Muswellbrook Coal Company Limited
No. 1 Open Cut Extension
Water Management Study

Prepared for

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HLA-Envirosciences Project No U888-7

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EXECUTIVE SUMMARY

This report presents the results of a water management study for a proposed extension to the No.1 Open Cut operations for Muswellbrook Coal Company Limited (MCC), which is the subject of a Development Application and Environmental Impact Assessment.

Muswellbrook Mine is located in the Hunter Valley, approximately 4km east of Muswellbrook town centre, off Coal Road (**Figure 1**). The mine has been operating for almost 100 years with both underground and open cut operations. The mine currently extracts 1.4 million tonnes per annum (Mtpa) of coal using open cut mining methods in the Greta Coal Measures. Coal is extracted from the Fleming, Hallet, Muswellbrook, St Heliers, Lewis, and Loder Seams. The No.1 and No.2 Open Cut pits are currently mined. Coal processing consists of crushing and sorting, with no production of tailings. The Coal Preparation Plant, mine offices and workshops are located at the southeast part of the mine lease. The current mine layout is shown in **Figure 2**.

MCC now proposes to expand its operations in the No.1 Open Cut within the existing mine lease by open cut operations in the future No.1 Open Cut Extensions A and B. The new operations will mine to the base of the Loder Seam, which lies approximately between 4 to 10m below the Lewis Seam. The expansion would maintain approximate current production levels. The proposed operations are shown in **Figure 3**.

Mining operations occur on high ground situated approximately between Muscle and Sandy Creeks. Most of the mines' internally draining catchments are situated in the Sandy Creek drainage area. Muscle and Sandy Creeks are located several kilometres to the south and north, respectively, of the mine, and drain westwards to the Hunter River which is located about 4km west of the mine.

The geology of the area comprises outcrops of the Greta Coal Measures, and residual soils. Alluvium associated with Muscle Creek, Sandy Creek, and the Hunter River is distant from the proposed works area and will not be impacted by mining. The groundwater system in the Greta Coal Measures at the mine site exhibits a northwest flow direction towards Sandy Creek, superimposed with the drawdown from current mining operations.

The existing mine water management system implements the following strategies:

- Separating clean water runoff produced by undisturbed catchments from dirty (sediment-laden) and contaminated runoff from disturbed catchments.
- Recycling and reusing practically all dirty and contaminated mine water for dust suppression and wash-down activities.
- Using clean water for fire-fighting supplies and sensitive equipment where required.
- Using disused open cuts and underground mines as water storages where possible, and where mine safety permits.
- Minimising any offsite discharge of saline mine water to within the amount allowed by the existing EPA discharge Licence No. 656 (1 ML/day when the Hunter River is in flood flow) under the Hunter River Salinity Trading Scheme (HRSTS)).

Mine water is pumped out of the open cut pits. This water is used mainly for dust suppression activities. The main water storages consist of the No.2 Underground mine and St Heliers Colliery,

Dams 1 and 2, the Workshop Dam, the Final Settling Pond, and Cut 11 (a storage within the No.2 Open Cut spoil).

For the proposed mine extension it is proposed to continue using the existing water management system with some modifications to accommodate any additional flows in wet conditions. Modifications include:

- Construction of a new discharge dam of up to 400 ML capacity (as part of the development consent for the Sandy Creek underground mine proposal), if warranted.
- Gradual elimination of up to 50% of the area of a clean and sediment-laden water catchment (Catchment Q_{C5}) by constructing new holding dams and runoff channelling structures.
- Use of evaporative spraying if wet conditions occur in Years 1 and 2 of development.

Water balance calculations for the proposed development indicate that the mine will operate in deficit for all years of development, for median and dry rainfall conditions.

For wet rainfall conditions the mine will operate in excess for all years. Years 1 and 2 exhibit the highest water balance excesses over the period of development, if wet rainfall conditions occur. The predicted excess in each of Years 1 and 2 is approximately 1 ML/day. Analysis of recent rainfall trends (assuming Year 1 is 2003), and behaviour of the Southern Oscillation, indicate that Years 1 and 2 are likely to exhibit median to dry rainfall conditions. Results indicate that there is a greater than 50% chance that additional mitigation measures (such as evaporative spraying) will not be required.

The modifications discussed above are designed to cope with the maximum predicted excesses in Years 1 and 2 of development, when the No.2 Open Cut is unavailable for water storage. The No.2 Open Cut will be available for water storage in Year 3 of development. The modifications are expected to be sufficient for the mine to remain a zero discharge operation during the No.1 Open Cut Extension development.

Water quality in Sandy and Muscle Creeks should not be affected by the proposed development, except in Muscle Creek by proposed HRSTS discharges from variations in the existing licence (which are the subject of another study). The proposed mining should improve the groundwater regime in the area because a large portion of mined workings will have been removed and replaced with spoil, creating a better environment for groundwater recovery and improvement in groundwater quality.

At least 80% of disturbed natural catchments in the proposed works area will be reclaimed by gradual rehabilitation of emplaced mine spoil.

The quality of water produced by the proposed open cut extension is expected to be similar to water quality measured in the current pits. Impacts on water quality within the mine water system are expected to be minimal.

Recommended monitoring includes installation of flow meters at strategic points in the mine water pumping circuit, water level and quality monitoring at various locations throughout the period of the development, and evaluation of water levels in tracts of spoil-filled open cut to be intersected by the proposed development in Years 5 to 10.

Licences may be required by MCC to undertake the following activities:

- Construction of dams where the Maximum Harvestable Right Dam Capacity is exceeded, and within ephemeral water courses in the works area.

- Use of water from an open cut mine.

A licence may be required for the following activity, when the Water Management Act 2000 comes into force:

- Removal or deposition of material that affects the quantity or flow of water in a water source, or carry out an aquifer interference activity.

1.0 INTRODUCTION

Muswellbrook Coal Company Limited (MCC) wishes to extend operations in the existing No. 1 Open Cut within its currently held mining lease (CCL 713). This report presents the results of a water management study for the proposed development. This study has been performed by HLA-Envirosciences Pty Limited (HLA) at the request of MCC.

The mine is located approximately 1.6km east of the nearest residential areas of Muswellbrook township (**Figure 1**).

1.1 Mine History

Mining has been conducted at the site for nearly a century. Refer to **Figure 1** for locations of the mines and workings discussed below.

The following decommissioned mines exist :

- No.1 Underground
- St Heliers Colliery
- No.2 Underground
- Common Open Cut
- No.1 Open Cut Southwest Extension
- No.2 Open Cut Southwest Extension

The following mines are in operation :

- No.1 Open Cut
- No.2 Open Cut

Six economic coal seams have been, and are, mined by MCC from the Greta Coal Measures. These are (in order from top to bottom):

- Fleming
- Hallet
- Muswellbrook
- St Heliers
- Lewis
- Loder

Underground mining in the area east of Muswellbrook township commenced in 1907 with the No.1 Underground mine. It consisted of bord and pillar workings in the Fleming, Muswellbrook, St Heliers, and Lewis Seams. Carr and Associates (1998) report that as late as 1980, pillar extraction of these workings from near the Muswellbrook Common (about 1.5km SSW of the No.1 Open Cut) was occurring.

In the 1920s underground mining began further east of the No.1 Underground with the St Heliers Colliery. These were bord and pillar workings in the Muswellbrook and St Heliers Seams. Mining ceased in the 1940s. It is suspected that in some areas in the northern part of the workings, the Upper Lewis Seam was also extracted.

In 1944 the No.1 Open Cut was commenced. Coal was extracted from the Fleming, Hallet, Muswellbrook, St Heliers, Lewis, and Loder Seams. Loder Seam mining occurred only in the southern parts of the pit. Extensive backfilling of the western and southern parts of the open cut occurred. The current void is about half of the mined area. Operations ceased in 1970 and the pit was subsequently used as a water storage until 2001 when mining operations recommenced. In mid 2001, the No.1 Open Cut Dam was pumped out, with water being pumped into the No.2 Underground workings. Water is currently applied to a bench above the buried portal area in an attempt to cool potential spontaneous combustion in the No.2 Underground mine (see below).

The No.1 Open Cut has a southwesterly trending extension which mined the Fleming and, in some parts, the Muswellbrook Seams. This extension is backfilled. Also in the vicinity is the Common Open Cut, which mined to the Lewis Seam and is now used as a waste depot by Muswellbrook Council.

In 1965 the No.2 Open Cut was commenced. This pit is still in operation. Coal is extracted from the Fleming, Hallet, Muswellbrook, St Heliers, and Lewis Seams. Loder Seam mining has occurred in the southern parts of the pit. Backfilling has occurred in the southern parts of the pit, ramping down to the working face which is located on the northern boundary of the pit. Cessation of coal extraction is planned to occur in 2005. The No.2 Open Cut has a southwesterly trending extension which mined the Muswellbrook Seam and is now backfilled. Parts of the pit top facilities overlie the extension.

The No.2 Underground commenced operations in 1981 in the area immediately east of the No.1 Open Cut. Mining occurred in the Fleming, Muswellbrook, St Heliers, and Lewis Seams. To the east, mining occurred in the Lower Lewis Seam underneath parts of the old St Heliers Colliery. In the western area, mine drifts linking one seam to another are common, due to displacement by faults. The St Heliers Seam workings of this mine are connected to the workings of the St Heliers Colliery from access drives connecting both sets of workings at the western end of the St Heliers Colliery. Access to the No.2 Underground was through the main headings in the eastern highwall of the No.1 Open Cut. Lewis Seam development headings were driven to the north, alongside the western boundary of the No.2 Open Cut. These headings rise upwards into the St Heliers Seam after encountering a long dyke trending NNW – SSE. Some mining occurred at the end of these headings prior to closure. In 1997 the portal entrances were backfilled with mine spoil and the mine closed, due to possibility of collapse of the main headings.

Apart from the portal in the No. 1 Open Cut (which has been covered with spoil) a minimum barrier of 40m occurs between the existing underground workings and current open cut operations.

1.2 Existing Operations

The existing MCC operations comprise the following:

- Open cut mining of the Loder Seam in the No.1 Open Cut using a front end loader and dozer. The water level at the base of the pit was approximately 141 mAHD in November 2001.

- Open cut mining in the northern part of the No.2 Open Cut using an electric and hydraulic face shovel. The water level at the base of the pit was approximately 82 mAHD in November 2001.

- A Coal Preparation Plant (CPP), workshop, and mine offices located at the southeastern end of the lease.

The layout of current operations and infrastructure is shown in **Figure 2**.

Coal preparation consists of crushing and sorting only. No washing is conducted hence no water is used for this process. Coal processing produces no rejects. Highway trucks haul coal from the site stockpiles to the Ravensworth Coal Terminal (for export) or to local power stations.

Current production is approximately 1.4 Mtpa of thermal coal for export and domestic markets, from the No.2 Open Cut. A total of approximately 0.3 Mt has been extracted from the No.1 Open Cut since 2001.

1.3 Future Mine Plans

Future mining proposed by MCC consists of the following :

- No.1 Open Cut Extensions A and B (the subject of this report).

- The Sandy Creek underground mine, located immediately north of the No.2 Open Cut. Mining is proposed in the Muswellbrook and St Heliers Seams using bord and pillar methods, with subsequent pillar extraction.

The present development application and Environmental Impact Statement (EIS) addresses only the proposed extensions of the No.1 Open Cut.

1.4 Proposed Development (No.1 Open Cut Extension)

The proposed extension will be an open cut operation and will be located along an arc joining the No. 1 and No. 2 Open Cuts. The extension consists of two separate parts (Extension A and Extension B). The extensions are shown in **Figure 3**. The area encompassed by these extensions will be referred to as the works area. Mining will be conducted to the base of the Loder Seam in both extensions.

Extension A will mine through seams that have been previously mined using bord and pillar methods (Muswellbrook, St Heliers, and Lewis Seams).

Extension B will mine through seams that have been previously mined using bord and pillar methods (Fleming, Muswellbrook, St Heliers, and Lewis Seams), and through backfilled open cut pits (southwest extension of the No.2 Open Cut) which mined to the base of the Muswellbrook Seam.

Highwall auger mining may also be conducted, subject to approval from the Department of Mineral Resources (DMR).

The mining sequence will begin in Project Year 1 with Extension A in the eastern highwall of the No.1 Open Cut pit. Mining will progress in an easterly direction until Year 4, at which time the No.2 Underground headings in the Lewis Seam will be intersected at a point which may be used for access to the Sandy Creek underground reserves further north.

In Year 5, mining is planned to commence in Extension B from the east. An initial box cut will be made, leaving a barrier with the southern extent of the main No.2 Open Cut Pit. Mining will then continue in a westerly direction until Year 10, when the eastern highwall of Extension A will be intersected. The final void will be located in this central area, and will be of larger volume than the volume of mined coal. The void may be used as the access area to the Sandy Creek underground mine.

Figure 4 shows the planned annual mining sequence (for both extensions) that was adopted by MCC in March 2002, wherein the time of development of Extension B was five years in total. In April 2002, one year was added to the time of development of Extension B (for a total time of six years, as discussed above).

The schedule adopted in April 2002 can be summarised as follows:

- Year 1 to Year 4 – Mining of Extension A
- 2005 – Cessation of coal extraction in the No.2 Open Cut
- Year 4 – Possible development of an alternative entry to Sandy Creek reserves
- Year 5 to Year 10 – Mining of Extension B

Coal Road will be diverted for the development, and MCC pit top facilities may be relocated as required.

Coal production from the Extensions commences at 0.1 Mtpa in Year 1 and gradually increases to 1.5 Mtpa in Year 4, and remains at this production rate for most of the life of the development.

The majority of spoil from the extension will be emplaced within the existing No.1 Open Cut void. The northern end of the No.1 Open Cut void is also intended to be used as a water storage facility, hence most of the spoil will probably be placed within the southern end of this void, and the extension mining area. Inert overburden material will be used for treatment of overburden spoil piles as a seal to control the potential for spontaneous combustion at the No.1 and No.2 Open Cuts.

At present the No.2 Underground workings are being used as a water storage facility. A water storage strategy has been developed for the No.2 Underground to allow the proposed extension to proceed (see Section 6.1.1).

The proposed development provides a number of benefits, including:

- Improvement of the post-mining groundwater quality and natural recovery of the groundwater regime in the works area.
- Elimination of the pothole subsidence area located in the works area.
- Allowing current production levels to be maintained.
- Allowing a more efficient entry to the Sandy Creek reserves (previously proposed as the northern highwall of the No.2 Open Cut).

1.5 Methodology of the Water Management Study

The methodology used in the water study consisted of the following steps:

- Review of all available relevant data:

  * Water level data for the underground workings, and extraction rates, and water level data for on-site boreholes.

  * Hydraulic testing (permeability) data.

  * Extent of underground workings, and information on the contour surface of a representative seam.

- Calculation of the expected water makes (groundwater and surface water) from proposed operations:

  * Numerical simulation for calculation of expected groundwater make.

  * For expected surface water make, utilisation of the parameters and catchments as adopted by ERM (2002), in their evaluation of future requirements for the mine if the Hunter River Salinity Trading Scheme (HRSTS) is to be used. Catchment areas were modified as required by the proposed development of No. 1 Open Cut Extensions A and B.

- Calculation of a water level versus volume ratings curve for the underground workings.

- Discussion of mitigation measures to be used for mine water storages, licensing requirements, and a water strategy for the No.2 Underground / St Heliers Colliery.

2.0 REGIONAL SETTING

2.1 Rainfall and Evaporation

The nearest Bureau of Meteorology rainfall gauging stations with long records are located at Scone (22km to the north) and Jerrys Plains (25km to the south). Both stations are within similar terrain to the study area. Three rainfall gauging stations located in Muswellbrook and operated by the Bureau of Meteorology were previously in operation but were all discontinued in the late 1990s. The Muswellbook High School station was discontinued in 1996 (records kept since 1870).

Table 1 lists the mean long-term rainfall for Scone, Jerrys Plains, and Muswellbrook High School, and the mean long-term pan evaporation from the Scone station. The area exhibits a mean annual rainfall of approximately 616 mm. Mean potential evaporation is higher than mean rainfall for all months, indicating that a soil moisture deficit occurs most of the year (mostly during the summer months). Evaporation exceeds rainfall by 700mm to 1200mm per annum. Rainfall patterns are distinguished by intense storms during late summer and early autumn, with low average rates of runoff and infiltration, and high rates of evaporation.

The variation in yearly rainfall can be seen in the calculated annual rainfall deciles for Scone, Jerrys Plains, and Muswellbrook High School (**Table 1**). Over the last century, annual rainfall has varied between around 400mm and 850mm for 80% of the time. Comparison of Decile 5 (median) and mean annual rainfall indicates that the annual rainfall values in the data are almost normally distributed, showing a slight skewness to the low end.

2.2 Topography and Drainage

Topography in the area ranges in elevation from 150mAHD on the alluvial floodplains of the Hunter River to around 250mAHD near the No.2 Open Cut. Topographic highs consist of Skeletar Ridge to the south of MCC operations (maximum elevation 333mAHD) and the ridge to the east incorporating Bells Mountain (maximum elevation 690mAHD). Ground slopes are steep to the east, and moderate within the study area. **Figures 1** and **2** illustrate the topography of the area.

Between the No.1 and No.2 Open Cuts (the works area) lies natural ground surface and out of pit rehabilitated spoil dumps. Ground elevation of natural surfaces ranges between 230 and 260mAHD, whilst rehabilitated spoil mounds can reach as high as 300mAHD. The No.1 pit has been excavated down to an elevation of around 135mAHD in the northern part. The No.2 pit has been excavated to an elevation of around 70mAHD in the northern part.

No surface subsidence due to mining is apparent, except in localised pothole subsidence areas. In the works area, a pothole subsidence zone occurs alongside Coal Road, approximately 400m east of the No.1 Open Cut. This area was where increased thicknesses of the Muswellbrook and St Heliers Seams were extracted in the No.2 Underground. The potholes range up to around 8m in diameter and are generally about 10m deep.

Ground slope varies from around 3^{o} directly over the proposed pits to around 9^{o} just north of the proposed pits.

2.3 Site Geology

Figure 5 shows the regional geology of the area (Hunter Coalfield 1:100000 Geology Map, NSW Department of Mineral Resources, 1987). The current MCC mining areas are also shown. Drilling at the mine has revealed that the surface expression of the Greta Coal Measures is not as extensive as shown on **Figure 5**.

The MCC mining operations lie within the zone of outcrop of the Greta Coal Measures, which are of early to middle Permian age, and are about 110m thick in the area. The Greta Coal Measures occur at the base of the Permian sequence of the Sydney Basin, and were deposited in a marine environment. The Coal Measures outcrop to the south of the works area, just north of Skeletar Ridge.

Alluvial deposits occur on the lower reaches of Muscle and Sandy Creeks, and within the Hunter River floodplain, however these deposits are distant from the works area and will not be impacted by mining of the proposed extensions. Residual soils over Permian Rocks range from 1m to 5m thickness.

The Greta Coal Measures are overlain by the Branxton Formation which consists of sandstone, conglomerate, and siltstone. Underlying the Coal Measures are the Gyarran Volcanics which are composed of basic lavas, breccias, rhyolite, and ignimbrite. **Figure 6** shows the stratigraphic sequence in the Upper Hunter Valley.

MCC extracts coal from (in descending stratigraphic order) the Fleming, Hallet, Muswellbrook, St Heliers, Lewis, and Loder Seams. These seams comprise the economic coal seams in the mine area, and occur over a stratigraphic interval of approximately 60m at the base of the Greta Coal Measures. The Muswellbrook and St Heliers Seams are known to coalesce to the west and north (down dip). Interburden consists mainly of sandstone and siltstone however numerous igneous dykes and sills are present.

A representative stratigraphic column for the lower Greta Coal Measures in the works area has been constructed from available data, and has been used for all calculations in this study. The stratigraphic column is shown in **Figure 7**.

The strata dip to the northwest at angles ranging from 4^o to 11^o. In the works area, the dip is around 7^o, however there are seven laterally extensive normal faults trending NW-SE, located east of the No.1 Open Cut, that displace the seams by as much as 20m. The locations of these faults are shown in **Figure 10**. The faults exhibit throws of around 2m or less except for the western-most fault, which exhibits a displacement of around 20m. The western fault has been observed in the eastern highwall of the No.1 Open Cut (Douglas Partners, 1997a). Faults similar to these have been observed elsewhere in the Hunter Valley (within similar rock types) to act as barriers to groundwater flow in a direction normal to the fault plane.

In parts of the works area, the coal seam outcrops are replaced by coal fired rock, which is a collapse breccia formed by the goafing of overburden into the void left by burned coal. The parent material of this rock (sandstone, siltstone, and shale) was subjected to temperatures thought to be as high as 900^{o}C. In some areas, fused iron-rich slag can be observed cementing the breccia. The coal combustion occurred through natural means. Coal fired rock is overlain by sandy and gravely clay, of probable colluvial origin, formed by infilling of the void left by goafing (Douglas Partners, 1997a).

Two glide planes have been identified and described in the highwall of the No.1 Open Cut (Douglas Partners, 1997a). These are bedding plane shears caused by movement associated with overthrusting to the east. Strata overlying a shear may have been displaced up to 100m in a westerly direction, and rotated by about 10^o to 15^o in an anticlockwise direction. The planes are located at the base of the Fleming Seam and about 1m below the top of the St Heliers Seam.

2.3.1 Regional Structure

The major regional geological structural features present in the area are:

- Muswellbrook Anticline : This trends approximately north-south, with steep dips on the eastern side. To the north (just south of the No.2 Open Cut), the anticline merges with the Aberdeen Thrust / St Heliers Fault.

- Aberdeen Thrust / St Heliers Fault : This fault dips to the east and trends approximately north-south. It intersects the No.2 Open Cut. The movement associated with this structure has been the westward movement of the upper block overthrusting the lower block. To the north, the dip of the fault is less and movement has been less severe. To the south (just east of the works area), significant displacement in strata has occurred. This structure has caused fracturing and the formation of bedding plane shears in the works area.

- Hunter Thrust : This occurs to the far east of the study area and dips to the east. Its surface strike circumvents the Bells Mountain ridge system. Thrusting of the eastern block over the western block has occurred. The overlying strata are of Late Carboniferous age (metamorphic and volcanic rocks) and form the boundary of the Sydney Basin.

2.4 Land Use and Surrounding Mines

Land use within the area consists of stock grazing along the alluvial floodplains associated with the Hunter River and Sandy and Muscle Creeks. The Hunter River floodplain is also used for agriculture and dairying.

Immediately to the north of the No.1 Open Cut existed an old brick-making operation. A small clay pit previously used for raw materials exists in this area.

Approximately 1.5km north of the No.1 Open Cut exists Keevers Quarry which quarries cream to light grey coloured conglomerate and sandstone from a ridge top.

The nearest mining operations to the MCC operations consist of:

- The Dartbrook underground mine, located approximately 10km to the northwest, on the west bank of the Hunter River.
- The Bengalla open cut mine, located approximately 10km to the west, on the west bank of the Hunter River.
- The Bayswater No.2 and No. 3 open cut mines, located approximately 12km to the south. The No.2 open cut mining ceased in 1998, and No.3 operations commenced in 1995. The No.2 mine is one of a few in the Hunter Valley that has recently mined the Greta Coal Measures. The No.3 mine does not mine the Greta Coal Measures.
- The Drayton open cut mine, located approximately 10km to the south (adjacent to the Bayswater mines). The mine has a planned closure date of 2010, and is the only other mine in the Hunter Valley that mines within the Greta Coal Measures.

Available water level data indicate that none of these operations appear to have significantly impacted groundwater levels in the MCC area.

3.0 SURFACE WATER HYDROLOGY

3.1 Natural Catchments

There are two main catchments in the area of mining. These are associated with Muscle Creek and Sandy Creek.

Surface drainage to the north of Skeletar Ridge is in a northerly to northwesterly direction towards Sandy Creek. Skeletar Ridge passes through Mount Skeletar (see **Figures 1** and **2**), and trends southwest – northeast. Sandy Creek flows southwestwards and joins the Hunter River about 3km west of the study area (**Figure 1**).

South of Skeletar Ridge, drainage is in a southerly to southwesterly direction towards Muscle Creek. Muscle Creek flows westwards and joins the Hunter River about 4km southwest of the study area

(**Figure 1**). The main channels of both creeks exhibit locally incised banks up to 4m in height in their lower reaches.

The works area contains undisturbed land surfaces that drain towards the northwest, however some surface runoff is captured by dams. Drainage is mostly along 1st order channels, however some tracts of 2nd order channels exist in the eastern part of the works area. The drainage lines are influenced by bedrock fractures and faults trending NW-SE.

The proposed works do not encroach on the 100-year flood limit of the Hunter River, as defined by Muswellbrook Shire Council in the Muswellbrook Shire Local Environmental Plan (1985).

3.2 Mine Catchments

There are eight catchments covering the current operations areas, as shown in **Figure 8**. These have been identified by other studies (ERM, 2002). Runoff from all these catchments except catchment Q_{C3} forms a part of the mine water balance and is not currently discharged offsite, except by licensed discharging according to the HRSTS with MCCs' current EPA licence. Details of each catchment are listed in **Table 2**. The mine catchments occur mainly in the Sandy Creek drainage area, however parts of the No.2 Open Cut, and the pit top facilities, have formed catchments that were previously part of the Muscle Creek drainage area. The No.2 Open Cut has intersected Skeletar Ridge. Catchment Q_{C3} produces no mine water; sediment-laden water is captured by two dams, and the water is not returned to the mine water system.

The area of Catchment Q_{C5} is in the process of being reduced by up to 50% within the next year, by the construction of new holding dams and runoff channelling structures. This will reduce future surface water inputs to the mine water balance.

In addition to these catchments, there exists a small catchment associated with the pothole subsidence area. This catchment directly overlies the works area. A small holding dam collects sediment-laden water which is understood to not be re-routed into the mine water reticulation system. This catchment will be eliminated, and converted to spoil and pit base, in Years 2, 3, and 4 of development.

The central part of the mine area (immediately north of proposed operations) consists of an undisturbed catchment which drains to clean water dams located north of the works area on MCC property; the water in these dams is not part of the mines water reticulation system.

Seven dams are located on or adjacent to the area of the proposed pit extensions (**Figure 8**). All are on MCC property. They are listed in **Table 3** along with the type of water they hold. These dams will need to be drained at various stages of the proposed development.

3.3 Water Flows

No flow gauging data are available for Sandy or Muscle Creeks. They are both ephemeral, however Muscle Creek is observed to flow more frequently than Sandy Creek. These creeks tend to flow only during periods of high rainfall.

The Hunter River flows southwards with average flows of approximately 200ML/day at the Muswellbrook gauging station.

3.4 Water Quality

Surface water quality data were collected from various sources (AGC, 1984; Douglas Partners, 1997b; CH2MHill, 1998; HLA, 1998; and MCC, 2001).

Electrical conductivity (EC) of water samples in Sandy Creek has been monitored regularly in the past by MCC, and varies according to rainfall. During dry conditions, EC of the water can reach as high as 3,000 µS/cm, and in wet conditions can fall to below 500 µS/cm. EC was measured at an average value of approximately 920 µS/cm in 1996 (HLA, 1998), compared to an average of 1,724 µS/cm during 1999 (data supplied by MCC, April 2002). pH is slightly alkaline (7.9).

Water quality in Muscle Creek (MCC, 2001) is monitored at two locations by MCC on a regular basis (**Figure 8**) and is known to vary according to rainfall. During dry conditions, EC of the water can reach as high as 10,000 µS/cm, and in wet conditions can fall to below 1,000 µS/cm. The average EC for the period January 2001 to December 2001 was 1,679 µS/cm at the upstream location and 2,267 µS/cm at the downstream location (data supplied by MCC, April 2002). This compares with average values of 3,833 µS/cm (upstream) and 4,103 µS/cm (downstream), for the period March 1995 to November 1997 (CH2MHill, 1998). pH measurements indicate slightly alkaline water (7.6).

Water quality of natural runoff from Greta Coal Measures terrain, calculated from nine measurements in AGC (1984), indicates a mean of about 380 µS/cm.

Water quality of runoff from mine spoil from Greta Coal Measures strata, calculated from four measurements in AGC (1984), indicates a mean of about 2,560 µS/cm.

Average EC for pit water was reported by MCC as 4,702 µS/cm for the No.2 Open Cut pond and 4,052 µS/cm for the No.1 Open Cut pond, for the period January 2001 to December 2001. EC data are available since 1981, and it appears that EC has steadily increased by about 1,000 µS/cm on average, over the last 20 years. pH measurements indicate slightly alkaline water (7.5 to 7.7).

Appendix A is a compilation of water quality data available at the time of these studies.

4.0 GROUNDWATER HYDROLOGY

The workings of the No.2 Underground mine and St Heliers Colliery are currently being used for water storage, therefore an understanding of the groundwater system is important with respect to the proposed works.

4.1 Aquifers

The works area is in elevated terrain and no alluvial deposits of high permeability exist. Residual soils are generally too thin to retain groundwater volumes of consequence. The Coal Measures have negligible intergranular porosity, but fissures, joints, and fractures impart porosity and permeability to the rock mass.

Permeability testing data at the mine site (AGC, 1984; Douglas Partners, 1997b) for rock strata indicate that the coal seams are the main aquifers in the Coal Measures. Permeability of the coal seams is, on average, two orders of magnitude higher than interburden. The Muswellbrook / St

Heliers Seam pairing will be the main aquifer in undisturbed ground. Coal Seams are observed to have closely spaced jointing with no preferred orientation (Douglas Partners, 1997a).

Old workings consist of partial extraction using bord and pillar operations. They will act as reservoirs of water, with non-Darcy flow occurring in the mine voids. They are essentially voids that release stored water, or accept formation water, according to the permeability of surrounding strata. The workings of the No.2 Underground and the overlying St Heliers Colliery are considered to be well connected, hence these mines can be considered a single entity for the purposes of water storage calculations. Water level monitoring data (see Appendix B) confirm the hydraulic connection of these mines. Movement of water within these workings will be by pipe flow rather than Darcy flow.

An open borehole that is called the Cross-Workings Drainage Hole (**Figure 2**) exists in the mine area. This borehole was drilled in 1991 in the northern (down-dip) part of the St Heliers Colliery within the lower levels of the workings. Its purpose was to drain any water in the Muswellbrook / St Heliers Seams of the St Heliers Colliery into the underlying Lewis Seam workings of the No.2 Underground. Mine water make for the No.2 Underground at this time was estimated by mine staff as approximately 0.3 ML/day, and it was thought by mine staff that most of the inflow was from water stored in overlying workings. This borehole provides a good hydraulic connection between the two sets of workings.

Water level data collected by Douglas Partners (1997b) indicate that Coal-Fired Rock will provide enhanced rainfall infiltration. The rock may behave similarly to a coarse unconsolidated gravel (high storage and high permeability).

The contact between the Gyarran Volcanics and Greta Coal Measures has been identified as a palaeosol horizon which may be permeable, and may form a groundwater pathway below the pit floors (Douglas Partners, 1997a). It is reported that significant water inflows occurred in the past, at points where the interface was encountered, and that at some locations, intersections of the interface with faults exhibited open voids (Douglas Partners, 1997a, from mine staff).

As discussed, there are large areas where old and young mine spoil is emplaced. Spoil is known to be heterogeneous due to the range of grain / boulder sizes in its constituents, and is known to be anisotropic according to the method of emplacement (Hawkins, 1994). The spoil has been generally laid in north-south strips in the No.1 Open Cut and in east-west strips in the No.2 Open Cut. In both cases, water flowing towards the open pits, from within the spoil, will be travelling normal to the strip direction.

4.2 Aquifer Parameters

A database of 20 packer test measurements conducted at the site at specific horizons is available (AGC, 1984; Douglas Partners, 1997b). These data are listed in **Appendix B**. A good relationship between depth of cover and horizontal permeability is apparent (**Figure 9**). The volume of data provides an acceptable platform for permeability estimates.

Overall, the coal seams exhibit permeabilities ranging from about 2 m/day near the surface to about 0.001 m/day at a depth of 130m. Overburden permeabilities range from about 0.01 m/day at the surface to about 0.0001 m/day at a depth of 100m. These data indicate a marked contrast between coal seams and overburden.

Two tests conducted in sintered coal (metamorphosed by diorite sills) indicate that sintered coal exhibits similar characteristics to overburden. Pockets of sintered coal in the works area are assumed to be localised.

The igneous sills in the works area are composed of very high strength, slightly weathered, unbroken diorite (Douglas Partners, 1997b). AGC (1984) provide test measurements for two sills in the Muswellbrook area with permeabilities slightly higher than the coal seams. The data presented are 1.5 m/day for a sill at a depth of 80m, and 1.4 m/day for a sill at a depth of 50m. The structure of the tested sills is not described.

The storativity of Coal Measures strata can be estimated from various data. Detailed study of piezometer water level data and mine inflow data at the Wambo Mine (HLA, 2000) indicates that the drainable overburden storage factor, within similar rock types to the overburden in the works area, is around 4×10^{-3}. Extensive pumpout testing at Ulan Coal Mine indicates that the specific storage of hardrock layers is around 3×10^{-6} m^{-1}. This is confirmed by a long duration test conducted at the Glendell Coal Lease (Rust PPK, 1996) where early time storativities indicated a specific storage of about 2.5×10^{-6} m^{-1}.

Experience with similar spoil at other mines in the Hunter Valley, and results of research (Hawkins, 1994), indicate that a reasonable estimate of horizontal permeability of open cut mine spoil at the Muswellbrook mine is 1 m/day considering the direction of flow in the spoil at the open cuts, and the measured surface of the water table in spoil in the No.1 Open Cut (Douglas Partners, 1997b). A reasonable estimate of storativity for mine spoil is 15%.

4.3 Groundwater Levels and Flow

A composite potentiometric water level surface was compiled by HLA for the period late 1980 / early 1981 (just prior to commencement of the No.2 Underground mine). Water levels were obtained from open exploration boreholes, dipped soon after drilling. This surface is shown in **Figure 10**. There is some distortion in the contours due to the position of measurement points. Additionally, the interpolation of data between points does not accommodate the discontinuous nature of the worked / unworked interface in the coal seams.

There are several features of note in the water level surface:

- Water levels indicate a westerly to northwesterly flow direction, from groundwater highs under Skeletar Ridge and Bells Mountain to the east, towards the discharge zone along Sandy Creek (see **Figure 1** for topographic highs).
- The St Heliers Colliery is seen as a depression with about 40m of drawdown.
- The No.2 Open Cut is seen as a depression with about 60m of drawdown.
- The No.1 Open Cut shows negligible drawdown, however there is an east-west trending low anomaly running through the open cut, which may indicate drainage into a lineament, possibly representing an igneous intrusion into the fault discussed previously. The anomaly is more apparent to the west of the open cut, where underground mining of the No.1 Underground may have come close to the lineament. The contours reflect the use of the pit for water storage.

- The No.1 Underground is not conspicuous. It may have already undergone substantial refilling with groundwater by this time. A pothole subsidence area west of the No.1 Open Cut, overlying the No.1 Underground, appears to maintain a groundwater mound in the Coal Measures, probably by leakage from water perched in sediments and rubble within the potholes.

Water level measurements collected since 1981 indicate that the regional flow field has remained unchanged, however drawdown around the No.2 Open Cut has increased. **Appendix B** is a compilation of water level data available at the time of these studies. A part of the data consists of two figures of hydrographs presented in AGC (1984), covering the period 1981 to 1983, for which actual values were unavailable.

The water level in the No.2 Underground workings in February 2002 was at an elevation of approximately 154mAHD. In mid-April the water level had fallen to approximately 152mAHD. The elevation of the base of the buried portal in the No.1 Open Cut highwall is approximately 168mAHD, however the Lewis Seam falls rapidly a short way into the headings, due to faulting.

Figure 11 is a hydrogeological cross-section oriented northeast – southwest, through the works area and both open cut pits. It shows the relative water levels within the workings at the end of 2001.

4.4 Groundwater Quality

Water quality analysis of samples from 12 wells intersecting unworked Greta Coal Measures (AGC, 1984; Douglas Partners, 1997b) indicate a mean EC of 5,535 µS/cm and mean pH of 7.6. The water is not suitable for potable uses or irrigation, and is generally only useful for stock consumption (excluding poultry). In contrast, the average EC from six measurements of groundwater in the overlying Whittingham Coal Measures at the Bengalla lease (MMA, 1993) was 3,230 µS/cm. This indicates the relatively higher salinities of the Greta Coal Measures compared to overlying Permian formations.

Results of water chemistry analysis are plotted in a Piper diagram in **Figure 12** to show the relative percentages of major cations and anions. The character of seawater is also plotted for reference. The results indicate that the groundwater in the Greta Coal Measures on the site is dominated by sulphate and chloride, whereas the groundwater in the overlying Whittingham Coal Measures is bicarbonate, and weakly sulphidic (MMA, 1993).

