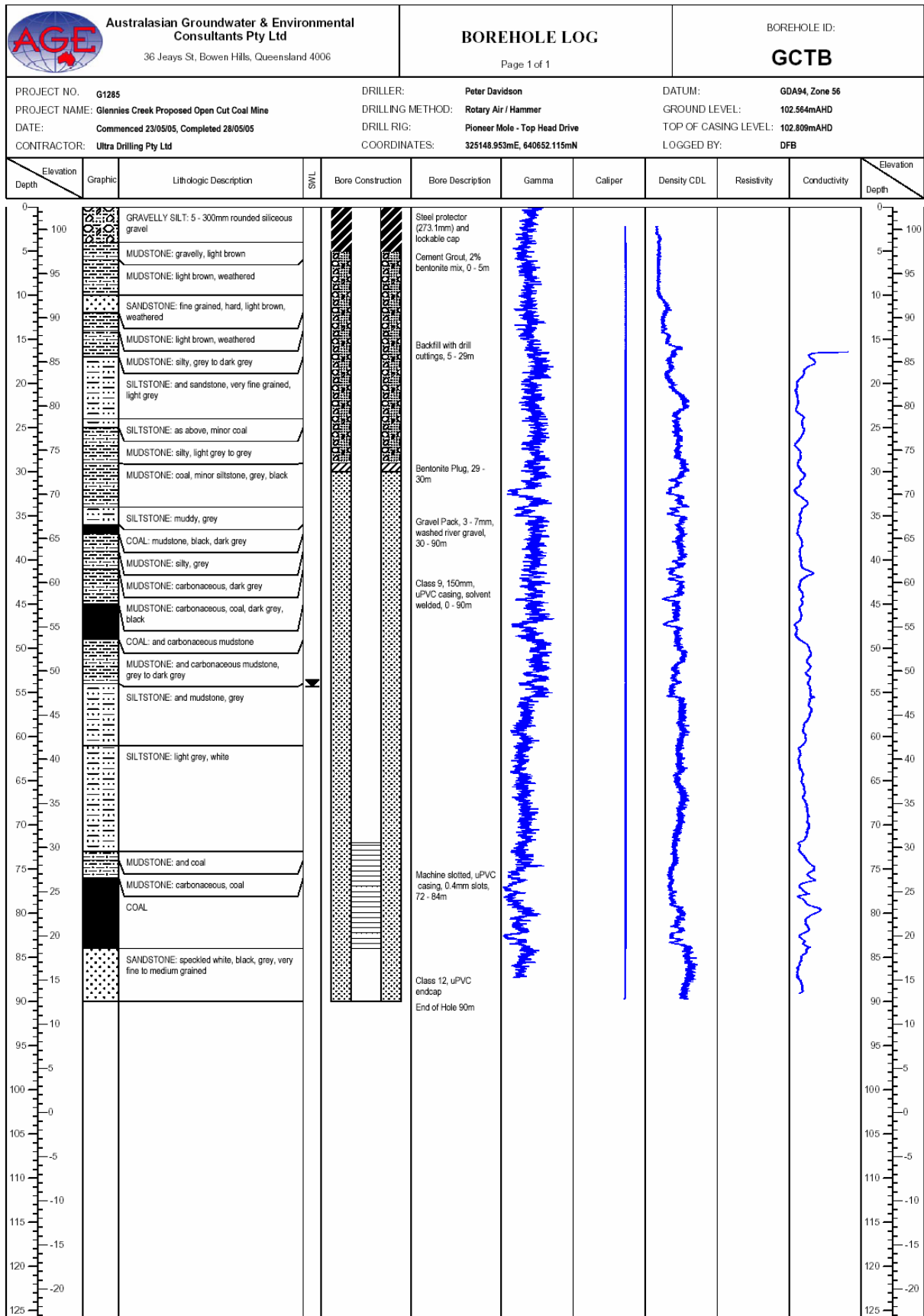












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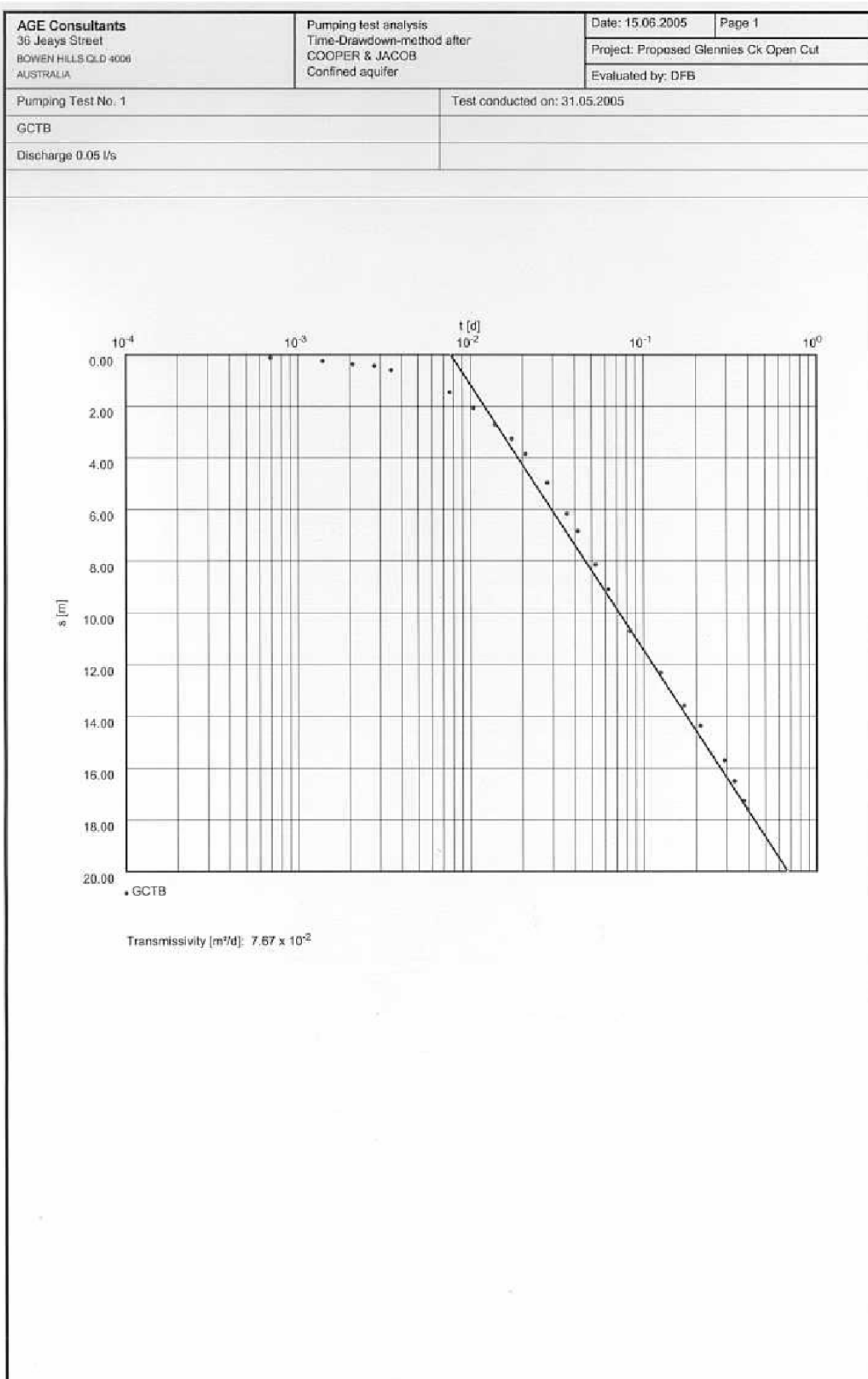
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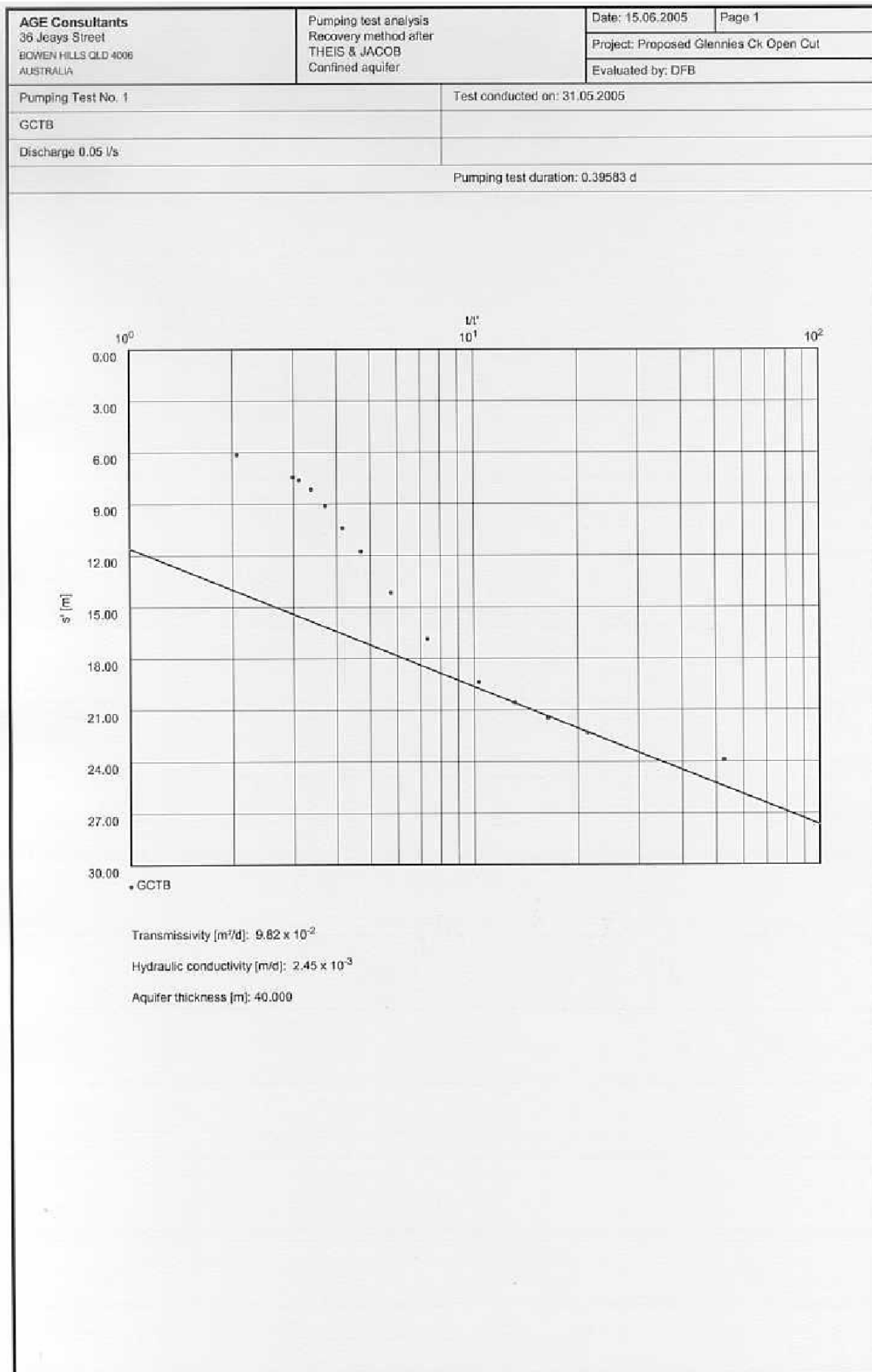
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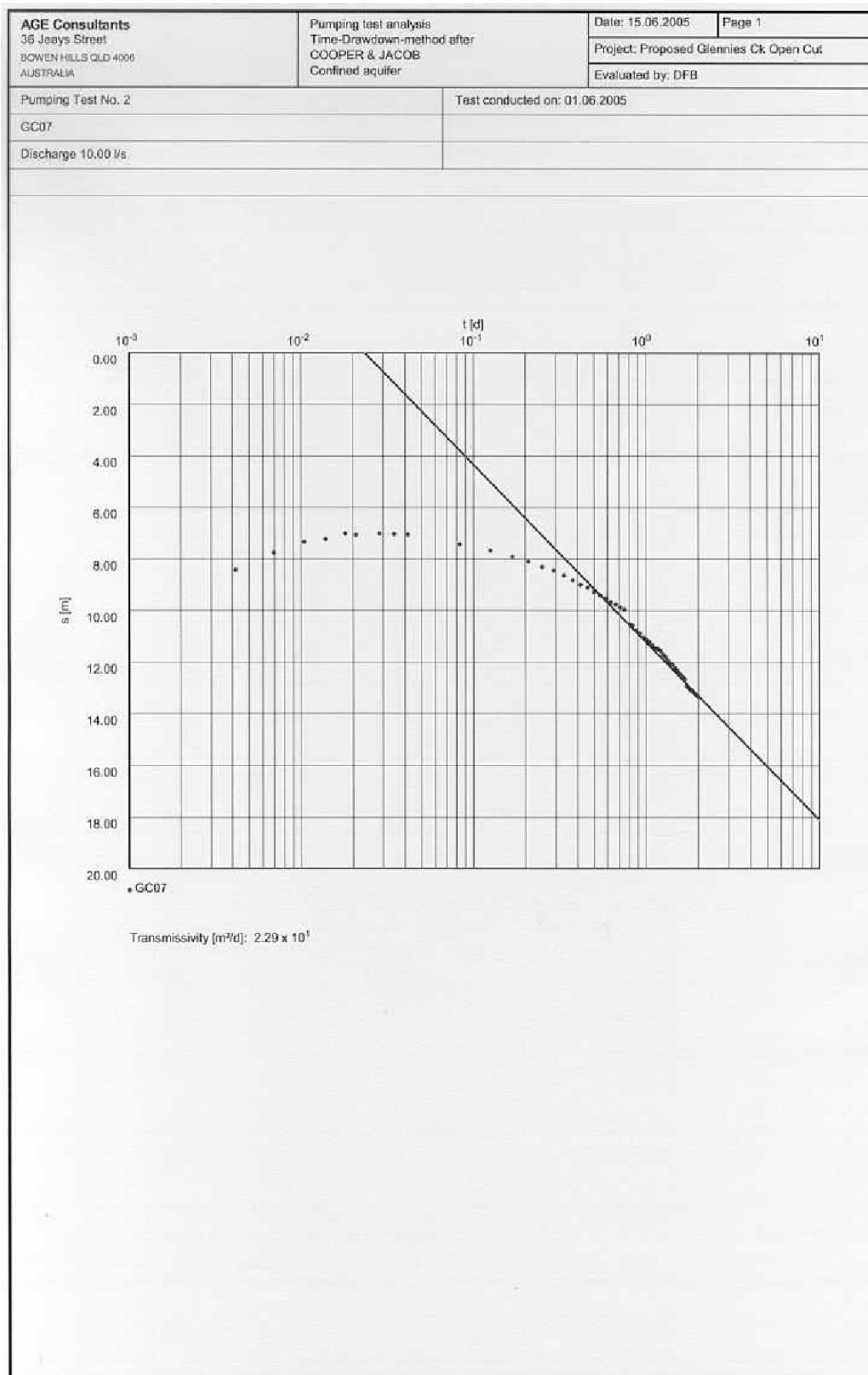