The higher percentage of sulphate ions reflects the greater sulphur content of the Greta Coal Measures, which are known to produce acid mine drainage at other locations in the Hunter Valley. It is noted that the open cut pond water at the MCC mine exhibits a pH of about 7.6, which suggests lower sulphur content or higher buffering capacity of the groundwater than elsewhere in the Greta Coal Measures.

One set of chemical analytical data is available for groundwater within mine spoil (Douglas Partners, 1997b). The data indicate a character similar to pit water.

4.5 Groundwater Use

Previous studies have identified a number of DLWC registered water bores in the region of the mine:

- All registered bores within a 3km radius of the No.1 Open Cut are located along the Hunter River, within alluvium. A majority of the wells were constructed of timber between 1912 and 1964 and may no longer be in operation (Douglas Partners, 1997b). All these bores are distant from the works area.

- The nearest bores to the south are located 4km from the works area, in alluvium along Muscle Creek. There are 3 bores within an area of about 1 km^2 (RCA, 1998).

- The nearest bores to the north are located 4.5km or more from the works area, in alluvium along Sandy Creek. There are several bores located along 5km of the reach of the creek (HLA, 1998).

The bores are generally used only for stock water supplies. There are no DLWC registered water bores near the works area that are likely to be impacted by the proposed extension.

5.0 EXISTING WATER MANAGEMENT SYSTEM

5.1 Background

Prior to 2001, the mine was in an approximate state of zero discharge. In 2001, the No.1 Open Cut was dewatered to allow further mining. This created an additional input of approximately 0.6 ML/day to the mine water system. Excess mine water was then either directed to the No.2 Underground workings or used for dust suppression.

Water extraction records for the No.2 Open Cut for the period December 2000 to February 2002, supplied by MCC, are understood to indicate pit water extraction of approximately 5 ML/day from the No.2 Open Cut. Field observations made by an HLA Hydrogeologist provided no evidence for seepage into the pit of this magnitude. Bulking calculations using electrical conductivity data indicate that approximately between 2 to 2.5 ML/day of pit water finds its way into the mine dam system.

5.2 Water Management Strategy

The water management strategy adopted for the existing operations and the proposed No.1 Open Cut Extension involves:

- Separating clean water runoff produced by undisturbed catchments from dirty (sediment-laden) and contaminated runoff from disturbed catchments.

- Recycling and reusing practically all dirty and contaminated mine water for dust suppression and wash-down activities.

- Using clean water for fire-fighting supplies and sensitive equipment where required.

- Using disused open cuts and underground mines as water storages where possible, and where mine safety permits.

- Minimising any offsite discharge of saline mine water to within the amount allowed by the existing EPA discharge Licence No. 656 (1 ML/day when the Hunter River is in flood flow) under the HRSTS.

5.3 Key Features of the Mine Water Management System

A schematic diagram of the current mine water management system is shown in **Figure 13**. Saline mine water is collected from the No.1 and No.2 open cuts and is handled by the mine water system. The main elements of this system consist of the following dams (see **Figure 13**):

- Dam 1 (20 ML capacity)
- Dam 2 (23 ML capacity)
- Workshop Dam (15 ML capacity)
- Final Settling Pond (20 ML capacity)

Mine water from the No.2 Open Cut is discharged into Dam 1 located at the northwest corner of the No.2 Open Cut. Overflow from Dam 1 drains into Dam 2.

Dam 2 was constructed in 2001 and receives water from the No.2 Underground and the No.2 Open Cut. It is located adjacent to Dam 1. Its water level is maintained by pumping into the Workshop Dam, located in the pit top facilities area to the southeast. Dam 2 has an emergency overflow system (used only during times of extremely intense rainfall) where water is temporarily pumped to a secondary storage.

The Workshop Dam meets most of the mines' operational water requirements. Water is drawn from it to supply dust suppression requirements. Excess water in this dam can drain by gravity feed into the Final Settling Pond, or is pumped to Cut 11 within the spoil, where it is assumed to report to the St Heliers Colliery underground workings or the No.2 Open Cut.

The Final Settling Pond is located in the southeast. Water is pumped from it whenever discharges under the current licence conditions are possible. Excess water is returned to the Workshop Dam.

The main mine usages consist of:

- Dust suppression on roads, pit floor, and other work areas.
- Dust suppression at the CPP, generally comprised of suppressing dust during dumping of coal into the hopper.

Negligible amounts of water are discharged off-site at the following location:

- From the Final Settling Pond into an un-named tributary of Muscle Creek, according to the current EPA discharge Licence 656 (reported by mine staff as approximately 10ML for the period July 2000 to June 2001).

Potable water consists of Muswellbrook Council town water supply. Site demand is of the order of 0.1ML/day and a negligible return is made to the mine water system (through low volume equipment washdown facilities). Most of this water is irrigated as effluent at the mine, and is not assumed to return to the mine water system. The input from this source to the mine water system is assumed to be nil.

Maps provided by MCC indicate that the old tracts of spoil-filled open cut associated with the No.2 Open Cut (the old southwest extensions of the No.2 Open Cut, and Cut 11) are connected to the underground workings of the St Heliers Colliery (and possibly the No.2 Underground) by tunnels in the Fleming and Muswellbrook Seams. These tunnels may well have been a source of water to the underground workings by enhanced rainfall infiltration into the spoil, and seepage into the tunnels.

5.4 Mine Water Balance in 2001

The water balance for the mine has been calculated based on data from various sources, and calculations of groundwater inflow and surface water make. Refer to **Appendix D** for groundwater inflow calculations, and **Appendix E** for surface water make calculations. The inflows and outflows to the mine water balance during 2001 are listed in **Table 4**.

Surface runoff (1.80 ML/day) comprises 81% of the total mine water make. The total groundwater inflow was estimated to be 0.43 ML/day (about 19% of the total mine water make). Outflows from the water balance were mostly by dust suppression (data supplied by MCC). The salient feature of the water balance is the mine water deficit of 0.30 ML/day.

6.0 PREDICTED CHANGES IN SURFACE WATER AND GROUNDWATER MAKE

6.1 Evaluation of Changes in Groundwater Inflows

6.1.1 No.2 Underground Mine / St Heliers Colliery Water Storage Strategy

The formulation of a water storage strategy for water within the No.2 Underground / St Heliers Colliery workings is necessary prior to evaluation of the impacts of the proposed development. The objective of this strategy is to prevent free water inrushes from the highwalls of the extensions into the pit.

As discussed, the water level in the No.2 Underground workings in February 2002 was at an elevation of approximately 154mAHD. In mid-April the water level had fallen to approximately 152mAHD. This level is just below the floor of the Lewis Seam development heading at the intersection with the westerly fault. This prevents seepage along the fault plane. Calculations presented below use the February 2002 water level as a starting level (154mAHD).

A cross-section has been compiled of coal seam elevations as they occur on the northern edge of Extensions A and B. **Figure 14** shows the coal seam elevations, and locations of the workings as they may appear in the northern highwall, based on coal seam elevation data provided by MCC. The portions of northern edge exposed for each development year are also shown. Since the coal seams dip to the northwest, the northern edge of the pit will approximately provide the lowest elevations of underground workings intersected by excavation in the works area. The worked sections are marked on the section based on the manner in which an intersected worked section connects with the main storage in the down dip parts of the No.2 Underground and St Heliers Colliery.

Reference to **Figure 14** indicates that in Year 1 of development, no old lower seam workings are intersected in the northern highwall. The eastern highwall will have intersected old Lewis Seam workings, but at a lowest level of approximately 160 mAHD, therefore an underground water level of 154.5 mAHD will probably be acceptable.

In Year 2, Lewis Seam workings at a lowermost elevation of approximately 140 mAHD are intersected, therefore the water level in the workings will need to be lowered by at least 15m prior to mining this area to prevent large water bursts at the face, and local flooding. With the inclusion of a safety factor, the water level in the No.2 Underground should be lowered to around 135 mAHD. Water storage versus water level calculations for the No.2 Underground are presented in **Appendix C**. These calculations indicate that approximately 400 ML will need to be pumped out of the workings to draw the water level down by 20m, from 155mAHD.

Water removed from the No.2 Underground in Year 2 will be stored in the pond in the northern area of the No.1 Open Cut. **Appendix C** provides calculations of storage availability in the No.1 Open Cut as it may appear at the end of Year 1 of development. Assuming a water level of 135 mAHD in the No.1 Open Cut northern area (just above the Loder Seam floor), the addition of 400 ML of water would raise the water level to about 146 mAHD. The coal seam floor structure indicates that the highest level the water in the No.1 Open Cut can reach, without seeping into the Year 2 (and beyond) extension workings, is about 150 mAHD, therefore the removal of the required water in Year 2 can be accommodated (refer to **Figure C1**, **Appendix C**).

From Year 2 to the middle of Year 4, the lowermost elevations of old workings are above 140 mAHD, however excavation of the 2nd part of the Year 4 area exposes old workings down to an elevation of approximately 128 mAHD. These excavations will uncover the possible access portal to the Sandy Creek reserves. At this point in time, there are two possible scenarios:

- Commencement of infrastructure development for the Sandy Creek underground mine within the mining area of the Extension, requiring that the entire underground workings be dewatered. This amounts to approximately 380 ML of water.

- The Sandy Creek mine does not commence, requiring that the water level in the underground workings be lowered to about 123mAHD (assuming a 5m safety factor). This amounts to approximately 240 ML of water.

The No.2 Open Cut will have ceased operations at the end of 2005 so the excess water to be removed from the No.2 Underground in Year 4 will be stored in this pit. **Appendix C** provides calculations of storage availability in the No.2 Open Cut pit as it may appear at the cessation of mining (2005). Assuming that the pit is left open for 2 years, the water level in the No.2 Open Cut may have risen to about 57 mAHD (based on 1ML/day total inflow for 2 years, from a starting level of 40mAHD). Addition of a maximum of 380 ML will raise the water level to approximately 61 mAHD, assuming that spoil in the No.2 Open Cut is completely dry. In reality, some water may be stored in the spoil. A likely water level rise to about 65 to 70 mAHD is possible, however this will depend on the spoil emplacement and pumping strategies in the No.2 Open Cut during Years 2 and 3 of the Extension development. However, the No.2 Open Cut has the capacity to contain the addition of 380 ML or less in Year 4.

In summary, the strategy for the No.2 Underground water storage is as follows :

- Water level of 155 mAHD maintained until the beginning of Year 2.

- Water level lowered to 135 mAHD in Year 2; extracted water placed into No.1 Open Cut.

- Water level maintained at 135 mAHD in Years 2 and 3.
- Water level is either lowered to 123 mAHD, or the workings are totally emptied, in Year 4; extracted water placed into No.2 Open Cut.

The evaluation of future groundwater make in Extensions A and B has been conducted using numerical simulation, and is based on the strategy for the No.2 Underground storage as discussed, combined with the March 2002 timing of the Extension development (9 years). The actual time frame of development is 10 years, however the calculated results would probably show little difference with results for a 10-year development. The methodology and technical aspects of the simulation are described in **Appendix D**.

6.1.2 Results

The predicted groundwater inflows for median rainfall conditions during Years 1 to 9 are listed in **Table 5**, and shown in **Figure D4** (**Appendix D**). Inflows gradually increase until Year 5 when a sharper rise in inflows occurs; this time coincides with the beginning of mining at the eastern end of Extension B. Maximum inflows to the extension of around 0.22 ML/day are calculated for Years 7 and 8. After Year 8 the inflows show a minor decrease.

Inflows to the No.2 Underground and the No.2 Open Cut (the combined No.2 mines) are lumped together. These voids act virtually as a single sink to the groundwater system due to their proximity and the geometry of the workings. Inflows to the combined No.2 mines drop markedly from Year 1, reaching a stable value of around 0.1 ML/day for most of the development. This appears to be caused by the depressurisation of the aquifer of the Gyarran Volcanics / Greta Coal Measures contact, and interception of rainfall recharge at the outcrop zones, by the open cut workings of the proposed development. Inflows to the No.1 Open Cut show a gradual decrease with time, from 0.14 ML/day to 0.12 ML/day.

Of the set of faults within the western part of the works area (see Section 2.3), the most likely to provide an avenue for transient, high volume, water inflows is the westernmost fault with a throw of 20m. This fault intersects the No.1 Open Cut and may, in the early years of development, provide enhanced inflow along its plane of movement. This is because the fault plane may link the water ponded in the No.1 Open Cut (at a level of around 150mAHD) to the floor of the proposed open cut (which reaches down to a level of around 130mAHD in Year 2).

There are also tracts of spoil-filled open cut (the old southwest extensions of the No.2 Open Cut, and Cut 11) that will be intersected by the proposed extension in Years 4 to 9. Maps provided by MCC indicate that the old extensions are connected to the underground workings by tunnels in the Fleming and Muswellbrook Seams, as is Cut 11. This may well have been a source of enhanced infiltration to the underground workings by enhanced rainfall infiltration into the spoil, and seepage into the tunnels. The precise geometry of the tunnel entries into the spoil-filled voids is unknown, therefore the water level in these voids cannot be estimated. Care should be taken, however, when this spoil is intersected, as additional fast water inflows may occur from these pits, due to the relatively high storativity and high hydraulic conductivity of spoil.

Water stored in sediments and rubble within potholes will provide nuisance groundwater inflows of short duration.

Water levels are completely influenced by the No.2 Underground storage strategy. By Year 9 the mined strata in the area are nearly completely dewatered.

Sensitivity analysis of rainfall and aquifer parameters indicates that for extreme conditions, groundwater inflows may vary by around 20%.

6.2 Evaluation of Changes in Surface Water Make

The evaluation of future surface water make in Extensions A and B has been conducted based on the March 2002 timing of the Extension development (9 years). The actual time frame of development is 10 years, however the calculated results would probably show little difference with results for a 10-year development.

6.2.1 Surface Mining Operations

The area excavated in each year of development will be referred to as a Block (for example, Block 1 is excavated in Year 1). The status of ground surfaces within any annual excavation in the works area, during development, is assumed to be as follows:

- Spoil from Block 1 is placed into the No.1 Open Cut in Year 1.
- Spoil from Block 2 is placed into the part of Block 1 which overlays catchment Q_{CB}, and into the part of the No.1 Open Cut floor within catchment Q_{CB} (and which has remained open from Year 1). This allows the northern arm of Block 1 (the part overlaying catchment Q_{C6}) to remain open according to the planned water storage strategy of the No.1 Open Cut.
- From Year 3 to Year 9, spoil from an excavated block is placed into the void of the previously mined block, except for the Block 4 void which will remain as a pit base from Years 4 to 9.
- Spoil excavated in a particular year remains unrehabilitated the following year, and is rehabilitated the year after that (for example, Block 3 spoil is placed into the Block 2 pit in Year 3; this spoil is classified as unrehabilitated in Year 4, and as rehabilitated in Year 5). Spoil therefore remains unrehabilitated for 2 years.

The areas generated according to this operations plan, and the respective components of surface type, are presented in **Appendix E**.

6.2.2 Results

The evaluation of surface water makes during Years 1 to 9 is described in **Appendix E**. Results for dry, median, and wet conditions are listed in **Table 6**.

The results show the reduction in water make when the No.2 Open Cut is decommissioned from the beginning of Year 3. Extreme conditions cause the water make to vary by about 40%, or approximately double the magnitude of variations seen in groundwater make (see **Appendix D**).

7.0 PROPOSED WATER MANAGEMENT SYSTEM

7.1 Proposed Water Management Strategy

The objectives of the proposed water management plan take into account the practical requirements to mine economically and safely, and the water management principles in Section 5 of the Water Management Act 2000. These objectives can be summarised as:

- Meet the water supply needs of the project.
- Protect the safety of people and equipment in the mine by minimising the risk of large uncontrolled inflows of water into the mine pit from the No.2 Underground.
- Eliminate or minimise the risk of off-site discharge of dirty or saline water, except as allowed under the EPA licence.

The water management strategy during the development will consist of the following:

- Use of the No.1 Open Cut as a water storage from 2003 until the end of the project. The water level in the pit will be kept below 150mAHD.
- Use of the No.2 Open Cut as a water storage from the beginning of 2006. From 2006, water will be allowed to accumulate in the pit; this eliminates the surface runoff produced by the pit from the mine water balance, whilst groundwater inflows to the pit will gradually decline because of the increasing head of water in the pit pond.
- Gradual reduction of the area of catchment Q_{C5} by up to 50%, thereby removing a portion of the water make from this catchment from the mine water system. This will be achieved by constructing new holding dams and runoff channelling structures in the catchment. This construction has commenced.
- Construction of a new dam of up to 400 ML capacity for mine water storage (as part of the development application for the Sandy Creek underground mine proposal) if required. It is assumed to have minimal catchment.

The storage in the No.1 Open Cut between levels of 146 mAHD and 150 mAHD will be the amount of freeboard available from the beginning of Year 2. This freeboard is approximately 360 ML. This allows for the average addition of approximately 1 ML/day, assuming the No.2 Open Cut pit becomes available as a water storage at the beginning of Year 3. In practice, the time lag between disposal of underground water into the No.1 Open Cut in Year 2 of development, and the availability of the No.2 Open Cut, would be less than 1 year.

The construction of earth bunds and dams to capture clean and silty water produced by catchment Q_{C5} will occur during the development, as spoil mounds in this catchment are rehabilitated. A Maximum Harvestable Right Dam Capacity (MHRDC) assessment will be conducted on these dams and works, and appropriate licences obtained if required.

7.1.1 Hunter River Salinity Trading Scheme

It is understood that studies are being conducted on the feasibility of using an un-named tributary of Muscle Creek as a discharge channel for MCC excess mine water under the rules of the HRSTS. This would be implemented using MCCs' 11 salt credits, and a proposed flood flow discharge of up to 175 ML/day. MCC has engaged a consultant to prepare a Tributary Impact Statement for this waterway.

MCC will be holding discussions with the NSW Environment Protection Authority (EPA) on the proposal. This water management study has not incorporated any HRSTS discharges from the mine. Discharges allowable under the current EPA discharge licence have been incorporated.

7.2 Water Balance Model for the Proposed Extension

7.2.1 Inputs to the System

There are 4 sources of water for the mine water balance. These consist of:

- Groundwater inflows to the combined No.2 Mines (the No.2 Underground, St Heliers Colliery, and No.2 Open Cut), the No.1 Open Cut, and the proposed pit extensions, as calculated in **Appendix D** (median rainfall conditions). Values for wet and dry conditions are the results for median conditions increased or decreased, respectively, by 20%.

- Surface water make from meteorological processes, as calculated in **Appendix E**.

- Drainage of the seven dams located on or adjacent to the area of the proposed pit extensions. These inputs can be assumed constant for all conditions. Dam volumes are approximate only, and are based on an average depth of 3m (except the Workshop Dam).

- Groundwater inflows from the proposed Sandy Creek underground mine which, for the purposes of water budget calculations, has been assumed to commence in Year 5. Predictions of groundwater inflows for this operation are 0.1 ML/day in the first year, rising uniformly to 0.4 ML/day in the tenth year (HLA, 1998).

The applied inflows are for a worst case scenario, where the No.2 Underground has been emptied of water, and the Sandy Creek mine has commenced and provides input to the water balance.

7.2.2 Outflows from the System

There are three sinks or outflows of water for the mine water balance. These consist of:

- Dust suppression. Mine staff indicate that dust suppression uses an average of 2.5 ML/day. A variation of 30% is applied for wet and dry conditions.

- Seepage losses from dams. These may occur from the various water storages but are expected to be minimal due to the age of the dams and the sealing effect of suspended sediment in the water. It has been assumed for water balance calculation purposes that the net seepage loss from the system is nil.

- Offsite discharges according to EPA Licence 656. These occur from time to time, and have been estimated as 0.03 ML/day for median conditions, 0.05 ML/day for wet conditions, and nil for dry conditions.

7.2.3 Results

The water balance for the period of the proposed development was calculated for wet, median and dry conditions to evaluate the sensitivity of the proposed water management system to a range of weather conditions, and to estimate the resultant requirements for water storage or for make-up water.

The definitions for wet, dry, and median conditions are provided in Section 2.1 of **Appendix E**, along with input parameters for rainfall and evaporation. The parameters revolve around the probabilistic characteristics of rainfall at Muswellbrook, and evaporation at Scone.

Wet conditions are the averaged effect of the wettest 9 consecutive years on record at Muswellbrook. Dry conditions are the averaged effect of the driest 9 consecutive years on record at Muswellbrook, between the period 1871 and 1997.

Calculated mine water budgets are listed in **Table 7**. The results indicate that the mine operates in deficit for all years in dry and median conditions, but operates in excess for all years in wet conditions. The maximum excess is approximately 1 ML/day in Years 1 and 2, but then drops markedly in Year 3.

The most sensitive years in terms of mine water make are Years 1 and 2. An analysis of recent rainfall trends, assuming that Year 1 is 2003 (March 2002 mine plan), and the variation in the Southern Oscillation, indicates that Years 1 and 2 are more likely to exhibit median to dry rainfall conditions. **Appendix F** provides results of the analysis. Results suggest that the earliest onset of wet conditions may not occur until mid to late 2004, about 1½ years prior to availability of the No.2 Open Cut for water storage.

7.3 Mine Water Quality

The quality of water produced by the proposed open cut extension is expected to be similar to water quality measured in the current pits. EC may be slightly less since the proposed operations are nearer one of the main rainfall recharge zones of the area (the outcrop of the coal seams).

Impacts on water quality within the mine water system are expected to be minimal.

8.0 POTENTIAL IMPACTS OF PROPOSED DEVELOPMENT

8.1 Surface Hydrology

The proposed development will occur on high ground and will be limited in extent, compared to the area covered by all mining operations. A number of small catchments will be modified by open cut mining, however these catchments mostly contain 1st order ephemeral streams that are dry for most of the year (a portion of a second order stream is affected in the northeast). These impacts are considered negligible.

Water quality in Sandy and Muscle Creeks will not be affected, except by proposed HRSTS discharges which are the subject of another study.

8.2 Groundwater Hydrology

The proposed extension mines through strata and groundwater regimes already disturbed by mining. Mining will lower the water levels in the Greta Coal Measures to the base of the Loder Seam over a small area. In the wider area, water levels will fall to the Lewis Seam when the Sandy Creek underground mine commences. The Loder Seam contains brackish water and is not considered a groundwater resource.

The proposed mining should improve the groundwater regime in the area because a large portion of mined workings will have been removed and replaced with spoil, creating a better environment for groundwater recovery and improvement in groundwater quality.

8.3 Cumulative Impacts

The changes in groundwater levels in the coal measures are largely dictated by the strategy for the No.2 Underground.

The proposed extension itself will have negligible impact on water levels and aquifers, except to lower the water levels to the base of the Loder Seam instead of the Lewis Seam (a drop in elevation of around 10m). The impacts of the extension are expected to be substantially masked by the development of the Sandy Creek underground mine, if it proceeds, which will depressurise the St Heliers and Muswellbrook Seams over a large area.

8.3.1 Post Mining Water Levels

The final void of the proposed extension will be located at Block 4, and will remain dewatered so that the proposed Sandy Creek underground mine can proceed. Recovery of water levels after mining will occur after completion of the Sandy Creek Underground mine project, previously estimated as taking approximately 10 years (HLA, 1998), if it proceeds. Current considerations by mine staff are a mine life of 20 years for the proposed Sandy Creek operations.

The post-mining water levels in the spoil-filled, and open, voids of the proposed No.1 Open Cut Extensions A and B should be evaluated once a mine operations plan for the Sandy Creek underground mine project is finalised, so that the ground disturbance from those workings is incorporated.

In general terms, the post-mining hardrock water levels in the proposed extension area will depend on the fate of the void in Block 4, once the mining in the Sandy Creek underground ceases.

9.0 PROPOSED MITIGATION MEASURES

9.1 Mine Water Storage

Make-up water will be required in dry and median conditions. The large amount of water stored in the No.1 and No.2 open cuts should be sufficient to meet the shortfall during drier conditions. In the unlikely event that the stored water is found to be insufficient, water stored in holding dams of the eliminated Q_{C3} catchment, and the reduced Q_{C5} catchment, can be used. As a last resort, appropriate licences would be applied for to obtain water from other sources.

In wet conditions, the mine operates with an excess of around 1 ML/day in Years 1 and 2. The freeboard available in the No.1 Open Cut is approximately 1 ML/day for 1 year, therefore an additional storage of approximately 360 ML would be required prior to availability of the No.2 Open Cut (assuming the availability is at the beginning of Year 3). The development application for the Sandy Creek mine (HLA, 1998) included a dam of up to 400 ML capacity (see Figure 8). It is understood that the dam has been approved by statutory authorities. As a last resort, the construction of a 400 ML dam would be sufficient to store the entire excess of 360 ML in wet conditions. A dam of half this size would allow storage of just over half of this excess, with the remainder able to be consumed by other means.

Should the variation in the discharge licence be approved (up to 175ML/day in flood conditions), this would probably be sufficient in itself to eliminate the excess water.

Other methods of water use are available, especially with the large tracts of spoil available at the mine. A water evaporation operation, using specialist evaporative equipment, can consume over 1 ML/day of water, depending on the scale of the operation. A good example is the set of large sprinklers being used for evaporative purposes at Ulan Coal Mine in the western Hunter Valley. If evaporative processes are commenced at the beginning of Year 1, the accrual of excess water at the mine will be mitigated, in case wet conditions are encountered.

There are two additional processes that will consume water, or eliminate water production, which have not been incorporated into the budget calculations. These consist of:

- Evaporation from the No.1 Open Cut pond - In Year 2 the No.1 Open Cut pond is likely to have a surface area of approximately 9 ha. Evaporation from the pond with this area would be approximately 0.1 ML/day in wet conditions.

- Elimination of a part of the surface water make from Catchment Q_{C5} - The area of Catchment Q_{C5} will be gradually reduced by up to 50%. When construction of new holding dams and runoff channelling structures is complete, and assuming the eliminated area consists of rehabilitated spoil, the decrease in surface water make would be approximately 0.2 ML/day in wet conditions.

9.2 Surface Water

The mine will operate essentially as a zero discharge operation (discharge limited by the current EPA licence which is capped at 1 ML/day during flood flow in the Hunter River) and therefore will not impact surrounding streams. The mine design will include provisions to ensure that any accidental discharge of saline and dirty water is contained by strategically located bunds and pits, and by installation of pressure-loss-activated switches on pumps.

Spoil mounds will be rehabilitated progressively to minimise the volumes of dirty water runoff and restore the water flow and quality of these catchments. It is anticipated that approximately 80% of the disturbed catchments can be restored, with the rest of the catchments remaining as open cut base or hardstand areas. On completion of mining all disturbed areas will be revegetated to restore the runoff and water quality characteristics of the area.

9.3 Groundwater

No mitigation measures are required for effects on groundwater from the proposed extension.

10.0 RECOMMENDED MONITORING

10.1 Monitoring Objectives

Monitoring should be carried out to confirm that the water management system is effective, and that the impacts of mining are consistent with the predictions made in this study and the various licence conditions.

In Year 1, water pumping volumes should be reviewed on a weekly basis to track the change in storage at the mine, and to determine the appropriate mitigation measure or measures which may be required for mine water storage, if wet conditions occur (as discussed in Section 9.1)

The monitoring data will be reviewed annually and it is recommended that more thorough reviews be carried out at the beginning of Year 2, when the lower levels of Lewis Seam underground workings are intersected in the highwalls, and at Year 4, when the development of the alternative entry to the Sandy Creek reserves may be commenced.

10.2 Water Management System Monitoring

It is recommended that flow meters be installed at key points in the water management system to monitor water flows (if they are not already installed). Recommended locations include:

- Pipelines to the No.2 Underground storage
- Pipelines to the Workshop Dam
- Pipelines to and from the No.2 Open Cut Pit.
- Pipelines to and from the No.1 Open Cut Pit
- Pipelines to any offsite discharge points

Water levels in the main water management dams should also be monitored regularly to assist with water balance calculations and to ensure sufficient freeboard is always available to contain the run-off from design storms specified in consent conditions, or by statutory authorities.

Water quality monitoring at the current monitoring locations should be continued.

10.3 Groundwater Levels and Quality

The current monitoring well network consists of the following bores (see **Figure 2**):

- RDH522: An observation well intersecting the St Heliers Seam of the No.2 Underground Mine. It is located approximately 50 metres east of the current dewatering bore for the No.2

Underground. An open piezometer was installed in January 2002 to enable water level measurements.

- RDH472: An observation well passing through both the Muswellbrook and St Heliers Seam workings in the older St Heliers Colliery. The bore is cased to below the Muswellbrook seam and measures water levels mostly representative of the St Heliers Seam workings.

Since the main component of the groundwater regime, as it affects the proposed development, will be the water stored in the No.2 Underground and the St Heliers Colliery, these two bores are considered sufficient for groundwater monitoring. A groundwater monitoring program will be put in place. Data from the monitoring program will then be used as a control on the mine water management system.

It is recommended that water quality in the workings be analysed on an annual basis throughout the life of the project.

10.4 Water Levels in Old Spoil-Filled Open Cut Pits

Water levels in the tracts of spoil-filled open cut pits (the old southwest extensions of the No.2 Open Cut) that will be intersected by the proposed extension in Years 4 to 9 should be determined prior to mining. It is recommended that at least one borehole be drilled into the deepest part of these filled areas (with drilling conducted to the base of the spoil), and water levels obtained. If water is present, the volume of stored water can be estimated, and appropriate mitigation measures formulated.

11.0 LICENSING AND REGULATORY CONSIDERATIONS

11.1 General

The main legislation governing water management for the proposed development is as stipulated in the following:

- The Rivers and Foreshore Improvement Act 1948

- The Water Act 1912

A new water management Act, the Water Management Act 2000 No.92 (NSW Government Gazette No. 168, December 2000) is expected to commence from mid 2002. Therefore, the requirements of this Act, particularly Section 5 (Water Management Principles) and Sections 90 and 91 (Licensing), have also been considered in project planning.

The probable licensing requirements for the development, under each of these Acts, are discussed in the following sections.

11.2 Rivers and Foreshore Improvements Act

A permit is required under Section 3A of this Act for any alteration of a natural water course or river. This is not expected to be applicable, as no water courses will be altered or diverted. In general terms, application for a permit is not required by a mine for works in an approved mining area.

11.3 Water Act 1912

Various licences are required under the Water Act 1912, especially for construction and use of water management works or water bores. The main licences which may be required for the proposed development are those that are covered under Section 10 of the Water Act 1912. This section deals with licences "to construct and use a work, and to take and use water, if any, conserved, or obtained by the work, and to dispose of the water for the use of occupiers of land".

The following is a list of activities that may require licensing:

- Construction of drains and settling dams in, and taking water from, ephemeral water courses associated with the works area.
- Construction of an open cut mine (No.1 Open Cut Extensions A and B) and taking and using surface water and groundwater entering the mine.
- Construction of dams with a total storage capacity in excess of the Maximum Harvestable Right Dam Capacity (MHRDC).

It is possible that further licences may be required once mine designs are finalised or when parts of the system are modified. These will be applied for at the time.

Licences would also be required under Section 116 of the Water Act 1912 to commence, enlarge, deepen or alter a bore for dewatering purposes.

11.4 Water Management Act 2000

When the Water Management Act 2000 becomes operative, applicable licences will be required under the following sections:

Section 90 Water management work approvals to construct and use water supply works, drainage works, and flood works.

Section 91 Activity approvals to carry out a controlled activity (that is, removal or deposition of material that affects the quantity or flow of water in a water source) or to carry out an aquifer interference activity.

11.5 Embargo on Dams

Under Section 22BB of the Water Act 1912 the Water Administration Corporation proclaimed on 16th March 2001 an embargo under Part 2 of the Act for many types of dams in the Hunter River Catchments. It is understood that the embargo applies to third order streams or above.

All of the water courses within the works area are either 1st or 2nd order streams. MCC have not finalised a strategy of proposed replacement dams for those affected by the development, however due regard to the legislation will be made.

11.6 Maximum Harvestable Right Dam Capacity

The MHRDC is the total allowable capacity of all dams on a property, constructed in 1st or 2nd order water courses, which do not need to be licensed. The MHRDC is calculated based on the percentage of runoff generated by rainfall in an area, and the size of the subject property. It does not apply to dams used for the following purposes:

- Control or prevention of soil erosion (gully control structures), provided no water is reticulated or pumped from such dams and the size of the structure is the minimum necessary to fulfil the erosion control function.
- Flood detention and mitigation, provided no water is reticulated or pumped from such dams.
- Capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by regulation to prevent the contamination of a water source.
- Dams endorsed by the DLWC for specific environmental management purposes.
- Dams without a catchment.

A Farm Dams Property Assessment should be conducted, in the context of the proposed development, for any new dams that are to be built. Existing mine water system dams should be included. MCC has made application to the DLWC for existing mine water system dams to be registered.

11.7 Embargo on Extracting Alluvial Groundwater

Under Section 113A of the Water Act 1912, the Water Administration Corporation proclaimed in April 2000 an embargo on the abstraction of groundwater from alluvium under Part 5 of the Act in the Hunter River catchments. This legislation is not applicable for the proposed development, since no embargoed aquifers will be affected.

Reference to the DLWC map "Embargoed Alluvial Aquifer Systems of the Hunter Valley" (2001) indicates that the nearest embargoed alluvial system is located about 1km southeast of the No.2 Open Cut, and extends southwards. This aquifer is associated with an un-named tributary of Muscle Creek, and is hydrogeologically separated from the works area by a major groundwater divide located underneath Skeletar Ridge, and by outcropping of the mined coal seams.

12.0 CONCLUSIONS

For the proposed No.1 Open Cut Extension the mine will remain essentially as a zero discharge operation due to development of linked alternative storages. Excess mine water will be stored in the No.1 Open Cut, the No.2 Open Cut, and parts of the No.2 Underground / St Heliers Colliery, at various times during the proposed development.

Water balance calculations indicate that the mine will operate in deficit for all years of development, for median and dry conditions. For wet conditions the mine will operate in excess for all years.

For wet conditions, additional storage may be provided by the new discharge dam, and / or a combination of storage within spoil and evaporative spraying. This will account for the maximum predicted excesses of approximately 1 ML/day in Years 1 and 2, when the No.2 Open Cut pit is unavailable for water storage.

The most important years in terms of the mine water balance are Years 1 and 2. Analysis of recent rainfall trends, assuming that Year 1 is 2003 (March 2002 mine plan), and behaviour of the Southern Oscillation, indicate that these years are likely to exhibit median to dry rainfall conditions. Results indicate that there is a greater than 50% chance that additional mitigation measures (such as evaporative spraying) will not be required.

During mining, short-term higher groundwater inflows may be experienced from the following sources:

- The normal fault of 20m throw, intersecting the No.1 Open Cut.
- The tracts of spoil-filled open cut pits consisting of the old southwest extensions of the No.2 Open Cut.

Water stored in sediments and rubble within potholes will provide nuisance groundwater inflows of short duration.

Water quality in Sandy and Muscle Creeks will not be affected, except by proposed HRSTS discharges into Muscle Creek which are the subject of another study. The proposed mining should improve the groundwater regime in the area because a large portion of mined workings will have been removed and replaced with spoil, creating a better environment for groundwater recovery and improvement in groundwater quality.

The quality of water produced by the proposed open cut extension is expected to be similar to water quality measured in the current pits. Impacts on water quality within the mine water system are expected to be minimal.

Recommended monitoring includes installation of flow meters at strategic points in the mine water pumping circuit, water level and quality monitoring at various locations throughout the period of the development, and evaluation of water levels in tracts of spoil-filled open cut to be intersected by the proposed development in Years 5 to 10.

Licences may be required by MCC to undertake the following activities:

- Construction of dams where the MHRDC is exceeded, and within ephemeral water courses in the works area.
- Use of water from an open cut mine.

A licence may be required for the following activity, when the Water Management Act 2000 comes into force:

- Removal or deposition of material that affects the quantity or flow of water in a water source, or carry out an aquifer interference activity.

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Muswellbrook Coal Company Limited
No.1 Open Cut Extension
Water Management Study

5 June 2002

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Quality Control Reviewer

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Chris Kidd
Principal Hydrogeologist / Managing Director

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TABLES

Table 1. Meteorological Data.

	Jerrys Plains PO* (Station 061086)	Muswellbrook HS# (Station 061053)	Scone SCS^ (Station 061089)	
	Mean monthly rainfall (mm)	Mean monthly rainfall (mm)	Mean monthly rainfall (mm)	Mean monthly pan evaporation
Jan	79	71	92	217
Feb	70	63	80	175
Mar	59	53	50	155
Apr	45	44	41	108
May	42	42	51	68
Jun	46	50	43	48
Jul	45	45	36	56
Aug	37	39	40	84
Sep	42	41	41	117
Oct	52	49	60	155
Nov	58	53	54	183
Dec	67	66	67	226
Annual	640	616	655	1592

	Jerrys Plains PO* (Station 061086)	Muswellbrook HS# (Station 061053)	Scone SCS^ (Station 061089)
	Decile Annual Rainfall (mm)	Decile Annual Rainfall (mm)	Decile Annual Rainfall (mm)
Decile 1	418	390	406
Decile 5	644	591	657
Decile 9	826	852	868

Notes:
* 116 years of records.
^ 49 years of records.
# 115 years of records.

Table 2. Mine Water Catchments (ERM, 2002)

Catchment Name	Area (ha)	Operations Type	Surface Types	Main Storage	Surface Area of Main Storage (ha)
QC_A	127.4	No.2 Open Cut	Spoil and pit base	No.2 Open Cut Pond	1.61
QC_B	38.0	South part of No.1 Open Cut	Spoil and pit base	None	None
QC_1	0.13	Dam No.1 Surface	Turkey nest dam	Dam 1	0.13
QC_2	19.4	Dam No.2 catchment	Natural ground	Dam 2	0.36
QC_4	2.7	Workshop Dam catchment	Disturbed area	Workshop Dam	0.2
QC_5	91.2	Final Settling Pond catchment	Disturbed area and rehabilitated spoil	Final Settling Pond	1.01
QC_6	40.3	North part of No.1 Open Cut	Spoil and pit base	No.1 Open Cut Pond	0.27

Note: Catchment QC3 is not part of the mine water system.

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Table 3. Dams Located in the Works Area

Dam Name	Description	Water Type	Approximate Area * (ha)	Approximate Volume (ML)
Dam A	Natural ground, No.1 Open Cut	clean	0.125	4 #
Dam B	Natural ground, No.1 Open Cut	clean	0.125	4 #
Dam C	Sediment dam of pothole area	sediment	0.3	9 #
Dam D	Large dam outside mine water system	clean	0.9	27 #
Dam E	Dam at east end of Extension A	clean	0.3	9 #
Dam F	Settlement dam near ROM hopper	mine	0.08	2 #
Workshop Dam	Part of mine water system	mine	0.2	15

* Estimated from 1:12500 map.
# Based on an average depth of 3m.

Table 4. Mine Water Balance in 2001

Budget Component	ML/day	% of Total Inputs
INPUTS		
Groundwater		
No.2 Mines	0.29	13
No1 Open Cut	0.14	6
Total Surface Water	1.80	81
TOTAL	2.23	100
OUTPUTS		
Dust Suppression	2.50	112
Licensed Discharge	0.03	1
TOTAL	2.53	113
DEFICIT	**0.30**	**13**

Table 5. Calculated Groundwater Inflows to the Proposed Extension (Median Rainfall Conditions)

Year of Development	Proposed Extension (ML/day)	No.2 Mines (ML/day)	No.1 Open Cut (ML/day)
1	0.056	0.269	0.14
2	0.09	0.095	0.137
3	0.102	0.099	0.131
4	0.123	0.097	0.133
5	0.173	0.096	0.129
6	0.198	0.102	0.126
7	0.219	0.097	0.123
8	0.217	0.097	0.119
9	0.203	0.097	0.117

Table 6. Total Mine Surface Water Make, Years 1 to 9.

Year of Development	Total Surface Water Make from Meteorologic Processes		
	Dry Conditions* (ML/day)	Median Conditions^ (ML/day)	Wet Conditions# (ML/day)
1	1.16	1.62	2.23
2	1.17	1.63	2.24
3	0.78	1.09	1.49
4	0.8	1.11	1.53
5	0.84	1.16	1.59
6	0.81	1.12	1.54
7	0.78	1.09	1.49
8	0.78	1.08	1.48
9	0.77	1.07	1.47

* 458 mm/year, approximately equal to the decile 2 annual rainfall at the Muswellbrook High School station.
^ 616 mm/year, equal to the mean annual rainfall at the Muswellbrook High School station.
# 830 mm/year, approximately equal to the decile 9 annual rainfall at the Muswellbrook High School station.

Table 7. Total Mine Water Balance During the Proposed Development

Median Conditions

Budget Component	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
INPUTS									
Groundwater									
Proposed Extension	0.056	0.090	0.102	0.123	0.173	0.198	0.219	0.217	0.203
No.2 Mines	0.269	0.095	0.099	0.097	0.096	0.102	0.097	0.097	0.097
No1 Open Cut	0.140	0.137	0.131	0.133	0.129	0.126	0.123	0.119	0.117
Sandy Creek Mine	0.000	0.000	0.000	0.000	0.100	0.133	0.167	0.200	0.233
Total Surface Water	1.620	1.630	1.090	1.110	1.160	1.120	1.090	1.080	1.070
Dam Removal	0.011	0.110	0.000	0.025	0.000	0.001	0.041	0.000	0.000
OUTPUTS									
Dust Suppression	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
Licensed Discharge	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
EXCESS	-0.43	-0.47	-1.11	-1.04	-0.87	-0.85	-0.79	-0.82	-0.81

Dry Conditions

Budget Component	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
INPUTS									
Groundwater									
Proposed Extension	0.045	0.072	0.082	0.098	0.138	0.158	0.175	0.174	0.162
No.2 Mines	0.215	0.076	0.079	0.078	0.077	0.082	0.078	0.078	0.078
No1 Open Cut	0.112	0.110	0.105	0.106	0.103	0.101	0.098	0.095	0.094
Sandy Creek Mine	0.000	0.000	0.000	0.000	0.080	0.106	0.134	0.160	0.186
Total Surface Water	1.160	1.170	0.780	0.800	0.840	0.810	0.780	0.780	0.770
Dam Removal	0.011	0.110	0.000	0.025	0.000	0.001	0.041	0.000	0.000
OUTPUTS									
Dust Suppression	3.250	3.250	3.250	3.250	3.250	3.250	3.250	3.250	3.250
Licensed Discharge	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EXCESS	-1.71	-1.71	-2.20	-2.14	-2.01	-1.99	-1.94	-1.96	-1.96

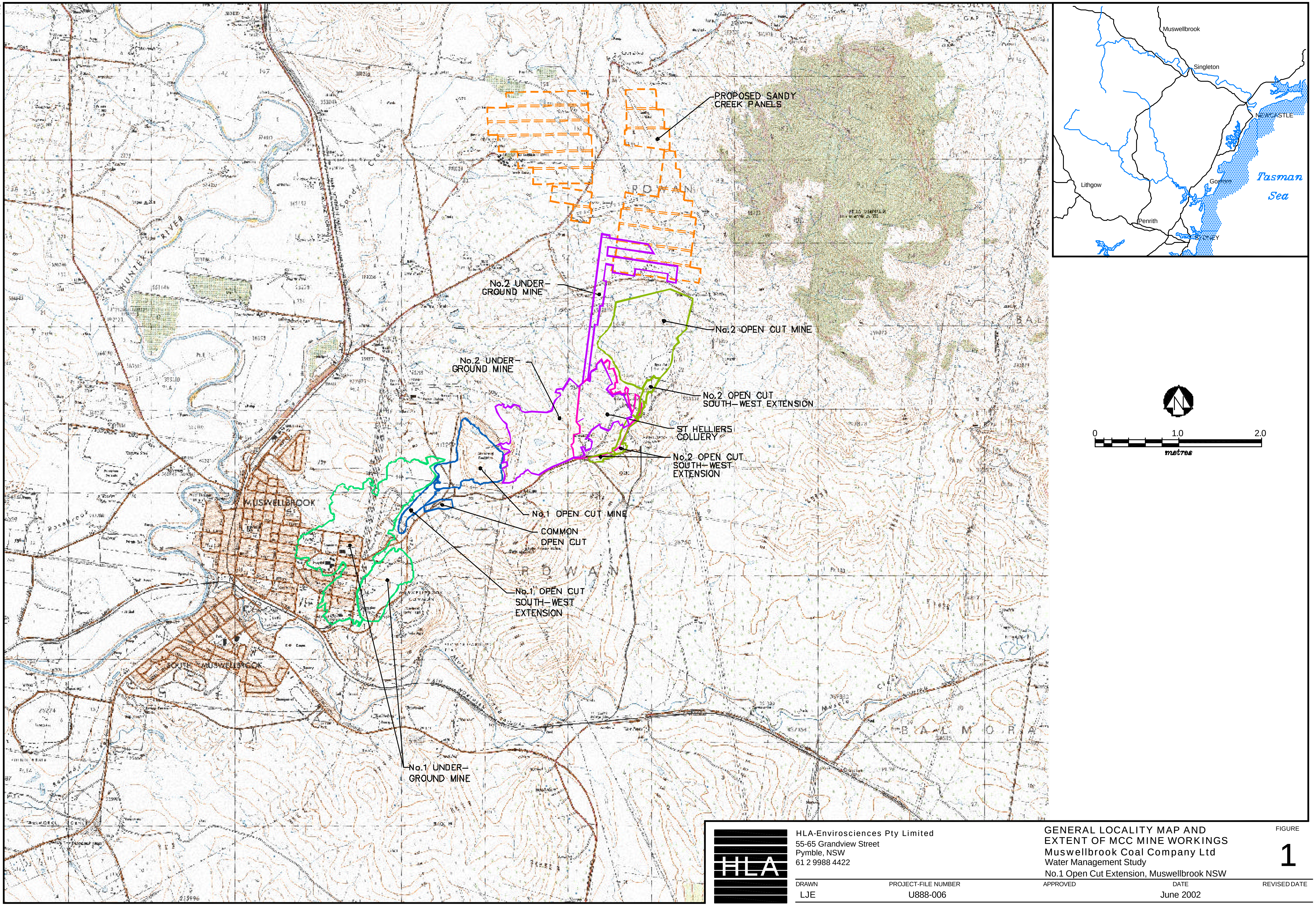
Wet Conditions

Budget Component	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
INPUTS									
Groundwater									
Proposed Extension	0.067	0.108	0.122	0.148	0.208	0.238	0.263	0.260	0.244
No.2 Mines	0.323	0.114	0.119	0.116	0.115	0.122	0.116	0.116	0.116
No1 Open Cut	0.168	0.164	0.157	0.160	0.155	0.151	0.148	0.143	0.140
Sandy Creek Mine	0.000	0.000	0.000	0.000	0.120	0.160	0.200	0.240	0.280
Total Surface Water	2.230	2.240	1.490	1.530	1.590	1.540	1.490	1.480	1.470
Dam Removal	0.011	0.110	0.000	0.025	0.000	0.001	0.041	0.000	0.000
OUTPUTS									
Dust Suppression	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750	1.750
Licensed Discharge	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
EXCESS	1.00	0.94	0.09	0.18	0.39	0.41	0.46	0.44	0.45

Note: All values are in ML/day.

FIGURES

A3



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GENERAL LOCALITY MAP AND EXTENT OF MCC MINE WORKINGS
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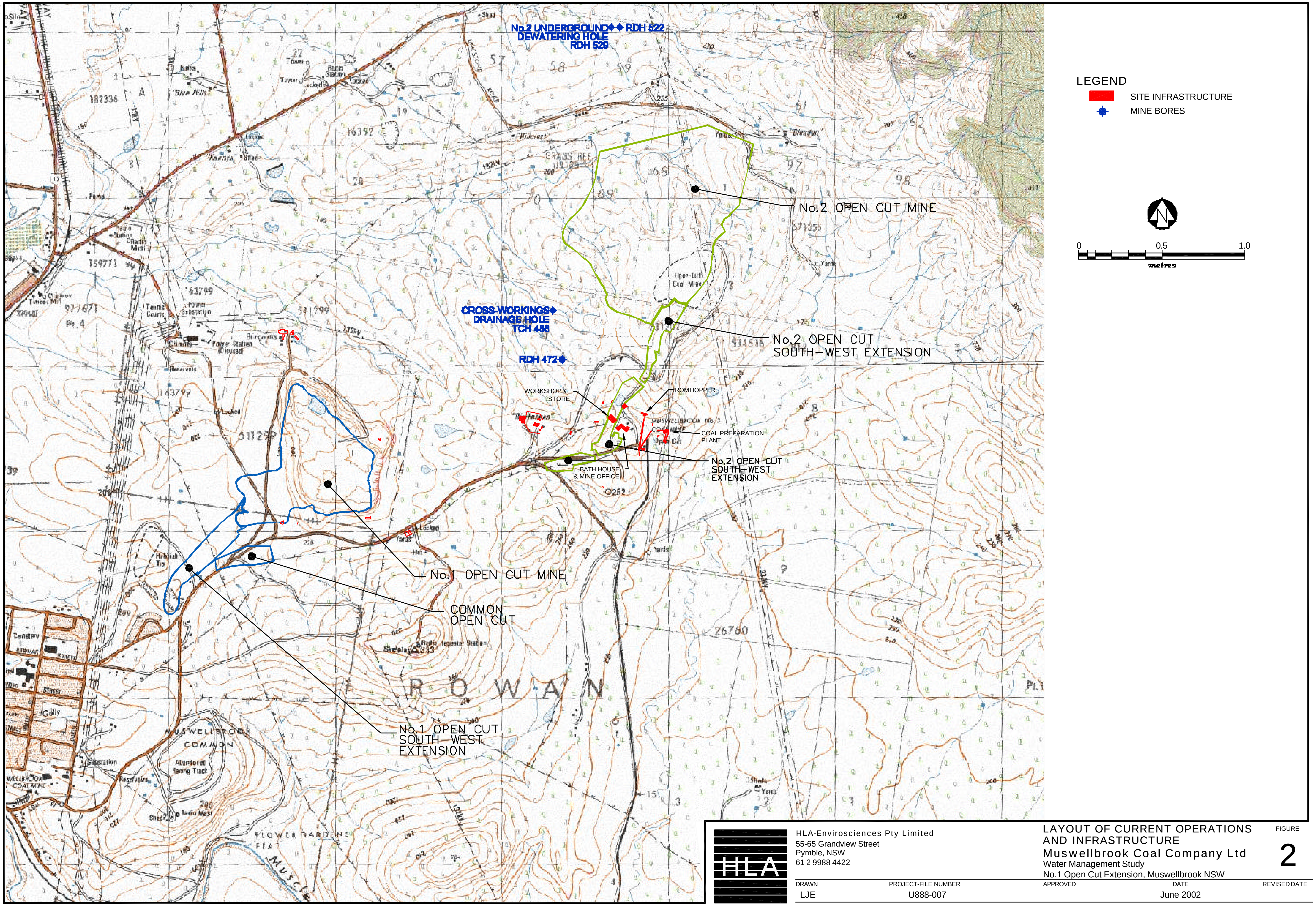
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE 1

DRAWN	PROJECT-FILE NUMBER	APPROVED	DATE	REVISED DATE
LJE	U888-006		June 2002	

A3



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LAYOUT OF CURRENT OPERATIONS AND INFRASTRUCTURE
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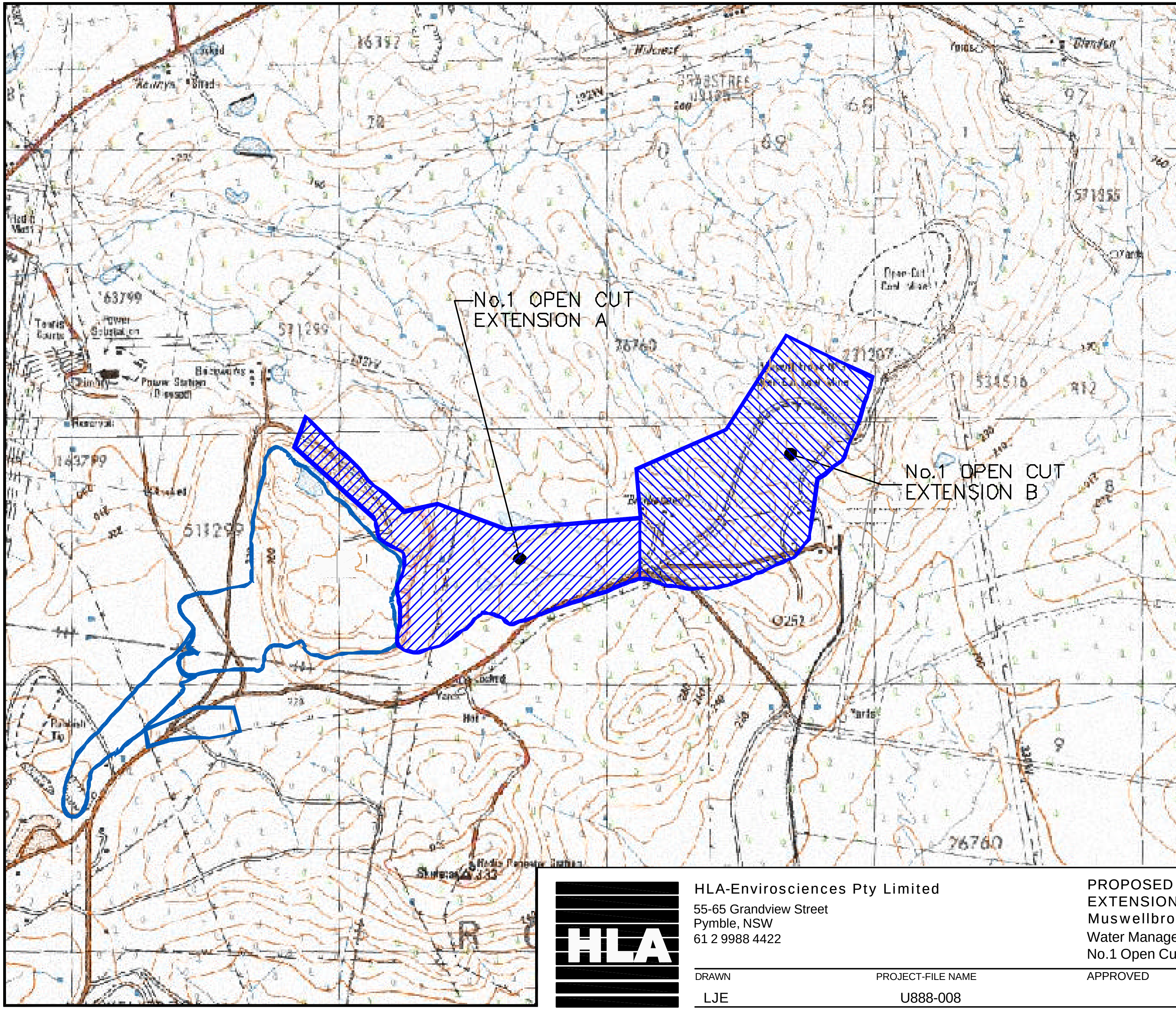
FIGURE 2

DRAWN	PROJECT-FILE NUMBER	APPROVED	DATE	REVISED DATE
LJE	U888-007		June 2002	



LEGEND

NO.1 OPEN CUT

N

0 0.5 1.0
metres

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PROPOSED NO.1 OPEN CUT
EXTENSIONS A AND B
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No.1 Open Cut Extension, Muswellbrook NSW

FIGURE 3

DRAWN	PROJECT-FILE NAME	APPROVED	DATE	REVISED DATE
LJE	U888-008		June 2002	

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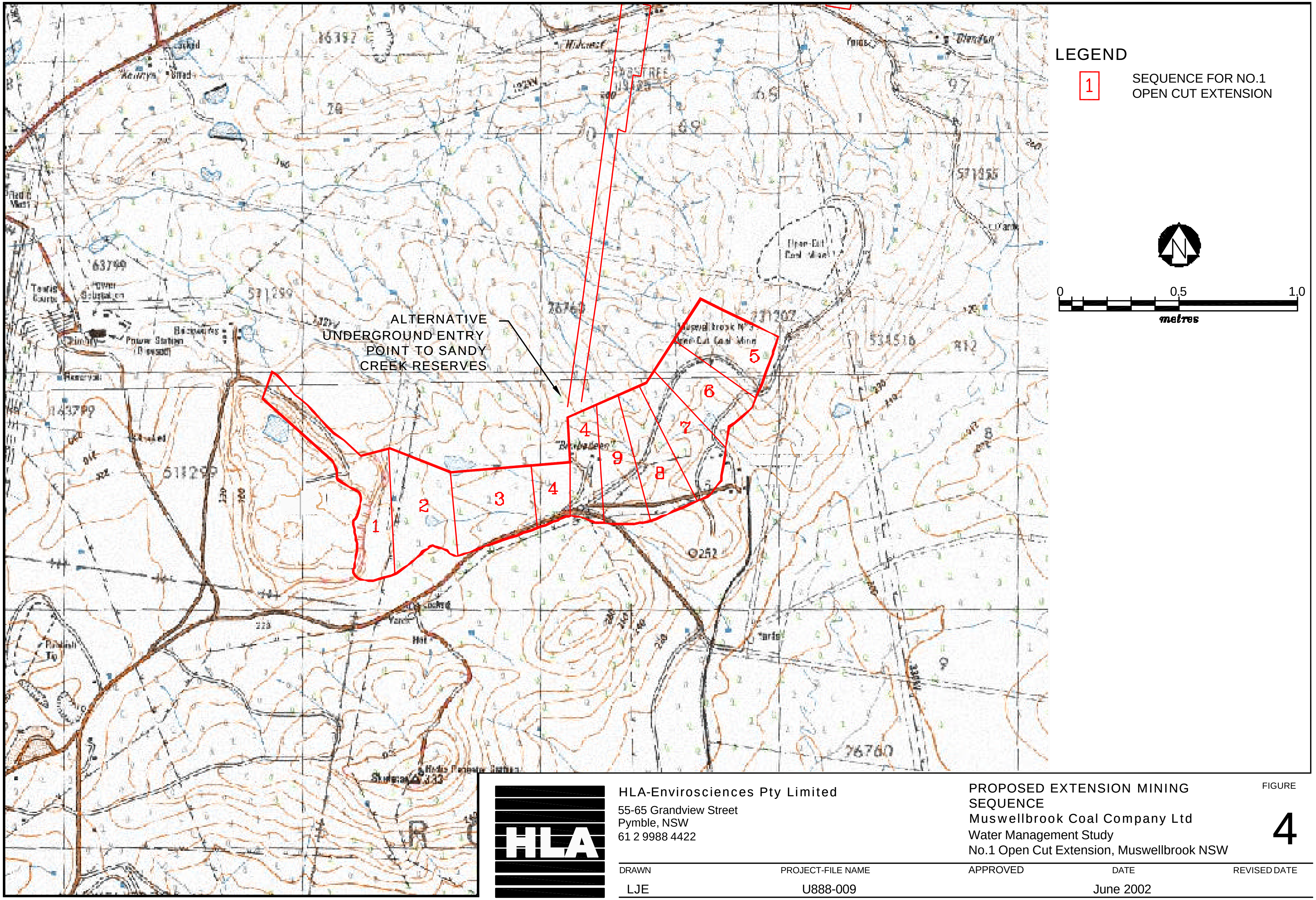

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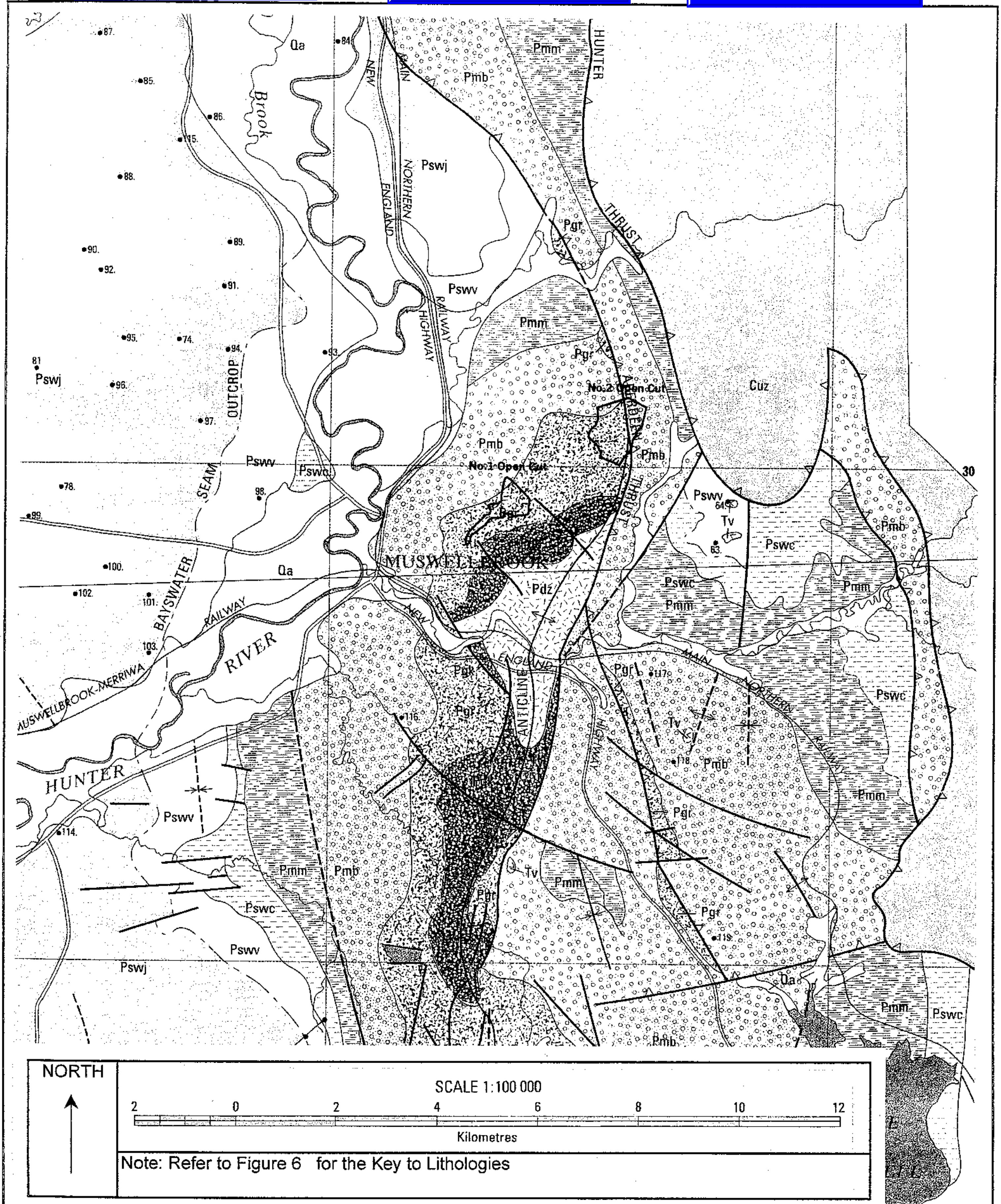
PROPOSED EXTENSION MINING SEQUENCE
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE 4

DRAWN	PROJECT-FILE NAME	APPROVED	DATE	REVISED DATE
LJE	U888-009		June 2002	



Reference: Hunter Coalfield 1:100000 Geology Map, DMR, 1987.

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REGIONAL GEOLOGY
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE **5**

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
	U888-7		March 2002	

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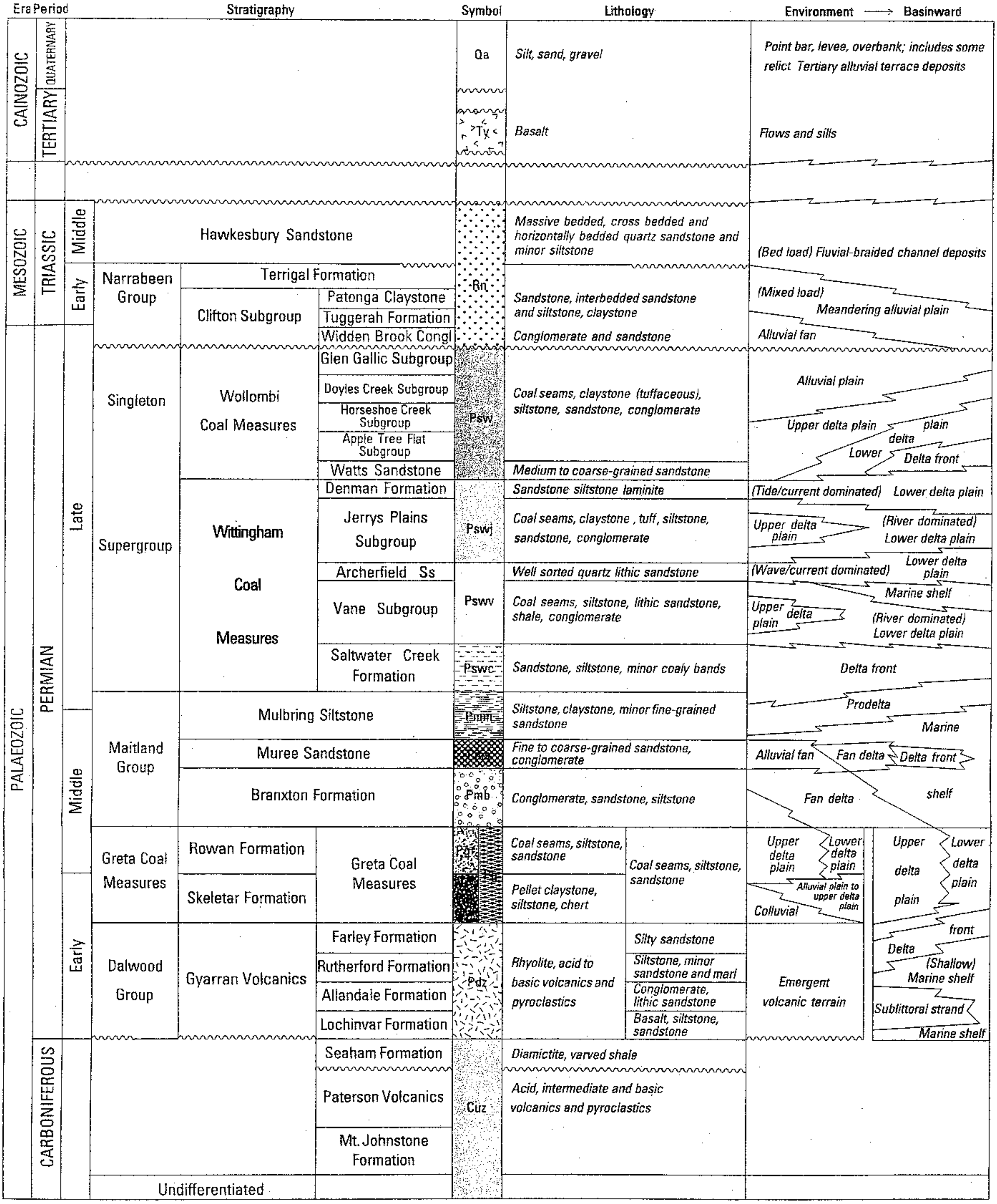

Reference: Hunter Coalfield 1:100000 Geology Map, DMR, 1987.

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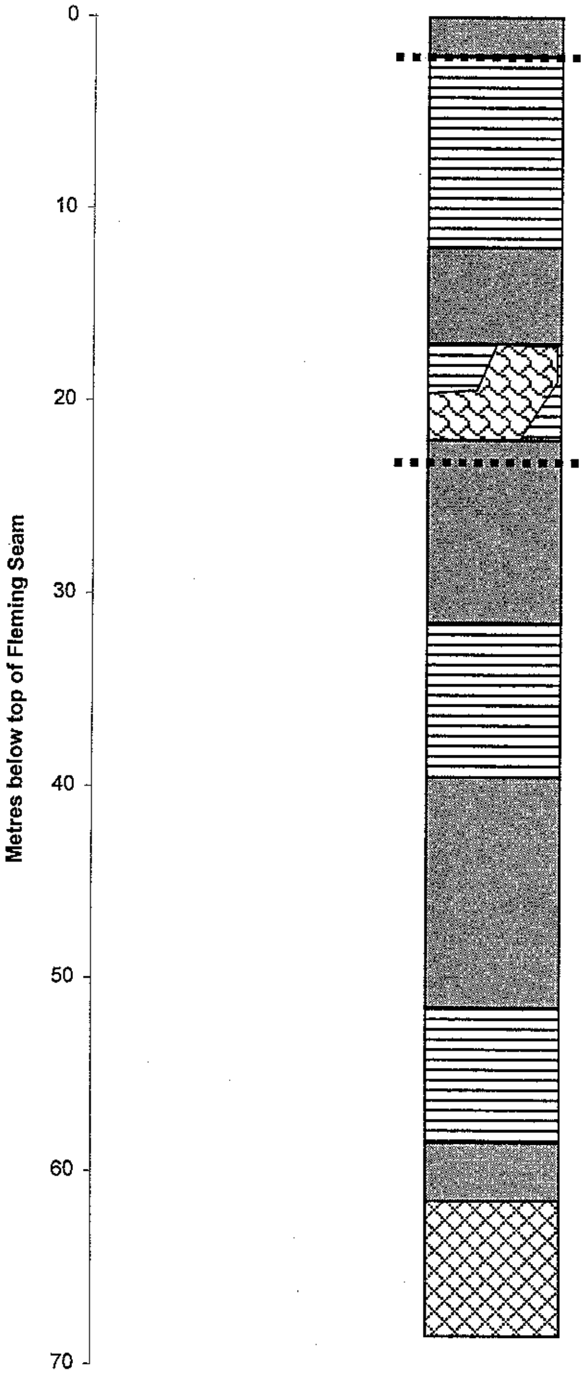
STRATIGRAPHY OF THE UPPER HUNTER VALLEY

Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE **6**

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
	U888-7		March 2002	



STRATUM	THICKNESS
Upper Greta Coal Measures	41.5m
Fleming Seam (Glide plane at base)	2m
Interbedded sandstone and siltstone (includes the Hallet Coal Seam)	10m
Muswellbrook Seam	5m
Siltstone (some diorite sills)	5m
St Helliers Seam (Glide plane 1m below top)	9.5m
Interbedded sandstone and siltstone	8m
Lewis Seam (upper and Lower splits)	12m
Claystone	7m
Loder Seam	3m
Skeletar Formation	7m
Gyarran Volcanics	Unknown

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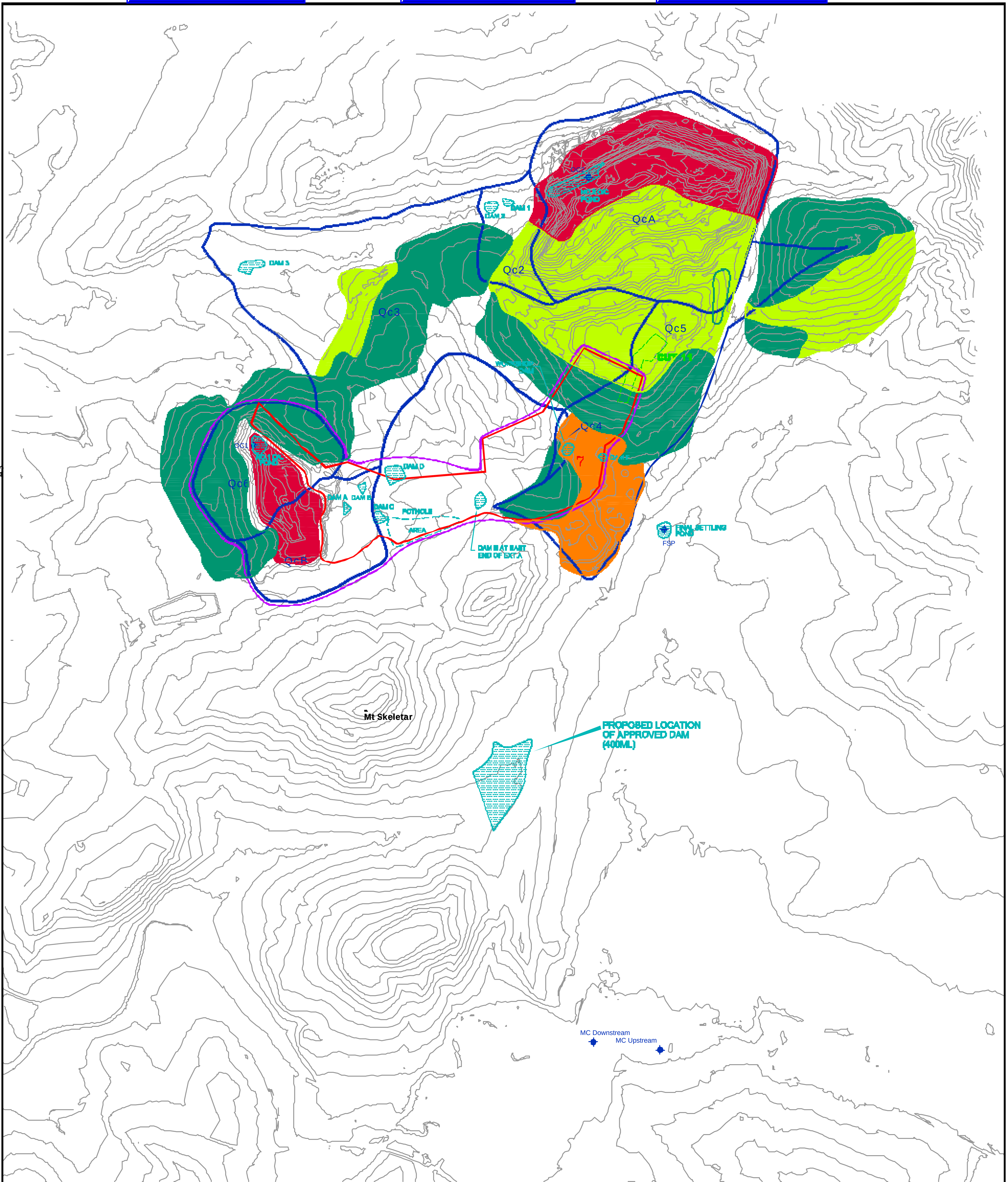
REPRESENTATIVE STRATIGRAPHY OF THE WORKS AREA
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE **7**