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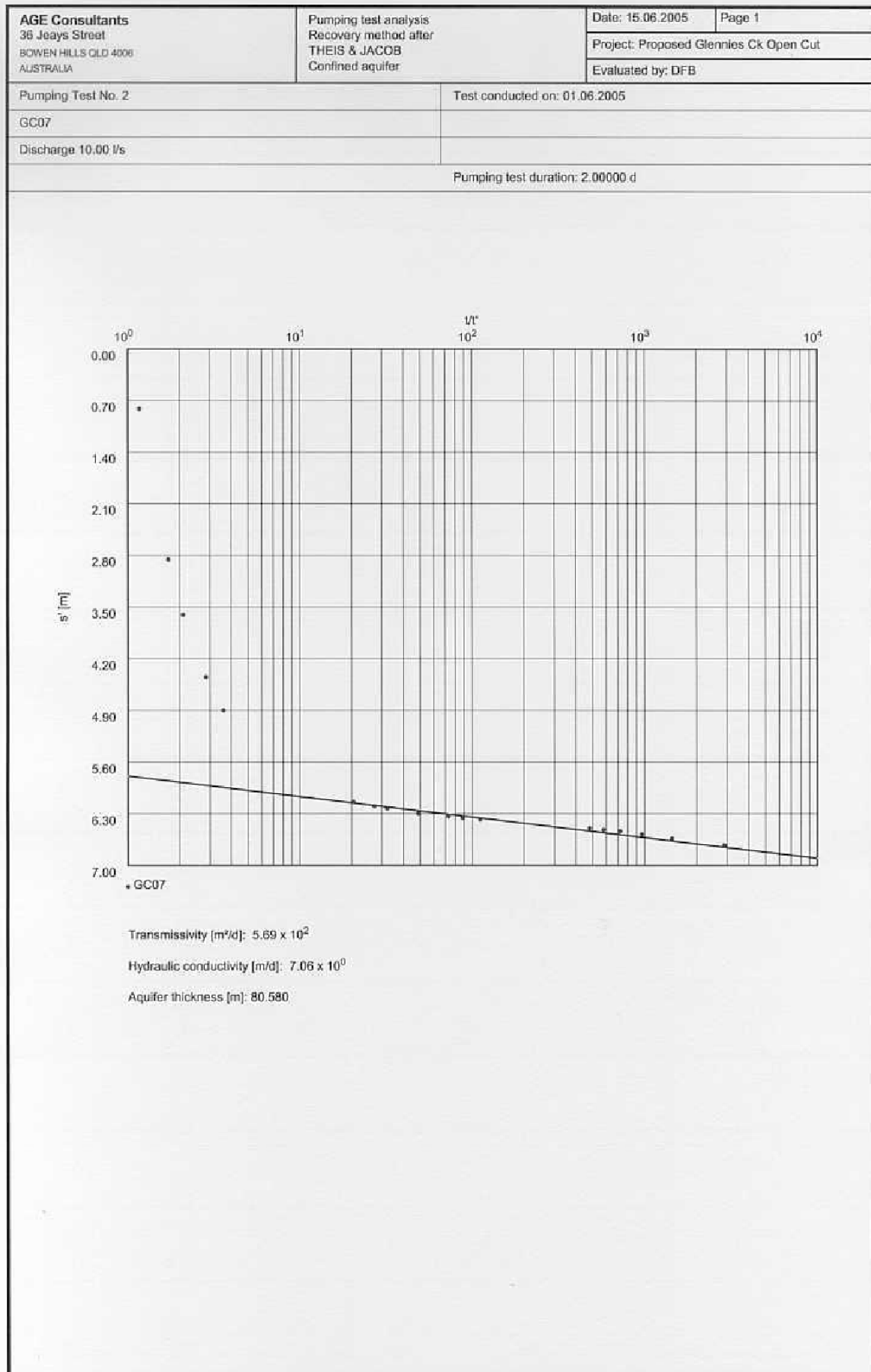
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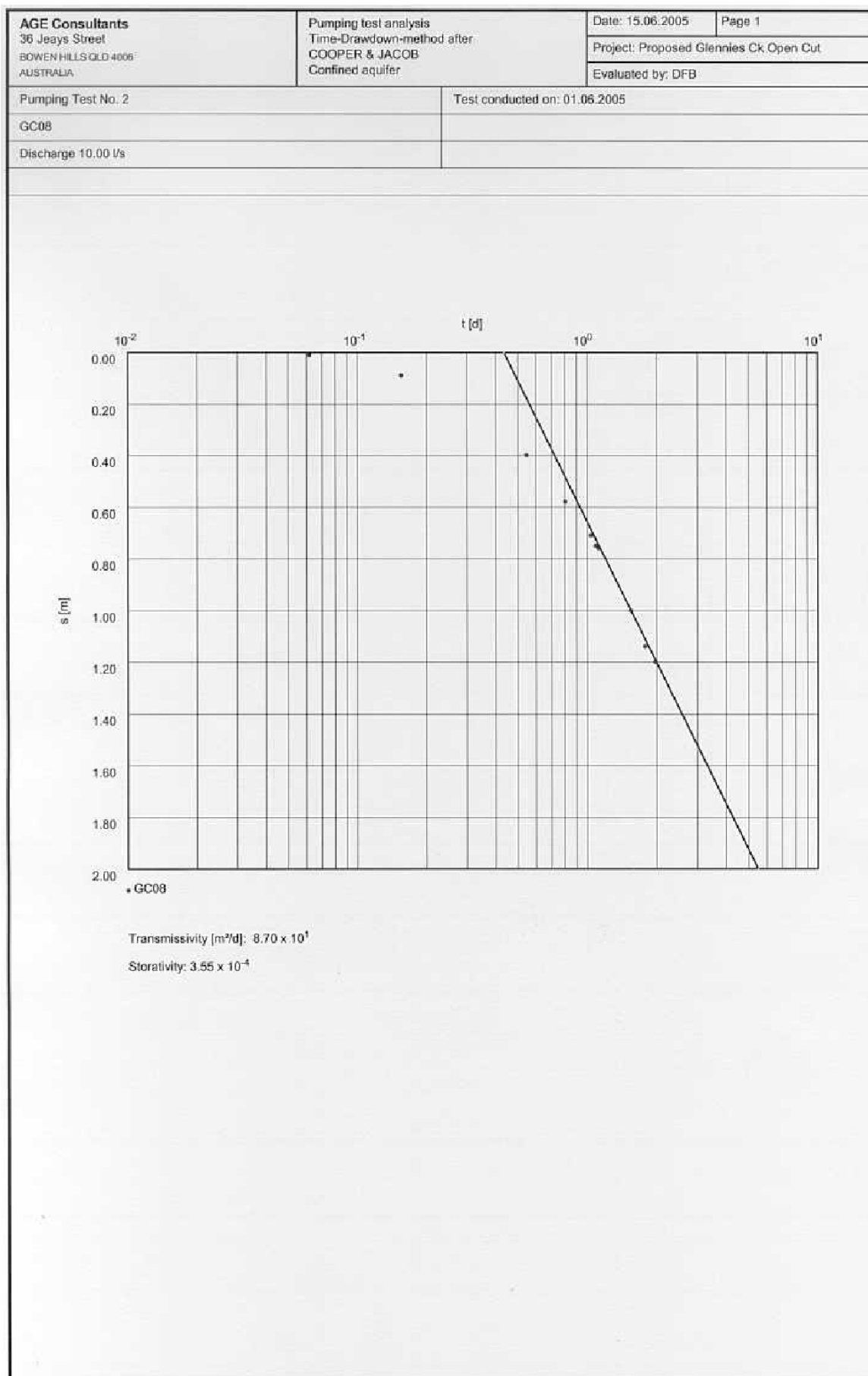
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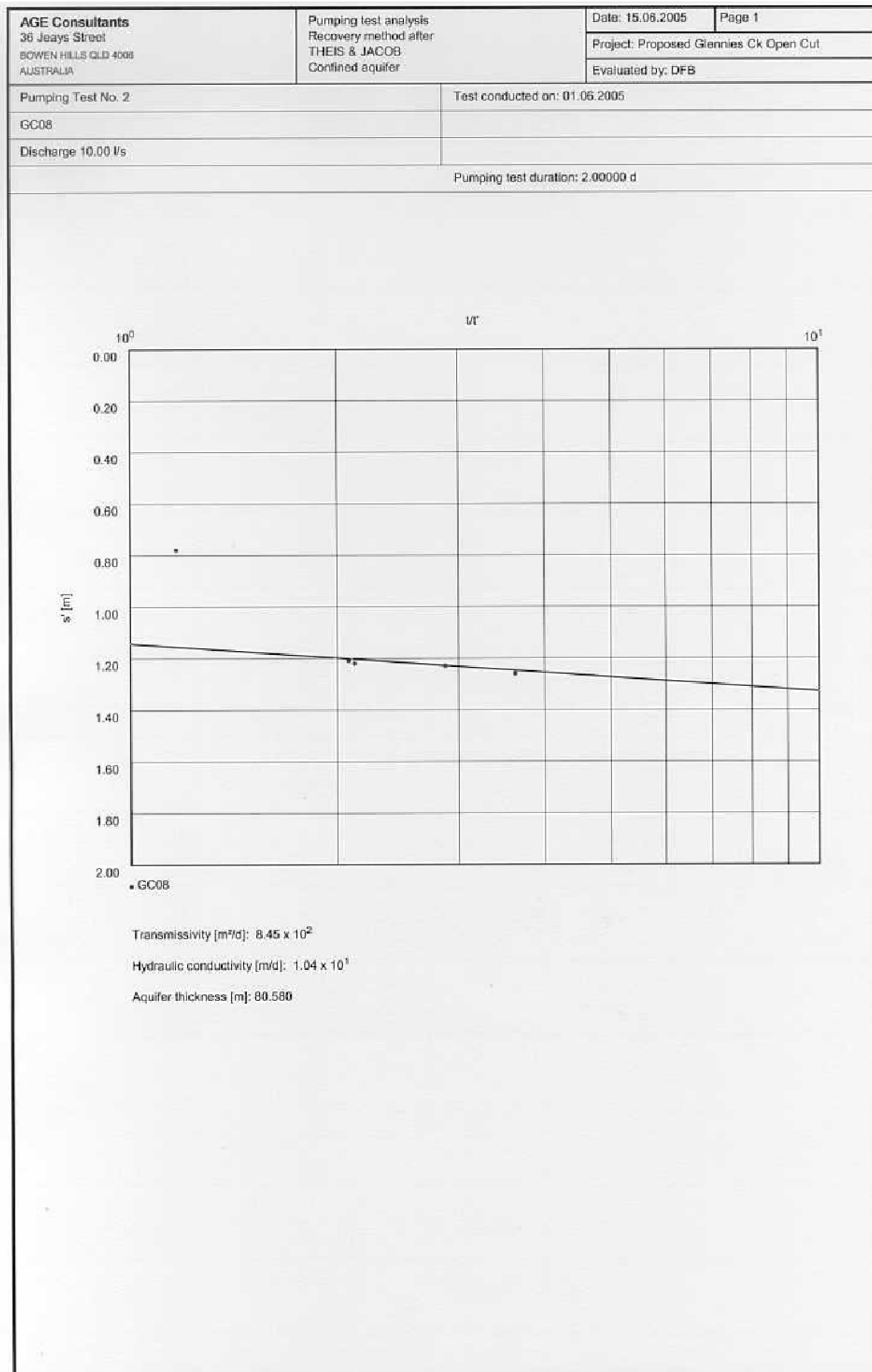