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
	U888-7		March 2002	



LEGEND

- PROPOSED EXTENSION
- CURRENT CATCHMENT BOUNDARIES
- NEW CATCHMENTS CREATED BY PROPOSAL
- MCC WATER MONITORING SITES
- ACTIVE MINING AREA
- REHABILITATED SPOIL
- UNREHABILITATED SPOIL
- INFRASTRUCTURE

0 0.5 1.0
metres

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MINE CATCHMENTS AND MCC WATER MONITORING LOCATIONS
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE 8

DRAWN	PROJECT-FILE NUMBER	APPROVED	DATE	REVISED DATE
LJE	U888-010		June 2002	

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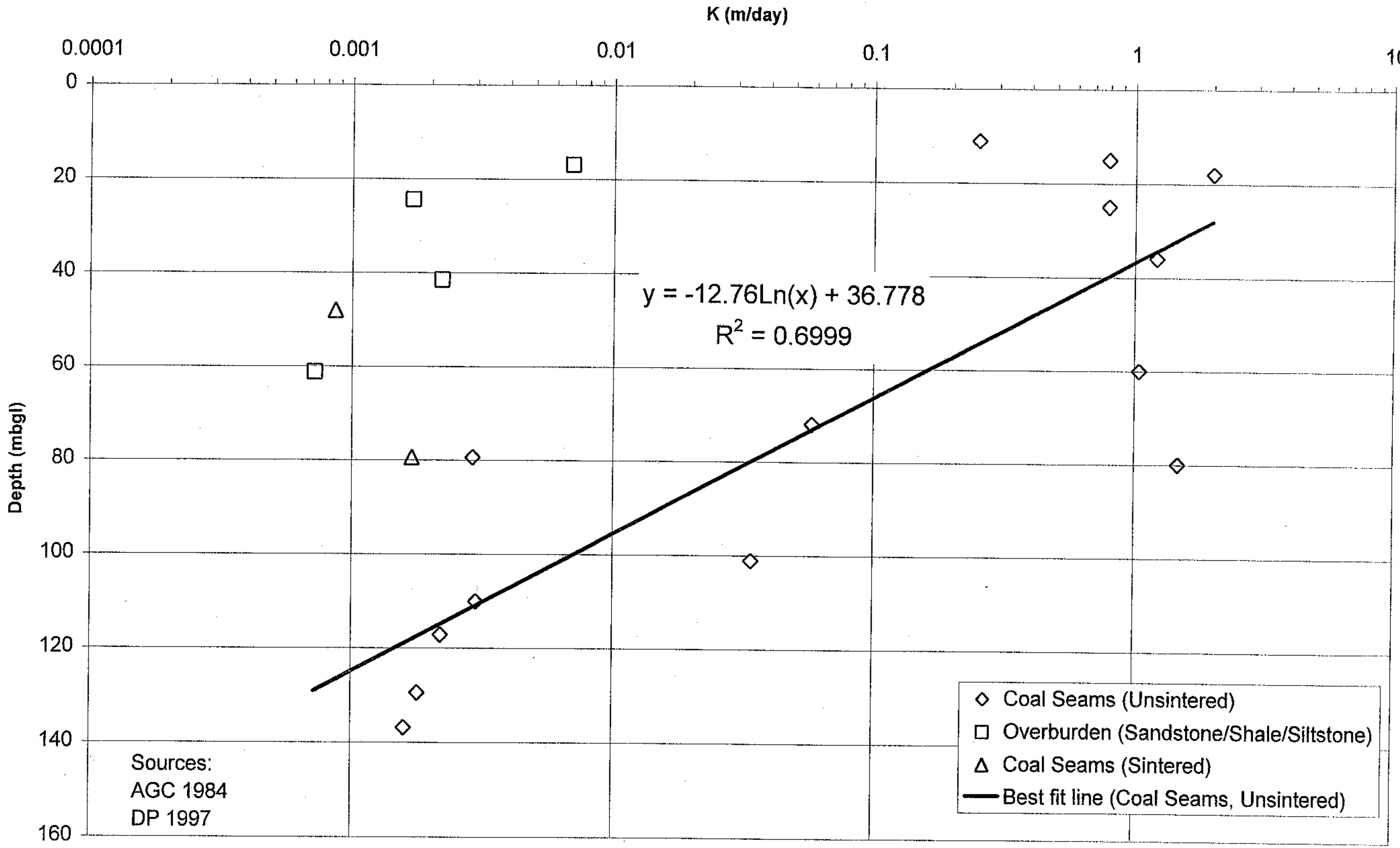

Reference:

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PACKER TEST DATA
GREAT COAL MEASURES
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE
9

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
	U888-7		March 2002	

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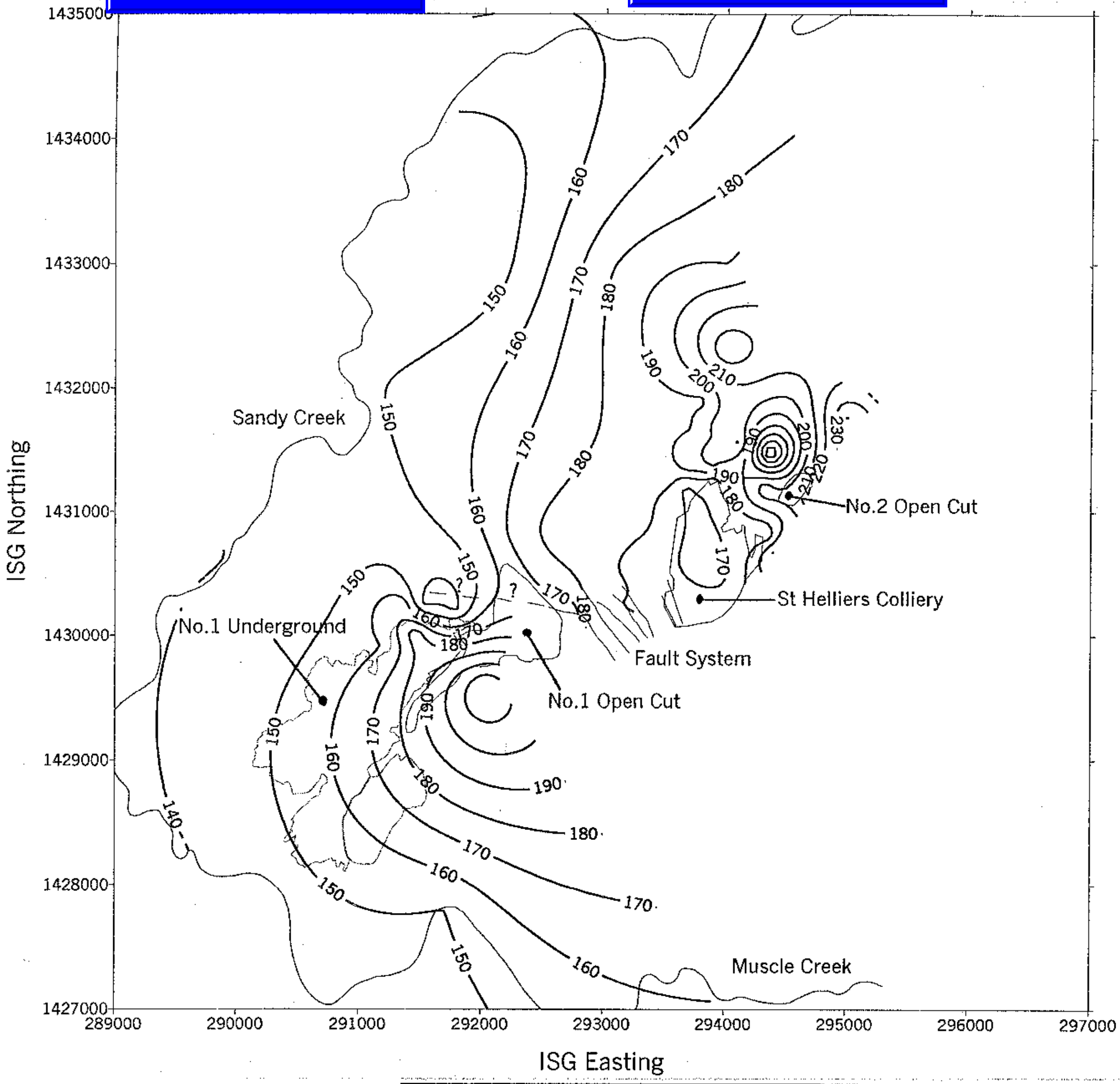

Notes:
Contours are water level in mAHD.
Data consists of 70 measurements taken in late 1980 or early 1981

Reference:

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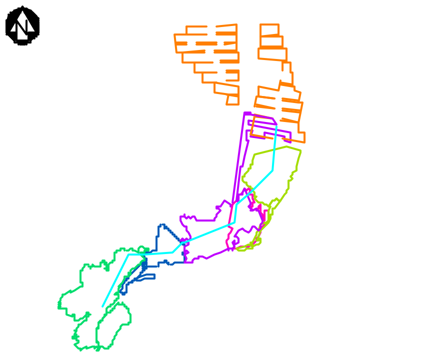
COMPOSITE POTENTIOMETRIC SURFACE OF HARDROCK, 1980/1981
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE **10**

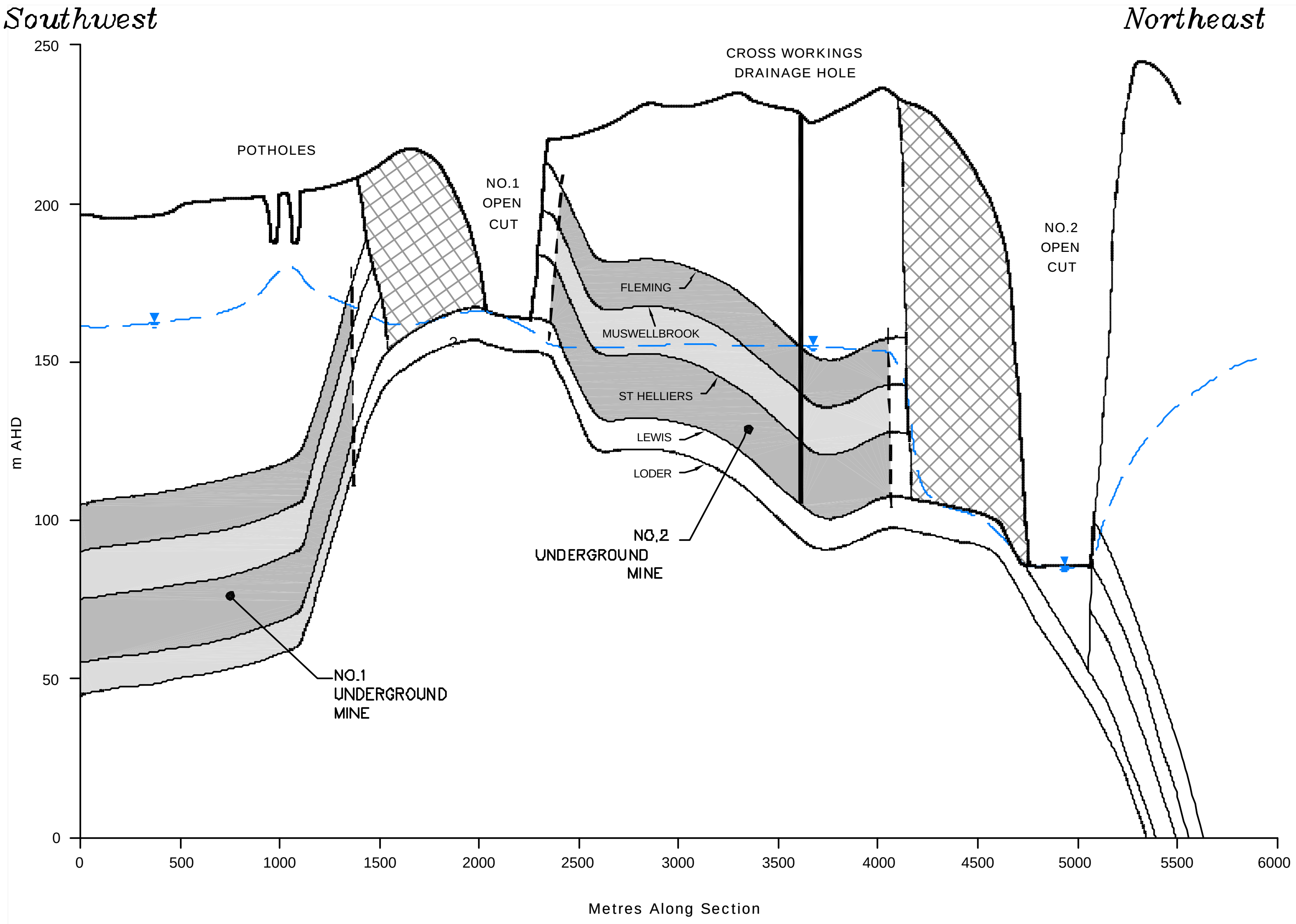
DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
	U888-7		March 2002	



LEGEND

CROSS SECTION LOCATION

INFERRED COMPOSITE POTENTIOMETRIC SURFACE IN HARD ROCK



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HYDROGEOLOGICAL CROSS SECTION
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE 11

DRAWN	PROJECT-FILE NAME	APPROVED	DATE	REVISED DATE
LJE	U888-011		March 2002	

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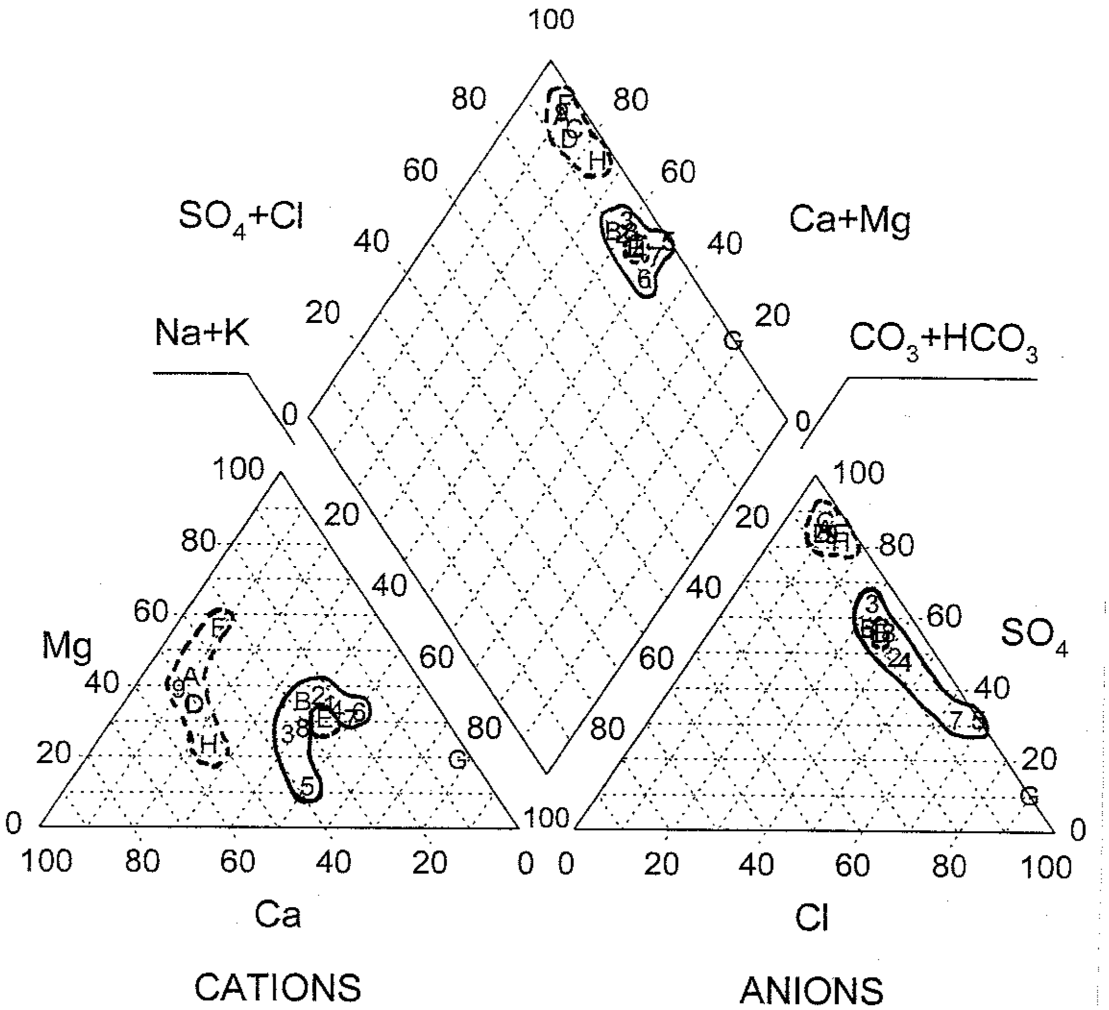

LEGEND

Undisturbed Greta Coal Measures Key	Sample No.	Pit water and Spoil Key	Sample No.	Seawater Key
1	BH273	A	DP102B	G
2	BH275	C	OC1_1981	
3	BH276	D	OC1_1984	
4	BH287	E	OC1_1997	
5	BH311	F	OCCOM_1984	
6	BH315	H	UG1_1984	
7	BH318	9	DP102A (Loder Seam, pit base)	
8	DP101	———	Undisturbed Greta Coal Measures	
B	DP103	---------	Pit water and spoil	

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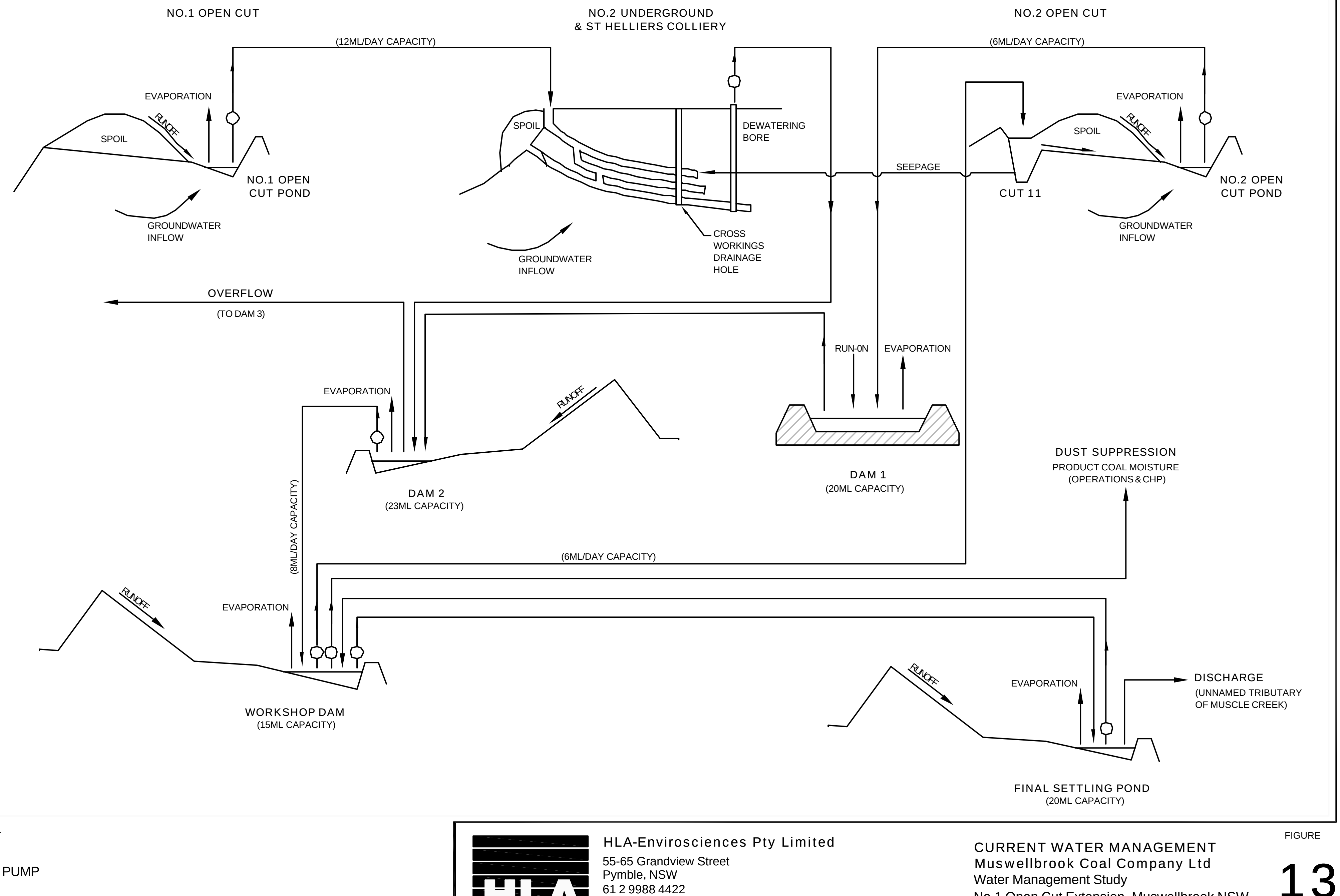
GROUNDWATER CHARACTER
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE **12**

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
	U888-7		March 2002	



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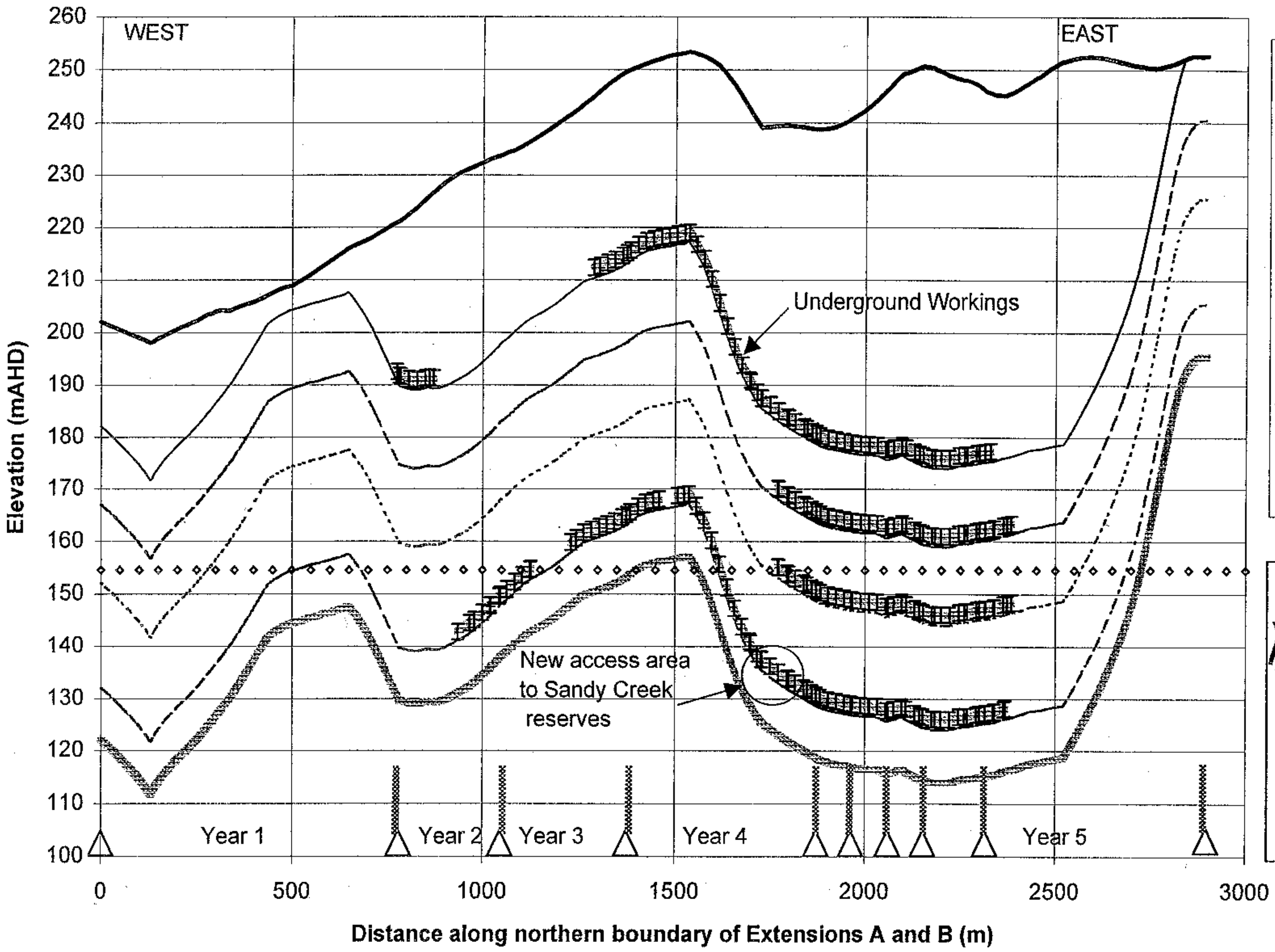
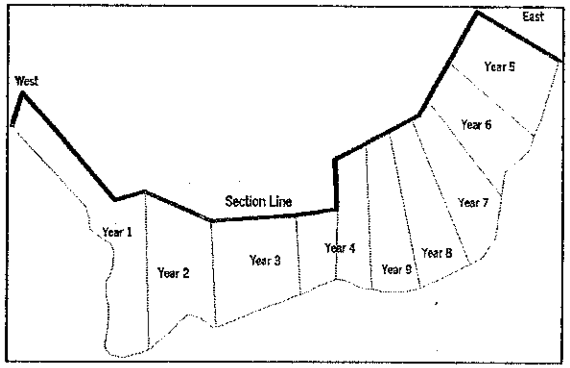
CURRENT WATER MANAGEMENT
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE 13

DRAWN	PROJECT-FILE NAME	APPROVED	DATE	REVISED DATE
LJE	U888-013		April 2002	



LOCATION OF CROSS-SECTION



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NORTHERN HIGHWALL CROSS-SECTION
EXTENSIONS A AND B
Muswellbrook Coal Company Ltd
Water Management Study
No.1 Open Cut Extension, Muswellbrook NSW

FIGURE **14**

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
	U888-7		March 2002	

Reference:

APPENDIX A

Muswellbrook Coal Company Limited
No.1 Open Cut Extension
Water Management Study

Water Quality Data

Note: All values in mg/L unless otherwise stated.

AGC 1984

GCM Spoil Runoff		EC(uS/cm)
4 values of dams below spoil :		1150
(Drayton and bayswater mines)		2000
1982 - 1983		2800
		6700
	geomean:	2563

AGC 1984

GCM Natural Pasture		EC(uS/cm)
9 values stock dams at Drayton mine :		275
1982		250
		2500
		157
		650
		185
		180
		250
		1250
	geomean:	384

RUST PPK 1996 (HLA 1998)

		EC(uS/cm)	Salinity(ppm)	pH
3 sets data PCM/GCM:		4980	2988	6.7
		6700	4020	7.2
		11300	6780	7.4
	geomean:	7224	4335	7.1
10 sets data Sandy Ck alluvium:		1360	816	7.5
		1330	798	7
		1690	1014	7
		1650	990	6.7
		1340	804	7
		2220	1332	7.5
		1220	732	7.4
		1280	768	7.1
		1820	1092	7.7
		2450	1470	7.1
	geomean:	1592	955	7.2
3 sets data Sandy Ck Stream:		1720	1032	7.8
		1560	936	7.8
		1350	810	8
	geomean:	1536	921	7.9

Muswellbrook Coal Company Limited
No.1 Open Cut Extension
Water Management Study

Water Quality Data

Note: All values in mg/L unless otherwise stated.

DP 1997

Location	101	102A	102B	103	No.1 OC			
Type	GCM	Loder (pit)	Spoil	GCM	pond			
Date	21-Nov-97	21-Nov-97	21-Nov-97	21-Nov-97	21-Nov-97			
Na	310	150	140	580	600			
K	10	33	31	25	36			
Ca	210	760	620	380	310			
Mg	110	340	330	290	220			
CO3	0	0	0	0	0			
HCO3	180	210	240	480	310	Geomean of GCM EC:		2600
Cl	560	280	250	870	790			4000
SO4	1100	2600	2800	2000	1600			5200
EC(uS/cm)	2600	4400	4000	5200	4600		geomean:	3782
TDS	2482	4376	4413	4625	3866			
pH	7.5	6.6	7.1	7.7	7.9			

CH2MHill

Data for Muscle Creek at Mine sampling points upstream and downstream of discharge point.

Averages for March 1995 to November 1997

	Upstream	Downstream
pH	7.54	7.5
EC(uS/cm)	3833	4103
TDS	2232	2692
TSS	8.56	6.32
Cl	902	813
SO4	432	774
NA	436	512

MCC 2001 AEMR

Averages for various points, July 2000 to June 2001.

	pH	EC(uS/cm)	TSS
Muscle Ck upstream	7.6	1495	7
Muscle Ck downstream	7.7	2195	7
No.2 OC Pond	7.6	4854	NT
No.1 OC Pond	7.6	4333	NT
Final Settling Pond	7.9	3442	72

Muswellbrook Coal Company Limited												
No.1 Open Cut Extension												
Water Management Study												
Water Character Analytical Data												
								Geomean				
Source	AGC 1984	AGC 1984	DP 1997	AGC 1984	AGC 1984	DP 1997	DP 1997		AGC 1984			
Location	No.1 OC	No.1 OC	No.1 OC	Com. OC	No.2 OC	102A	102B		No.1 UG			
Type	pond	pond	pond	pond	pond	Loder (pit)	Spoil		UG mine			
Date	pre-1984	Oct-81	21-Nov-97	pre-1984	pre-1984	21-Nov-97	21-Nov-97		pre-1984			
Na	120	122	600	140	80	150	140		300			
K	12	15	36	40	5.1	33	31		9			
Ca	361	388	310	520	295	760	620		590			
Mg	146	156	220	500	70	340	330		150			
CO3	0	0	0	0	0	0	0		0			
HCO3	165	113	310	145	510	210	240		200			
Cl	138	123	790	340	36	280	250		410			
SO4	1536	1600	1600	2800	820	2600	2800		2950			
EC(uS/cm)		2850	4600			4400	4000	3897	NT			
TDS	2500	2500	3866	4520	1770	4376	4413	3238	5320			
pH	8.1	NT	7.9	6.9	6.6	6.6	7.1	7.2	NT			
												Geomean
Source	AGC 1984	AGC 1984	AGC 1984	AGC 1984	AGC 1984	AGC 1984	AGC 1984	AGC 1984	AGC 1984	DP 1997	DP 1997	
Location	BH315	BH276	BH316	BH273	BH287	BH311	BH318	BH317	BH275	101	103	
Type	GCM	GCM	GCM	GCM	GCM	GCM	GCM	GCM	GCM	GCM	GCM	
Date	pre-1984	pre-1984	9-Sep-81	pre-1984	pre-1984	pre-1984	28-Jul-81	28-Jul-81	28-Jul-81	21-Nov-97	21-Nov-97	
Na	1196	700	1166	1181	1321	610	2101	117	891	310	580	
K	27	31	21	49	36	11	56	9	37	10	25	
Ca	361	570	13	550	550	412	737	181	472	210	380	
Mg	401	250	95	500	500	70	675	60	440	110	290	
CO3	0	0	0	0	0	0	0	0	0	0	0	
HCO3	732	320	1475	542	604	13	583	416	566	180	480	
Cl	1312	900	1300	2000	2071	1300	4272	104	1540	560	870	
SO4	3025	2530	40	2780	2900	790	2750	433	2348	1100	2000	
EC(uS/cm)	6500	5610	5100	9000	9300	4550	13900	1560	7200	2600	5200	5535
TDS	7310	5300	3370	7970	8300	3430	11200	1200	6300	2482	4625	4766
pH	7.5	7.9	8.2	7.8	7.8	6.1	7.8	7.7	7.8	7.5	7.7	7.6

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Sandy Creek Authorisation Monitoring Locations

MCC ID No.	DLWC ID No.	Owner	Structure	Easting mAMG	Northing mAMG	Ground Level mAHD	Equipped	Comments
1001	13869	Department of Corrective Services	Well	302193	6433060	156	Pump	Concrete, SWL measured from grate = GL + 0.30m
1002	13980	Department of Corrective Services	Well	303679	6433727	158	Pump	Concrete, SWL measured from grate = GL + 0.30m
1003		Department of Corrective Services	Well	303448	6433545	156.5	Pump	Concrete, SWL measured from grate = GL + 0.30m
1004	15083	Madden & Wilkes	Well	302714	6431712	149	Pump	Concrete, SWL measured from top lip = GL + 1.15m
1005		Madden & Wilkes	Well	302518	6431012	150	Pump	Wood, SWL measured from top structure = GL + 0.75m
1006	12987	Sanson	Well	302796	6433653	158	Nil	Concrete, SWL measured from top lip = GL
1007		Wilkinson	Well	303309	6434128	160	Windmill	Concrete, SWL measured from top lip = GL + 0.70m
1008		Watts, Neville	Well	303789	6434069	157	Pump	Wood, SWL measured from top structure = GL
1008a		Watts, Neville	Well	303795	6434069	157	Nil	Concrete, SWL measured from top lip = GL + 1.3m
1009	67112	Watts, Neville	Well	303800	6434020	158	Nil	Concrete, SWL measured from top lip = GL + 1.0m
1010		Watts, Neville	Well	303963	6435129	168	Nil	Wood, GL = top of structure.
1011		Watts, Neville	Well	304079	6435137	168	Nil	Concrete, SWL measured from top of stand pipe = GL + 0.5m
1012	65481	French	Well	304591	6433978	162	Pump	Concrete, SWL measured from top lip = GL + 0.20m
1013		French	Creek	305191	6433780	161	Pump	From running water into domestic supply draw point pool.
1014	26972	Watts, Kevin	Creek	305343	6434260	161.5	Nil	Abandoned well on bank adjacent to creek.
1015		Watts, Kevin	Well	305447	6434346	165	Pump	Wood, GL = top of structure.
1016		Wells Gully Road crossing	Creek	306204	6434186	167	Nil	Upstream of crossing.
1017		Watts, Neville	Bore				Nil	Nil
1018		Watts, Ray	Well			199.5	Nil	PVC capped bore, measured from top of pipe.
1019		French	Creek				Pump	
1020		Watts, Neville	Creek				Nil	