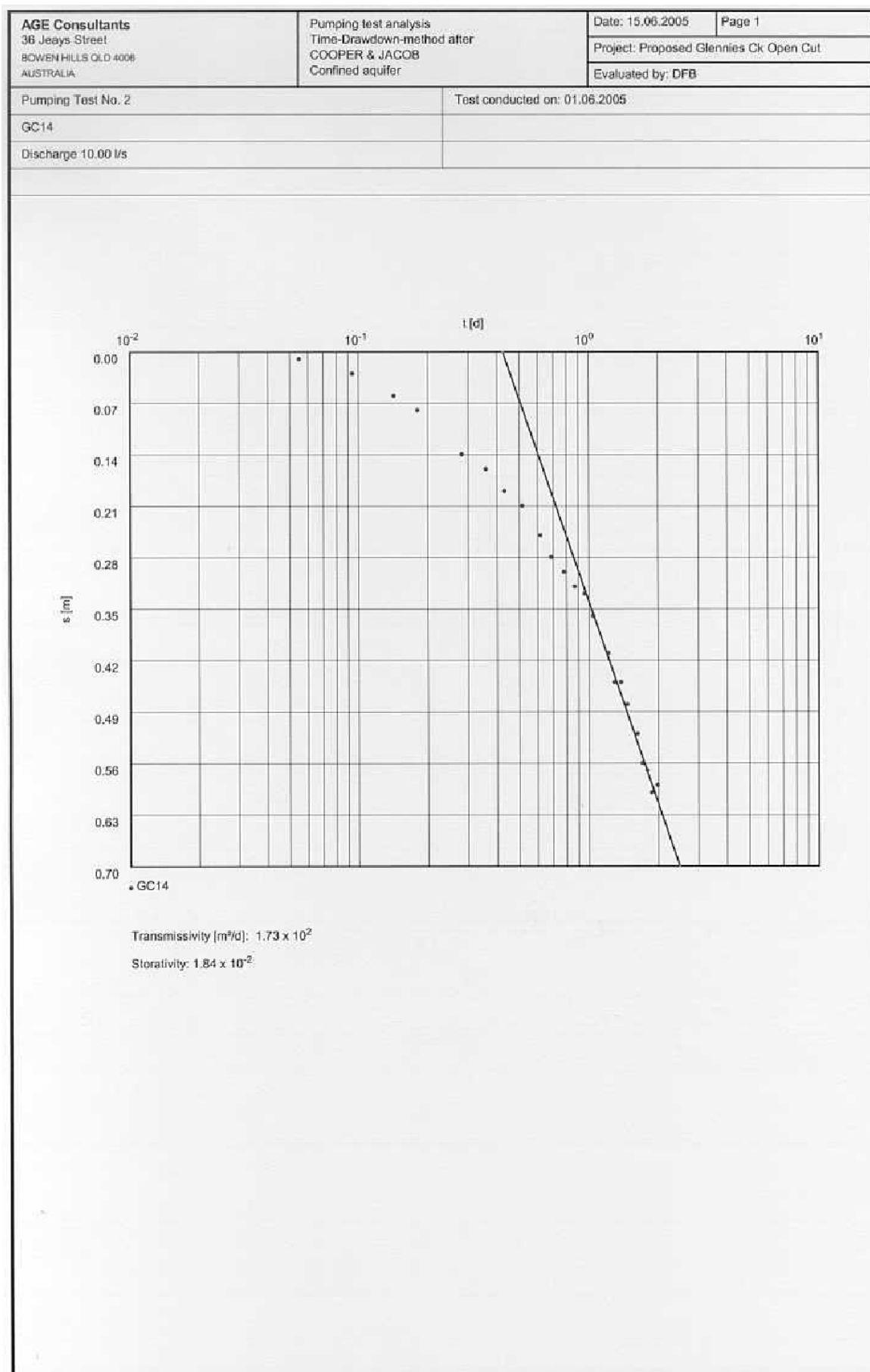


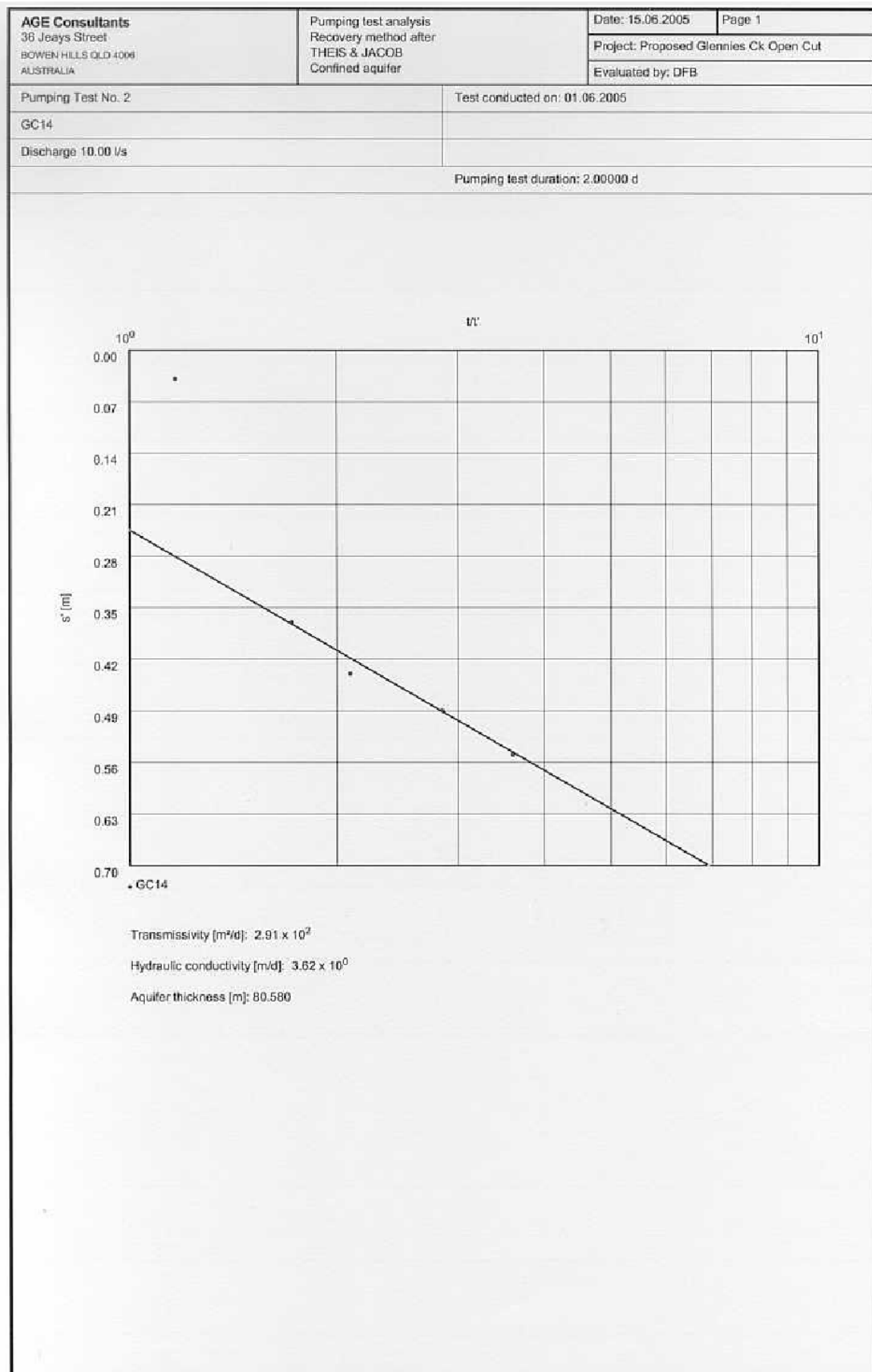


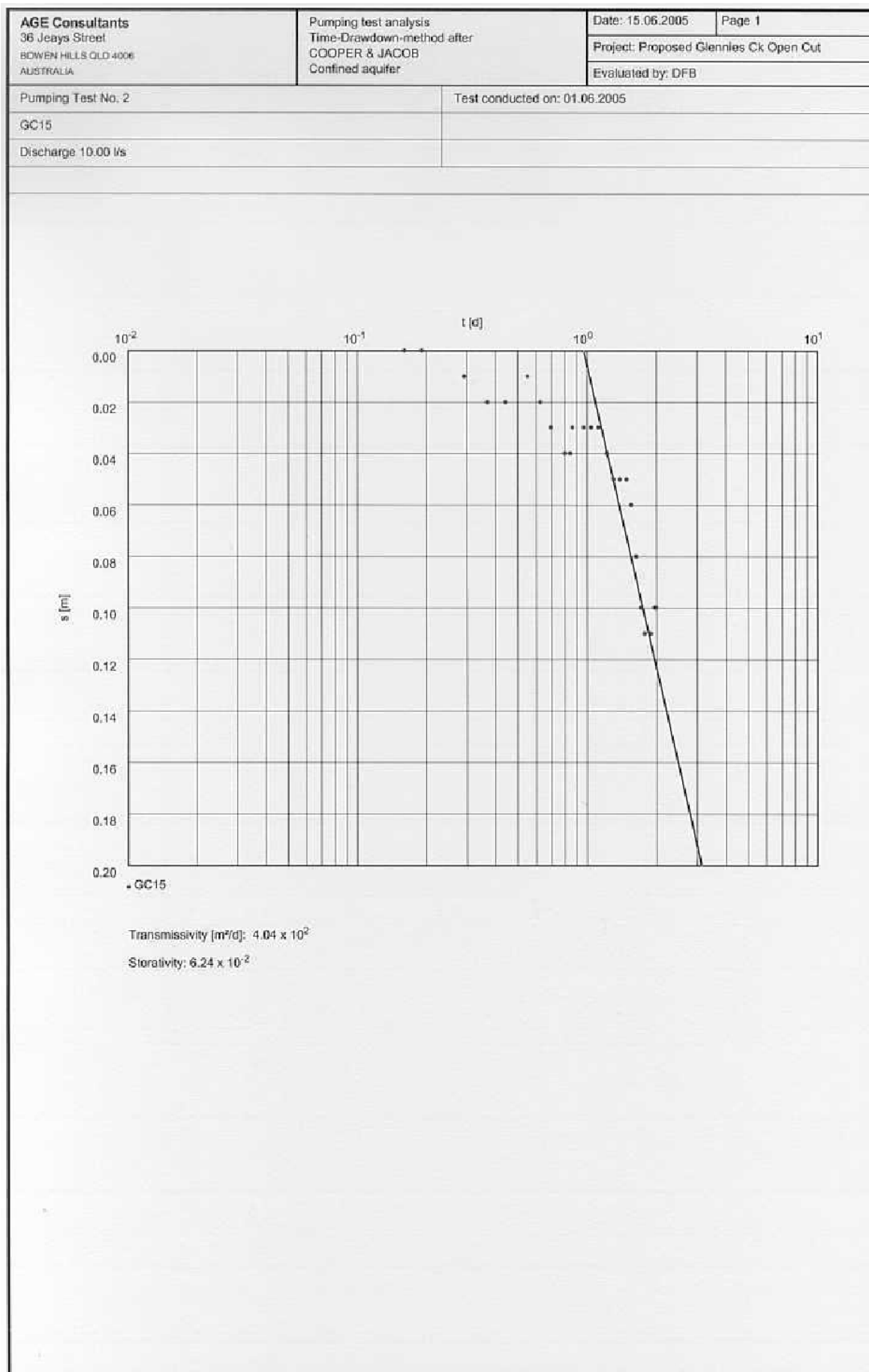


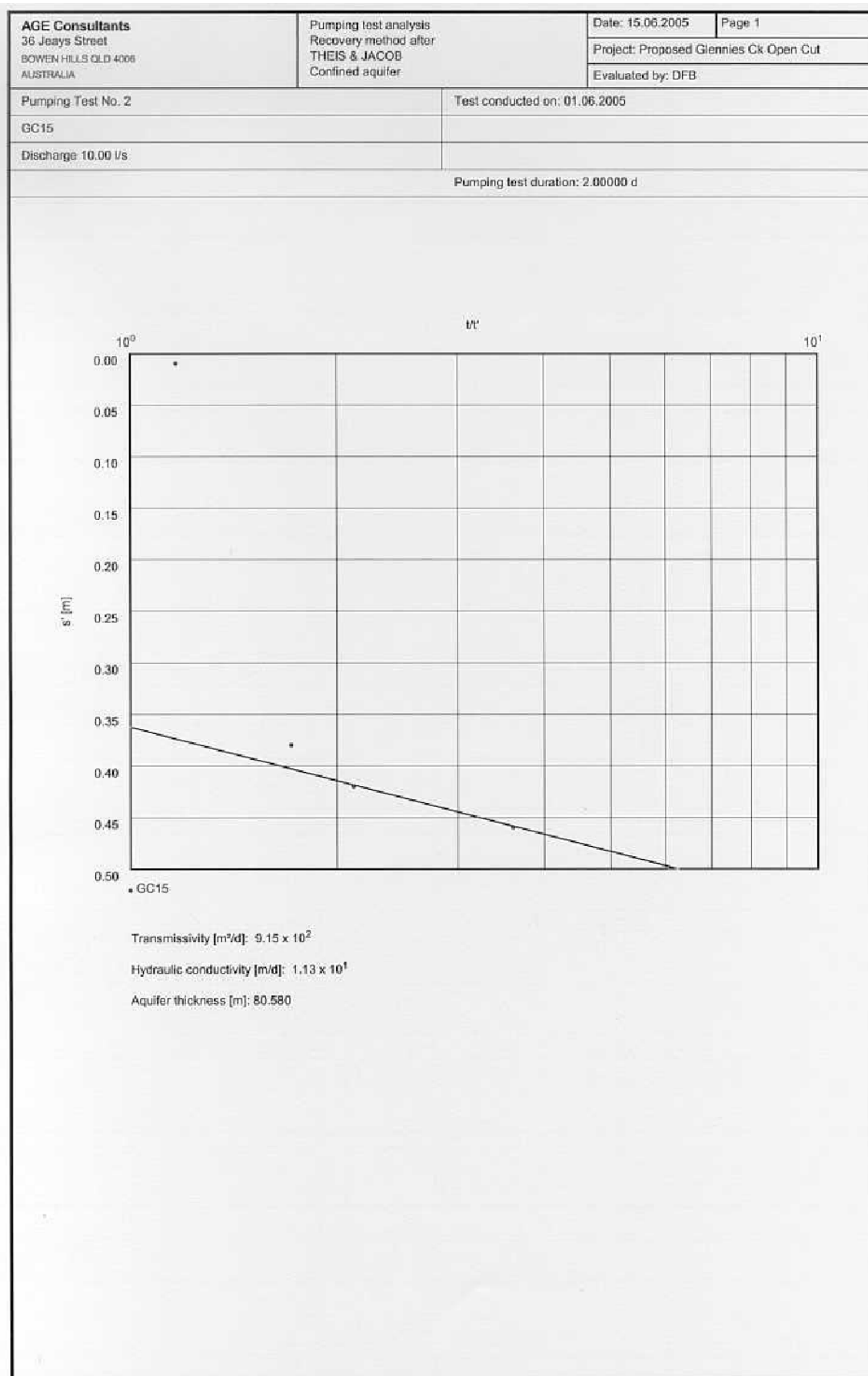


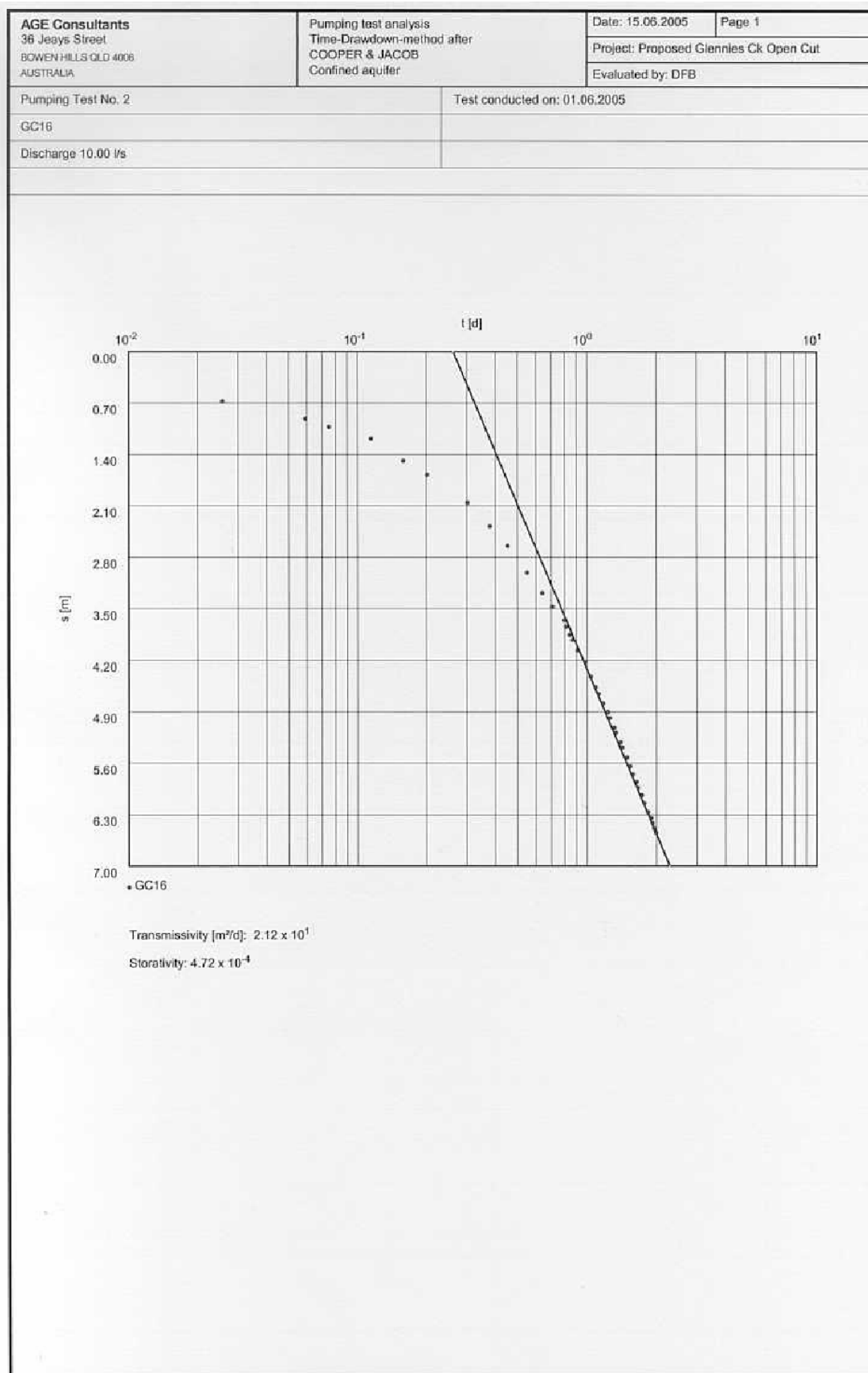


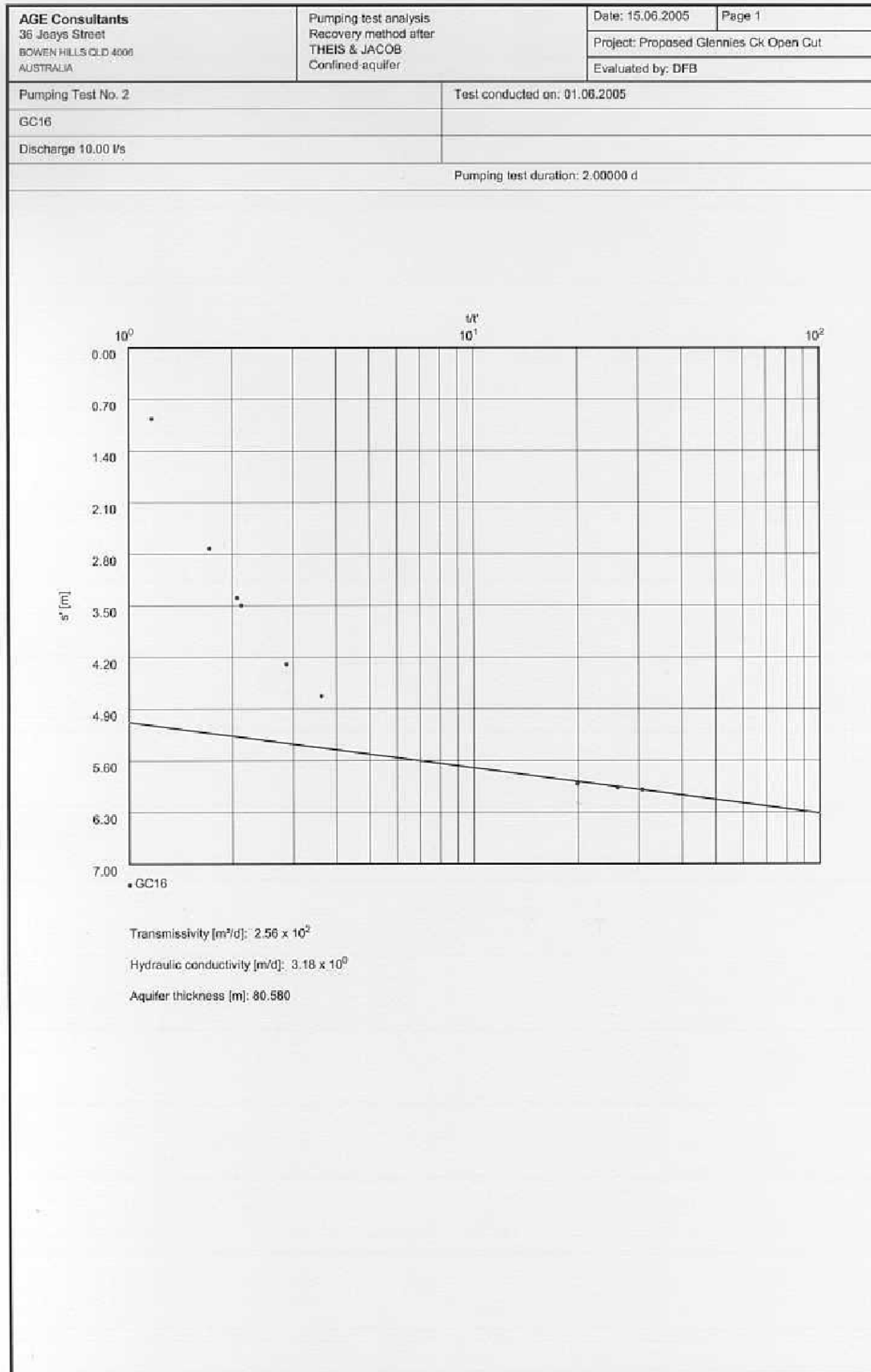












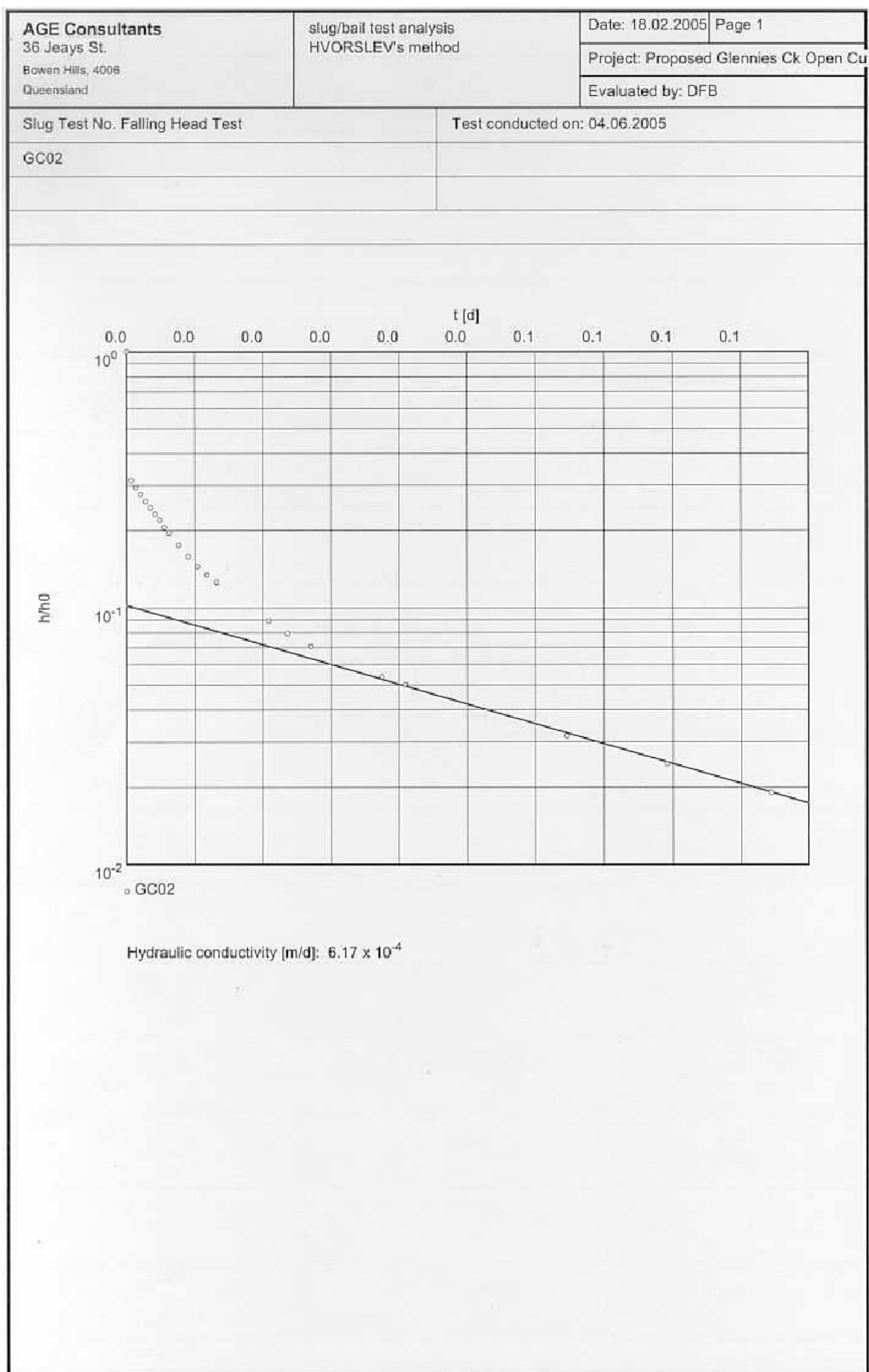
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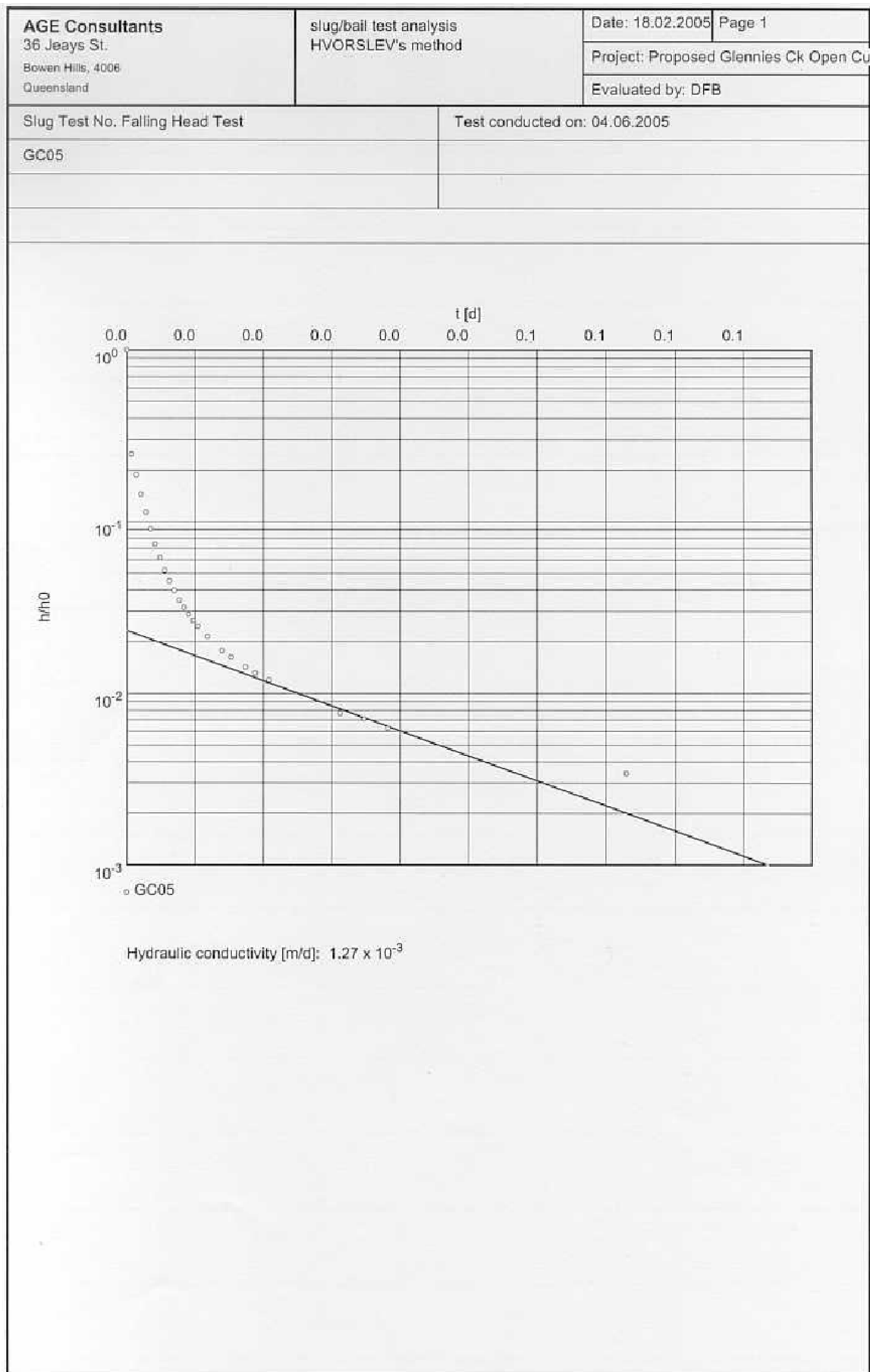
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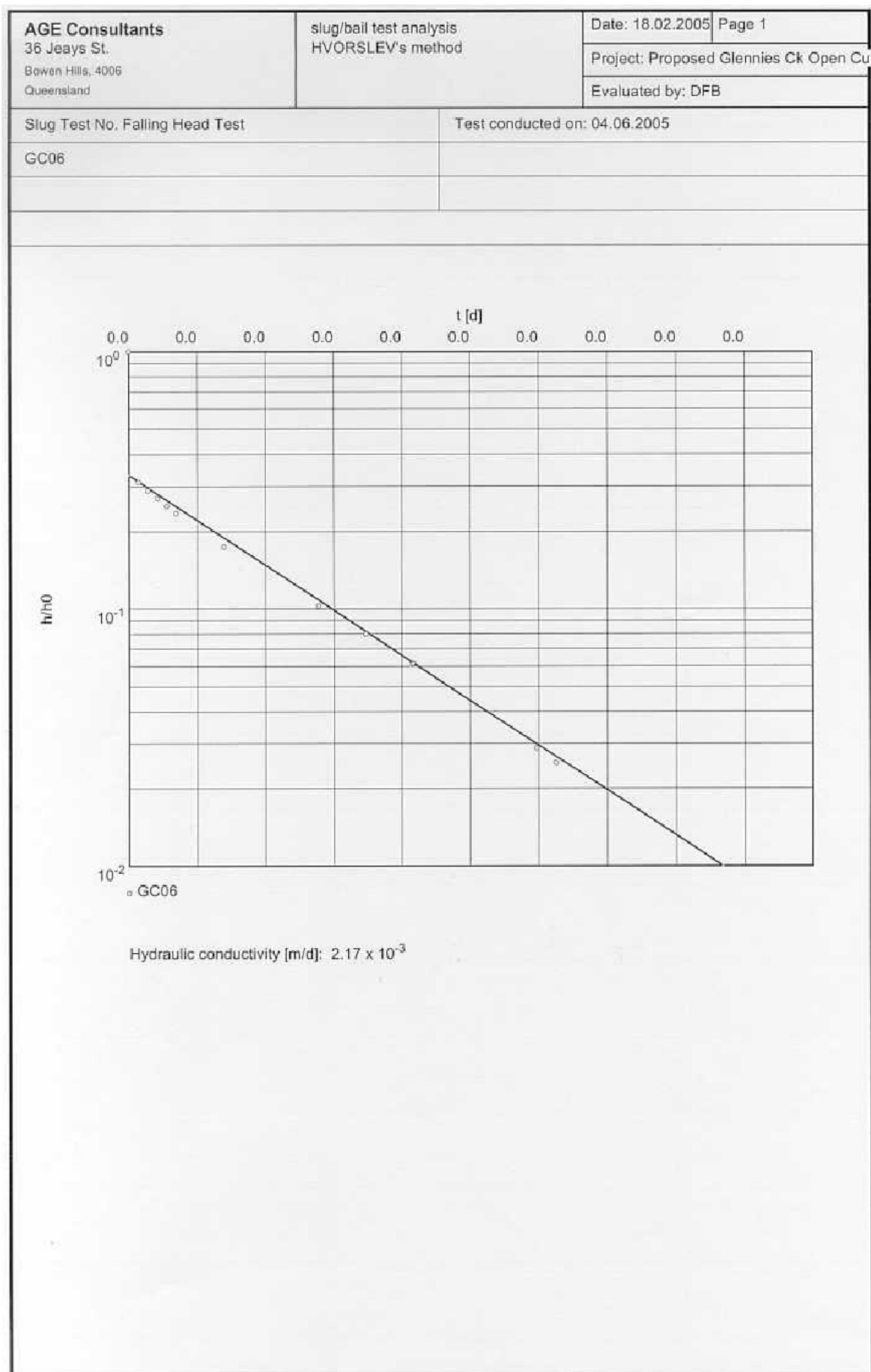
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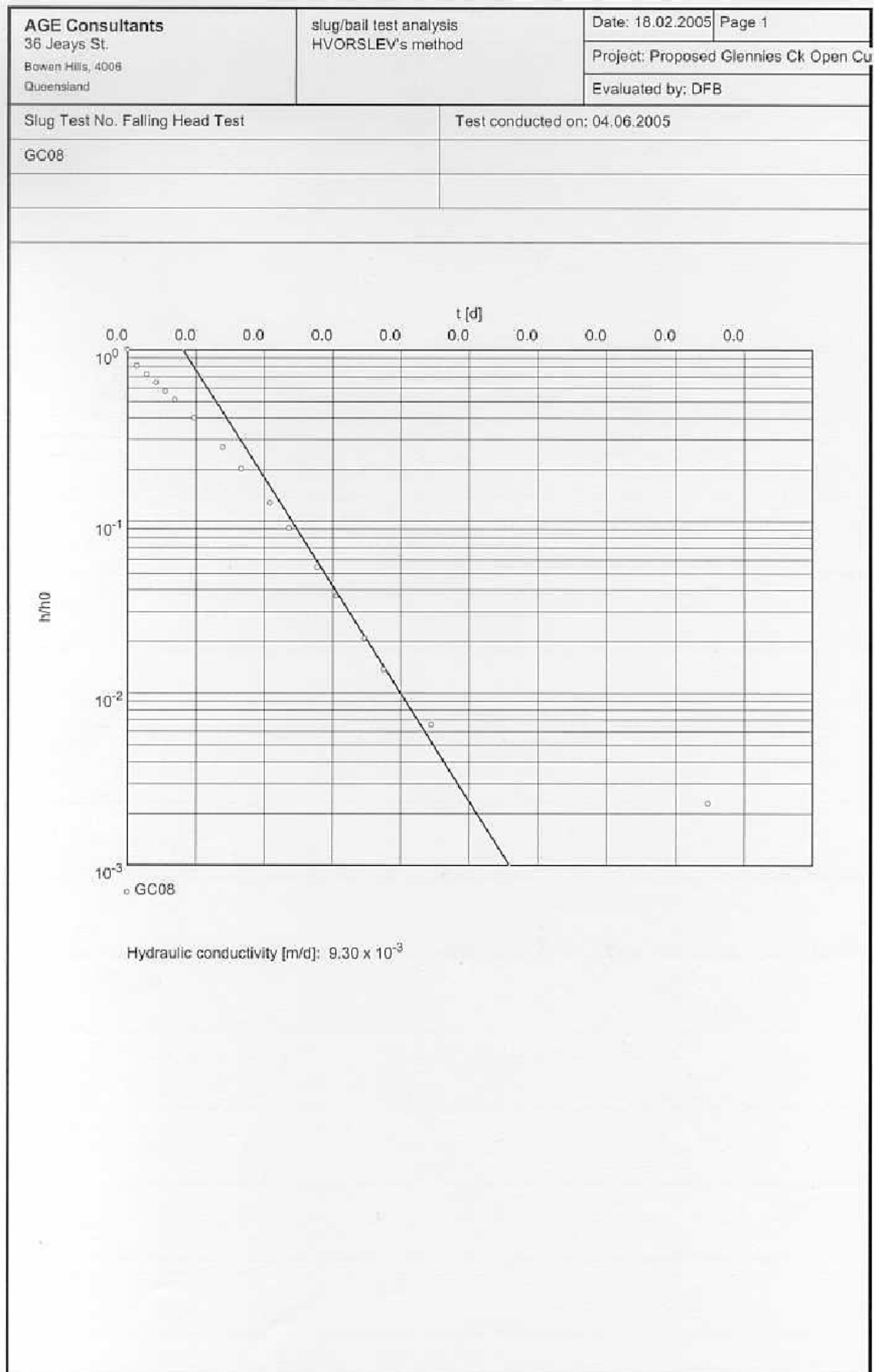
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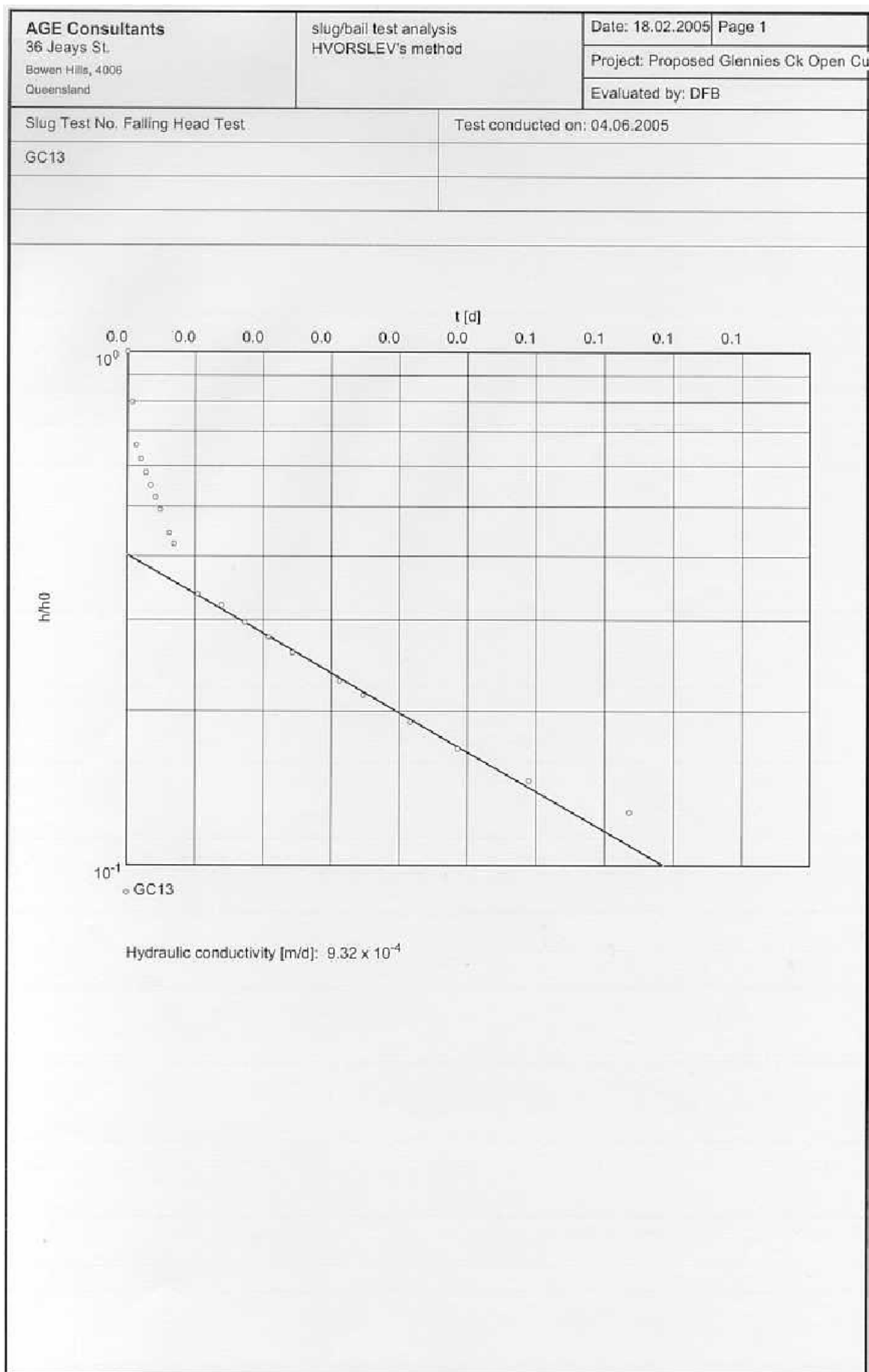
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Appendix 4