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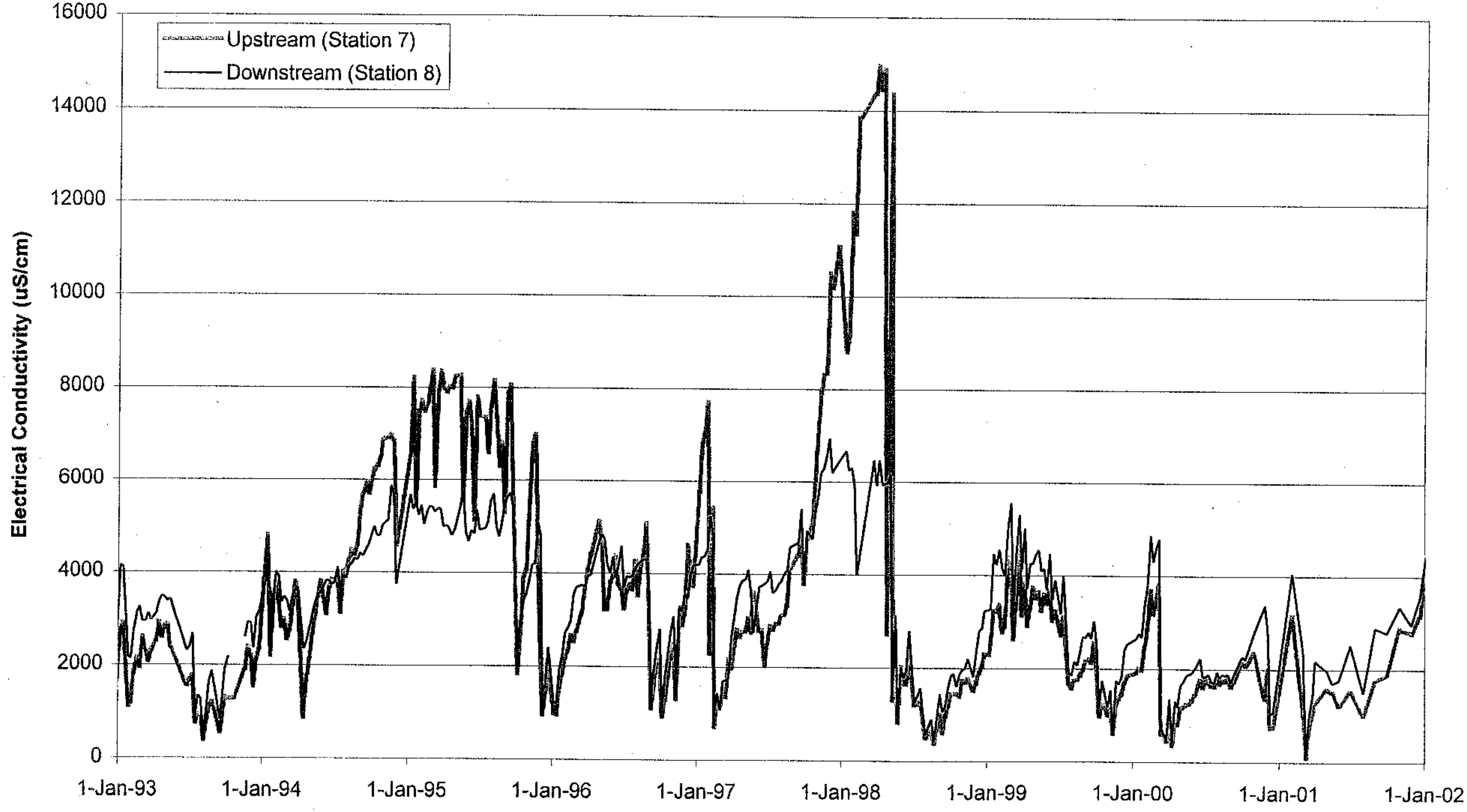
Water Quality Monitoring, Muscle Creek



Muscle Creek Water Monitoring Data

Date	Station 7 (Up-stream) (uS/cm)	Station 8 (Down-stream) (uS/cm)	Date	Station 7 (Up-stream) (uS/cm)	Station 8 (Down-stream) (uS/cm)	Date	Station 7 (Up-stream) (uS/cm)	Station 8 (Down-stream) (uS/cm)	Date	Station 7 (Up-stream) (uS/cm)	Station 8 (Down-stream) (uS/cm)
11-Dec-92	650	2080	24-Mar-95	8350	5370	07-Mar-97	1530	1710	23-Apr-99	3740	4260
23-Dec-92	910	1870	31-Mar-95	7980	5000	14-Mar-97	1360	1720	30-Apr-99	3510	4440
06-Jan-93	2750	4140	07-Apr-95	7910	5020	21-Mar-97	2170	1760	07-May-99	3650	4550
13-Jan-93	2910	4110	13-Apr-95	8020	4980	28-Mar-97	1980	2620	14-May-99	3250	4100
27-Jan-93	1130	2170	21-Apr-95	7990	4800	11-Apr-97	2800	3500	21-May-99	3590	4150
02-Feb-93	1200	2150	28-Apr-95	8230	4940	18-Apr-97	2650	3750	28-May-99	3400	3700
10-Feb-93	1850	2750	11-May-95	8270	5430	25-Apr-97	2750	3860	04-Jun-99	3710	4470
18-Feb-93	2160	3150	19-May-95	5490	5780	02-May-97	2770	3880	11-Jun-99	3030	3480
24-Feb-93	1960	3260	26-May-95	7450	4870	09-May-97	3050	4090	18-Jun-99	3240	3900
04-Mar-93	2600	2950	02-Jun-95	7700	4680	16-May-97	2740	3630	25-Jun-99	3010	3540
12-Mar-93	2300	2950	09-Jun-95	7260	4910	23-May-97	3610	2740	02-Jul-99	2710	3180
19-Mar-93	2080	3130	16-Jun-95	5140	4840	06-Jun-97	2770	3730	09-Jul-99	3110	3990
26-Mar-93	2330	2970	23-Jun-95	7800	5350	13-Jun-97	2800	3750	23-Jul-99	1680	1930
08-Apr-93	2520	3120	30-Jun-95	7400	4930	20-Jun-97	2030	3800	30-Jul-99	1590	1870
15-Apr-93	2920	3370	14-Jul-95	7350	4960	27-Jun-97	2520	3850	06-Aug-99	1740	2150
22-Apr-93	2600	3490	21-Jul-95	6600	5100	04-Jul-97	2880	4060	13-Aug-99	1780	2080
30-Apr-93	2850	3450	28-Jul-95	7610	5550	11-Jul-97	2810	3600	20-Aug-99	1860	2350
06-May-93	2890	3380	04-Aug-95	8150	5710	18-Jul-97	2920	3660	27-Aug-99	1980	2680
14-May-93	2390	3420	11-Aug-95	7370	5020	25-Jul-97	2950	3790	03-Sep-99	2150	2660
25-Jun-93	1570	2320	18-Aug-95	6300	4780	01-Aug-97	3100	3850	10-Sep-99	2200	2770
02-Jul-93	1710	2410	25-Aug-95	6820	5070	08-Aug-97	3140	4010	17-Sep-99	2140	2650
09-Jul-93	1780	2680	01-Sep-95	5310	5510	15-Aug-97	3340	4090	24-Sep-99	2550	3030
16-Jul-93	760	920	08-Sep-95	7900	5640	22-Aug-97	4140	4580	01-Oct-99	1980	2460
23-Jul-93	950	1350	15-Sep-95	8060	5730	12-Sep-97	4400	4680	08-Oct-99	980	1190
30-Jul-93	890	1280	22-Sep-95	5600	5440	19-Sep-97	4800	5410	15-Oct-99	1230	1750
06-Aug-93	400	480	06-Oct-95	1850	2270	26-Sep-97	3800	3870	22-Oct-99	1160	1470
12-Aug-93	750	990	13-Oct-95	2690	2970	03-Oct-97	4780	4940	29-Oct-99	1010	1190
20-Aug-93	1120	1660	20-Oct-95	3970	3410	17-Oct-97	5080	4760	05-Nov-99	1110	1550
27-Aug-93	1210	1880	27-Oct-95	4070	3550	24-Oct-97	6130	5350	12-Nov-99	610	610
17-Sep-93	570	840	03-Nov-95	5510	3820	31-Oct-97	7120	5680	19-Nov-99	1230	1750
29-Sep-93	1310	1940	10-Nov-95	6800	4180	07-Nov-97	7940	6190	26-Nov-99	1370	1680
08-Oct-93	1280	2190	17-Nov-95	7000	4200	14-Nov-97	8310	6300	03-Dec-99	1460	1820
22-Oct-93	1300		24-Nov-95	4590	5090	21-Nov-97	8350	6550	10-Dec-99	1690	2410
19-Nov-93	1920	2600	01-Dec-95	2600	4810	28-Nov-97	10500	6940	17-Dec-99	1840	2530
26-Nov-93	2400	2930	08-Dec-95	960	1470	05-Dec-97	10180	6200	07-Jan-00	1930	2640
03-Dec-93	2200	2910	15-Dec-95	1430	1590	19-Dec-97	11070	6400	14-Jan-00	2010	2760
10-Dec-93	1550	2370	22-Dec-95	2180	2400	09-Jan-98	8800	6670	21-Jan-00	1980	2680
17-Dec-93	2150	3040	05-Jan-96	1000	1230	16-Jan-98	9170	6250	28-Jan-00	2440	3340
24-Dec-93	2350	3170	12-Jan-96	960	1220	23-Jan-98	11810	6310	04-Feb-00	2860	3800
07-Jan-94	4110	3760	19-Jan-96	1540	1930	30-Jan-98	11340	5940	11-Feb-00	3700	4870
14-Jan-94	4800	3920	26-Jan-96	1840	2230	06-Feb-98	13850	3990	18-Feb-00	3180	4310
21-Jan-94	2200	3600	02-Feb-96	2170	2710	20-Mar-98	14370	6470	25-Feb-00	3520	4610
28-Jan-94	3250	3320	09-Feb-96	2340	2820	27-Mar-98	14960	5930	03-Mar-00	3820	4790
04-Feb-94	3770	4020	16-Feb-96	2650	2990	03-Apr-98	14450	6480	10-Mar-00	620	730
11-Feb-94	3340	3910	23-Feb-96	2540	3550	10-Apr-98	14880	5950	17-Mar-00	580	630
18-Feb-94	2820	3360	01-Mar-96	2750	3700	24-Apr-98	2720	5980	24-Mar-00	460	490
25-Feb-94	3000	3470	15-Mar-96	3170	3750	01-May-98	14360	6160	31-Mar-00	1000	1360
04-Mar-94	2560	3400	22-Mar-96	3680	3710	08-May-98	1310	1430	07-Apr-00	360	450
11-Mar-94	2760	3170	29-Mar-96	4080	3940	15-May-98	2260	3140	14-Apr-00	900	1310
18-Mar-94	3300	3510	05-Apr-96	4400	3970	22-May-98	830	850	20-Apr-00	800	1190
25-Mar-94	3800	3620	26-Apr-96	5130	4690	29-May-98	2020	2020	28-Apr-00	1160	1660
31-Mar-94	3450	3680	03-May-96	4590	4830	05-Jun-98	1670	1800	05-May-00	1180	1730
15-Apr-94	880	2360	10-May-96	3230	4740	12-Jun-98	1660	1950	12-May-00	1240	1860
22-Apr-94	1670	2510	17-May-96	3230	4200	19-Jun-98	2250	2790	19-May-00	1260	1900
13-May-94	3030	3330	24-May-96	3810	4020	03-Jul-98	1210	1270	26-May-00	1330	1920
20-May-94	3500	3500	31-May-96	3930	4360	10-Jul-98	1240	1400	02-Jun-00	1450	2010
27-May-94	3810	3560	07-Jun-96	4380	3920	17-Jul-98	1260	1570	16-Jun-00	1780	2230
10-Jun-94	3110	3820	14-Jun-96	3760	4160	31-Jul-98	510	580	23-Jun-00	1610	1830
17-Jun-94	3680	3820	21-Jun-96	3670	4590	14-Aug-98	710	900	30-Jun-00	1780	1850
24-Jun-94	3840	3740	28-Jun-96	3250	3710	21-Aug-98	390	430	07-Jul-00	1720	1890
01-Jul-94	3800	3790	05-Jul-96	3630	3940	28-Aug-98	690	910	14-Jul-00	1650	1740
08-Jul-94	3870	4110	12-Jul-96	3760	3920	04-Sep-98	1010	1450	21-Jul-00	1630	1720
15-Jul-94	3150	3600	19-Jul-96	3660	3960	11-Sep-98	610	1070	28-Jul-00	1820	1940
22-Jul-94	4020	3930	26-Jul-96	4270	4090	18-Sep-98	970	1200	04-Aug-00	1690	1820
29-Jul-94	4070	3870	02-Aug-96	3530	4200	25-Sep-98	1180	1570	11-Aug-00	1750	1890
05-Aug-94	4300	4130	09-Aug-96	4160	4260	02-Oct-98	1450	1850	18-Aug-00	1740	1870
12-Aug-94	4480	4190	16-Aug-96	4440	4300	09-Oct-98	1450	1880	25-Aug-00	1820	1890
19-Aug-94	4380	4300	23-Aug-96	5090	4310	16-Oct-98	1460	1610	01-Sep-00	1630	1720
26-Aug-94	4600	4280	30-Aug-96	3340	3740	23-Oct-98	1400	1870	08-Sep-00	1750	1890
02-Sep-94	5400	4420	06-Sep-96	1110	1330	30-Oct-98	1740	1970	29-Sep-00	2130	2270
09-Sep-94	5720	4360	13-Sep-96	1610	1970	06-Nov-98	1710	1990	06-Oct-00	2080	2210
19-Sep-94	5940	4540	20-Sep-96	2110	2410	13-Nov-98	1770	2200	27-Oct-00	2340	2770
23-Sep-94	5710	4600	27-Sep-96	2140	2810	27-Nov-98	1530	1830	24-Nov-00	1370	3370
07-Oct-94	6230	5000	04-Oct-96	930	1100	04-Dec-98	1690	2320	01-Dec-00	1990	2840
14-Oct-94	6300	4800	11-Oct-96	1300	1800	11-Dec-98	1910	2800	08-Dec-00	750	1050
21-Oct-94	6460	4800	25-Oct-96	2230	2760	18-Dec-98	2050	2860	15-Dec-00	750	1070
28-Oct-94	6860	5030	01-Nov-96	2480	3090	24-Dec-98	2300	3230	31-Jan-01	3150	4060
04-Nov-94	6900	5080	08-Nov-96	1310	1820	04-Jan-99	2300	3260	28-Feb-01	1190	2400
11-Nov-94	6920	5140	15-Nov-96	3110	3310	08-Jan-99	2540	3300	09-Mar-01	102	126
18-Nov-94	6980	5880	22-Nov-96	2900	3190	15-Jan-99	3230	4460	16-Mar-01	740	1000
25-Nov-94	6830	5680	29-Nov-96	3140	3570	22-Jan-99	3220	4230	26-Mar-01	1077	1492
02-Dec-94	4600	3750	06-Dec-96	4620	3460	29-Jan-99	3360	4550	30-Mar-01	1300	2180
06-Jan-95	6540	5690	13-Dec-96	3910	3970	05-Feb-99	2770	4150	30-Apr-01	1570	1970
13-Jan-95	8210	5370	20-Dec-96	3740	4180	12-Feb-99	2900	4000	14-May-01	1500	1700
20-Jan-95	5420	5510	03-Jan-97	5770	4200	19-Feb-99	4170	5020	30-May-01	1230	1770
27-Jan-95	7490	5250	10-Jan-97	6820	4370	26-Feb-99	4380	5560	28-Jun-01	1520	2520
03-Feb-95	7720	5450	17-Jan-97	7080	4370	05-Mar-99	2630	3350	31-Jul-01	1020	1500
10-Feb-95	7480	5050	24-Jan-97	7710	4520	12-Mar-99	3370	4450	29-Aug-01	1740	2890
17-Feb-95	7640	5310	31-Jan-97	2290	5250	19-Mar-99	4680	5310	28-Sep-01	1910	2780
24-Feb-95	8000	5420	07-Feb-97	5430	4900	26-Mar-99	3140	4140	30-Oct-01	2880	3350
03-Mar-95	8370	5420	14-Feb-97	720	1000	02-Apr-99	3820	5020	29-Nov-01	2770	2960
09-Mar-95	5860	5310	21-Feb-97	1270	1450	09-Apr-99	2920	3720	21-Dec-01	3160	3580
17-Mar-95	7930	5380	28-Feb-97	1130	1080	16-Apr-99	3320	4260	30-Jan-02	6330	5850

APPENDIX B

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Packer Test Data

Test Name or Bore	Test Interval (mbgl) From	To	Tested Coal Seam *	Hydraulic Conductivity (m/day)	Average Test Depth (mbgl)	Testing Company	Reference	Location (Mine Lease)	Date	Comments
315	36.9	46.0	OB	2.200E-03	41.4	AGC	AGC 1984	Muswellbrook	Nov-83	
315	55.5	66.9	OB	7.200E-04	61.2	AGC	AGC 1984	Muswellbrook	Nov-83	
315	66.9	77.0	COAL	5.800E-02	71.9	AGC	AGC 1984	Muswellbrook	Nov-83	
315	74.9	84.0	COAL	2.900E-03	79.4	AGC	AGC 1984	Muswellbrook	Nov-83	
315	96.2	106.0	FLM	3.400E-02	101.1	AGC	AGC 1984	Muswellbrook	Nov-83	
315	105.1	115.0	HAL	3.000E-03	110.1	AGC	AGC 1984	Muswellbrook	Nov-83	
315	112.3	122.0	MUS	2.200E-03	117.2	AGC	AGC 1984	Muswellbrook	Nov-83	
315	124.9	134.0	ST.HEL	1.800E-03	129.5	AGC	AGC 1984	Muswellbrook	Nov-83	
315	131.6	142.0	LEW.U	1.600E-03	136.8	AGC	AGC 1984	Muswellbrook	Nov-83	
			BRG	1.990E+00	18.0		AGC 1984	BalmoralSouth		
			GRT	1.210E+00	36.0		AGC 1984	BalmoralSouth		
			GRT	7.900E-01	15.0		AGC 1984	BalmoralSouth		
			PUX	1.040E+00	60.0		AGC 1984	BalmoralSouth		
			PUX	7.900E-01	25.0		AGC 1984	BalmoralSouth		
			BAL	1.470E+00	80.0		AGC 1984	BalmoralSouth		
101	13.5	20.25	OB	6.900E-03	16.9	DP	DP 1997	Muswellbrook	1997	
101	19.3	29.5	OB	1.700E-03	24.4	DP	DP 1997	Muswellbrook	1997	
102	7	15	LOD	0.25	11.0	DP	DP 1997	Muswellbrook	1997	
103	45	51	MUS	8.600E-04	48.0	DP	DP 1997	Muswellbrook	1997	Sintered coal (diorite IB)
103	75	83.8	LEW	1.700E-03	79.4	DP	DP 1997	Muswellbrook	1997	Sintered coal (diorite IB)

* Key (Greta Coal Measures Seams):

PUX	Puxtrees
BAL	Balmoral
GRT	Grasstrees
BRG	Brougham

HLA

FLM	Flemming									
HAL	Hallet									
MUS	Muswellbrook									
ST.HEL	St. Helliers									
LEW.U	Upper Lewis									
LOD	Loder Seam									
OB	Overburden									

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Bore	Easting ISG	Northing ISG	collar (mAHD)	TD (m)	SWL (m)	SWL (mAHD)	Date	Comments
SC4	294006	1433001	204.77	331.48	15	190	1980	Sandy Creek bore (Authorisation 176)
SC7	293155	1432929	183.7	316.48	0	184	1981	Sandy Creek bore (Authorisation 176)
SC9	292006	1433783	158.26	168	15	143	1981	Sandy Creek bore (Authorisation 176)
SC10	291972	1432953	162.2	406.48	20	142	1981	Sandy Creek bore (Authorisation 176)
SC13	292816	1436023	176.14	368.66	8	168	1981	Sandy Creek bore (Authorisation 176)
SC15	292171	1437510	269.7	301.98	50	220	1982	Sandy Creek bore (Authorisation 176)
273	294065	1431275	219.1	121	30	189	1980	Resource Bore (DDH)
274R	294365	1431481	218.09	118	80	138	1980	Resource Bore (DDH)
277	290528	1430498	180.9	282.79	40	141	1980	Resource Bore (DDH)
290	294873	1431160	259.02	182.74	13	246	1980	Resource Bore (DDH)
291	294109	1431781	214.55	94	9	206	1981	Resource Bore (DDH)
292	291523	1430259	217.45	124.54	80	137	1981	Resource Bore (DDH)
294	292305	1430814	185.44	86	10	175	1981	Resource Bore (DDH)
295	291456	1430013	218.78	103.54	33	186	1981	Resource Bore (DDH)
296	292028	1429598	222.43	29.44	3	219	1981	Resource Bore (DDH)
297	292024	1429545	223.525	28.3	3	221	1981	Resource Bore (DDH)
307	294002	1432318	234.3	246.77	6	228	1981	Resource Bore (DDH)
308	294530	1432251	243.84	235.15	30	214	1981	Resource Bore (DDH)
314	295313	1431967	250.74	360.3	40	211	1981	Resource Bore (DDH)
315	294106	1431551	232.21	143.5	21	211	1981	Resource Bore (DDH)
316	294448	1431120	240.16	99.1	38	202	1981	Resource Bore (DDH)
318	294321	1431191	245.37	145	38.5	207	1981	Resource Bore (DDH)
320	292748	1430177	228.15	90	67.8	160	1981	Resource Bore (DDH)
321	292856	1430235	230.89	102	47	184	1981	Resource Bore (DDH)
322	292877	1430148	228.26	81	43.5	185	1981	Resource Bore (DDH)
326	293132	1430341	241.01	109	57.6	183	1981	Resource Bore (DDH)
327	293165	1430261	238.96	106.5	60	179	1981	Resource Bore (DDH)
328	293026	1430184	239.45	106	54.6	185	1981	Resource Bore (DDH)

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Bore	Easting ISG	Northing ISG	collar (mAHD)	TD (m)	SWL (m)	SWL (mAHD)	Date	Comments
329	292977	1430286	233.43	122	48	185	1981	Resource Bore (DDH)
330B	293451	1430582	247.47	141	75.2	172	1981	Resource Bore (DDH)
331	293830	1431743	201.09	157	3	198	1981	Resource Bore (DDH)
332	293313	1430162	249.85	97	70.4	179	1981	Resource Bore (DDH)
333	293137	1430085	242.37	92	56.4	186	1981	Resource Bore (DDH)
335	293378	1430087	252.74	80	70.4	182	1981	Resource Bore (DDH)
339	291786	1430211	218.57		80	139	1981	Resource Bore (DDH)
340	291996	1430197	226.56	98	67.8	159	1981	Resource Bore (DDH)
351	292980	1430538	222.62	134	36	187	1981	Resource Bore (DDH)
352	293158	1430549	232.79	130	55	178	1981	Resource Bore (DDH)
353	293288	1430937	227.62	154	43	185	1981	Resource Bore (DDH)
368	292798	1430215	230.32	104	51	179	1982	Resource Bore (DDH)
369	292914	1430264	231.64	116	47	185	1981	Resource Bore (DDH)
370	292951	1430163	236.32	110	50.8	186	1981	Resource Bore (DDH)
374	294763	1431372	252.91	135	58.7	194	1983	Resource Bore (DDH)
375	294682	1431407	242.12	128	44.7	197	1983	Resource Bore (DDH)
376	294393	1431149	237	116	43.3	194	1982	Resource Bore (DDH)
380	291246	1430016	213.04	128	74	139	1982	Resource Bore (DDH)
381	291088	1429992	205.25	140	50	155	1982	Resource Bore (DDH)
383	291078	1429897	203.9	129	46	158	1982	Resource Bore (DDH)
384	291265	1429901	219.6	91	59	161	1981	Resource Bore (DDH)
385	294999	1431779	269.03	208.39	28	241	1981	Resource Bore (DDH)
386	294569	1431954	222.04	181	20	202	1981	Resource Bore (DDH)
387	293899	1431595	219.28	142	19	200	1981	Resource Bore (DDH)
388	293797	1431645	206.75	154	10	197	1981	Resource Bore (DDH)
389	293902	1431257	237.93	150	62	176	1981	Resource Bore (DDH)
390	293879	1431366	222.76	152	22	201	1981	Resource Bore (DDH)
391	293912	1431431	209.66	134	7	203	1981	Resource Bore (DDH)

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Bore	Easting ISG	Northing ISG	collar (mAHD)	TD (m)	SWL (m)	SWL (mAHD)	Date	Comments
393	293684	1431379	218.49	154	22	196	1981	Resource Bore (DDH)
394	291346	1430253	209.64	147	43	167	1981	Resource Bore (DDH)
395	293810	1431892	206.76	172	19	188	1981	Resource Bore (DDH)
396	293693	1431689	199.65	147	11	189	1981	Resource Bore (DDH)
397	293667	1431211	212.48	144	44	168	1981	Resource Bore (DDH)
398	292855	1430803	209.6	148	26	184	1981	Resource Bore (DDH)
399	292670	1430775	198.8	142	13	186	1981	Resource Bore (DDH)
400	293514	1431229	208.67	148	26	183	1981	Resource Bore (DDH)
401	293426	1431371	197.33	154	14	183	1981	Resource Bore (DDH)
404	294584	1430886	281.08	105	85	196	1981	Resource Bore (DDH)
405	294393	1430974	254.01	104	66	188	1981	Resource Bore (DDH)
408	294341	1430821	260.32	98	88	172	1981	Resource Bore (DDH)
412	294378	1430618	271.13	81	66	205	1981	Resource Bore (DDH)
413	294675	1430894	269.92	173	65.6	204	1981	Resource Bore (DDH)
414	294609	1430855	271.33	125	62	209	1981	Resource Bore (DDH)
415	294557	1430801	271.17	112	67.4	204	1981	Resource Bore (DDH)
416	294512	1430751	270.42	107	66.8	204	1981	Resource Bore (DDH)
418	294445	1430670	265.16	93	60	205	1981	Resource Bore (DDH)
419	294347	1430495	270.29	114	78	192	1981	Resource Bore (DDH)
421	293965	1430456	256	111	87.8	168	1981	Resource Bore (DDH)
423	292240	1430724	187.91	88	18.4	170	1981	Resource Bore (DDH)
425	294823	1431327	269.03	160	64	205	1982	Resource Bore (DDH)
426	294795	1431629	233.88	123	44	190	1982	Resource Bore (DDH)
427	294556	1430634	241.52	116	23.6	218	1982	Resource Bore (DDH)
428	294624	1430759	249.61	122	32	218	1982	Resource Bore (DDH)
429	294541	1430530	232.7	132	32	201	1982	Resource Bore (DDH)
433	294411	1430509	260.96	123	59	202	1982	Resource Bore (DDH)
434	294436	1430596	261.53	112	42.5	219	1982	Resource Bore (DDH)

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Bore	Easting ISG	Northing ISG	collar (mAHD)	TD (m)	SWL (m)	SWL (mAHD)	Date	Comments
435	294179	1430874	267.01	134	85.8	181	1982	Resource Bore (DDH)
437	292829	1430682	207.42	133	21.6	186	1982	Resource Bore (DDH)
439	293783	1431405	221.61	147	24.5	197	1982	Resource Bore (DDH)
440	293950	1431684	218.07	146	19.5	199	1982	Resource Bore (DDH)
441	293992	1431786	207.17	154	7.5	200	1982	Resource Bore (DDH)
442	294043	1431643	222.26	153	25	197	1982	Resource Bore (DDH)
443	294114	1431973	209.62	172	17	193	1982	Resource Bore (DDH)
444	293956	1431990	215.14	178	20.4	195	1982	Resource Bore (DDH)
446	293901	1431895	202.2	178	7.6	195	1982	Resource Bore (DDH)
447	292839	1430396	221.75	116	62.5	159	1982	Resource Bore (DDH)
448	292904	1430562	217.3	86	28.7	189	1982	Resource Bore (DDH)
453	293081	1430158	244.21	104	37	207	1982	Resource Bore (DDH)
454	293038	1430149	242.14	104	45	197	1982	Resource Bore (DDH)
462	293588	1431306	207.47	146	11	196	1983	Resource Bore (DDH)
467	293666	1431573	205.4	153	17.6	188	1983	Resource Bore (DDH)
468	294016	1432076	224.36	194	28	196	1983	Resource Bore (DDH)
470	294647	1431763	221.73	152	26	196	1983	Resource Bore (DDH)
472	293776	1430677	244.46	108.5	77	167	1983	Resource Bore (DDH)
473	293844	1430290	270.62	159	127.7	143	1983	Resource Bore (DDH)
474	293830	1431112	230.75	113	64	167	1983	Resource Bore (DDH)
478	294126	1431412	234.5	147	25	210	1983	Resource Bore (DDH)
485	292782	1430321	225.16	101	75.7	149	1991	Resource Bore (DDH)
486	292799	1430313	230.02	94	80	150	1991	Resource Bore (DDH)
1001	290740	1433835				156	1996	Bores Dipped 1996 (Rust PPK)
1002	292230	1434510				158	1996	Bores Dipped 1996 (Rust PPK)
1003	292000	1434320				156	1996	Bores Dipped 1996 (Rust PPK)
1004	291260	1432485				148	1996	Bores Dipped 1996 (Rust PPK)

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Bore	Easting ISG	Northing ISG	collar (mAHD)	TD (m)	SWL (m)	SWL (mAHD)	Date	Comments
1005	291070	1431790				149	1996	Bores Dipped 1996 (Rust PPK)
1006	291350	1434440				158	1996	Bores Dipped 1996 (Rust PPK)
1007	291860	1434910				159	1996	Bores Dipped 1996 (Rust PPK)
1008	292340	1434800				157	1996	Bores Dipped 1996 (Rust PPK)
1009	292340	1434860				157	1996	Bores Dipped 1996 (Rust PPK)
1010	292500	1435920				168	1996	Bores Dipped 1996 (Rust PPK)
1011	292620	1435930				168	1996	Bores Dipped 1996 (Rust PPK)
1012	293140	1434760				162	1996	Bores Dipped 1996 (Rust PPK)
1015	294000	1435130				165	1996	Bores Dipped 1996 (Rust PPK)
101	292260	1429710	210.67	48	30.58	180.1	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
102A	292480	1430100	164.04	18.9	2.1	161.9	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
102B	292480	1430100	164.11	5.5	2.25	161.9	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
103	292480	1430830	179.76	83.3	10.4	169.4	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
107	292260	1430000	201.24	47	38.94	162.3	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
108	292220	1430110	203.23	50	40.92	162.3	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
109	292230	1430245	203.83	48.1	41.52	162.3	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
101	292260	1429710	210.67	48	33.903	176.8	1998	DP Bores (No.1 O/C 1997) SWLs from March 1998.
102A	292480	1430100	164.04	18.9	2.925	161.1	1998	DP Bores (No.1 O/C 1997) SWLs from March 1998.
102B	292480	1430100	164.11	5.5	3.054	161.1	1997	DP Bores (No.1 O/C 1997) SWLs from December 1997.
103	292480	1430830	179.76	83.3	11.435	168.3	1998	DP Bores (No.1 O/C 1997) SWLs from March 1998.
107	292260	1430000	201.24	47	40.021	161.2	1998	DP Bores (No.1 O/C 1997) SWLs from March 1998.
108	292220	1430110	203.23	50	42.2	161.0	1998	DP Bores (No.1 O/C 1997) SWLs from March 1998.
IP489	294280	1430473	244.09	16.5	dry	<228	1995	Cut 11 - Blast hole rig
IP490	294287	1430466	243.8	13.5	dry	<230	1995	Cut 11 - Blast hole rig
IP491	294276	1430459	244.8	16.5	dry	<228	1995	Cut 11 - Blast hole rig

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Muswellbrook Coal Company Limited
No.1 Open Cut Extension
Water Management Study

Water level Database

Bore	Easting ISG	Northing ISG	collar (mAHD)	TD (m)	SWL (m)	SWL (mAHD)	Date	Comments
IP492	294283	1430452	244.67	16.5	dry	<228	1995	Cut 11 - Blast hole rig
IP493	294419	1430783	246.05	20	dry	<226	1995	Cut 11 - Blast hole rig
IP494	294428	1430817	242.79	18	dry	<225	1995	Cut 11 - Blast hole rig
IP495	294449	1430797	242.78	18	dry	<225	1995	Cut 11 - Blast hole rig
IP496	294479	1430799	239.57	19	dry	<221	1995	Cut 11 - Blast hole rig
IP497	294487	1430809	239.48	20	dry	<219	1995	Cut 11 - Blast hole rig
IP498	294495	1430822	239.6	20	dry	<220	1995	Cut 11 - Blast hole rig
IP499	294479	1430833	239.25	20	dry	<219	1995	Cut 11 - Blast hole rig
IP500	294469	1430820	239.46	20	dry	<219	1995	Cut 11 - Blast hole rig
IP501	294450	1430824	238.71	20	dry	<219	1995	Cut 11 - Blast hole rig
IP502	294460	1430865	238.97	20	dry	<219	1995	Cut 11 - Blast hole rig
IP503	294418	1430853	242.6	20	dry	<223	1995	Cut 11 - Blast hole rig
IP506	294084	1431387	104.79	9	dry	<96	1996	Cut 12 - Blast hole rig
IP507	294066	1431426	101.28	9	dry	<92	1996	Cut 12 - Blast hole rig
IP508	294053	1431448	99.8	9	dry	<91	1996	Cut 12 - Blast hole rig
IP509	294029	1431402	103.24	8.5	dry	<95	1996	Cut 12 - Blast hole rig
IP510	294006	1431382	105.42	8.5	dry	<97	1996	Cut 12 - Blast hole rig
IP511	294022	1431352	108.98	8.2	dry	<101	1996	Cut 12 - Blast hole rig
IP512	294052	1431406	103.24	9	dry	<94	1996	Cut 12 - Blast hole rig
IP504	294766	1431649	188.54	15.5	dry	<173	1997	Cut 13 - Blast hole rig
IP505	294791	1431626	189.07	14	dry	<175	1997	Cut 13 - Blast hole rig
IP513	294759	1431683	175.56	19.5	dry	<156	1997	Cut 13 - Blast hole rig
IP514	294791	1431656	175.94	18.5	dry	<157	1997	Cut 13 - Blast hole rig
IP515	294840	1431625	176.61	8.9	dry	<168	1997	Cut 13 - Blast hole rig
IP516	294874	1431642	176.64	19.8	dry	<157	1997	Cut 13 - Blast hole rig
IP517	294848	1431688	176.21	18	dry	<158	1997	Cut 13 - Blast hole rig

Muswellbrook Coal Company Limited
No.1 Open Cut Extension
Water Management Study

Water level Database

Bore	Easting ISG	Northing ISG	collar (mAHD)	TD (m)	SWL (m)	SWL (mAHD)	Date	Comments
IP518	294816	1431702	175.56	9	dry	<167	1997	Cut 13 - Blast hole rig
IP519	294820	1431733	175.14	9	dry	<166	1997	Cut 13 - Blast hole rig
IP520	294800	1431753	175.13	20.4	dry	<155	1997	Cut 13 - Blast hole rig
Special Bores								
TCH487	293744	1431107	226.9	130.5			1991	Old U/G Borehole Pump. BOH 97mAHD (Lower Lewis Seam)
TCH488	293721	1430972	218.08	114.5			1991	
								Seam)
RDH529	294072	1432673	213.65	247.4			1997	
								BOH -35mAHD (St Helliers Seam)
RDH522	294122	1432673	215.7				1997	Monitoring piezometer for Current Dewatering hole
RDH472	293776	1430677	245.47	108.5			1983	

Muswellbrook Coal Company Limited
No.1 Open Cut Extension
Water Management Study

Water level Database

Hydrograph for DP Piezometer 101 (DP, 1997b)

Date	SWL(mAHD)
31-Oct-97	169.67
4-Dec-97	181.87
9-Dec-97	180.5
15-Dec-97	180.09
5-Mar-98	176.77

Creeks and Rivers
(Taken from 1:25,000 topographic map contours)

Sandy Creek			Hunter River			Muscle Creek		
Easting ISG	Northing ISG	SWL (mAHD)	Easting ISG	Northing ISG	SWL (mAHD)	Easting ISG	Northing ISG	SWL (mAHD)
296420	1435580	180	288940	1429200	138	289620	1428270	140
295380	1435460	175				290580	1427160	145
294360	1435270	170				291700	1427810	150
293600	1434520	165				292860	1426870	155
292580	1435060	160				294060	1427060	160
291540	1433950	155				294800	1427140	165
290840	1432200	150				295600	1427070	170
290520	1431560	145				296600	1426940	175
289600	1430340	140				297500	1427250	180