DIPNR Registered Groundwater Facilities

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Date/Time :11-Mar-2005 1:23 PM
User :PCLARKE
Report :RMGW001D.QRP
Executable :S:\G5\PROD32\Ground.exe
Exe Date :13-Dec-2004
System :Groundwater
Database :Edbp

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW011543

Converted From HYDSYS

License :20BL004898		Authorised Purpose(s)	Intended Purpose(s) NOT KNOWN
Work Type :Well			
Work Status :(Unknown)			
Construct. Method :Hand Dug			
Owner Type :Private			
Commenced Date :	Final Depth :	5.50 m	
Completion Date :01-Jan-1925	Drilled Depth :	5.50 m	
Contractor Name :			
Driller :			
Property : - N/A		Standing Water Level :	
GWMA :017 - HUNTER		Salinity :	Good
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish AUCKLAND AUCKLAND	Portion/Lot DP 93 93
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6407420	Latitude (S) :32° 27' 23"
Elevation Source :(Unknown)		Easting :324220	Longitude (E) :151° 7' 47"
GS Map :0053A2	AMG Zone :56	Coordinate Source :GD,,ACC,MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Timber	0.00	0.00	1524			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
4.60	5.50	0.90	Unconsolidated	4.60					Good

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	5.49	5.49	Descriptive	Soil	Drilling Water Supply

Remarks

*** End of GW011543 ***

Warning To Clients: This raw data has been supplied to the Department of Land and Water Conservation (DLWC) by drillers, licensees and other sources. The DLWC does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW013603

Converted From HYDSYS

License :20BL009051		Authorised Purpose(s) IRRIGATION	Intended Purpose(s) IRRIGATION
Work Type :Well			
Work Status :(Unknown)			
Construct. Method :Hand Dug			
Owner Type :Private			
Commenced Date :	Final Depth :	12.80 m	
Completion Date :01-Jan-1938	Drilled Depth :	0.00	
Contractor Name :			
Driller :			
Property : - N/A		Standing Water Level :	
GWMA :603 - SYDNEY BASIN		Salinity :	Fair
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish AUCKLAND AUCKLAND	Portion/Lot DP 72 PT 72
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6405125	Latitude (S) :32° 28' 37"
Elevation Source :(Unknown)		Easting :323160	Longitude (E) :151° 7' 5"
GS Map :0053A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Masonry	0.00	7.90	3658			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
26.00	42.00	16.00	(Unknown)	26.00					Fair

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
----------	--------	--------------	----------------------	---------------------	----------

Remarks

*** End of GW013603 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW018328

Converted From HYDSYS

License :20BL010403	Authorised Purpose(s) NOT KNOWN	Intended Purpose(s) NOT KNOWN
Work Type :Well		
Work Status :Supply Obtained		
Construct. Method :(Unknown)		
Owner Type :Private		
Commenced Date :	Final Depth : 5.80 m	
Completion Date :01-Jan-1959	Drilled Depth : 0.00	
Contractor Name :		
Driller :		
Property : - N/A	Standing Water Level :	
GWMA :017 - HUNTER	Salinity :	1001-3000 ppm
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP 69 69
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6407550	Latitude (S) :32° 27' 15"
Elevation Source :(Unknown)		Easting :318135	Longitude (E) :151° 3' 55"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD,,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Timber	0.00	0.00	1219			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
4.60	5.80	1.20	Unconsolidated	4.60					1001-3000 ppm

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
----------	--------	--------------	----------------------	---------------------	----------

Remarks

*** End of GW018328 ***

Warning To Clients: This raw data has been supplied to the Department of Land and Water Conservation (DLWC) by drillers, licensees and other sources. The DLWC does not verify the accuracy of this data. The data is presented for use by you at your own risk. You should consider verifying this data before relying on it. Professional hydrogeological advice should be sought in interpreting and using this data.

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW018329

Converted From HYDSYS

License :20BL010402		Authorised Purpose(s) NOT KNOWN	Intended Purpose(s) NOT KNOWN
Work Type :Well			
Work Status :Collapsed Bore			
Construct. Method :(Unknown)			
Owner Type :Private			
Commenced Date :	Final Depth :	4.90 m	
Completion Date :01-Jan-1959	Drilled Depth :	0.00	
Contractor Name :			
Driller :			
Property : - N/A		Standing Water Level :	
GWMA :017 - HUNTER		Salinity :	1001-3000 ppm
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP 69 69
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6407485	Latitude (S) :32° 27' 17"
Elevation Source :(Unknown)		Easting :318190	Longitude (E) :151° 3' 57"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Backfill	Backfill	4.90	5.80	0			
1	1	Casing	Timber	0.00	0.00	1219			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
4.60	5.80	1.20	(Unknown)	4.60					1001-3000 ppm

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

Changed from 5.791m to 4.877m on 09/11/59 WELL CAVED IN

*** End of GW018329 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW018949

Converted From HYDSYS

License :20BL011142		Authorised Purpose(s) IRRIGATION STOCK	Intended Purpose(s) NOT KNOWN
Work Type :Well			
Work Status :(Unknown)			
Construct. Method :(Unknown)			
Owner Type :Private			
Commenced Date :	Final Depth :	3.70 m	
Completion Date :01-Jan-1960	Drilled Depth :	0.00	
Contractor Name :			
Driller :			
Property : - TREVALLYN		Standing Water Level :	
GWMA :603 - SYDNEY BASIN		Salinity :	(Unknown)
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish GOORANGOOOLA GOORANGOOOLA	Portion/Lot DP 9 9
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6413710	Latitude (S) :32° 24' 1"
Elevation Source :(Unknown)		Easting :328450	Longitude (E) :151° 10' 33"
GS Map :0053A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete Cylinder	-1.20	-1.20	1219			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
1.20	1.20	0.00	(Unknown)	0.90		1.01			(Unknown)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW018949 ***

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DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW019565

Converted From HYDSYS

License :20BL012970	Authorised Purpose(s) DOMESTIC STOCK	Intended Purpose(s) NOT KNOWN
Work Type :Well		
Work Status :Supply Obtained		
Construct. Method :(Unknown)		
Owner Type :Private		
Commenced Date :	Final Depth : 7.30 m	
Completion Date :01-Nov-1962	Drilled Depth : 0.00	
Contractor Name :		
Driller :		
Property : - DULWICH	Standing Water Level :	
GWMA :017 - HUNTER	Salinity :	Good
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish AUCKLAND AUCKLAND	Portion/Lot DP 71 71
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6405875	Latitude (S) :32° 28' 13"
Elevation Source :(Unknown)		Easting :323250	Longitude (E) :151° 7' 9"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete Cylinder	-0.30	-0.30	1219			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW019565 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW024385

Converted From HYDSYS

License :20BL017861			Authorised Purpose(s)		Intended Purpose(s)
Work Type :Well			IRRIGATION		NOT KNOWN
Work Status :(Unknown)			STOCK		
Construct. Method :(Unknown)					
Owner Type :Private					
Commenced Date :		Final Depth :	4.60 m		
Completion Date :01-Jan-1926		Drilled Depth :	0.00		
Contractor Name :					
Driller :					
Property : - N/A			Standing Water Level :		
GWMA :017 - HUNTER			Salinity :		(Unknown)
GW Zone : -			Yield :		

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
		Form A :DURHAM	VANE	97
		Licensed :DURHAM	VANE	97
Region :20 - HUNTER			CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER			Grid Zone :56/1	Scale :1:25,000
Area / District :				
Elevation :			Northing :6409625	Latitude (S) :32° 26' 8"
Elevation Source :(Unknown)			Easting :317565	Longitude (E) :151° 3' 34"
GS Map :0053.A2		AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
(No Construction Details Found)									

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW024385 ***

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DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW035474 - "Ravensworth"

Converted From HYDSYS

License :20BL028920	Authorised Purpose(s) G/WATER XPLORE	Intended Purpose(s) G/WATER XPLORE
Work Type :Bore open thru rock		
Work Status :Test Hole		
Construct. Method :Auger		
Owner Type :Private		
Commenced Date :	Final Depth : 0.00	
Completion Date :	Drilled Depth : 0.00	
Contractor Name :		
Driller :		
Property : - RESTHAVEN	Standing Water Level :	
GWMA :603 - SYDNEY BASIN	Salinity :	Poor
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish LIDDELL LIDDELL	Portion/Lot DP 150 4 6842
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6412100	Latitude (S) :32° 24' 47"
Elevation Source :(Unknown)		Easting :317625	Longitude (E) :151° 3' 38"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Backfill	Backfill	0.00	3.90	152			

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
3.90	3.90	0.00	(Unknown)						Poor

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW035474 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW045084

Converted From HYDSYS

License :20BL104306	Authorised Purpose(s) DOMESTIC	Intended Purpose(s) DOMESTIC
Work Type :Bore Work Status :(Unknown) Construct. Method :Rotary Owner Type :Private		
Commenced Date : Completion Date :01-Mar-1976	Final Depth : 0.00 Drilled Depth : 18.90 m	
Contractor Name : Driller :1493	LINTON, Alec	
Property : - N/A GWMA : - GW Zone : -	Standing Water Level : Salinity : Yield :	(Unknown)

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP L6 (67) L6 (P+ Port 67)
Region :20 - HUNTER River Basin :210 - HUNTER RIVER Area / District :		CMA Map :9133-3S Grid Zone :56/1	CAMBERWELL Scale :1:25,000
Elevation : Elevation Source :(Unknown)		Northing :6406630 Easting :321935	Latitude (S) :32° 27' 47" Longitude (E) :151° 6' 19"
GS Map :0053.A2 AMG Zone :56		Coordinate Source :GD,,ACC.MAP	

Construction Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Backfill	Backfill	0.00	18.90	152			

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
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(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	0.15	0.15	Subsoil		
0.15	6.10	5.95	Loam Clay		
6.10	7.01	0.91	Clay Grey		
7.01	18.90	11.89	Quartz		
				Invalid Code	

Remarks

*** End of GW045084 ***

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DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW046786

Converted From HYDSYS

License :20BL107142		Authorised Purpose(s) DOMESTIC	Intended Purpose(s) DOMESTIC
Work Type :Well			
Work Status :(Unknown)			
Construct. Method :(Unknown)			
Owner Type :Private			
Commenced Date :	Final Depth :	6.90 m	
Completion Date :01-Jan-1972	Drilled Depth :	7.00 m	
Contractor Name :			
Driller :			
Property : - N/A		Standing Water Level :	
GWMA : -		Salinity :	(Unknown)
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP 1 P+ Port 4
Region :20 - HUNTER River Basin :210 - HUNTER RIVER Area / District :		CMA Map :9133-3S Grid Zone :56/1	CAMBERWELL Scale :1:25,000
Elevation :		Northing :6408900	Latitude (S) :32° 26' 31"
Elevation Source :(Unknown)		Easting :317150	Longitude (E) :151° 3' 18"
GS Map :0053A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete Cylinder	0.00	0.00	762			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
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(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	6.95	6.95	Description Nominal	Alluvium	
0.00	6.95	6.95	Clay Nominal	Clay	
0.00	6.95	6.95	Sand Nominal	Sand	
0.00	6.95	6.95	Gravel Nominal	Gravel	

Remarks

*** End of GW046786 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW046787

Converted From HYDSYS

License :20BL107141	Authorised Purpose(s) DOMESTIC	Intended Purpose(s) DOMESTIC
Work Type :Well		
Work Status :(Unknown)		
Construct. Method :(Unknown)		
Owner Type :Private		
Commenced Date :	Final Depth : 6.20 m	
Completion Date :	Drilled Depth : 8.00 m	
Contractor Name :		
Driller :		
Property : - N/A	Standing Water Level :	
GWMA : -	Salinity :	(Unknown)
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP 1 P+ Port 1
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6409040	Latitude (S) :32° 26' 26"
Elevation Source :(Unknown)		Easting :317090	Longitude (E) :151° 3' 16"
GS Map :0053A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	(Unknown)	0.00	0.00	1200			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	8.00	8.00	Description Nominal	Alluvium	
0.00	8.00	8.00	Sand Nominal	Sand	
0.00	8.00	8.00	Clay Nominal	Clay	
0.00	8.00	8.00	Gravel Nominal	Gravel	

Remarks

*** End of GW046787 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW046788

Converted From HYDSYS

License :20BL107143	Authorised Purpose(s) DOMESTIC	Intended Purpose(s) DOMESTIC
Work Type :Well		
Work Status :(Unknown)		
Construct. Method :(Unknown)		
Owner Type :Private		
Commenced Date :	Final Depth : 6.10 m	
Completion Date :	Drilled Depth : 6.20 m	
Contractor Name :		
Driller :		
Property : - N/A	Standing Water Level :	
GWMA : -	Salinity :	(Unknown)
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP 1 P+ Port 1
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6408790	Latitude (S) :32° 26' 35"
Elevation Source :(Unknown)		Easting :317220	Longitude (E) :151° 3' 20"
GS Map :0053A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
(No Construction Details Found)									

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material (Unknown) Gravel	Comments
0.00	6.15	6.15			
6.15	6.20	0.05	Gravel		

Remarks

*** End of GW046788 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW046789

Converted From HYDSYS

License :20BL107144	Authorised Purpose(s) DOMESTIC	Intended Purpose(s) DOMESTIC
Work Type :Well		
Work Status :(Unknown)		
Construct. Method :(Unknown)		
Owner Type :Private		
Commenced Date :	Final Depth : 6.90 m	
Completion Date :	Drilled Depth : 6.90 m	
Contractor Name :		
Driller :		
Property : - N/A	Standing Water Level :	
GWMA : -	Salinity :	(Unknown)
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP 1 P+ Port 1
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6408730	Latitude (S) :32° 26' 37"
Elevation Source :(Unknown)		Easting :317240	Longitude (E) :151° 3' 21"
GS Map :0053A2	AMG Zone :56	Coordinate Source :GD,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete Cylinder	0.00	0.00	914			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
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(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	3.05	3.05	Drillers	Clay	
3.05	6.86	3.81	Gravel	Gravel	

Remarks

*** End of GW046789 ***

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DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW047999

Converted From HYDSYS

License :20BL116765		Authorised Purpose(s)	Intended Purpose(s)
Work Type :Well		DOMESTIC	IRRIGATION
Work Status :Supply Obtained		IRRIGATION	
Construct. Method :(Unknown)		STOCK	
Owner Type :Private			
Commenced Date :	Final Depth :	12.50 m	
Completion Date :01-Mar-1981	Drilled Depth :	12.50 m	
Contractor Name :			
Driller :1432	WILSON, Daryl George		
Property : - NOT KNOWN		Standing Water Level :	
GWMA : -		Salinity :	(Unknown)
GW Zone : -		Yield :	

Site Details

Site Chosen By	County	Parish	Portion/Lot DP
	Form A :NORTHUMBERLAND	WHITTINGHAM	12
	Licensed :NORTHUMBERLAND	WHITTINGHAM	6 3348
Region :20 - HUNTER		CMA Map :9132-4N	SINGLETON
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6396080	Latitude (S) :32° 32' 30"
Elevation Source :(Unknown)		Easting :330285	Longitude (E) :151° 11' 34"
GS Map :0053A3	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete Cylinder	0.00	8.80	1800			Seated

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
8.80	12.50	3.70	Unconsolidated	8.80					(Unknown)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	4.57	4.57	Drillers	Loam	
4.57	5.49	0.92	Gravel Bearing	Gravel	
5.49	10.67	5.18	Sandy	(Unknown)	
10.67	12.50	1.83	Gravel Sand	Gravel	

Remarks

*** End of GW047999 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW049285

Converted From HYDSYS

License :20BL109471		Authorised Purpose(s) FARMING	Intended Purpose(s) NOT KNOWN
Work Type :Well			
Work Status :Supply Obtained			
Construct. Method :(Unknown)			
Owner Type :Private			
Commenced Date :	Final Depth :	9.10 m	
Completion Date :01-Jan-1979	Drilled Depth :	0.00	
Contractor Name :			
Driller :			
Property : - N/A		Standing Water Level :	
GWMA : -		Salinity :	(Unknown)
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish AUCKLAND AUCKLAND	Portion/Lot DP 79 P+ Port 79
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6408310	Latitude (S) :32° 26' 55"
Elevation Source :(Unknown)		Easting :324775	Longitude (E) :151° 8' 9"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
(No Construction Details Found)									

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

HOSING DAIRY YARDS AFTER MILKING WATER HIGH IN COLIFORM

*** End of GW049285 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW052121

Converted From HYDSYS

License :20BL119274		
Work Type :Bore	Authorised Purpose(s) DOMESTIC	Intended Purpose(s) DOMESTIC
Work Status :Supply Obtained	STOCK	STOCK
Construct. Method :Rotary		
Owner Type :Private		
Commenced Date :	Final Depth : 30.50 m	
Completion Date :01-Jan-1981	Drilled Depth : 30.50 m	
Contractor Name :		
Driller :		
Property : - N/A	Standing Water Level :	
GWMA : -	Salinity :	(Unknown)
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish DARLINGTON DARLINGTON	Portion/Lot DP 61 61
Region :20 - HUNTER		CMA Map :9132-4N	SINGLETON
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6400335	Latitude (S) :32° 31' 15"
Elevation Source : (Unknown)		Easting :327290	Longitude (E) :151° 9' 40"
GS Map :0053A3	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	P.V.C.	0.00	30.50	130			Seated on Bottom
1	1	Opening	Slots - Vertical	24.50	30.50	130		1	SL: 0mm; A: 6mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
28.00	30.50	2.50	Fractured	6.00					(Unknown)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
0.00	1.75	1.75		Clay	
1.75	24.38	22.63	Shale	Shale	
24.38	27.00	2.62	Coal	Coal	
27.00	30.49	3.49	Shale Water Supply	Shale	

Remarks

*** End of GW052121 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW052859

Converted From HYDSYS

License :20BL114996		Authorised Purpose(s) DOMESTIC STOCK	Intended Purpose(s) NOT KNOWN
Work Type :Well			
Work Status :Supply Obtained			
Construct. Method :(Unknown)			
Owner Type :Private			
Commenced Date :	Final Depth :	9.10 m	
Completion Date :	Drilled Depth :	0.00	
Contractor Name :			
Driller :			
Property : - NUNDAH		Standing Water Level :	
GWMA : -		Salinity :	Hard
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish AUCKLAND AUCKLAND	Portion/Lot DP L7 (72) L7 (72)
Region :20 - HUNTER River Basin :210 - HUNTER RIVER Area / District :		CMA Map :9133-3S Grid Zone :56/1	CAMBERWELL Scale :1:25,000
Elevation : Elevation Source :(Unknown)		Northing :6404740 Easting :323060	Latitude (S) :32° 28' 49" Longitude (E) :151° 7' 1"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete Cylinder	0.00	7.60	0			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW052859 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW052917

Converted From HYDSYS

License :20BL121779			Authorised Purpose(s)		Intended Purpose(s)
Work Type :Bore open thru rock			DOMESTIC		FARMING
Work Status :Abandoned Bore			STOCK		
Construct. Method :Rotary Air					
Owner Type :Private					
Commenced Date :	Final Depth :	15.20 m			
Completion Date :01-Oct-1981	Drilled Depth :	15.20 m			
Contractor Name :					
Driller :					
Property : - N/A			Standing Water Level :		
GWMA : -			Salinity :		3001-7000 ppm
GW Zone : -			Yield :		

Site Details

Site Chosen By		County	Parish	Portion/Lot DP
		Form A :DURHAM	GOORANGOOOLA	9
		Licensed :DURHAM	GOORANGOOOLA	P+ Port 9
Region :20 - HUNTER			CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER			Grid Zone :56/1	Scale :1:25,000
Area / District :				
Elevation :			Northing :6414312	Latitude (S) :32° 23' 41"
Elevation Source :(Unknown)			Easting :327280	Longitude (E) :151° 9' 49"
GS Map :0053A2		AMG Zone :56	Coordinate Source :	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Welded Steel	-0.40	7.00	165			
1	1	Casing	Welded Steel	-0.34	7.00	165			
1	1	Casing	Welded Steel	-0.30	7.00	165			Driven into Hole
1	1	Casing	Nil	7.00	14.60				

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
3.70	3.90	0.20	(Unknown)	0.50		7.97			(Unknown)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	0.60	0.60	Description	Topsoil	
0.60	4.30	3.70	Clay	Clay	
4.30	6.70	2.40	Basalt Decomposed	Basalt	
6.70	15.20	8.50	Basalt Water supply	Basalt	

Remarks

Mr. M. Comins - company director, owner's address - 630 Falbrook Rd, Greenlands via Singleton, Ph. 02 6577 3165. Bore not used often.

*** End of GW052917 ***

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DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW054627 - "Thoryburn"

Converted From HYDSYS

License :20BL116905		Authorised Purpose(s) STOCK	Intended Purpose(s) STOCK
Work Type :Bore			
Work Status :Abandoned Bore			
Construct. Method :Rotary Air			
Owner Type :Private			
Commenced Date :	Final Depth :	35.00 m	
Completion Date :01-Oct-1981	Drilled Depth :	35.00 m	
Contractor Name :			
Driller :			
Property : - N/A		Standing Water Level :	
GWMA : -		Salinity :	Fair
GW Zone : -		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish BROUGHTON BROUGHTON	Portion/Lot DP 21 21
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation : 94.00 m (A.H.D.)		Northing :6409494	Latitude (S) :32° 26' 19"
Elevation Source :R.L. at Surface		Easting :329835	Longitude (E) :151° 11' 24"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Welded Steel	-0.30	15.50	165			Driven into Hole
1	1	Casing	Welded Steel	-0.30	15.50	165			
1	1	Casing	Welded Steel	-0.20	15.50	165			
1	1	Casing	Nil	15.50	23.35				

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
21.30	21.90	0.60	(Unknown)	3.60		0.15			Fair

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	0.60	0.60	Description	Topsoil	
0.60	7.30	6.70	Clay	clay	
7.30	7.90	0.60	Gravel	Gravel	
7.90	15.20	7.30	Clay Sandy	clay	
15.20	35.00	19.80	Conglomerate Water Supply	conglomerate	

Remarks

Owner's address: 'Thoryburn' 1388 Bridgman Road, Singleton 2330, Ph. 02 6577 3135. Coordinates surveyed on 4/9/2000. Bore is open, needs cap to protect from debris fall in.

*** End of GW054627 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW056703

Converted From HYDSYS

License :20BL123557	Authorised Purpose(s) STOCK	Intended Purpose(s) STOCK
Work Type :Bore open thru rock		
Work Status :Abandoned Bore		
Construct. Method :Rotary Air		
Owner Type :Private		
Commenced Date :	Final Depth : 22.90 m	
Completion Date :01-Oct-1981	Drilled Depth : 22.90 m	
Contractor Name :		
Driller :		
Property : - NOT KNOWN	Standing Water Level :	
GWMA : -	Salinity :	1001-3000 ppm
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish GOORANGOOOLA GOORANGOOOLA	Portion/Lot DP 31 31 752462
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6413167	Latitude (S) :32° 24' 17"
Elevation Source :(Unknown)		Easting :325200	Longitude (E) :151° 8' 29"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD,ACC,MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	P.V.C.	-0.25	12.00	0			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
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(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	0.90	0.90	Description	Topsoil	
0.90	9.10	8.20	Clay	clay	
9.10	21.30	12.20	Basalt	Basalt	
21.30	21.90	0.60	Coal Seam	Coal	
21.90	22.90	1.00	Basalt	Basalt	

Remarks

TDS=2606 MG/L Owner address: 257 Cooragoolan Rd, Singleton, Ph. 02 6577 3156 Coordinates surveyed on 4/9/2000

*** End of GW056703 ***

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DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW063740

Converted From HYDSYS

License :20BL135390		Authorised Purpose(s)		Intended Purpose(s)
Work Type :Bore		DOMESTIC		DOMESTIC
Work Status :(Unknown)		STOCK		STOCK
Construct. Method :Rotary Air				
Owner Type :Private				
Commenced Date :		Final Depth :	39.60 m	
Completion Date :01-Oct-1986		Drilled Depth :	39.60 m	
Contractor Name :				
Driller :1530		JONES, Clive Francis		
Property : - N/A		Standing Water Level :		
GWMA : -		Salinity :		
GW Zone : -		Yield :		
		(Unknown)		

Site Details

Site Chosen By		County Form A :DURHAM Licensed :CUMBERLAND	Parish GOORANGOOOLA PETERSHAM	Portion/Lot DP L1 DP217291 (9) 1 217291
Region :20 - HUNTER River Basin :210 - HUNTER RIVER Area / District :		CMA Map :9133-3S Grid Zone :56/1		CAMBERWELL Scale :1:25,000
Elevation : Elevation Source :(Unknown)		Northing :6414485 Easting :327300		Latitude (S) :32° 23' 36" Longitude (E) :151° 9' 50"
GS Map :0053A2		AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
(No Construction Details Found)									