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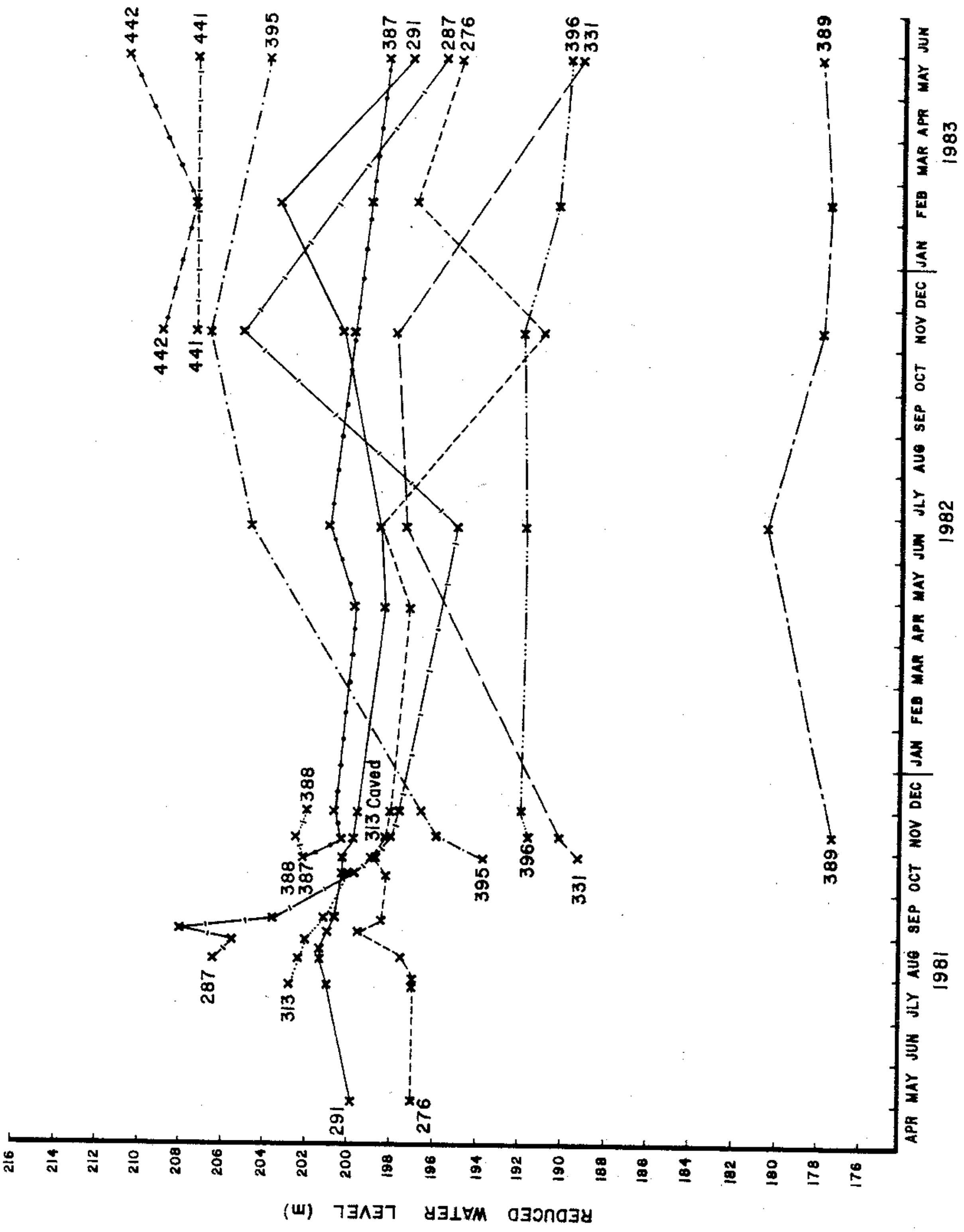


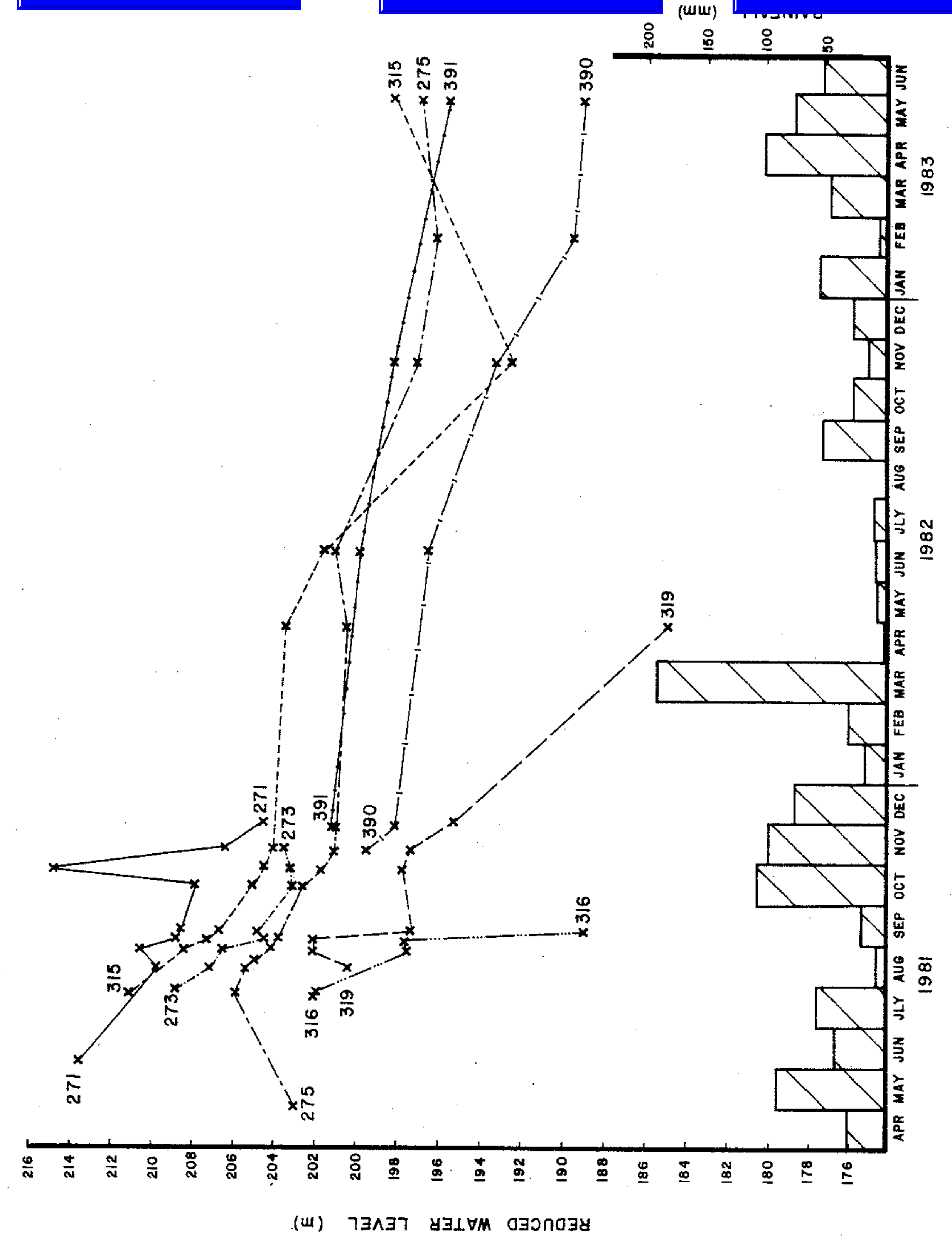
AUSTRALIAN GROUNDWATER CONSULTANTS PTY. LIMITED

NEW SOUTH WALES COAL ASSOCIATION

EFFECTS OF COAL MINING ON GROUNDWATER RESOURCES

WATER LEVELS
MUSWELLBROOK OPEN CUT
1981 TO 1983

DATE NOV '83	DWG. No. 667	FIG. No. A2.6



AUSTRALIAN GROUNDWATER CONSULTANTS PTY. LIMITED

NEW SOUTH WALES COAL ASSOCIATION

EFFECTS OF COAL MINING ON GROUNDWATER RESOURCES

WATER LEVELS

MUSWELLBROOK OPEN CUT

1981 TO 1983

DATE NOV '83	DWG. No. 667	FIG. No. A2.7

Muswellbrook Coal Company
Borehole Water Level Monitoring
Borehole Pump
(Steel Casing, St Heliers Seam, No.2 Underground Mine)

RL of Surface at pump 212.65
top of casing 213.65 ******measure from this level

date	time	Water Level Depth from Surface	Water Level RL	
5/30/01		71.47	142.18	
5/31/01		71.55	142.1	
6/1/01		71.44	142.21	
6/4/01	17:00	70.01	143.64	
6/5/01	16:10	69.7	143.95	
6/6/01	15:19	69.61	144.04	
6/7/01	15:24	69.37	144.28	
6/14/01	17:05	67.02	146.63	
6/21/01	17:05	63.6	150.05	
7/2/01	7:00	62.48	151.17	
7/13/01	15:00	61.4	152.25	1.08
8/15/01	15:00	58.7	154.95	2.7

Muswellbrook Coal Company
Borehole Water Level Monitoring
RDH 472
(Steel Casing, St Heliers Seam, St Heliers Colliery)

top of casing RL 245.47
Surface RL 244.31

date	time	Water Level Depth from Surface	Water Level RL
1/9/02	12:30	91.4	152.91
1/9/02	16:30	91.4	152.91
1/10/02	9:30	91.4	152.91
1/30/02	12:00	90.23	155.24
2/7/02	13:00	91.53	153.94
2/19/02	13:00	91.54	153.93
4/3/02	13:30	93.2	151.11
4/12/02	14:00	93.7	150.61

Muswellbrook Coal Company
Borehole Water Level Monitoring
RDH 522
(Piezometer, St Heliers Seam, No.2 underground Mine)

RL of Surface at pump	214.5	
top of casing	215.7	******measure from this level

date	time	Water Level Depth from Surface	Water Level RL
1/30/02	12:00	60.07	154.66
2/7/02	13:00	60.85	154.85
2/19/02	13:15	61.35	154.35
4/3/02	13:45	62.95	152.75
4/12/02	14:30	63.8	151.9

Muswellbrook Coal Company
Borehole Water Level Monitoring
RDH 564

RL of Surface at pump	272.6	
top of casing	272.6	******measure from this level

date	time	Water Level Depth from Surface	Water Level RL
2/7/01	12:00	91	181.6

HLA

APPENDIX C

APPENDIX C

No.1 OPEN CUT EXTENSION

WATER STORAGE CALCULATIONS AND RATINGS CURVES

Water storage versus water level ratings curves have been calculated for the No.1 Open Cut, the No.2 Open Cut, and the No.2 Underground. Each storage is discussed below.

1.0 NO.1 OPEN CUT

Figure C1 shows the inferred extent of the No.1 Open Cut workings at the end of 2003, just prior to Year 2 of the proposed development. **Figure C1** also shows the extent of spoil at the beginning of 2002, and the inferred extent at the end of 2003 (Year 1 of the development).

The following assumptions have been made:

- Mining to the base of the Loder Seam will occur only in the area not covered by spoil at the beginning of 2002 (the eastern part of the mined area). The rest of the pit will have only been mined to the base of the Lewis Seam. The Loder Seam is assumed to lie 10m below the Lewis Seam.

- The excavated extent of the No.1 Open Cut at the end of 2003 will be a combination of the extent shown on the plan supplied by MCC ("Location of Underground and Open Cut Workings", 1/7/1999), and the extent of workings in the early part of Year 1 of development, shown on MCC plan "MCC – Bimbadeen Project, Provisional Layout A + B Extension" (30/10/2001).

- Spoil storativity is 15%.

Calculations were conducted by finding the volume occupied by spoil, and the volume occupied by free water, contained by the pit (with floor contours as defined) from the pit base to a prescribed elevation (the notional water level elevation). The spoil volume was multiplied by 15% to obtain the relevant water storage, and the free volume was multiplied by 100%; both volumes were added to arrive at the total volume to a prescribed elevation. Volumes were obtained at 5 prescribed elevations (from 130mAHD, in increments of 10m) to obtain a ratings curve.

The resulting water storage versus water level ratings curve is shown in **Figure C2**.

2.0 NO.2 OPEN CUT

Figure C3 shows the inferred extent of the No.2 Open Cut workings at cessation of mining (late 2004). **Figure C3** also shows the extent of spoil at the beginning of 2002, and the inferred extent at the end of mining.

The following assumptions have been made:

- Mining has been conducted only to the base of the Lower Lewis Seam.

- The excavated extent of the No.1 Open Cut at the end of 2003 will be a combination of the extent shown on the plan supplied by MCC ("Location of Underground and Open Cut Workings", 1/7/1999), and the northern extent of workings as shown in a DXF plan supplied by MCC on electronic media.

- Spoil storativity is 15%.

Calculations were conducted by finding the volume occupied by spoil, and the volume occupied by free water, contained by the pit (with floor contours as defined) from the pit base to a prescribed elevation (the notional water level elevation). The spoil volume was multiplied by 15% to obtain the relevant water storage, and the free volume was multiplied by 100%; both volumes were added to arrive at the total volume to a prescribed elevation. Volumes were obtained at 7 prescribed elevations (from 50mAHD, in increments of 10m) to obtain a ratings curve.

The resulting water storage versus water level ratings curve is shown in **Figure C4**.

3.0 NO.2 UNDERGROUND

Mine staff indicate that the amount of water stored in the underground workings is approximately 20 ML/m between water levels of 133 mAHD and 155 mAHD (M Howes, MCC, pers. Comm., 21/2/2002).

An analysis of the geometry of the underground workings indicates that the storage capacity changes markedly, north of the cross workings drainage hole. The drainage hole is located at the northern end of the St Helliers Colliery, within the lowermost parts of the workings. The base of the St Helliers Seam is at an elevation of approximately 121 mAHD at the drainage hole. Combined with the shape of the Lewis Seam workings, 121 mAHD is considered the level at which the storage factor of 20 ML/m decreases significantly, since upper seam workings cease below this level.

Geometrical calculations have been conducted by dividing the Lewis and St Helliers Seam workings that drive north from cross-workings drainage hole into up-dip and down dip sections. The down-dip section covers the workings that drive eastwards along the north boundary of the No.2 Open Cut. The up-dip area is the long stretch of development headings linking the main part of the No.2 Underground to the down dip area.

The following criteria have been used:

- The water storage versus depth relation of 20 ML/m applies to elevations from 121mAHD to 155mAHD.
- Analysis of development drive tunnel geometry indicates a tunnel void to total area of workings ratio of 6,744m3 of void per 1.8905 ha of workings in plan view. This ratio is assumed to hold for the up-dip and down-dip areas only, as defined above.

The resultant calculations provide the following water storage volumes:

- From 155mAHD to 121 mAHD: Approximately 680 ML (20 ML/m).
- From 121 mAHD to 15 mAHD: Approximately 60 ML (0.57 ML/m).
- From 15 mAHD to -52 mAHD (base of workings): Approximately 40 ML (note that the northern-most extremity of the workings is within the St Helliers Seam) (0.60 ML/m).

The resulting water storage versus water level ratings curve is shown in **Figure C5**.

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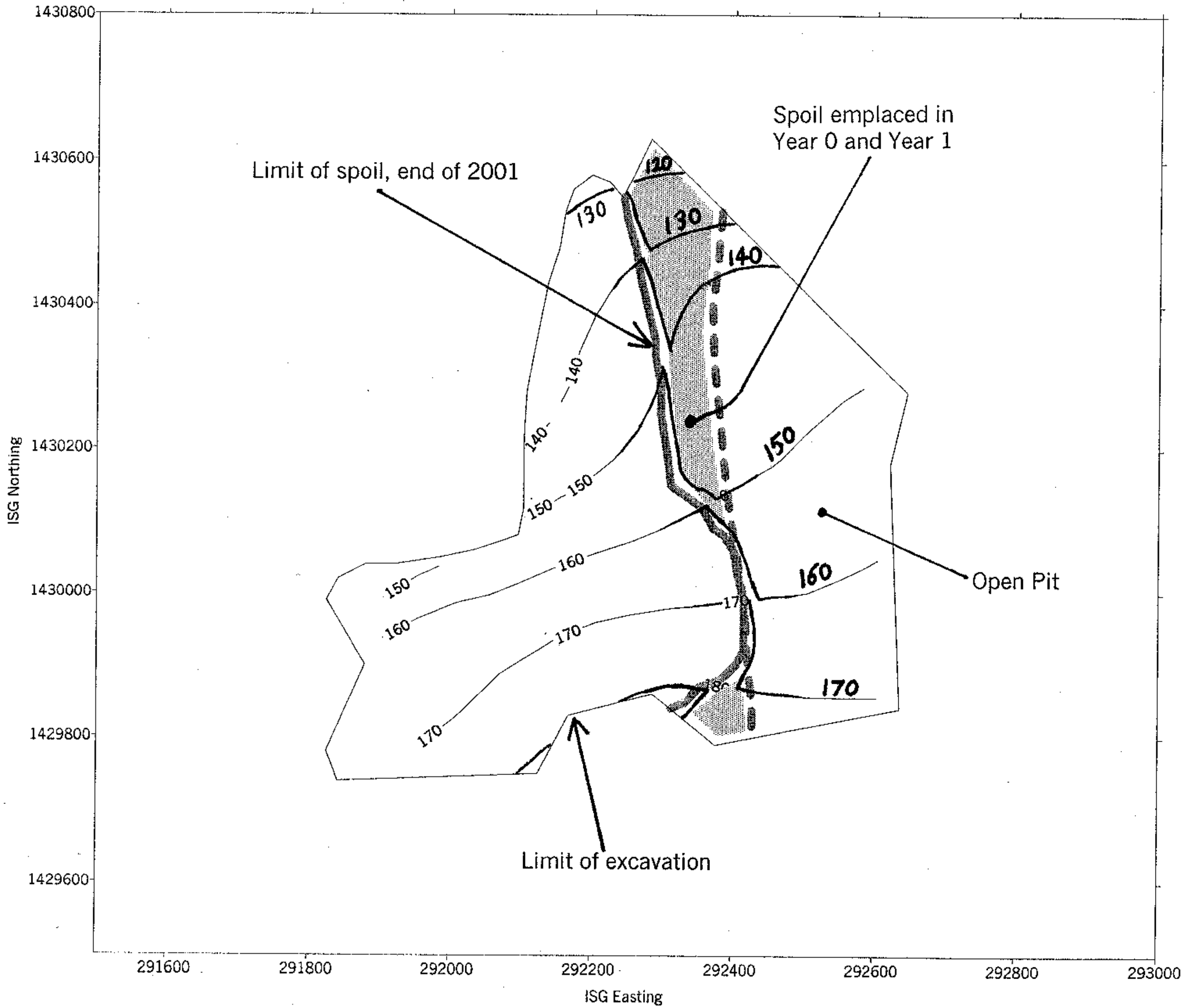
Inferred Extent of No.1 Open Cut Workings at the end of Year 1



Notes:
Contours are of base of pit, in mAHD

FIGURE C1

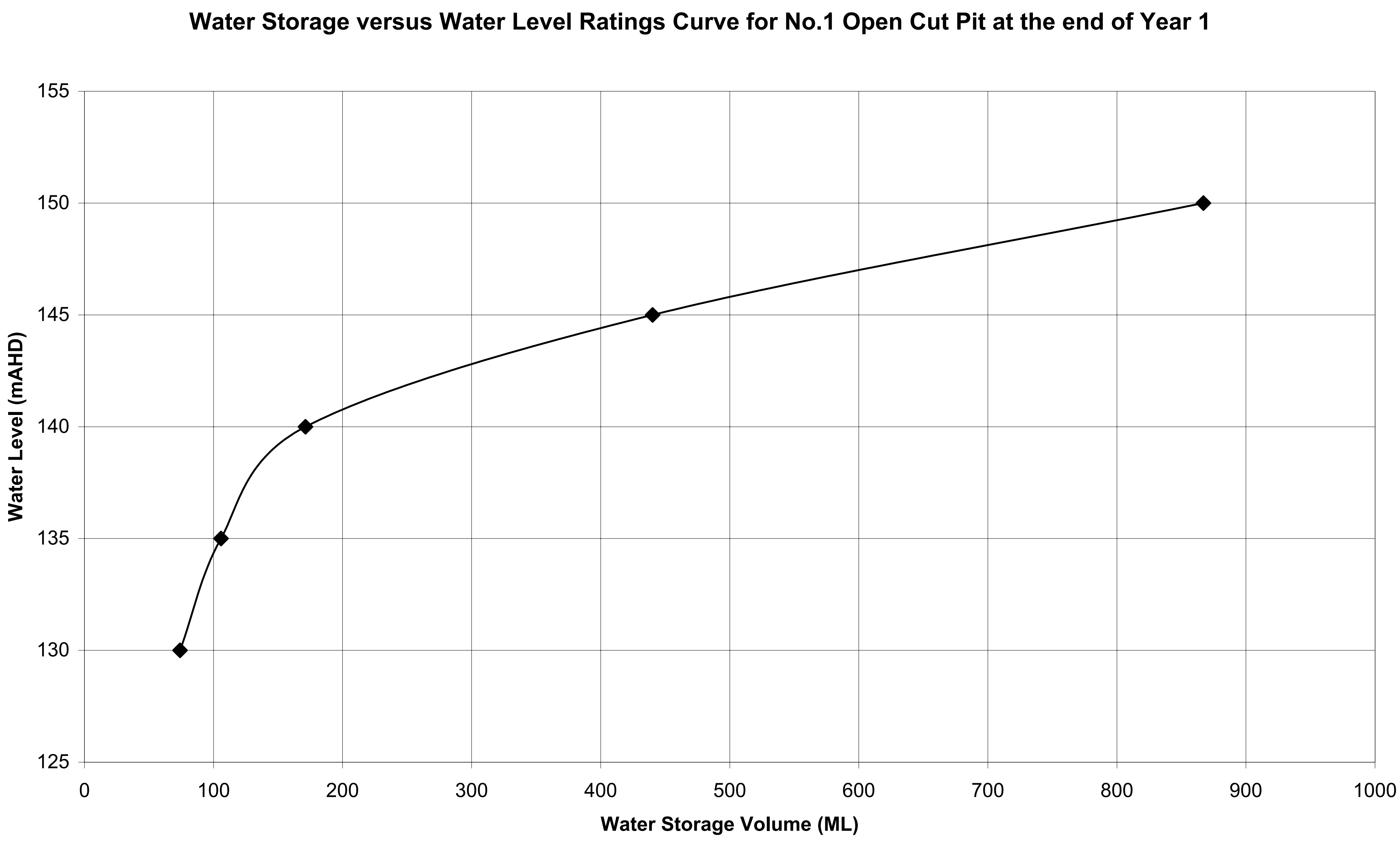

Water Storage versus Water Level Ratings Curve for No.1 Open Cut Pit at the end of Year 1
Water Level (mAHD)
155
150
145
140
135
130
125
0
100
200
300
400
500
600
700
800
900
1000
Water Storage Volume (ML)

FIGURE C2

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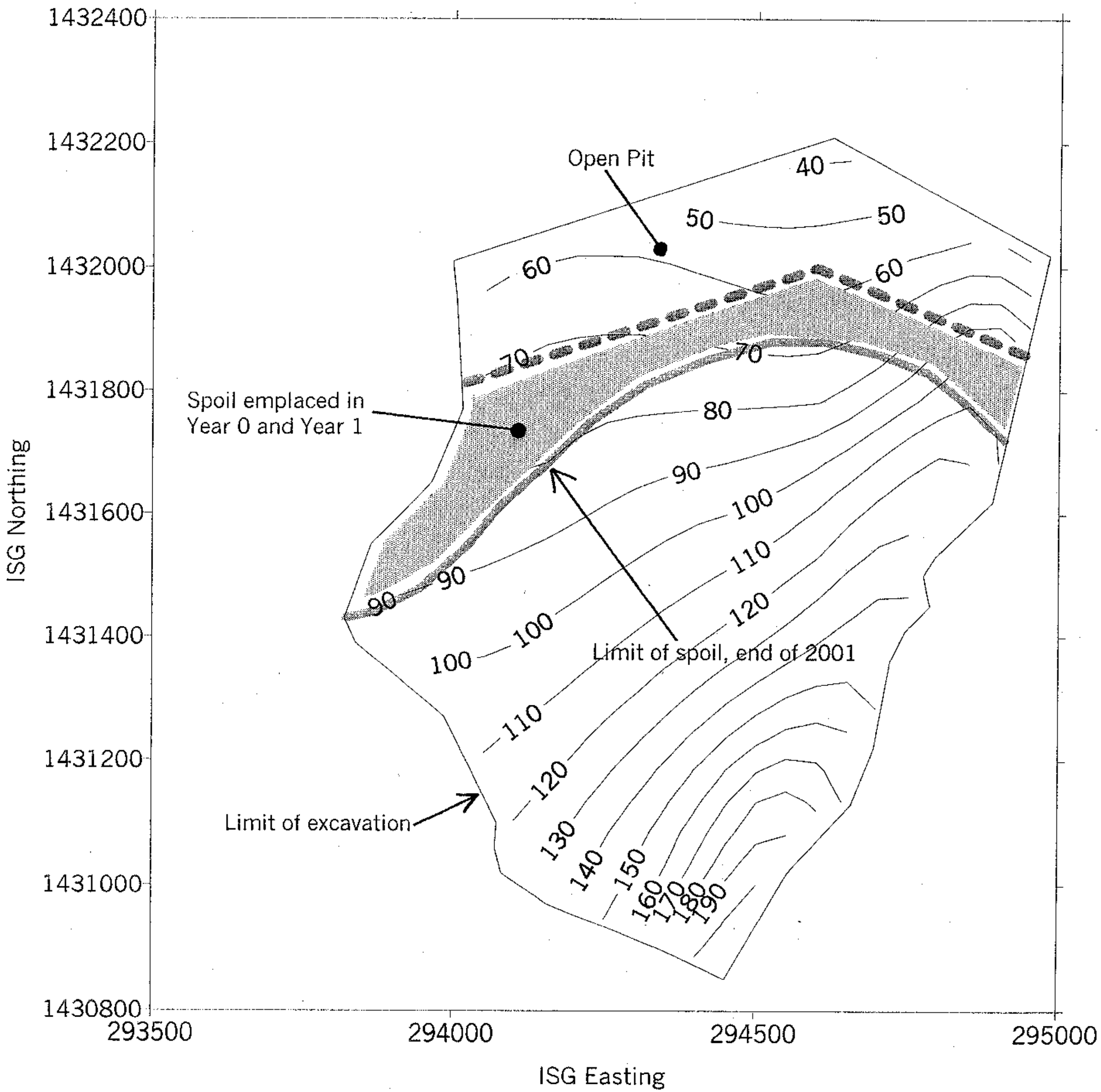

Inferred Extent of No.2 Open Cut Workings at Cessation of Mining (2005)

Notes:
Contours are of Lower Lewis Seam floor, in mAHD.

FIGURE C3

HLA

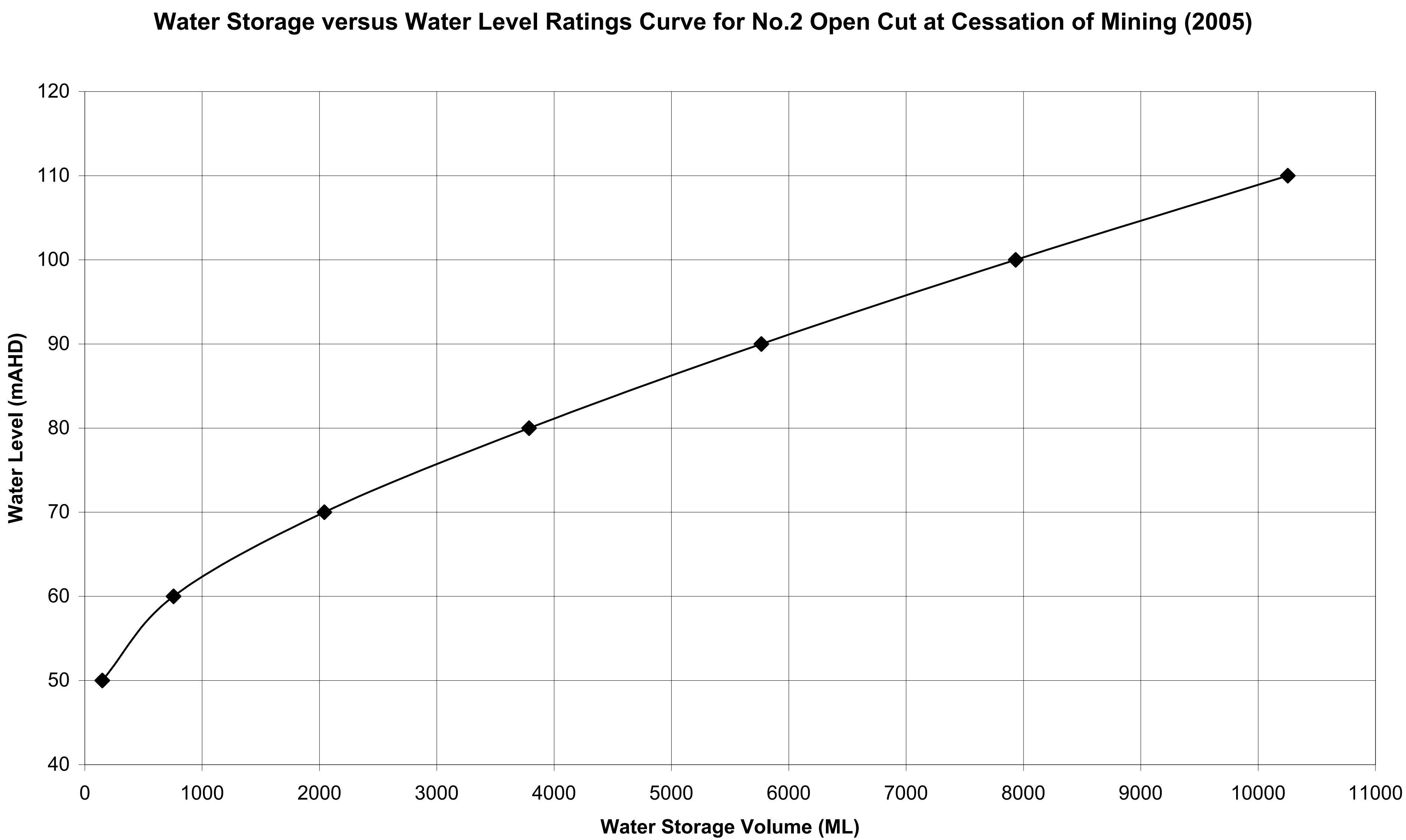
Water Storage versus Water Level Ratings Curve for No.2 Open Cut at Cessation of Mining (2005)
120
110
100
90
80
70
60
50
40
Water Level (mAHD)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Water Storage Volume (ML)

FIGURE C4

Start Screen

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Appendices

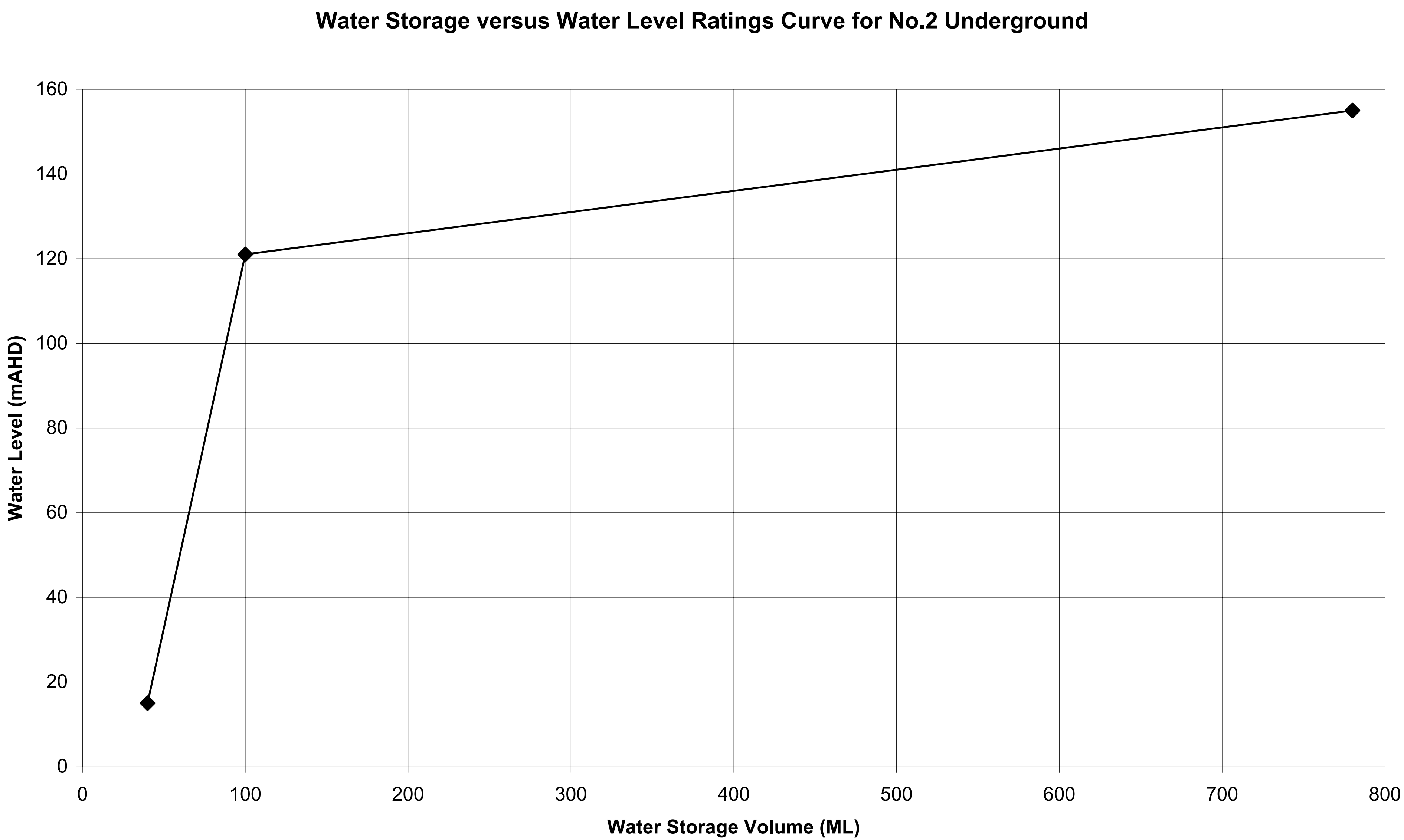

FIGURE C5

HLA

APPENDIX D

APPENDIX D

No.1 OPEN CUT EXTENSION

GROUNDWATER MODELLING

1.0 MODEL SET-UP

1.1 Introduction

The numerical model of the groundwater system at the site was developed using MODFLOW (McDonald and Harbaugh, 1988), a quasi-three-dimensional, finite difference, block centered flow model. MODFLOW is an internationally recognised and verified groundwater modelling package accepted by most water resource authorities. The modelling was conducted for the following purposes:

- To predict groundwater inflows to the proposed open cut operations from Years 1 to 9 of development.
- To calculate the rate of groundwater inflow to the No.1 and No.2 Open Cut pits.

1.2 Conceptual Groundwater Regime

The conceptual model for the groundwater regime of the area is based on the hydrogeological section shown in Figure 11 of the main text. This model was used to develop the numerical groundwater model.

1.3 Assumptions

For modelling purposes the stratigraphy of the area has been represented by 10 layers as defined below.

Layer 1:	Upper Branxton Formation and Mulbring Siltstone
Layer 2:	Upper Greta Coal Measures and Lower Branxton Formation
Layer 3:	Upper Greta Coal Measures
Layer 4:	Fleming Seam and overburden
Layer 5:	Muswellbrook Seam and overburden
Layer 6:	St Helliers Seam and overburden
Layer 7:	Lewis Seam (and splits) and overburden
Layer 8:	Loder Seam and overburden
Layer 9:	Skeletar Formation (Greta Coal Measures)
Layer 10:	Gyarran Volcanics

Layers 4 to 8 each consist of a combination of a mined coal seam and the overburden to the next mined coal seam. This homogenisation has been applied by the averaging of permeability field test data curves.

The layers exhibit substantial dips. All the mined seams outcrop, or come very close to the surface, within the model domain. This was simulated by designating areas of the layers that pinch out in the real system as inactive areas in the model. Rainfall infiltration still accedes to the outcrop areas because it is applied to the uppermost active cell in any column of the domain.

1.4 Boundary Conditions

Water level measurements indicate that the area is hydrogeologically controlled by Sandy Creek to the north, Muscle Creek to the south, and the Hunter River to the west.

The modeling domain covers a square area 8km by 8km in extent, centered approximately on the works area. It terminates at streams listed above, on the northern, southern, and western boundaries. The eastern boundary terminates at the groundwater divide underneath Bells Mountain.

The model domain consists of 88 columns by 88 rows with cell dimensions varying from 50m by 50m over the works area to 250m by 250m at the domain boundary. The increase of cell dimensions from any cell to its neighbour is by a maximum factor of 1.2 times the appropriate dimension, with the finest grid overlaying the works area.

Recharge is applied uniformly over the domain, to the uppermost active cell in the domain grid.

2.0 MODEL CALIBRATION

The calibration was conducted in steady state simulation with the primary control on hard rock aquifer parameters being a single water level measurement taken in each of 6 open resource holes (drilled during coal exploration activities) in late 1980 or early 1981. These boreholes were DDHSC4, DDHSC7, DDH297, DDH314, BH384, and BH399 (**Figure D2**). The water levels in these boreholes were considered to be unaffected by mining operations. The model used for calibration had no mined zones within it, and was essentially a model of virgin conditions, used to calibrate hydraulic conductivities and rainfall infiltration for undisturbed strata.

Calibration proceeded by using the model-calculated heads in layers 1 to 7 at each bore location to calculate a single transmissivity-weighted head at each location. At each bore location, this transmissivity-weighted head was compared to the field water level measurement. Layers 1 to 7 were used in the weighting since these were the layers penetrated by the boreholes.

Figure D1 shows the results of the calibration. Residuals from this exercise indicate an approximately normal distribution (centered around a zero mean) with an average residual of ± 10.2m. The residuals are considered acceptable, when compared to the low hydraulic conductivities of the strata, and the total pressure column of water within the respective layers (up to several hundred metres). The application of a uniform rainfall over the domain also introduces some error, because in outcrop areas the coal-fired rock will provide enhanced infiltration and therefore higher heads.

Areas at high surface elevation showed water pressures decreasing with depth, whilst areas at low elevation showed water pressures increasing with depth. For virgin conditions, the gradient in pressure with depth was very small, on the order of a few centimeters pressure head change per 100m change in depth. For this reason, the calibrated piezometric surface in layer 10 (the most extensive layer) is thought to be a fair approximation to the pre-mining (virgin conditions) composite piezometric surface (**Figure D2**).

2.1 Calibrated Parameters

2.1.1 Hydraulic Conductivity

The calibration was achieved with hydraulic conductivity functions varying with depth for layers 3 to 10. The functions are of the form:

$$10^{((z - B) / M)}$$

(where B and M are constants).

For Layers 4 to 8 (coal + overburden) the calibrated horizontal hydraulic conductivity function is denoted by $f_1(z)$ and is given by:

$$10^{((z + 15) / -41.9)}$$

For Layers 3, 9, and 10 (rock with minimal or no coal seams), the calibrated horizontal hydraulic conductivity function is denoted by $f_2(z)$ and is given by:

$$10^{((z + 20) / -47.4)}$$

For both cases, the horizontal hydraulic conductivity for depths of 10m or less is fixed at the value calculated by the functions at 10m depth. This depth was evaluated from packer test data and probably indicates the weathering depth. It is noted that this depth is less than the depth inferred from packer test data at mine locations at lower surface elevations (around 30m near Singleton). This depth probably reflects the weathering process at higher elevations, and the smaller thicknesses of surface unconsolidated sediments.

Figure D3 shows the calibrated horizontal hydraulic conductivity functions superimposed on the field packer test data.

Vertical hydraulic conductivity was calibrated as 100% of the horizontal value for depths of 10m or less, and 50% of the horizontal value for depths greater than 10m. The ratio of horizontal to vertical hydraulic conductivity was the most sensitive parameter in the calibration process.

Layers 1 and 2 were assigned uniform permeabilities over the entire layer.

2.1.2 Rainfall Infiltration

The calibrated annual rainfall recharge was 3.1 % of the rainfall at Muswellbrook High School between July 1980 and June 1981 (504 mm). This was applied uniformly over the domain and reflects increased recharge from coal-fired rock outcrop areas.

Calibrated aquifer parameters are listed in **Table D1**.

3.0 PREDICTIVE MODELLING

Predictive modelling has been undertaken in two stages:

- Stage 1. Development of a model, from the calibrated model, that incorporates the hydrogeological regime in November 2001, and steady state simulation of this model to obtain starting heads for the simulation of active mining during the proposed development.

- Stage 2. Use of the Stage 1 Model in transient simulation, to simulate No.1 Open Cut Extension mining activities from 2003 to 2011, using the calculated heads from the Stage 1 Model as the starting heads in 2003.

3.1 Stage 1 Modelling

This model was the same as the calibrated model, but also incorporated the hydrogeological regime as at November 2001, consisting of:

- No.1 and No.2 Open Cuts, with water levels of 140.8 and 81.7 mAHD respectively.

- The No.2 Underground with a water level of 154.5 mAHD

- Workings of the No.1 Underground, St Helliers Colliery, Common Open Cut, and old extensions of the No.1 and No.2 Open Cuts.

- Horizontal hydraulic conductivity of 1,000 m/day for underground workings

- Vertical hydraulic conductivity of 0.1 m/day for underground workings, except at the cross-workings drainage hole (vertical conductivity of 100 m/day, as an average for the bore diameter with respect to the size of the appropriate model cell (2,500m^2)), and where the Lewis Seam workings drift up into the St Helliers Seam workings in the north (vertical conductivity of 1000 m/day).

- Vertical and horizontal conductivity of spoil set to 1 m/day.

The base of the No.1 Open Cut was described as it may appear at the end of 2002, which is very similar to the current situation.

Rainfall infiltration was applied according to the rainfall recorded at the MCC mine weather station from July 2000 to June 2001, using the calibrated infiltration rate.

3.1.1 Stage 1 Results

This model was run in steady state mode and calculated heads in each layer were extracted for use in Stage 2. Several notable results were obtained:

- Inflow to the No.1 Open Cut was approximately 0.14 ML/day
- Total inflow to the No.2 Open Cut and No.2 Underground was approximately 0.29 ML/day

In comparison, water level monitoring data for the No.2 Underground indicate that from closure in 1997 (assumed to be mid year), to early 2001, the water level rose from the base of the workings to 133 mAHD. This equates to an inflow volume of 340 ML in 3.8 years or an average inflow rate over this period of approximately 0.25 ML/day.

The version of MODFLOW being used precluded the simulation of seepage faces, therefore separate inflows to the No.2 Underground and the No.2 Open Cut could not be extracted (because of the workings geometry). Consideration of calculated heads and hardrock storativity would appear to indicate that approximately 1/3 of the inflow would have reported to the No.2 Open Cut (0.10 ML/day), and the remainder to the No.2 Underground (0.19 ML/day).

The water budget discrepancy for the entire domain was –2%.

3.1.2 Inflow Estimates from Previous Studies

A note on groundwater inflow estimates made in previous studies is presented here for comparison to estimates calculated in this study. A literature review produced the following:

- AGC (1984): Prediction of groundwater inflows to the No.2 Open Cut, beginning with the current conditions (probably 1981) when the pit extent covered approximately 40 ha in the southern part of the 2002 pit extent. Calculated inflows indicated:

    - Inflow for current conditions (Year –1, thought to be 1981) of approximately 0.2 ML/day.
    - An increase with time, from about 0.35 ML/day in Year 1 to a maximum of 0.59 ML/day in the summer of Year 2 /Year 3.
    - From Year 3, a gradual decline in inflows to around 0.3 ML/day at the end of Year 5.

  Comparison with actual pumping rates were good; in August 1982 virtually no rain had fallen in the area (minimal runoff make) and extraction from the pit averaged 0.45 ML/day. 1982 was presumably Year 1 of the simulation.

- DP (1997b): Estimation of current (1997) groundwater outflow from the No.1 Open Cut of 0.2 ML/day or less, but noted as being sensitive to pumping estimates provided by MCC, and considered to be much less than 0.2 ML/day. At this time, the water level in the pit was 162 mAHD.

- HLA (1998): Prediction of groundwater inflows to the Sandy Creek underground mine. Calculated inflows were 0.1 ML/day to 0.4 ML/day, rising uniformly from Year 1 to Year 10 of the underground mining. An estimate of current inflow to the No.2 Open Cut was 0.22 ML/day (May

1998). The study also reported current groundwater inflow to the No.2 Underground (just prior to closure in 1997) of 0.345 ML/day.

- ERM (2002): Estimation of current (November 2001) groundwater inflow to the No.1 and No.2 Open Cuts of 2ML per kilometre of pit face per month, with a No.1 pit face length 1.75 km and No.2 pit face length of 0.5km. This equates to 0.12 ML/day for the No.1 Open Cut and 0.03 ML/day for the No.2 Open Cut.

These estimates are variable. Groundwater inflow estimates calculated in this current study are considered to be realistic and rigorous.

3.2 Stage 2 Modelling

Stage 2 modelling comprised the evaluation of groundwater inflows to the proposed open cut operations. The Stage 2 model is the same as the Stage 1 model but is run in transient mode, with changes as discussed below.

Open cut mining was simulated by use of the drain package, with drain elevations set to 0.1m above the base of the Loder Seam. This head difference has a negligible effect due to the range of drawdowns to be experienced. The hydraulic conductance of all drain cells was set equal to 10 m^2/day, to simulate typical rates of inflow observed in nearby mines. Any water flowing into a drain is assumed to leave the model system (extraction performed by pumps, or by evaporation from the pit floor).

The time structure for the predictive phase consisted of 9 stress periods, all of 1 year in length, which simulated Project Years 1 (2003) to 9 (2011). At the start of each year, drains are assigned to the entire pit area excavated in the current year and previous years. The number of drain cells therefore accumulates, and reaches a maximum in Year 9.

The mean annual rainfall from Muswellbrook High School (616 mm/year) was used to assign an infiltration rate for all years of development, based on the percentage determined during calibration. This is equivalent to average rainfall conditions over the life of the development.

Water levels in the main storages have been described according to the No.2 Underground storage strategy (see Section 6.1.1 in the main text) and have been simplified to the following:

- No.1 Open Cut pit: 140.8 mAHD in 2003, 145 mAHD from 2004 to 2005, 135 mAHD from 2006 to 2011.

- No.2 Open Cut pit: 81.7 mAHD from 2003 to 2011.

- No.2 Underground: 154.5 mAHD in 2003, 140 mAHD from 2004 to 2005, -35 mAHD from 2006 to 2011.

These heads are higher than will probably be the case, and so will provide results for groundwater inflows (to the proposed development) that will be overestimates of actual inflows.

Layer storage parameters have been assigned according to **Table D1**. These values are uncalibrated however they are reasonable estimates made from various data. Note that for the underground workings, the specific yield (0.03) was calculated from the volume ratings curve for the No.2 Underground, averaged over the thickness of the layers affected.

3.2.1 Stage 2 Results

The water flowing into the proposed extension with time, calculated by the model, is shown in **Figure D4**. Results are presented in **Table D2**.

Table D2. Calculated Groundwater Inflows to the Proposed Extension

Year	Proposed Extension (ML/day)	No.2 Mines (ML/day)	No.1 Open Cut (ML/day)
2003	0.056	0.269	0.140
2004	0.090	0.095	0.137
2005	0.102	0.099	0.131
2006	0.123	0.097	0.133
2007	0.173	0.096	0.129
2008	0.198	0.102	0.126
2009	0.219	0.097	0.123
2010	0.217	0.097	0.119
2011	0.203	0.097	0.117

Inflows gradually increase until Year 5 (2007) when a sharper rise in inflows occurs; this time coincides with the beginning of mining at the eastern end of Extension B. Maximum inflows to the extension of around 0.22 ML/day are calculated for Years 7 and 8 (2009 and 2010). After Year 8 the inflows show a minor decrease.

Inflows to the No.2 Underground and the No.2 Open Cut (the combined No.2 mines) are lumped together. These voids act virtually as a single sink to the groundwater system due to their proximity and the geometry of the workings. Inflows to the combined No.2 mines drop markedly from 2003, reaching a stable value of around 0.1 ML/day for most of the development. This may be caused by the depressurisation of the aquifer of the Gyarran Volcanics / Greta Coal Measures contact, and/or interception of rainfall recharge at the outcrop zones, by the open cut workings of the proposed development. Inflows to the No.1 Open Cut show a gradual decrease with time, from 0.14 ML/day to 0.12 ML/day.

Water levels are completely influenced by the No.2 Underground storage strategy. By Year 9 the mined strata in the area are nearly completely dewatered.

4.0 SENSITIVITY ANALYSIS

The Stage 1 predictive model was used to investigate the sensitivity of model-calculated groundwater inflows to changes in selected model input parameters.

The most sensitive parameters with respect to water levels for the current model were found to be the horizontal and vertical hydraulic conductivity distributions in undisturbed strata, and the rate of rainfall infiltration. The vertical to horizontal hydraulic conductivity ratio was the parameter with the largest effects on water levels.

The behaviour of the model output to changes in model parameters was investigated by the following:

- Doubling the calibrated value of the ratio of vertical to horizontal hydraulic conductivity.
- Increasing the rainfall to 3.1% of the Decile 9 rainfall recorded at Muswellbrook High School (852mm). This simulates abnormally wet conditions.

In both cases, all parameters except the varied parameter are the same as in the Stage 1 base case model.

4.1 Sensitivity Analysis Results

The calculated groundwater inflows to the No.1 Open Cut, and the combined inflows to the No.2 Underground and No.2 Open Cut, were evaluated for each perturbation of parameters. Results are summarized in **Table D3**.

Table D3. Sensitivity Analysis Results

Storage Entity	Inflows for Stage 1 base case (ML/day)	Inflows for case of rainfall infiltration increased by 39% (ML/day)	Inflows for case of K_v/K_h doubled (ML/day)
No.2 Mines	0.288	0.349	0.326
No.1 Open Cut	0.142	0.178	0.119

The results indicate that for both cases of parameter change, the inflows to the No.2 Open Cut and No.2 Underground increase by around 20%. The No.1 Open Cut inflow shows an increase of 25% for the increased rainfall case, but shows a decrease for the increased vertical permeability case. This may reflect the shallower depth of the No.1 Open Cut pit base compared with the No.2 Open Cut pit base.

The results show that for extreme conditions, groundwater inflows may vary by around 20%.

5.0 LIMITATIONS

The discretisation of the model domain, the limited observation data, and the modelling code used, introduce a number of limitations to the model. These limitations have not, however, impacted significantly on the calculated inflows to the open cut operations of the proposed development. The limitations are discussed below.

5.1 Open Cut Mining Inflows

Open cut mining has been simulated using the drain mechanism. This means that water stored in strata overlying the pit base will report to the drains, and also that the overlying strata may not de-saturate fully. In reality, some water in storage will remain in removed overburden, and no saturation will remain above the pit base. These effects are contrary and the net effect is considered to be minimal. The calculated inflows do not incorporate evaporative losses (which can remove a substantial component of the groundwater inflow) nor do they incorporate surface runoff from in-pit overburden areas into the pit base.

5.2 Rainfall Infiltration

Input from rainfall in the model is a daily constant, over the period of simulation. This constrains the flow to the drains to be dependent only on subsurface geometry, subsurface structure, and hydraulic head distribution. In practice, the seasonal rainfall will superimpose a higher frequency to the variation in model-calculated inflows, however over a year the total flows will be approximately the same.

5.3 Fracture Flow

Transient, high-volume inflows from large fractures having high storage are not described by the model because the aquifer parameters have been selected to equate the local-scale fracturing of the hard rock to a porous medium which can be modelled by Darcy theory. The cell sizes make this assumption valid.

There is a set of fractures within the western part of the works area (see Section 4.2 in the main text), of which the most likely to provide an avenue for transient, high volume inflows is the westernmost fault with a throw of 20m. This fault intersects the No.1 Open Cut and may provide enhanced inflow along its strike, because the fault will link the water in the No.1 Open Cut (at a level of around 150mAHD), to the open cut floor (reaching down to a level of around 130mAHD in Year 2).

5.4 Inflows to the Combined No.2 Mines

As discussed, the inflow to the combined No.2 Mines drops markedly from Year 1 of simulation. It is likely that this is caused by several factors that can be due to the natural system, or to the model solution. One factor that could cause the drop in inflow is equilibration of water levels from the effects of stored water. Storage parameters for the simulation could not be calibrated, but are considered realistic. The overall results are not considered to be significantly affected by this process.

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Table D1. Calibrated Model Parameters

Layer	Stratum	Horizontal Hydraulic Conductivity (m/day)	Vertical Hydraulic Conductivity (m/day)	Rainfall Infiltration Rate (%)	Specific Yield #	Specific Storage (1/m) #
1	Upper Branxton Formation and Mulbring Siltstone	0.05	0.02	3.1	0.005	3×10^{-6}
2	Upper Greta Coal Measures and Lower Branxton Formation	0.03	0.01	3.1	0.005	3×10^{-6}
3	Upper Greta Coal Measures	$f_2(10)$ if z is $\leq$ 10m $f_2(z)$ if z is $>$ 10m	1 x $f_2(10)$ if z is $\leq$ 10m 0.5 x $f_2(z)$ if z is $>$ 10m	3.1	0.005	3×10^{-6}
4 to 8	Coal Seam and Overburden	$f_1(10)$ if z is $\leq$ 10m $f_1(z)$ if z is $>$ 10m	1 x $f_1(10)$ if z is $\leq$ 10m 0.5 x $f_1(z)$ if z is $>$ 10m	3.1	0.005	3×10^{-6}
9 and 10	Skeletar Formation and Gyarran Volcanics	$f_2(10)$ if z is $\leq$ 10m $f_2(z)$ if z is $>$ 10m	1 x $f_2(10)$ if z is $\leq$ 10m 0.5 x $f_2(z)$ if z is $>$ 10m	3.1	0.005	3×10^{-6}
Various	Open Cut Mine Spoil ^	1	1	3.1	0.15	3×10^{-6}
Various	Underground Mine Workings ^	1000	0.1*	3.1	0.03	3×10^{-6}

NOTES

* Set to 100 at cross-workings drainage hole cell, and 1000 at zone of change from Lewis Seam to St Helliers Seam, in the north.

\# Used in the Stage 2 predictive model only.

^ Used in the Stage 1 and Stage 2 predictive models only.

$$f_1(z) = 10^{((z+15)/-41.9)}$$

$$f_2(z) = 10^{((z+20)/-47.4)}$$

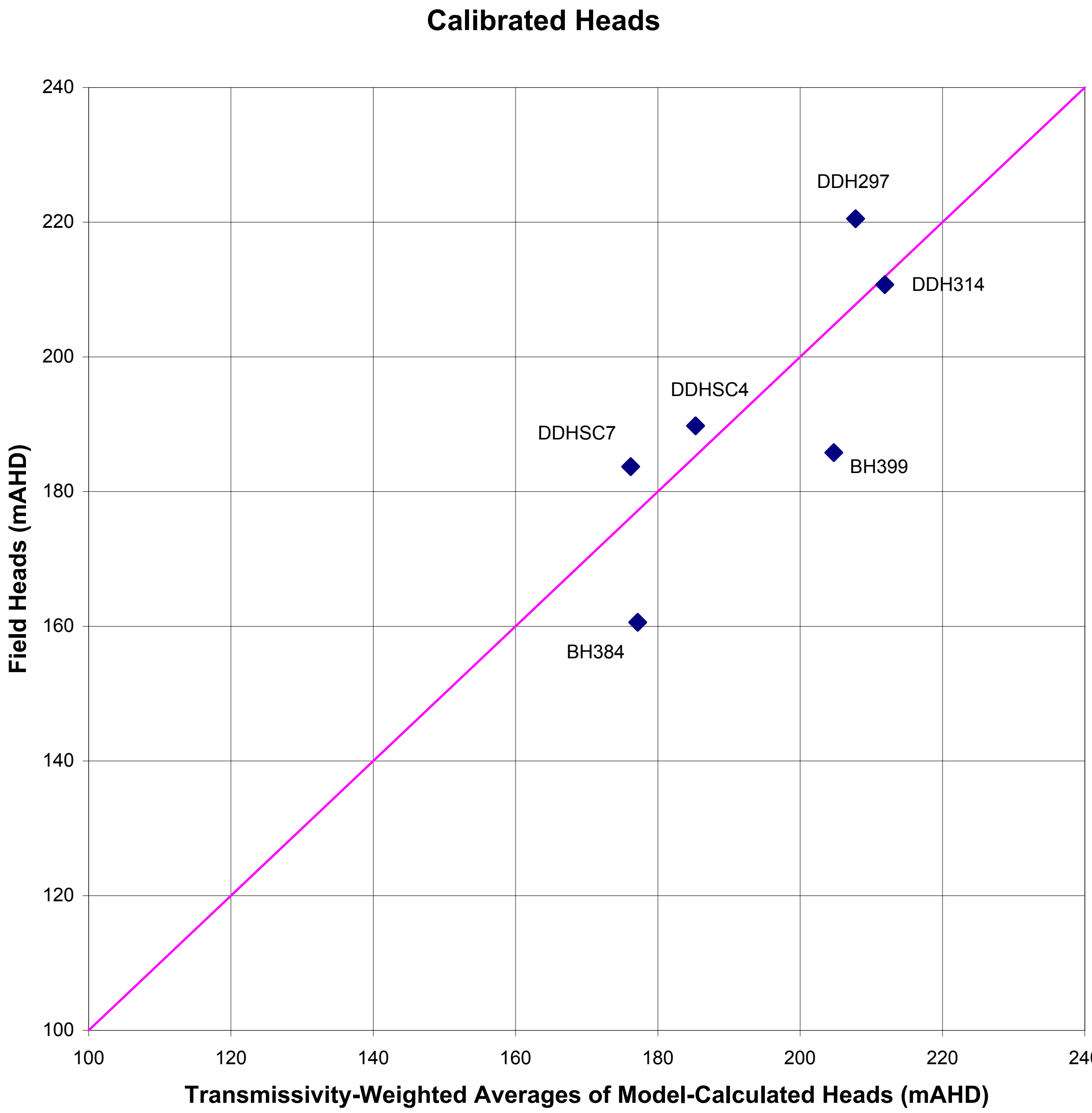
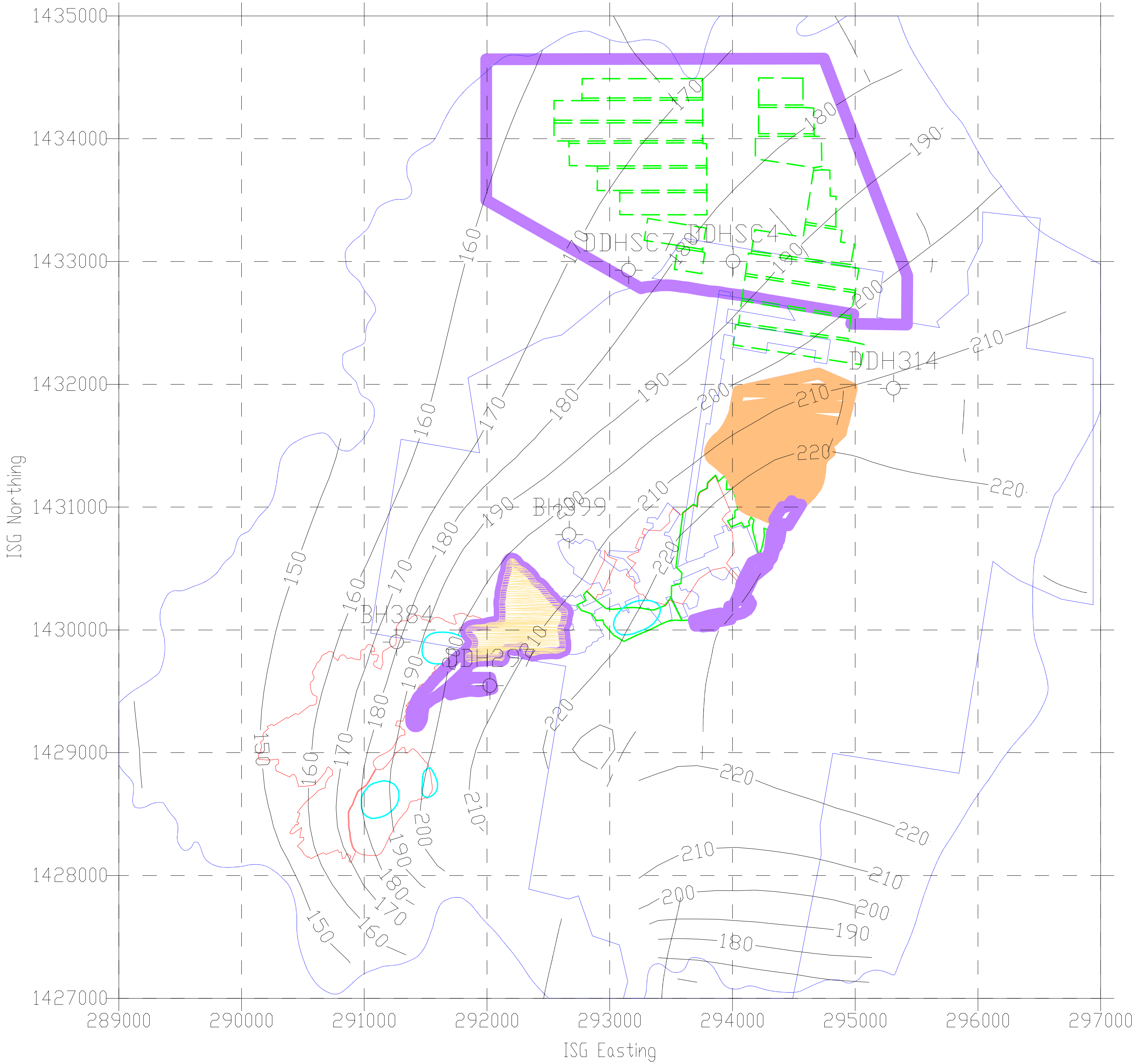


FIGURE D1

HLA



Calibrated model heads in Layer 10 for the case of no mining (virgin conditions)

Notes:

Contours are piezometric head, in mAHD.

Calibration bore.

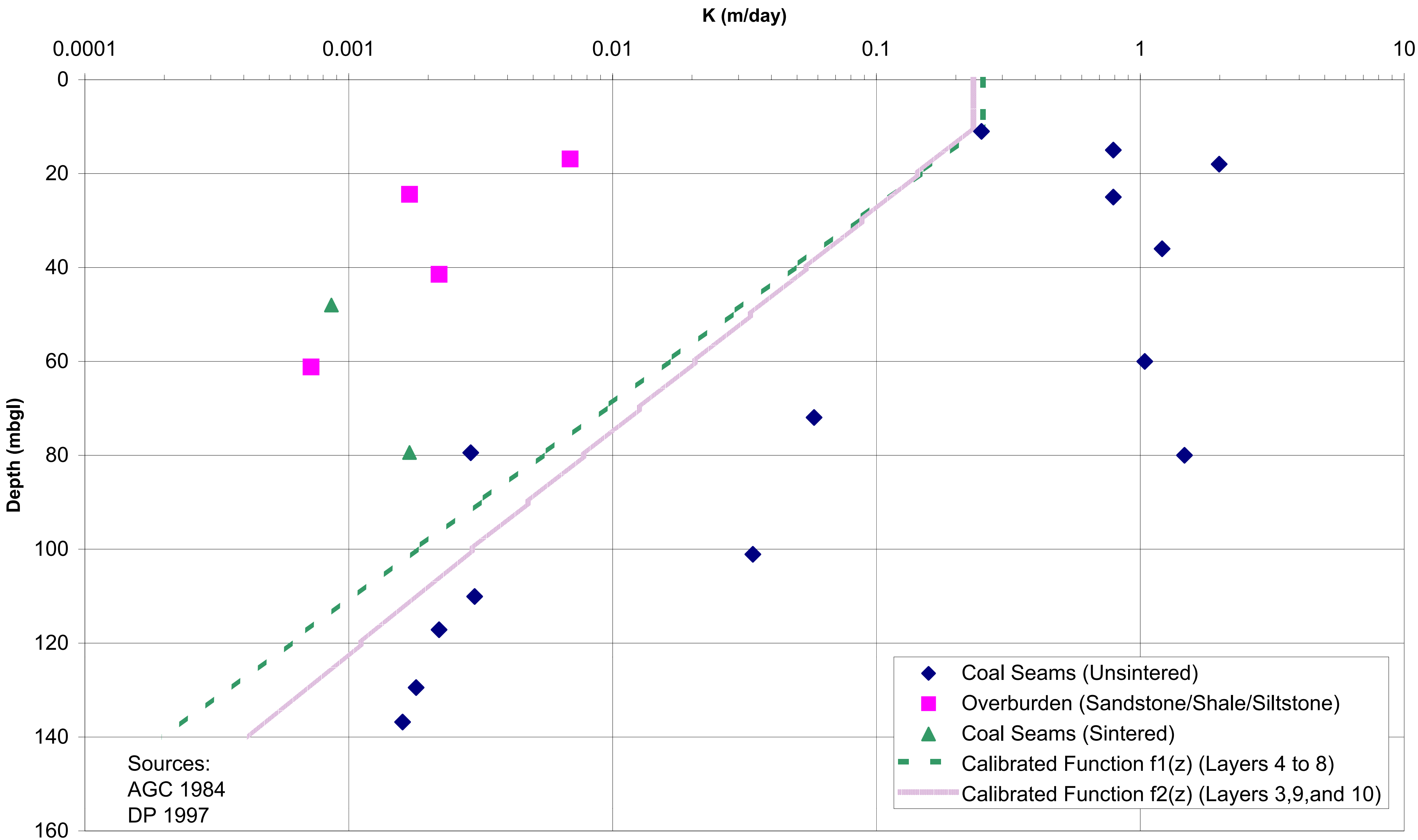
FIGURE D2

Start Screen

Search

Appendices

Calibrated Horizontal Conductivity Functions and Field Packer Test Data



HLA

FIGURE D3

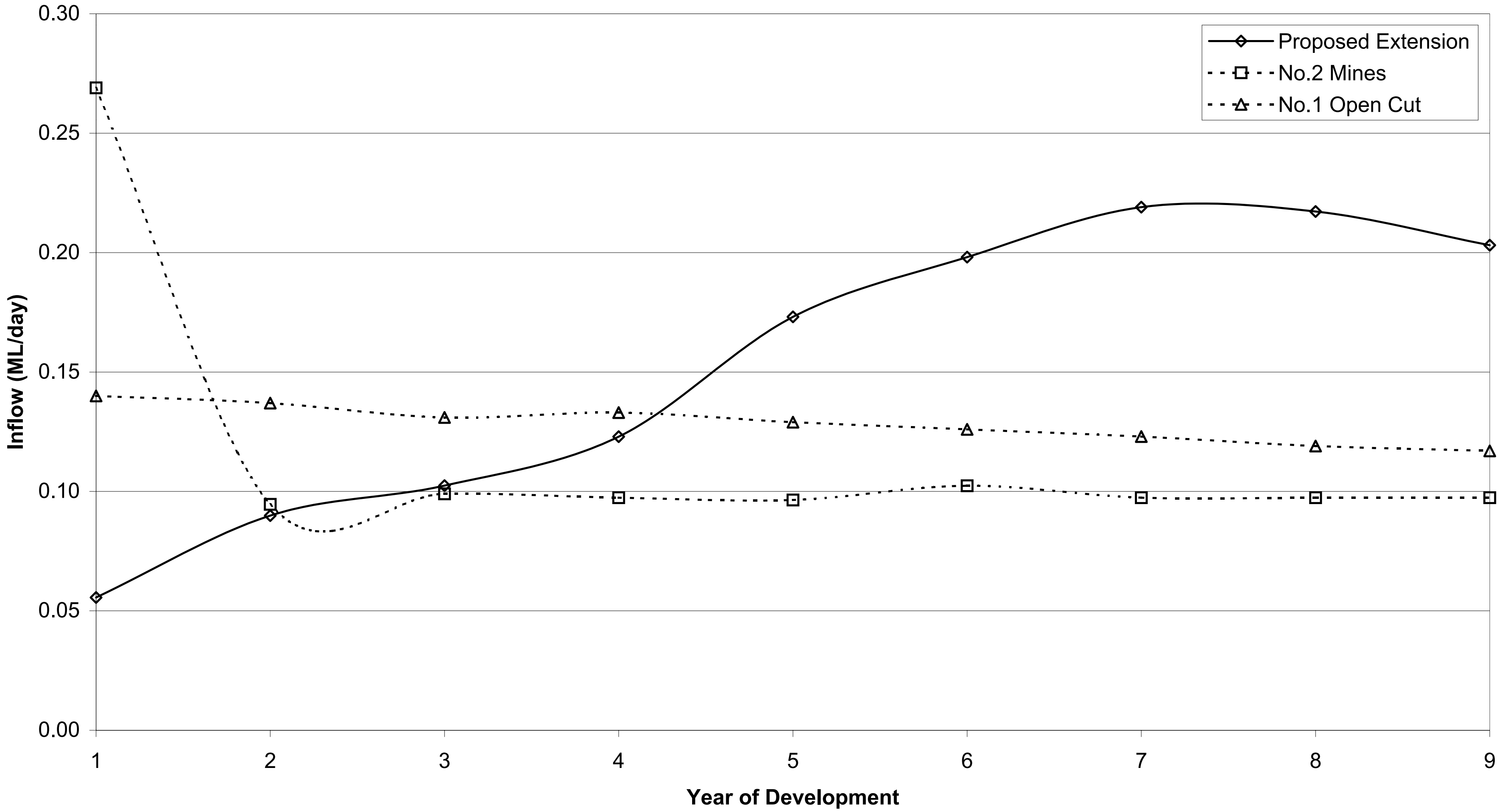

0.30
0.25
0.20
0.15
0.10
0.05
0.00
Inflow (ML/day)
1
2
3
4
5
6
7
8
9
Year of Development
Proposed Extension
No.2 Mines
No.1 Open Cut

FIGURE D4

APPENDIX E

APPENDIX E

No.1 OPEN CUT EXTENSION

EVALUATION OF SURFACE WATER MAKE

Evaluation of current and future surface water make for the mine catchments is based on the catchment identification and parameters presented in ERM (2002)

1.0 CURRENT SURFACE WATER MAKE

The current mine water catchments are as shown in Figure 8 in the main text. The surface types which occur, and the runoff coefficients applied to these surface types, are listed in **Table E1**. The runoff coefficients are applicable for yearly rainfall analysis.

Table E1. Surface Types and Runoff Coefficients

Land Surface Type	Runoff Coefficient
Natural ground	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

These runoff coefficients are applied for current and future water make calculations. Evaporation is applied only to the portion of a catchment covered by dam surface (free water). The applied evaporation rate is 80% of the pan evaporation measured at the Scone Meteorological Station.

Rainfall was defined as the amount that fell at the MCC weather station from July 2000 to June 2001 (690mm). The applied evaporation rate was 80% of the mean evaporation from the data records collected at Scone station (80% of 1592mm/year).

The calculated surface water make for 2001 for each catchment is shown in **Table E2**. The total make was 2.59 ML/day.

2.0 FUTURE SURFACE WATER MAKE

Surface water make for the years 2003 to 2011 has been calculated according to the proposed surface mining operations detailed in Section 6.2.1 in the main text, and the elimination of catchment Q_{C3} prior to Year 1 (2003).

2.1 Meteorological Definitions

Calculations have been made for dry, median, and wet conditions, using a composite rainfall data set consisting of:

- 115 years of records from the Muswellbrook High School station (No. 61053), covering the years 1871 to 1966, and 1983 to 1995.
- 18 years of records from the Muswellbrook Lindisfarne station (No. 61168) to fill the gaps in the Muswellbrook High School data, covering the years 1967 to 1982, and 1996 to 1997.

The composite data set therefore comprises 133 years of unbroken rainfall data. Dry, median, and wet conditions are defined as:

- Dry: The driest 9 consecutive years in the composite rainfall record, averaged over the 9 years of the development. This period occurred from 1875 to 1883 inclusive. A total of 4123 mm of rain fell, for an average rate of 458 mm/year. The minimum annual rainfall in this period occurred in 1875 (361 mm, with a 92 % probability of being exceeded in any year of the 133 years of data record). The decile 1 annual rainfall at the Muswellbrook High School station is 390 mm by comparison.

- Median: The mean annual rainfall of 616 mm, applied over the entire 9 years of development.

- Wet: The wettest 9 consecutive years in the composite rainfall record, averaged over the 9 years of the development. This period occurred from 1947 to 1955 inclusive. A total of 7474 mm of rain fell, for an average rate of 830 mm/year. The maximum annual rainfall in this period occurred in 1949 (1103 mm, with a 2 % probability of being exceeded in any year of the 133 years of data record). The decile 9 annual rainfall at the Muswellbrook High School station is 852 mm by comparison.

Evaporation also varies from year to year, behaving inversely to rainfall. Analysis of evaporation records from the Scone station indicate the following evaporation rates:

- Decile 1 (dry rainfall conditions): 1844mm/year
- Decile 5 (median rainfall conditions): 1556mm/year
- Decile 9 (wet rainfall conditions): 1327mm/year

These rates have been applied at 80% to dam surfaces, for the respective rainfall conditions.

2.2 Detailed Mine Operations

The areas for each mined block of extensions A and B are given in **Table E3a**. In most years, the mined block for the year partially (or fully) overlies an existing catchment. The proposed works will therefore change the surface types of existing catchments, and create new catchments, as shown in Figure 8 in the main text.

Table E3a. Block Areas

Block	Area (ha)
1	13.45
2	10.42
3	10.51
4	3.72 + 5.86
5	9.24
6	8.09
7	8.33
8	8.36
9	7.62

Block 1 will create an additional catchment area of 0.45 ha of natural ground. Block 2 will create an additional catchment area of 3.5 ha of natural ground. Block 3 will create an additional catchment area of 4.5 ha of natural ground. Block 4 will create an additional catchment area of 1.1 ha of natural ground.