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
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(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	0.30	0.30	Description	Topsoil	
0.30	7.60	7.30	Clay	Clay	
7.60	7.90	0.30	Shale	Shale	
7.90	9.10	1.20	Gravel	Gravel	
9.10	39.60	30.50	Basalt Shale	Basalt	

Remarks

*** End of GW063740 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW064515

Converted From HYDSYS

License :20BL136766	Authorised Purpose(s) DOMESTIC	Intended Purpose(s) DOMESTIC
Work Type :Well		
Work Status :(Unknown)		
Construct. Method :Hand Dug		
Owner Type :Private		
Commenced Date :	Final Depth : 5.50 m	
Completion Date :01-Jan-1919	Drilled Depth : 5.50 m	
Contractor Name :		
Driller :		
Property : - NOT KNOWN	Standing Water Level :	
GWMA : -	Salinity :	(Unknown)
GW Zone : -	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :DURHAM	Parish AUCKLAND AUCKLAND	Portion/Lot DP SEC 7 11 758214
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation :		Northing :6405870	Latitude (S) :32° 28' 11"
Elevation Source :(Unknown)		Easting :320290	Longitude (E) :151° 5' 16"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete	0.00	0.00	762			(Unknown)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	5.50	5.50	Glennies Creek	Gravel	

Remarks

LOT 12 SECTION 7 CAMBERWELL

*** End of GW064515 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES
Work Summary

GW067291

Converted From HYDSYS

License :20BL142106		
Work Type :	Authorised Purpose(s)	Intended Purpose(s)
Work Status : (Unknown)	DOMESTIC	
Construct. Method :	FARMING	
Owner Type :	STOCK	
Commenced Date :	Final Depth :	
Completion Date :	Drilled Depth :	
Contractor Name :		
Driller :		
Property : - N/A	Standing Water Level :	
GWMA : -	Salinity :	
GW Zone : -	Yield :	

Site Details

Site Chosen By	County	Parish	Portion/Lot DP
	Form A :DURHAM	VANE	65
	Licensed :DURHAM	VANE	65
Region :20 - HUNTER		CMA Map :	
River Basin :210 - HUNTER RIVER		Grid Zone :	Scale :
Area / District :			
Elevation : 68.00 m (A.H.D.)		Northing :6407937	Latitude (S) :32° 27' 7"
Elevation Source :Est. Contour 8-15M.		Easting :326162	Longitude (E) :151° 9' 2"
GS Map :0053.A2	AMG Zone :56	Coordinate Source :GD.,ACC.MAP	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	Concrete	0.00	90.00	1200			Cemented

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW067291 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW078054

License :20BL166290			Authorised Purpose(s) INDUSTRIAL		Intended Purpose(s) DOMESTIC STOCK
Work Type :Bore					
Work Status :Unknown					
Construct. Method :Rotary					
Owner Type :					
Commenced Date :	Final Depth :	16.20 m			
Completion Date :	Drilled Depth :	16.20 m			
Contractor Name :DRILLWELL CONSTRUCTION					
Driller :1493 LINTON, Alec					
Property : - N/A			Standing Water Level :		
GWMA :017 - HUNTER			Salinity :		Fair
GW Zone : -			Yield :		

Site Details

Site Chosen By Diviner		County Form A :DURHAM Licensed :DURHAM	Parish VANE VANE	Portion/Lot DP LOT 1 DP 124977 1 124977
Region :20 - HUNTER		CMA Map :		Scale :
River Basin :		Grid Zone :		
Area / District :		Northing :6409296		Latitude (S) :32° 26' 18"
Elevation :		Easting :316964.97		Longitude (E) :151° 3' 13"
Elevation Source :				
GS Map :		AMG Zone :56	Coordinate Source :	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1		Hole	Hole	0.00	16.20	190			Rot. Rev. Circ Mud
1	1	Casing	Steel	0.60	16.20	168.3			Welded; Seated on Bottom; Casing Shoe
1	1	Opening	Slots - Vertical	11.00	16.20	168.3			Steel; Oxy-Acetylene Slotted; SL: 5.2mm; A: 4mm

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
11.40	12.00	0.60		6.90		1.12	16.20	0.20	Fair

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers	Geological Material	Comments
0.00	0.05	0.05	0.05	Topsoil	
0.05	3.00	2.95	2.95	Brown Clay Bands	
3.00	10.80	7.80	7.80	Gravel	
10.80	16.20	5.40	5.40	White Sandstone	

Remarks

*** End of GW078054 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW079793 - Ravensworth Heritage House

License :		Authorised Purpose(s)	Intended Purpose(s)
Work Type :Well			DOMESTIC
Work Status :Abandoned Bore			
Construct. Method :Hand Dug			
Owner Type :Mines			
Commenced Date :	Final Depth :	2.82 m	
Completion Date :	Drilled Depth :		
Contractor Name :			
Driller :			
Property :		Standing Water Level :	
GWMA :		Salinity :	
GW Zone :		Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :	Parish LIDDELL	Portion/Lot DP LT228 DP752470
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation : 86.00 m (A.H.D.)		Northing :6411773	Latitude (S) :32° 24' 58"
Elevation Source :R.L. at Surface		Easting :317625	Longitude (E) :151° 3' 38"
GS Map :	AMG Zone :56	Coordinate Source :GPS - Global Positioning System	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
1	1	Casing	(Unknown)	0.00	0.00				
1	1	Casing	Timber	0.00	2.82				

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
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(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

Old well at Ravensworth Homestead currently leased by Jeff and Jenny Marshall, Ph. 02 6576 1109 from Glendell Coal, Ph. 02 6570 9900 or 6570 0883, fax 65761643. Current Glendell Coal site manager is Val Istomin. Coordinates surveyed on 4/9/2000.

*** End of GW079793 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW080177

License :	Authorised Purpose(s)	Intended Purpose(s)
Work Type :Bore		
Work Status :		
Construct. Method :		
Owner Type :		
Commenced Date :	Final Depth :	
Completion Date :02-Apr-2002	Drilled Depth :	
Contractor Name :		
Driller :		
Property :	Standing Water Level :	
GWMA :	Salinity :	
GW Zone :	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :	Parish LIDDELL	Portion/Lot DP LT9 DP6842
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation : 0.00		Northing :6413442	Latitude (S) :32° 24' 5"
Elevation Source :(Unknown)		Easting :319621	Longitude (E) :151° 4' 58"
GS Map :	AMG Zone :56	Coordinate Source :	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
(No Construction Details Found)									

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
(No Water Bearing Zone Details Found)									

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW080177 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES

Work Summary

GW080178

License :	Authorised Purpose(s)	Intended Purpose(s)
Work Type :Bore		
Work Status :		
Construct. Method :		
Owner Type :		
Commenced Date :	Final Depth :	
Completion Date :02-Apr-2002	Drilled Depth :	
Contractor Name :		
Driller :		
Property :	Standing Water Level :	
GWMA :	Salinity :	
GW Zone :	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :	Parish LIDDELL	Portion/Lot DP LT9 DP6842
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation : 0.00		Northing :6413181	Latitude (S) :32° 24' 14"
Elevation Source :(Unknown)		Easting :319763	Longitude (E) :151° 5' 3"
GS Map :	AMG Zone :56	Coordinate Source :	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
									(No Construction Details Found)

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
									(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW080178 ***

DEPARTMENT OF INFRASTRUCTURE, PLANNING AND NATURAL RESOURCES Work Summary

GW080179

License :	Authorised Purpose(s)	Intended Purpose(s)
Work Type :Bore		
Work Status :		
Construct. Method :		
Owner Type :		
Commenced Date :	Final Depth :	
Completion Date :02-Apr-2002	Drilled Depth :	
Contractor Name :		
Driller :		
Property :	Standing Water Level :	
GWMA :	Salinity :	
GW Zone :	Yield :	

Site Details

Site Chosen By	County Form A :DURHAM Licensed :	Parish VANE	Portion/Lot DP LT3 DP859544
Region :20 - HUNTER		CMA Map :9133-3S	CAMBERWELL
River Basin :210 - HUNTER RIVER		Grid Zone :56/1	Scale :1:25,000
Area / District :			
Elevation : 0.00		Northing :6411804	Latitude (S) :32° 24' 59"
Elevation Source :(Unknown)		Easting :320439	Longitude (E) :151° 5' 28"
GS Map :	AMG Zone :56	Coordinate Source :	

Construction

Negative depths indicate Above Ground Level;H-Hole;P-Pipe;OD-Outside Diameter;ID-Inside Diameter;C-Cemented;SL-Slot Length;A-Aperture;GS-Grain Size;Q-Quantity

H	P	Component	Type	From (m)	To (m)	OD (mm)	ID (mm)	Interval	Details
(No Construction Details Found)									

Water Bearing Zones

From (m)	To (m)	Thickness (m)	WBZ Type	S.W.L. (m)	D.D.L. (m)	Yield (L/s)	Hole Depth (m)	Duration (hr)	Salinity (mg/L)
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(No Water Bearing Zone Details Found)

Drillers Log

From (m)	To (m)	Thickness(m)	Drillers Description	Geological Material	Comments
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Remarks

*** End of GW080179 ***

*** End of Report ***

Appendix 5

Bore Census Data

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Glennies Creek Coal Mine Bore Census Summary

Name	Address	Phone Number	Distance	DIPNR Bore	Contact Log
M. Leggett & ND Allison		6543 5142 ?	within 3km		Called 9/4/05 1:28pm, left message on answering machine, Lesia Leggett called back on the 12/4/05, she does not live on the property, she said that there was no bores or wells on the property
Trevor Dallas			within 3km	DIPNR Bore located on property	
BH & BL Evans	304 Stoney Creek Road, Mt Olive	6577 3111	within 3km		Called 9/4/05 1:28pm, left message on answering machine, mobile no. provided on machine, arranged time to meet, he said that he had no bores, wells or springs
CI Payne	3 Middle Falbrook Road	6577 3152	within 3km		Called 9/4/05 1:50pm, Mrs Payne answered, has no bores, wells or springs
TA & GA Green	Bridgeman Rd, Mt Olive	6577 3208	within 3km		A friend answered their phone, said that they do not have any bores, only two dams
RE & WL Gardner	Bridgeman Rd, Mt Olive	6577 3308	within 3km		Rodney Gardner answered the phone, he has three dams, no bores or well
NJ Carroll & AD Casellidine			within 3km		
GJ & KH Cheesham	Vennura, Middle Falbrook Rd, Glennies Creek	6577 3119	within 3km	DIPNR Bore located on property	Called 9/4/05 1:39pm, number busy, called 30/5/05 1:29pm, left message, they have a well
DR & MK Bridge	Windy Hill, Glennies Creek, Mt Olive	6577 3154	within 3km		Called 9/4/05 1:39pm, number rang out, called 30/5/05 1:39pm, spoke with Mr Bridge has said that they pump directly from the creek, no bores or wells
BW & RA Cherry	893 Falbrook Rd, Glennies Creek	6577 3057	within 3km		Mr Cherry answered the phone, stated that he had no bores or wells, just 1 dam
JH & MR Moore	Winbourne, Mt Olive	6577 3014	within 3km		Called 9/4/05 1:43pm, told me that it wasn't convenient to talk and asked me to call back this afternoon, called 30/5/05 1:08pm Mr Moore said that they had no bores or wells on their property
HL Castledine	4 Myall Pl, Singleton	6571 4146	within 3km		Spoke with maybe the son, he said that they do not have any bores or wells but pump directly from the creek
DM Moran	762 Glennies Creek Rd	6577 3148	within 3km		Friendly, said that they had no bores or wells but he has only had the place for 5 years and the guy that owned it before him may have had some, said he has some springs on his property, found an abandoned well on the creek flats on his property
BJ Scott & SG Hunter	Middle Falbrook Rd, Middle Falbrook	6577 3011	within 3km		Called 9/4/05 1:51pm, left message on answering machine, called 30/5/05 1:42pm, left message on answering machine, called 5:35pm, Mrs Scott said that they did not have any bores or wells on their property
S & JM Moran	Falbrook Rd, Middle Falbrook	6577 3008	within 3km		Mrs Moran answered the phone, she said that they pump from the creek and have dams but no bores or well
BW & YE Scott	Middle Falbrook Rd, Falbrook	6577 3140	within 3km		Called 9/4/05 2:09pm, left message on answering machine, spoke with Mrs Scott, they have no bores, wells only have a dam
Kemp			within 3km		
DJ & CL Purcell	1064 Middle Falbrook Rd, Glennies Creek	6577 3350	within 3km		Spoke with the son, the father was busy, he took my number and said he'd get back to me, he rang back and said that they did not have any bores, wells or springs
MA & DM Lancaster	1149 Middle Falbrook Rd, Glennies Creek	6577 3330	within 3km		Mr Lancaster answered the phone, said that he had no bores or wells and no springs that he could think of
PJ Higgins	730 Glennies Creek Road, Middle Falbrook	6576 1553	within 3km		Called 9/4/05 2:18pm, left message on answering machine, called 30/5/05 1:54pm, left message
ET & DG Foster			within 3km		
GS & MJ Watson	6 Dominion Ave, Singleton	6573 2235	within 3km		Spoke with Graham Watson (0427 485 660) said that they only have a small block, no bores, wells or springs, was an old exploration bore but has been since dozed over and covered
SJ McInerney			within 3km		
MJ & GM Smith		6576 1300 7	within 3km		
BHA Pastoral Co.			within 3km		
AC Noble	Glennies Creek, Ravensworth	6576 1214	within 3km		Called 30/5/05 1:56pm, phone rang out
WE & AM Gardner	797 Falbrook Rd, Glennies Creek	6577 3167	within 3km	DIPNR Bore located on property	Called 30/5/05 1:26pm, left message on an answering machine
Camberwell Coal			within 3km		
GJ Donnellan	Green Acres, Glennies Creek Road, Glennies Creek	6576 1280	within 4km		Called 30/5/05 2:28pm, left message on an answering machine
BK Johnson			within 4km		
PJ & JE Flynn	Middle Falbrook Rd, Glennies Creek	6577 3040	within 4km		Called 30/5/05 2:51pm, Mr Flynn said they don't have any bores or wells
BG & DJ Wilson	531 Middle Falbrook Rd, Glennies Creek	6577 3199	within 4km		Called 30/5/05 3:16pm, Mrs Wilson said they have no bores or wells on their property
MH & JA Westcott	Middle Falbrook Rd, Glennies Creek	6577 3157	within 4km		Called 30/5/05 2:49pm, Mrs Westcott said that they pump from the creek and have no bores or well
TW & B Watson	Falbrook Rd, Glennies Creek	6574 6137	within 4km		Called 30/5/05 2:52pm, left message on answering machine, Mr Watson returned my call, he sold the property 12 months ago, but at the time of selling had no bores or wells
BA Baigent			within 4km		Called 30/5/05 3:25pm, the lady who answered said that they sold the property 2 years ago, the person who bought it lived in for 12 months and the house has been abandoned ever since, she said that they were no bores or wells, on top of a hill and received runoff when it rained
VM Conroy			within 4km		
E, CL & KL Meyn	10 Northcott Ave, Singleton Heights	6572 1042	within 4km		Called 30/5/05 2:12pm, spoke with Kerry, he said that they rely on creek water and dams and have no bores or well
JA Welsh		6573 3232	within 4km		Called 30/5/05 2:17pm, left message on answering machine, Mrs Welsh phoned back, they no longer have any property out there, has all been sold
JR Burdon		6543 3817	within 4km		Not sure whether this is the owner or not, called 30/5/05 3:10pm, left message on answering machine
MA & RP Porter	Falbrook	6577 3114	within 4km		Called 30/5/05 2:43pm, left message with a lady there she said they would call me back, spoke with Mrs Porter she said that they pump from the creek and have no bores or wells
ED & FW Upward			within 4km		
Xstrata Mining	Middle Falbrook Rd, Falbrook	6577 3088	within 4km		
ED & J Upward			within 4km		
DJ & P Baker	145 Glennies Road, Mt Olive	6577 3167	within 4km		Called 30/5/05 2:40pm, spoke with Mrs Upward, said they irrigate from the creek and have no bore, wells or spring

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Appendix 6

Glossary of Hydrogeological Terms

(after C.W. Fetter, "Applied Hydrogeology", 1988)

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Glossary of Hydrogeological Terms (after C.W. Fetter, "Applied Hydrogeology", 1988)

Adsorption The attraction and adhesion of a layer of ions from an aqueous solution to the solid mineral surfaces with which it is in contact.

Advection The process by which solutes are transported by the motion of flowing ground water.

Alluvium Sediments deposited by flowing rivers. Depending upon the location in the floodplain of the river, different-sized sediments are deposited.

Anisotropy The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.

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, semiconfined 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.

Aquifuge An absolutely impermeable unit that will neither store nor transmit water.

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

Artificial recharge The process by which water can be injected or added to an aquifer. Dug basins, drilled wells, or simply the spread of water across the land surface are all means of artificial recharge.

Barrier boundary An aquifer-system boundary represented by a rock mass that is not a source of water.

Baseflow That part of stream flow that originates from ground water seeping into the stream.

Baseflow recession The declining rate of discharge of a stream fed only by baseflow for an extended period. Typically, a baseflow recession will be exponential.

Baseflow-recession hydrograph A hydrograph that shows a baseflow-recession curve.

Cation exchange capacity The ability of a particular rock or soil to absorb cations.

Cementation The process by which some of the voids in a sediment are filled with precipitated materials, such as silica, calcite, and iron oxide, and which is a part of diagenesis.

Confining bed A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers. It may lie above or below the aquifer.

Contact spring A spring that forms at a lithologic contact where a more permeable unit overlies a less permeable unit.

Darcian velocity An apparent velocity calculated from Darcy's law; represents the flow rate at which water would flow in an aquifer if the aquifer were an open conduit.

Darcy's law An equation that can be used to compute the quantity of water flowing through an aquifer.

Depression spring A spring formed when the water table reaches a land surface because of a change in topography.

Digital computer model A model of ground-water flow in which the aquifer is described by numerical equations, with specified values for boundary conditions, that are solved on a digital computer.

Direct precipitation Water that falls directly into a lake or stream without passing through any land phase of the runoff cycle.

Dirichlet condition A boundary condition for a ground-water computer model where the head is known at the boundary of the flow field.

Discharge The volume of water flowing in a stream or through an aquifer past a specific point in a given period of time.

Discharge area An area in which there are upward components of hydraulic head in the aquifer. Ground water is flowing toward the surface in a discharge area and may escape as a spring, seep, or baseflow or by evaporation and transpiration.

Dispersion The phenomenon by which a solute in flowing ground water is mixed with uncontaminated water and becomes reduced in concentration. Dispersion is caused by both differences in the velocity that the water travels at the pore level and differences in the rate at which water travels through different strata in the flow path.

Distribution coefficient The slope of a linear Freundlich isotherm.

Drainage basin The land area from which surface runoff drains into a stream system.

Drainage divide A boundary line along a topographically high area that separates two adjacent drainage basins.

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.

Dupuit assumptions Assumptions for flow in an unconfined aquifer that (1) the hydraulic gradient is equal to the slope of the water table, (2) the streamlines are horizontal, and (3) the equipotential lines are vertical.

Dupuit equation An equation for the volume of water flowing in an unconfined aquifer; based upon the Dupuit assumptions.

Dynamic equilibrium A condition in which the amount of recharge to an aquifer equals the amount of natural discharge.

Effective pore fraction The ratio of the porosity available for fluid flow to the total porosity of a rock or sediment.

Effective porosity The volume of the void spaces through which water or other fluids can travel in a rock or sediment divided by the total volume of the rock or sediment.

Equipotential line A line in a two-dimensional ground-water flow field such that the total hydraulic head is the same for all points along the line.

Equipotential surface A surface in a three-dimensional ground-water flow field such that the total hydraulic head is the same everywhere on the surface.

Evaporation The process by which water passes from the liquid to the vapor state.

Evapotranspiration The sum of evaporation plus transpiration.

Evapotranspiration, actual The evapotranspiration that actually occurs under given climatic and soil-moisture conditions.

Evapotranspiration, potential The evapotranspiration that would occur under given climatic conditions if there were unlimited soil moisture.

Fault spring A spring created by the movement of two rock units on a fault.

Finite-difference model A particular kind of a digital computer model based upon a rectangular grid that sets the boundaries of the model and the nodes where the model will be solved.

Finite-element model A digital ground-water-flow model where the aquifer is divided into a mesh formed of a number of polygonal cells.

Flow, steady The flow that occurs when, at any point in the flow field, the magnitude and direction of the specific discharge are constant in time.

Flow, unsteady The flow that occurs when, at any point in the flow field, the magnitude or direction of the specific discharge changes with time. Also called transient flow or non-steady flow.

Fracture spring A spring created by fracturing or jointing of the rock.

Fracture trace The surface representation of a fracture zone. It may be a characteristic line of vegetation or linear soil-moisture pattern or a topographic sag.

Glacial-lacustrine sediments Silt and clay deposits formed in the quiet waters of lakes that received meltwater from glaciers.

Glacial outwash Well-sorted sand, or sand and gravel, deposited by the meltwater from a glacier.

Glacial till A glacial deposit composed of mostly unsorted sand, silt, clay, and boulders and laid down directly by the melting ice.

Gouge Soft, ground-up rock formed between the moving surfaces of a geological fault.

Ground water The water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer.

Ground-water basin A rather vague designation pertaining to a ground-water reservoir that is more or less separate from neighboring ground-water reservoirs. A ground-water basin could be separated from adjacent basins by geologic boundaries or by hydrologic boundaries.

Ground water, confined The water contained in a confined aquifer. Pore-water pressure is greater than atmospheric at the top of the confined aquifer.

Ground-water flow The movement of water through openings in sediment and rock; occurs in the zone of saturation.

Ground-water mining The practice of withdrawing ground water at rates in excess of the natural recharge.

Ground water, perched The water in an isolated, saturated zone located in the zone of aeration. It is the result of the presence of a layer of material of low hydraulic conductivity, called a perching bed. Perched ground water will have a perched water table.

Ground water, unconfined The water in an aquifer where there is a water table.

Head, total The sum of the elevation head, the pressure head, and the velocity head at a given point in an aquifer.

Heterogeneous Pertaining to a substance having different characteristics in different locations. A synonym is non-uniform.

Homogeneous Pertaining to a substance having identical characteristics everywhere. A synonym is uniform.

Hydraulic conductivity A coefficient of proportionality describing the rate at which water can move through a permeable medium. The density and kinematic viscosity of the water must be considered in determining hydraulic conductivity.

Hydraulic diffusivity A property of an aquifer or confining bed defined as the ratio of the transmissivity to the storativity.

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.

Hydrodynamic dispersion The process by which ground water containing a solute is diluted with uncontaminated ground water as it moves through an aquifer.

Hydrogeology The study of the interrelationships of geologic materials and processes with water, especially ground water.

Hydrologic equation An expression of the law of mass conservation for purposes of water budgets. It may be stated as inflow equals outflow plus or minus changes in storage.

Hydrology The study of the occurrence, distribution, and chemistry of all waters of the earth.

Hydrostratigraphic unit A formation, part of a formation, or group of formations in which there are similar hydrologic characteristics allowing for grouping into aquifers or confining layers.

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

Infiltration capacity The maximum rate at which infiltration can occur under specific conditions of soil moisture. For a given soil, the infiltration capacity is a function of the water content.

Interflow The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water moving as interflow discharges directly into a stream or lake.

Intrinsic permeability Pertaining to the relative ease with which a porous medium can transmit a liquid under a hydraulic or potential gradient. It is a property of the porous medium and is independent of the nature of the liquid or the potential field.

Isotropy The condition in which hydraulic properties of the aquifer are equal in all directions.

Karst The type of geologic terrane underlain by carbonate rocks where significant solution of the rock has occurred due to flowing ground water.

Laminar flow That type of flow in which the fluid particles follow paths that are smooth, straight, and parallel to the channel walls. In laminar flow, the viscosity of the fluid damps out turbulent motion. *Compare with* Turbulent flow.

Langmuir isotherm An empirical equation that describes the amount of solute adsorbed onto a soil surface.

Land pan A device used to measure free-water evaporation.

Leaky confining layer A low-permeability layer that can transmit water at sufficient rates to furnish some recharge to a well pumping from an underlying aquifer. Also called aquitard.

Lineament A natural linear surface longer than a mile (1500 meters).

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.

Model field verification The process by which a digital computer model that has been calibrated and verified is tested to see if it can predict the field response of an aquifer to some transient condition.

Model verification The process by which a digital computer model that has been calibrated against a steady-state condition is tested to see if it can generate a transient response, such as the decline in the water table with pumping, that matches the known history of the aquifer.

Observation well A non-pumping well used to observe the elevation of the water table or the potentiometric surface. An observation well is generally of larger diameter than a piezometer and typically is screened or slotted throughout the thickness of the aquifer.

Overland flow The flow of water over a land surface due to direct precipitation. Overland flow generally occurs when the precipitation rate exceeds the infiltration capacity of the soil and depression storage is full. Also called Horton overland flow.

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

Phreatic water Water in the zone of saturation.

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.

Piezometer nest A set of two or more piezometers set close to each other but screened to different depths.

Pore space The volume between mineral grains in a porous medium.

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

Porosity, effective The volume of the void spaces through which water or other fluids can travel in a rock or sediment divided by the total volume of the rock or sediment.

Porosity, primary The porosity that represents the original pore openings when a rock or sediment formed.

Porosity, secondary The porosity that has been caused by fractures or weathering in a rock or sediment after it has been formed.

Potentiometric map A contour map of the potentiometric surface of a particular hydrogeologic unit.

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 cone The area around a discharging well where the hydraulic head in the aquifer has been lowered by pumping. Also called cone of depression.

Pumping test A test made by pumping a well for a period of time and observing the change in hydraulic head in the aquifer. A pumping test may be used to determine the capacity of the well and the hydraulic characteristics of the aquifer. Also called aquifer test.

Recharge area An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.

Recharge basin A basin or pit excavated to provide a means of allowing water to soak into the ground at rates exceeding those that would occur naturally.

Recharge boundary An aquifer system boundary that adds water to the aquifer. Streams and lakes are typically recharge boundaries.

Recharge well A well specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.

Recovery The rate at which the water level in a well rises after the pump has been shut off. It is the inverse of drawdown.

Retardation A general term for the many processes that act to remove the solutes in ground water; for many solutes the solute front will travel more slowly than the rate of the advecting ground water.

Rock, igneous A rock formed by the cooling and crystallization of a molten rock mass called magma.

Rock, metamorphic A rock formed by the application of heat and pressure to pre-existing rocks.

Rock, plutonic An igneous rock formed when magma cools and crystallizes within the earth.

Rock, sedimentary A rock formed from sediments through a process known as diagenesis or formed by chemical precipitation in water.

Rock, volcanic An igneous rock formed when molten rock called lava cools on the earth's surface.

Root zone The zone from the land surface to the depth penetrated by plant roots. The root zone may contain part or all of the unsaturated zone, depending upon the depth of the roots and the thickness of the unsaturated zone.

Runoff The total amount of water flowing in a stream. It includes overland flow, return flow, interflow, and baseflow.

Saturated zone The zone in which the voids in the rock or soil are filled with water at a pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined aquifer.

Sediment An assemblage of individual mineral grains that were deposited by some geologic agent such as water, wind, ice, or gravity.

Seepage velocity The actual rate of movement of fluid particles through porous media.

Sinkhole spring A spring created by ground water flowing from a sinkhole in karst terrane.

Slug test An aquifer test made either by pouring a small instantaneous charge of water into a well or by withdrawing a slug of water from the well. A synonym for this test, when a slug of water is removed from the well, is a bail-down test.

Soil Moisture The water contained in the unsaturated zone.

Specific capacity An expression of the productivity of a well, obtained by dividing the rate of discharge of water from the well by the drawdown of the water level in the well. Specific capacity should be described on the basis of the number of hours of pumping prior to the time of drawdown measurement is made. It will generally decrease with time as the drawdown increases.

Specific discharge An apparent velocity calculated from Darcy's law; represents the flow rate at which water would flow in an aquifer if the aquifer were an open conduit.

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.

Stagnation point A place in a ground-water flow field at which the ground water is not moving. The magnitude of vectors of hydraulic head at the point are equal but opposite in direction.

Storage, specific The amount of water released from or taken into storage per unit volume of a porous medium per unit change in head.

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. It is equal to the product of specific storage and aquifer thickness. In an unconfined aquifer, the storativity is equivalent to the specific yield. Also called storage coefficient.

Storm hydrograph A graph of the discharge of a stream over the time period when, in addition to direct precipitation, overland flow, interflow, and return flow are adding to the flow of the stream. The storm hydrograph will peak owing to the addition of these flow elements.

Stream, gaining A stream or reach of a stream, the flow of which is being increased by inflow of ground water. Also known as an effluent stream.

Stream, losing A stream or reach of a stream that is losing water by seepage into the ground. Also known as an influent stream.

Throughflow The lateral movement of water in an unsaturated zone during and immediately after a precipitation event. The water from throughflow seeps out at the base of slopes and then flows across the ground surface as return flow, ultimately reaching a stream or lake.

Time of concentration The time it takes for water to flow from the most distant part of the drainage basin to the measuring point.

Transmissivity The rate at which water of a prevailing density and viscosity is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media.

Turbulent flow That type of flow in which the fluid particles move along very irregular paths. Momentum can be exchanged between one portion of the fluid and another. Compare with Laminar flow.

Uniformity coefficient The ratio of the grain size that is 60 percent finer by weight to the grain size that is 10 percent finer by weight on the grain-size distribution curve. It is a measure of how well or poorly sorted sediment is.

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.

Vadose water Water in the zone of aeration.

Vadose zone See unsaturated zone.

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

Water table The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric. It can be measured by installing shallow wells extending a few feet into the zone of saturation and then measuring the water level in those wells.

Water-table cave A cave that forms at the approximate position of the water table.

Water-table map A specific type of potentiometric-surface map for an unconfined aquifer; shows lines of equal elevation of the water table.

Well casing A solid piece of pipe, typically steel or PVC plastic, used to keep a well open in either unconsolidated materials or unstable rock.

Well development The process whereby a well is pumped or surged to remove any fine material that may be blocking the well screen or the aquifer outside the well screen.

Well, fully penetrating A well drilled to the bottom of an aquifer, constructed in such a way that it withdraws water from the entire thickness of the aquifer.

Well interference The result of two or more pumping wells, the drawdown cones of which intercept. At a given location, the total well interference is the sum of the drawdowns due to each individual well.

Well log See lithologic log.

Well, partially penetrating A well constructed in such a way that it draws water directly from a fractional part of the total thickness of the aquifer. The fractional part may be located at the top or the bottom or anywhere in between in the aquifer.

Well screen A tubular device with either slots, holes, gauze, or continuous-wire wrap; used at the end of a well casing to complete a well. The water enters the well through the well screen.