Detailed mine operations are described below, for each year of development.

Year 0 (2002): 20% of unrehabilitated spoil in catchment Q_{C2} is converted to rehabilitated spoil.

Year 1 (2003): 6.5 ha of Q_{CB} catchment natural ground is converted to pit floor, and 0.76 ha of No.1 Open Cut pit floor is converted to unrehabilitated spoil (Block 1 activities).

6.5 ha of Q_{C6} catchment rehabilitated area is converted to pit floor, and 4.56 ha of No.1 Open Cut pit floor is converted to unrehabilitated spoil (Block 1 activities). The 9.76 ha of pit floor so produced will remain as such for the rest of the development (according to the No.1 Open Cut water storage strategy).
Block 1 creates an additional 0.45 ha of pit floor outside any existing catchments.
A further 20% of unrehabilitated spoil in catchment Q_{C2} (from 2002) is converted to rehabilitated spoil. This eliminates all unrehabilitated spoil in this catchment.
9.1 ha of unrehabilitated spoil in catchment Q_{C5} (from 2002) is converted to rehabilitated spoil.

Year 2 (2004): 6.5 ha of Q_{CB} catchment natural ground is converted to pit floor, and 7.3 ha of No.1 Open Cut pit floor is converted to unrehabilitated spoil (Block 2 activities).
Block 2 creates an additional 3.92 ha of pit floor outside any existing catchments, and causes an additional 3.5 ha of natural ground catchment to be produced.
20% of unrehabilitated spoil in catchment Q_{CA} (from 2002) is converted to rehabilitated spoil.

Year 3 (2005): Block 3 creates an additional 10.51 ha of pit floor outside any existing catchments, and causes an additional 4.5 ha of natural ground catchment to be produced.
Catchment Q_{CA} is eliminated (the No.2 Open Cut pit ceases operations, and is allowed to fill naturally; it will also receive mine water).

Year 4 (2006): Block 4 creates an additional 9.58 ha of pit floor outside any existing catchments, and causes an additional 1.1 ha of natural ground catchment to be produced. The pit floor so produced will remain as such for the rest of the development (the staging area for the Sandy Creek underground mine)

Year 5 (2007): 3.7 ha of Q_{C5} catchment hardstand area is converted to pit floor (Block 5 activities).
Block 5 creates an additional 5.54 ha of pit floor outside any existing catchments.

Year 6 (2008): 5.66 ha of Q_{C5} catchment hardstand area is converted to pit floor (Block 6 activities).
0.4 ha of Q_{C4} catchment hardstand area is converted to pit floor (Block 6 activities).
Block 6 creates an additional 2.03 ha of pit floor outside any existing catchments.

Year 7 (2009): 4.17 ha of Q_{C5} catchment hardstand area is converted to pit floor (Block 7 activities).
1.6 ha of Q_{C4} catchment hardstand area is converted to pit floor (Block 7 activities).
Block 7 creates an additional 2.56 ha of pit floor outside any existing catchments.

Year 8 (2010): 3.34 ha of Q_{C5} catchment hardstand area is converted to pit floor (Block 8 activities).
0.7 ha of Q_{C4} catchment hardstand area is converted to pit floor (Block 8 activities). Catchment Q_{C4} thus becomes eliminated.
Block 8 creates an additional 4.32 ha of pit floor outside any existing catchments.

Year 9 (2011): 2.67 ha of Q_{C5} catchment hardstand area is converted to pit floor (Block 9 activities).
Block 9 creates an additional 4.95 ha of pit floor outside any existing catchments.

Table E3b lists the surface types and total areas of the catchments in Year 0 (prior to development).

2.3 Results

Tables E4a to E4i show the calculations for Years 1 to 9 of development respectively, for median rainfall conditions. Calculations for dry and wet conditions use the same spreadsheet calculation. In these tables, the column labelled "Additional Area" applies to the Blocks, and represents the area of a Block that does not overlie an existing catchment.

The surface water make for the entire mine for dry, median, and wet conditions, for Years 1 to 9, is listed in **Table E5**.

Table E5. Total Mine Surface Water Make, Years 1 to 9.

Year	Total Surface Water Make, Dry Conditions (ML/day)	Total Surface Water Make, Median Conditions (ML/day)	Total Surface Water Make, Wet Conditions (ML/day)
1	1.16	1.62	2.23
2	1.17	1.63	2.24
3	0.78	1.09	1.49
4	0.80	1.11	1.53
5	0.84	1.16	1.59
6	0.81	1.12	1.54
7	0.78	1.09	1.49
8	0.78	1.08	1.48
9	0.77	1.07	1.47

The results show the reduction in water make when the No.2 Open Cut is decommissioned from the beginning of 2005 (Year 3). Extreme conditions cause the water make to vary by about 40%, or approximately double the variations seen in groundwater make (see Appendix D).

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Table E2. Current Surface Water Make (2001)

Catchment	Total Surface Area (ha)	Total Dam Surface Area (ha)	Natural ground area (%)	Rehabilitated spoil area (%)	Unrehabilitated spoil area (%)	Pit floor area (%)	Hardstand area (%)	Total Dam Surface area (%)	Surface water make (ML/day)
QCA	127.40	1.61	0	0	60	39	0	1.3	0.66
QCB	38.00	0.00	60	10	0	30	0	0.0	0.25
QC1	0.13	0.13	0	0	0	0	0	100	0.00
QC2	19.40	0.36	38	20	40	0	0	1.9	0.07
QC4	2.70	0.20	0	0	0	0	92	7.4	0.02
QC5	91.20	1.01	0	50	10	0	40	1.1	0.60
QC6	40.30	0.27	0	80	0	20	0	0.7	0.19
TOTAL	319.13								1.80

Notes:
Applied rainfall is 690 mm/year (rainfall at MCC weather station, July 2000 to June 2001).
Applied evaporation is 1,270 mm/year (mean conditions).
Catchment QC3 is not part of the mine water system.

Table E3b. Catchment Areas and Surface Types in 2002 (Prior to Development)

Catchment	Natural area (ha)	Rehabilitated area (ha)	Unrehabilitated area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha)
QCA	0.0	0.0	76.2	49.6	0.0	1.6	127.4
QCB	22.8	3.8	0.0	11.4	0.0	0.0	38.0
QC1	0.0	0.0	0.0	0.0	0.0	0.1	0.1
QC2	7.4	7.8	3.9	0.0	0.0	0.4	19.4
QC4	0.0	0.0	0.0	0.0	2.5	0.2	2.7
QC5	0.0	45.6	9.1	0.0	35.5	1.0	91.2
QC6	0.0	32.2	0.0	7.8	0.0	0.3	40.3

Notes:
Catchment QC3 eliminated for the development.

Table E4a. Surface Water Make, Year 1, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B

Rainfall	**0.616**	**m/year**
Evaporation	**1.245**	**m/year**

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	127.4	1.61	0	0	60	39	0	1.3	0	0	70631	153033	0	9918	-20447	213.1
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	40	20	0	0	1.9	13623	9560	3585	0	0	2218	-4572	24.4
TOTAL:																237

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	3.8	0.76	17.14	0	0	38.00	30122	4682	702	52791	0	0	0	88.3
QC4	2.70	0	0	0	0	2.5	0.2	2.70	0	0	0	0	9240	1232	-2490	8.0
QC5	91.20	0	54.7	0	0	35.49	1.01	91.20	0	67390	0	0	131171	6222	-12575	192.2
QC6	40.30	0	25.73	4.56	9.74	0	0.27	40.30	0	31699	4213	29999	0	1663	-3362	64.2
Block 1	0.45	0	0	0	0.45	0	0	0.45	0	0	0	1386	0	0	0	1.4
Block 2	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 3	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 4	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 5	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 6	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 7	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 8	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																354

MINE TOTAL:	**591**	**ML/year**
	1.62	**ML/day**

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

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Table E4b. Surface Water Make, Year 2, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B
Surface Water Make, Year 2, Mean Rainfall (Mean at Muswellbrook H.S. : 616mm/year)
Rainfall **0.616 m/year**
Evaporation **1.245 m/year**

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	127.4	1.61	0	20	40	39	0	1.3	0	31391	47087	153033	0	9918	-20447	221.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																246

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	4.6	10.6	6.5	0	0	38.00	30122	5667	9794	20020	0	0	0	65.6
QC4	2.70	0	0	0	0	2.5	0.2	2.70	0	0	0	0	9240	1232	-2490	8.0
QC5	91.20	0	54.7	0	0	35.49	1.01	91.20	0	67390	0	0	131171	6222	-12575	192.2
QC6	40.30	0	25.73	4.56	9.74	0	0.27	40.30	0	31699	4213	29999	0	1663	-3362	64.2
Block 1	0.45	0	0	0.45	0	0	0	0.45	0	0	416	0	0	0	0	0.4
Block 2	7.42	3.5	0	0	3.92	0	0	7.42	6468	0	0	12074	0	0	0	18.5
Block 3	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 4	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 5	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 6	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 7	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 8	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																349

MINE TOTAL: **595 ML/year**
1.63 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

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Table E4c. Surface Water Make, Year 3, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B
Surface Water Make, Year 3, Mean Rainfall (Mean at Muswellbrook H.S. : 616mm/year)
Rainfall 0.616 m/year
Evaporation 1.245 m/year

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																25

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	15.2	6.5	0	0	0	38.00	30122	18726	6006	0	0	0	0	54.9
QC4	2.70	0	0	0	0	2.5	0.2	2.70	0	0	0	0	9240	1232	-2490	8.0
QC5	91.20	0	54.7	0	0	35.49	1.01	91.20	0	67390	0	0	131171	6222	-12575	192.2
QC6	40.30	0	30.29	0	9.74	0	0.27	40.30	0	37317	0	29999	0	1663	-3362	65.6
Block 1	0.45	0	0	0.45	0	0	0	0.45	0	0	416	0	0	0	0	0.4
Block 2	7.42	3.5	0	3.92	0	0	0	7.42	6468	0	3622	0	0	0	0	10.1
Block 3	15.01	4.5	0	0	10.51	0	0	15.01	8316	0	0	32371	0	0	0	40.7
Block 4	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 5	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 6	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 7	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 8	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																372

MINE TOTAL: 397 ML/year
1.09 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

HLA

Table E4d. Surface Water Make, Year 4, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B
Surface Water Make, Year 4, Mean Rainfall (Mean at Muswellbrook H.S. : 616mm/year)
Rainfall 0.616 m/year
Evaporation 1.245 m/year

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																25

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	15.2	6.5	0	0	0	38.00	30122	18726	6006	0	0	0	0	54.9
QC4	2.70	0	0	0	0	2.5	0.2	2.70	0	0	0	0	9240	1232	-2490	8.0
QC5	91.20	0	54.7	0	0	35.49	1.01	91.20	0	67390	0	0	131171	6222	-12575	192.2
QC6	40.30	0	30.29	0	9.74	0	0.27	40.30	0	37317	0	29999	0	1663	-3362	65.6
Block 1	0.45	0	0.45	0	0	0	0	0.45	0	554	0	0	0	0	0	0.6
Block 2	7.42	3.5	0	3.92	0	0	0	7.42	6468	0	3622	0	0	0	0	10.1
Block 3	15.01	4.5	0	10.51	0	0	0	15.01	8316	0	9711	0	0	0	0	18.0
Block 4	10.68	1.1	0	0	9.58	0	0	10.68	2033	0	0	29506	0	0	0	31.5
Block 5	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 6	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 7	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 8	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																381

MINE TOTAL: 406 ML/year
1.11 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

Table E4e. Surface Water Make, Year 5, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B
Surface Water Make, Year 5, Mean Rainfall (Mean at Muswellbrook H.S. : 616mm/year)
Rainfall 0.616 m/year
Evaporation 1.245 m/year

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																25

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	21.7	0	0	0	0	38.00	30122	26734	0	0	0	0	0	56.9
QC4	2.70	0	0	0	0	2.5	0.2	2.70	0	0	0	0	9240	1232	-2490	8.0
QC5	91.20	0	54.7	0	3.7	31.79	1.01	91.20	0	67390	0	11396	117496	6222	-12575	189.9
QC6	40.30	0	30.29	0	9.74	0	0.27	40.30	0	37317	0	29999	0	1663	-3362	65.6
Block 1	0.45	0	0.45	0	0	0	0	0.45	0	554	0	0	0	0	0	0.6
Block 2	7.42	3.5	3.92	0	0	0	0	7.42	6468	4829	0	0	0	0	0	11.3
Block 3	15.01	4.5	0	10.51	0	0	0	15.01	8316	0	9711	0	0	0	0	18.0
Block 4	10.68	1.1	0	0	9.58	0	0	10.68	2033	0	0	29506	0	0	0	31.5
Block 5	5.54	0	0	0	5.54	0	0	5.54	0	0	0	17063	0	0	0	17.1
Block 6	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 7	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 8	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																399

MINE TOTAL: 424 ML/year
1.16 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

Table E4f. Surface Water Make, Year 6, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B
Surface Water Make, Year 6, Mean Rainfall (Mean at Muswellbrook H.S. : 616mm/year)
Rainfall 0.616 m/year
Evaporation 1.245 m/year

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																25

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	21.7	0	0	0	0	38.00	30122	26734	0	0	0	0	0	56.9
QC4	2.70	0	0	0	0.4	2.1	0.2	2.70	0	0	0	1232	7762	1232	-2490	7.7
QC5	91.20	0	54.7	3.7	5.66	26.13	1.01	91.20	0	67390	3419	17433	96576	6222	-12575	178.5
QC6	40.30	0	30.29	0	9.74	0	0.27	40.30	0	37317	0	29999	0	1663	-3362	65.6
Block 1	0.45	0	0.45	0	0	0	0	0.45	0	554	0	0	0	0	0	0.6
Block 2	7.42	3.5	3.92	0	0	0	0	7.42	6468	4829	0	0	0	0	0	11.3
Block 3	15.01	4.5	10.51	0	0	0	0	15.01	8316	12948	0	0	0	0	0	21.3
Block 4	10.68	1.1	0	0	9.58	0	0	10.68	2033	0	0	29506	0	0	0	31.5
Block 5	5.54	0	0	5.54	0	0	0	5.54	0	0	5119	0	0	0	0	5.1
Block 6	2.03	0	0	0	2.03	0	0	2.03	0	0	0	6252	0	0	0	6.3
Block 7	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 8	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																385

MINE TOTAL: **409 ML/year**
1.12 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

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Table E4g. Surface Water Make, Year 7, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B

Rainfall 0.616 m/year
Evaporation 1.245 m/year

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																25

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	21.7	0	0	0	0	38.00	30122	26734	0	0	0	0	0	56.9
QC4	2.70	0	0	0.4	1.6	0.5	0.2	2.70	0	0	370	4928	1848	1232	-2490	5.9
QC5	91.20	0	54.7	9.36	4.17	21.96	1.01	91.20	0	67390	8649	12844	81164	6222	-12575	163.7
QC6	40.30	0	30.29	0	9.74	0	0.27	40.30	0	37317	0	29999	0	1663	-3362	65.6
Block 1	0.45	0	0.45	0	0	0	0	0.45	0	554	0	0	0	0	0	0.6
Block 2	7.42	3.5	3.92	0	0	0	0	7.42	6468	4829	0	0	0	0	0	11.3
Block 3	15.01	4.5	10.51	0	0	0	0	15.01	8316	12948	0	0	0	0	0	21.3
Block 4	10.68	1.1	0	0	9.58	0	0	10.68	2033	0	0	29506	0	0	0	31.5
Block 5	5.54	0	0	5.54	0	0	0	5.54	0	0	5119	0	0	0	0	5.1
Block 6	2.03	0	0	2.03	0	0	0	2.03	0	0	1876	0	0	0	0	1.9
Block 7	2.56	0	0	0	2.56	0	0	2.56	0	0	0	7885	0	0	0	7.9
Block 8	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																372

MINE TOTAL: **396 ML/year**
1.09 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

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Table E4h. Surface Water Make, Year 8, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B
Surface Water Make, Year 8, Mean Rainfall (Mean at Muswellbrook H.S. : 616mm/year)
Rainfall 0.616 m/year
Evaporation 1.245 m/year

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																25

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	21.7	0	0	0	0	38.00	30122	26734	0	0	0	0	0	56.9
QC4	2.70	0	0	2	0.7	0	0	2.70	0	0	1848	2156	0	0	0	4.0
QC5	91.20	0	58.4	9.83	3.34	18.62	1.01	91.20	0	71949	9083	10287	68820	6222	-12575	153.8
QC6	40.30	0	30.29	0	9.74	0	0.27	40.30	0	37317	0	29999	0	1663	-3362	65.6
Block 1	0.45	0	0.45	0	0	0	0	0.45	0	554	0	0	0	0	0	0.6
Block 2	7.42	3.5	3.92	0	0	0	0	7.42	6468	4829	0	0	0	0	0	11.3
Block 3	15.01	4.5	10.51	0	0	0	0	15.01	8316	12948	0	0	0	0	0	21.3
Block 4	10.68	1.1	0	0	9.58	0	0	10.68	2033	0	0	29506	0	0	0	31.5
Block 5	5.54	0	5.54	0	0	0	0	5.54	0	6825	0	0	0	0	0	6.8
Block 6	2.03	0	0	2.03	0	0	0	2.03	0	0	1876	0	0	0	0	1.9
Block 7	2.56	0	0	2.56	0	0	0	2.56	0	0	2365	0	0	0	0	2.4
Block 8	4.32	0	0	0	4.32	0	0	4.32	0	0	0	13306	0	0	0	13.3
Block 9	0.00	0	0	0	0	0	0	0.00	0	0	0	0	0	0	0	0.0
TOTAL:																369

MINE TOTAL: 394 ML/year
1.08 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

HLA

Table E4i. Surface Water Make, Year 9, Mean Rainfall

Muswellbrook Coal Company
No.1 Open Cut Extensions A and B
Surface Water Make, Year 9, Mean Rainfall (Mean at Muswellbrook H.S. : 616mm/year)
Rainfall 0.616 m/year
Evaporation 1.245 m/year

Catchments that remain unaltered

Catchment Name	Total Area (ha)	Dam Area (ha)	% natural area	% rehab	% unrehab	% pit floor area	% hard-stand area	% dam area	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCA	0	0	0	0	0	0	0	0.0	0	0	0	0	0	0	0	0.0
QC1	0.13	0.13	0	0	0	0	0	100.0	0	0	0	0	0	801	-1651	-0.9
QC2	19.4	0.36	38	60	0	0	0	1.9	13623	14340	0	0	0	2218	-4572	25.6
TOTAL:																25

New catchments and catchments that are altered

Catchment Name	Additional area (ha)	Natural area (ha)	Rehab area (ha)	Unrehab area (ha)	Pit floor area (ha)	Hardstand area (ha)	Dam area (ha)	Total area (ha) (check)	Natural runoff (m3/year)	Rehab runoff (m3/year)	Unrehab runoff (m3/year)	Pit runoff (m3/year)	Hardstand runoff (m3/year)	Dam runon (m3/year)	Evaporation (m3/year)	TOTAL (ML/year)
QCB	38.00	16.3	21.7	0	0	0	0	38.00	30122	26734	0	0	0	0	0	56.9
QC4	2.70	0	0.4	2.3	0	0	0	2.70	0	493	2125	0	0	0	0	2.6
QC5	91.20	0	64.06	7.51	2.67	15.95	1.01	91.20	0	78922	6939	8224	58951	6222	-12575	146.7
QC6	40.30	0	30.29	0	9.74	0	0.27	40.30	0	37317	0	29999	0	1663	-3362	65.6
Block 1	0.45	0	0.45	0	0	0	0	0.45	0	554	0	0	0	0	0	0.6
Block 2	7.42	3.5	3.92	0	0	0	0	7.42	6468	4829	0	0	0	0	0	11.3
Block 3	15.01	4.5	10.51	0	0	0	0	15.01	8316	12948	0	0	0	0	0	21.3
Block 4	10.68	1.1	0	0	9.58	0	0	10.68	2033	0	0	29506	0	0	0	31.5
Block 5	5.54	0	5.54	0	0	0	0	5.54	0	6825	0	0	0	0	0	6.8
Block 6	2.03	0	2.03	0	0	0	0	2.03	0	2501	0	0	0	0	0	2.5
Block 7	2.56	0	0	2.56	0	0	0	2.56	0	0	2365	0	0	0	0	2.4
Block 8	4.32	0	0	4.32	0	0	0	4.32	0	0	3992	0	0	0	0	4.0
Block 9	4.95	0	0	0	4.95	0	0	4.95	0	0	0	15246	0	0	0	15.2
TOTAL:																367

MINE TOTAL: 392 ML/year
1.07 ML/day

Land Surface Type	Runoff Coefficient
Natural	0.3
Rehabilitated spoil	0.2
Unrehabilitated spoil	0.15
Open Cut Pit Floor	0.5
Hardstand	0.6
Dam Surface	1

HLA

APPENDIX F

APPENDIX F

No.1 OPEN CUT EXTENSION

ANALYSIS OF RAINFALL TRENDS

1.0 INTRODUCTION

The Southern Oscillation (experienced in the southern Pacific Ocean) is a process that can be correlated to the annual variations in rainfall (from the long-term annual mean) in the Hunter Valley. This process is tracked through calculation of the Southern Oscillation Index (SOI).

Recent trends in rainfall at the Jerrys Plains weather station (which has one of the longest unbroken precipitation data sets in the Hunter Valley) indicate that the Southern Oscillation has a significant and measurable effect on rainfall. Prediction of the behaviour of this process is evaluated in an attempt to predict the likely annual rainfall pattern at Muswellbrook for the period 2003 to 2004. This period is sufficiently close to the present time to allow a meaningful evaluation to be made.

2.0 GENERAL RELATIONSHIPS

2.1 Southern Oscillation Index

The following information is taken from the Australian Bureau of Meteorology (ABM) web site *http://www.bom.gov.au/climate/glossary/soi.shtml*.

The Southern Oscillation Index (SOI) is calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin.

Sustained negative values of the SOI often indicate El Niño episodes. These negative values are usually accompanied by sustained warming of the central and eastern tropical Pacific Ocean, a decrease in the strength of the Pacific Trade Winds, and a reduction in rainfall over eastern and northern Australia. The most recent strong El Niño was in 1997/98.

Positive values of the SOI are associated with stronger Pacific trade winds and warmer sea temperatures to the north of Australia, popularly known as a La Niña episode. Waters in the central and eastern tropical Pacific Ocean become cooler during this time. Together, these give an increased probability that eastern and northern Australia will be wetter than normal. The most recent strong La Niña was in 1988/89; a moderate La Niña event occurred in 1998/99, which weakened back to neutral conditions before reforming for a shorter period in 1999/2000. This last event finished in Autumn 2000.

There are a few different methods of how to calculate the SOI. The method used by the ABM is the Troup SOI which is the standardised anomaly of the Mean Sea Level Pressure (MSLP) difference between Tahiti and Darwin. It is calculated as follows:

$$SOI = 10 \times (P_{diff} - P_{diffav})/(SD(P_{diff}))$$

where

P_{diff} = (average Tahiti MSLP for the month) - (average Darwin MSLP for the month),
P_{diffav} = long term average of P_{diff} for the month in question, and
$SD(P_{diff})$ = long term standard deviation of P_{diff} for the month in question.

The multiplication by 10 is a convention. Using this convention, the SOI ranges from about -35 to about +35, and the value of the SOI can be quoted as a whole number. The SOI is usually computed on a monthly basis, with values over longer periods such as a year being sometimes used. Daily or weekly values of the SOI do not convey much in the way of useful information about the current state of the climate, and accordingly the ABM does not issue them. Daily values in particular can fluctuate markedly because of daily weather patterns, and should not be used for climate purposes.

Table F1 lists the monthly SOI calculated by the ABM.

3.0 RECENT TRENDS IN RAINFALL IN THE HUNTER VALLEY

Figure F1 shows the annual variation in rainfall at Jerrys Plains since 1947, and the average annual SOI for the same period. Analysis of the data sets indicates a correlation of 43%, which can be seen in Figure F1.

Figure F2 shows the monthly SOI from 1979 up to February 2002. This period indicates a slowly varying trend with a wavelength of approximately 7 years, punctuated with sharp downturns of 1 to 2 years' duration. Sharp upswings usually occur after sharp downturns, and are generally not observed to occur after slow variation in the SOI.

4.0 POSSIBLE FUTURE TRENDS

The trend in SOI from 1998 has been a gradual decline. If a sharp change occurs, it will most likely be a downturn. Frequency analysis of the SOI, and use of the spectral density function to evaluate probabilities, suggests that there is a 50% or less probability of a trend being maintained for 2.4 years or more. The current trend started in 1998, and from then until 2006 (8 years), there is a 90% probability that the current trend will be broken. From the present (March 2002), the probability that the trend will be broken prior to the end of 2006 is approximately 70% (that is, it has a 30% chance of surviving to 2006).

The most likely change in the trend, if it occurs prior to 2006, would be a sharp downturn of short duration (dry conditions), probably followed by a sharp upswing. If the trend continues, as in the period 1989 to 1994, a major drought will occur, however this is highly improbable. It is noted that this drought occurred during a period of sustained negative SOI, and a maximum in the 11-year solar cycle (a maximum in the solar sunspot activity). This occurrence is unusual, and it is known that the solar cycle affects weather patterns. The magnitude of this effect is still being determined by international research.

Assuming the trend breaks soon (say mid 2002), and the break consists of a sharp downturn, dry conditions would ensue probably until early to mid 2004, during which a substantial amount of water in storage at the mine would be consumed, creating extra freeboard. Wet conditions may ensue in late 2004 (similar to the rainfall behaviour in 1998), which could be handled by the mine until availability of the No.2 Open Cut at the beginning of 2005.

If the trend breaks later than mid 2002, and the break consists of a sharp downturn, the availability of the No.2 Open Cut will be sufficient to mitigate the effects of wet conditions when they begin.

LIST OF FIGURES AND TABLES

Tables

Figures

Table F1. Monthly Southern Oscillation Index, Australian Bureau of Meteorology

National Climate Centre

Climate Analysis Section

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
1876	11.3	11.0	0.2	9.4	6.8	17.2	-5.6	12.3	10.5	-8.0	-2.7	-3.0	5.0
1877	-9.7	-6.5	-4.7	-9.6	3.6	-16.8	-10.2	-8.2	-17.2	-16.0	-12.6	-12.6	-10.0
1878	-8.7	-21.1	-15.5	-8.8	2.1	-3.1	15.9	13.0	17.7	10.9	15.1	17.9	3.0
1879	12.7	14.3	13.2	12.7	2.1	16.4	21.8	22.6	18.9	15.2	9.8	-5.5	12.9
1880	10.8	7.7	14.3	5.3	12.3	9.1	1.6	14.3	8.1	4.8	7.2	-1.9	7.8
1881	-7.3	-5.5	1.8	0.3	-4.3	-4.7	-5.6	-11.4	-13.6	-23.9	7.2	9.8	-4.8
1882	-6.8	-1.3	5.1	1.2	6.8	-12.0	-21.3	-25.6	-14.8	-2.5	2.6	10.3	-4.9
1883	6.0	9.1	-25.3	14.4	13.9	3.4	-10.2	1.4	-8.2	4.8	5.2	-15.2	-0.1
1884	-12.5	-5.0	9.4	-15.4	1.3	9.1	-3.0	-5.0	-7.0	4.2	-1.4	-12.6	-3.2
1885	-16.3	1.6	5.1	-0.5	-4.3	-14.4	-5.0	-9.5	-4.0	-17.8	-15.9	5.2	-6.3
1886	-0.6	1.6	2.9	4.5	6.0	5.0	7.4	13.6	13.5	13.4	10.5	14.4	7.7
1887	12.2	11.0	10.0	9.4	-4.3	5.0	4.8	4.6	5.1	4.8	-5.3	5.2	5.2
1888	-3.0	-2.2	-11.7	-23.6	-9.8	-16.0	-16.7	-8.9	-9.4	-14.7	-12.6	-2.4	-10.9
1889	-25.9	-1.7	-27.5	-0.5	-1.9	22.0	1.6	2.1	11.1	4.2	23.0	22.0	2.4
1890	20.8	11.0	14.3	6.9	3.6	5.8	-2.3	-3.1	9.3	3.6	2.6	0.6	6.1
1891	15.6	-3.6	-9.5	4.5	-0.3	-1.5	-6.3	-8.9	-10.6	0.6	-4.7	-4.5	-2.4
1892	2.7	-10.2	11.1	6.9	10.0	19.6	7.4	5.9	6.3	8.5	-0.7	3.7	5.9
1893	11.3	7.7	-1.4	1.2	-3.5	10.7	14.0	7.8	5.7	7.9	2.6	1.6	5.5
1894	17.5	10.0	5.6	-3.0	-5.1	-1.5	-2.3	-5.7	-1.6	1.8	7.2	0.1	1.9
1895	5.6	3.0	-0.3	-7.1	-8.2	-4.7	-0.4	-6.3	-4.0	-5.6	-8.6	-3.5	-3.3
1896	1.3	4.9	-6.3	-8.8	-42.2	-30.6	-20.6	-22.4	-19.0	-19.0	-11.9	-14.2	-15.7
1897	-12.5	-7.4	-16.6	-17.8	-16.9	0.2	-2.3	0.8	0.2	1.8	-8.0	10.3	-5.7
1898	7.0	6.3	19.2	11.1	-1.9	-2.3	6.1	2.1	3.2	-0.7	-2.7	-0.4	3.9
1899	13.2	9.1	13.8	4.5	-7.4	-10.4	-5.6	-10.1	-1.6	6.1	15.8	-3.0	2.0
1900	-7.3	-6.5	-25.3	-18.7	-7.4	26.1	10.0	7.8	-16.6	-17.2	-6.0	-5.5	-5.6
1901	-0.1	3.0	9.4	4.5	-0.3	19.6	14.6	9.8	-16.0	-22.1	-8.6	-1.9	1.0
1902	17.0	-2.2	11.6	7.8	7.6	2.6	1.6	-8.9	-17.8	-7.4	-3.4	-3.0	0.5
1903	-9.2	-10.2	17.6	17.7	7.6	-0.6	6.1	0.1	8.7	4.2	1.3	15.9	4.9
1904	14.1	16.2	9.4	31.7	9.2	-7.1	-8.9	0.8	0.2	1.2	-17.2	2.6	4.4
1905	-9.2	-16.8	-30.2	-42.6	-37.4	-31.4	-21.3	-7.6	-7.0	-5.6	-17.9	-13.1	-20.0
1906	-3.5	-7.4	-5.2	-8.8	1.3	-3.9	6.8	15.5	18.3	9.1	21.7	4.7	4.1
1907	5.1	1.6	-0.3	4.5	10.0	8.3	-4.3	-8.2	0.2	0.6	-2.0	8.8	2.0
1908	-10.6	7.7	0.2	16.8	-1.1	-2.3	2.2	5.3	17.7	7.9	2.6	-5.5	3.4
1909	-2.5	-3.2	-0.3	-14.5	2.1	22.8	10.7	9.8	0.8	4.2	9.2	4.7	3.7
1910	5.6	15.2	12.7	5.3	0.5	22.0	20.5	9.8	15.3	10.3	19.7	15.9	12.7
1911	3.2	1.6	3.5	2.0	-8.2	-12.0	-12.8	-12.1	-8.8	-11.7	-7.3	-1.4	-5.3
1912	-9.7	-17.3	-9.0	-21.1	-13.0	-6.3	-0.4	-7.6	-4.0	-8.0	2.6	-8.0	-8.5
1913	-3.5	-5.0	1.3	-6.3	-8.2	-3.9	-1.7	-7.6	-9.4	-9.2	-11.9	-7.0	-6.0
1914	-5.4	2.0	9.4	-14.5	-0.3	-16.8	-18.0	-17.2	-12.4	-8.6	-11.9	-1.4	-7.9
1915	-21.6	-2.2	-20.4	-17.8	-12.2	6.6	14.0	7.2	7.5	2.4	-14.6	9.8	-3.4
1916	5.6	-3.6	-6.3	-0.5	6.8	9.1	25.7	16.2	4.5	6.1	9.8	15.4	7.4
1917	5.1	10.0	18.1	21.8	21.8	21.2	28.3	34.8	29.7	15.2	21.0	22.5	20.8
1918	14.6	16.6	-2.0	16.8	10.0	-4.7	-14.1	-4.4	-8.2	-5.0	1.3	-8.0	1.1
1919	-14.9	-11.2	-12.8	-3.0	-7.4	-10.4	-8.9	-6.9	-5.8	-10.5	-11.3	-9.1	-9.4
1920	1.8	-1.7	-4.1	0.3	-2.7	6.6	9.4	5.3	5.1	-4.3	-0.1	9.8	2.1
1921	10.8	6.7	8.9	-7.1	2.1	22.0	2.9	-6.9	5.1	9.7	8.5	8.2	5.9
1922	8.0	9.1	5.6	-5.5	-5.1	5.8	2.2	-1.2	5.1	6.1	8.5	11.8	4.2
1923	5.6	4.4	8.9	8.6	2.1	1.0	-11.5	-18.5	-14.8	-6.2	-12.6	2.1	-2.6
1924	-5.4	1.1	2.4	-15.4	11.5	8.3	7.4	10.4	8.1	7.9	11.8	5.2	4.4
1925	5.6	13.8	14.9	14.4	-1.1	-4.7	-13.4	-10.8	-6.4	-12.9	-9.3	-7.0	-1.4

Table F1. Monthly Southern Oscillation Index, Australian Bureau of Meteorology

National Climate Centre
Climate Analysis Section

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
1926	-5.4	-14.5	-13.3	-7.1	-2.7	-7.1	-1.0	-7.6	1.4	4.2	1.3	6.2	-3.8
1927	5.1	1.1	18.1	6.9	6.0	8.3	6.1	-5.0	-0.4	-4.3	-8.0	7.7	3.5
1928	-10.1	10.5	13.8	11.9	-2.7	-7.9	-0.4	9.8	8.1	9.1	2.6	11.8	4.7
1929	16.0	18.0	5.1	4.5	-12.2	1.0	1.6	0.1	-0.4	7.9	11.1	5.7	4.9
1930	12.7	7.7	1.8	-3.8	2.1	-5.5	-4.3	-1.8	-7.0	3.6	1.9	-1.4	0.5
1931	7.0	-14.9	5.6	8.6	13.1	18.8	9.4	0.1	5.1	-12.9	-4.7	4.7	3.3
1932	1.8	-3.6	-2.5	-2.1	2.8	-4.7	-5.0	-6.9	-8.8	-4.3	-4.7	3.2	-2.9
1933	-11.1	4.9	-2.0	3.6	6.0	-3.9	3.5	-0.5	2.0	3.6	7.2	8.2	1.8
1934	6.5	0.1	0.2	6.1	-7.4	10.7	2.9	-22.4	-6.4	4.2	13.1	-2.4	0.4
1935	6.5	-4.6	12.2	2.8	-6.6	-2.3	-0.4	2.1	6.3	7.3	3.9	-4.0	1.9
1936	-2.0	0.6	1.8	22.6	4.4	-1.5	4.2	-8.9	2.6	-0.1	-13.9	0.6	0.9
1937	9.4	-5.0	6.2	2.0	-0.3	3.4	-5.6	3.3	0.8	-2.5	-2.0	6.7	1.4
1938	7.5	3.4	-3.6	3.6	13.1	18.0	18.5	13.0	7.5	12.8	1.9	13.8	9.1
1939	17.0	7.7	11.6	9.4	-1.1	-1.5	8.1	-0.5	-9.4	-14.7	-8.0	-8.6	0.8
1940	-0.1	-4.1	-10.6	-9.6	-14.5	-19.3	-15.4	-18.5	-19.6	-18.4	-6.7	-29.4	-13.9
1941	-9.7	-15.4	-10.6	-11.2	-6.6	-14.4	-20.6	-19.1	-8.2	-20.2	-9.3	-8.6	-12.8
1942	-13.0	-3.6	-5.8	-5.5	5.2	8.3	-1.0	4.0	8.7	8.5	-4.0	13.8	1.3
1943	9.4	10.5	4.0	13.5	2.8	-7.9	2.9	7.8	5.7	9.1	3.9	-8.6	4.4
1944	-8.2	3.9	5.6	-5.5	-1.1	-3.9	-8.9	3.3	2.6	-8.6	-6.7	4.2	-1.9
1945	5.1	6.3	13.2	-7.1	-0.3	8.3	3.5	11.7	8.7	2.4	-3.4	6.7	4.6
1946	-2.5	4.4	-2.0	-9.6	-11.4	-9.6	-10.2	-4.4	-16.0	-12.3	-1.4	-5.5	-6.7
1947	-4.9	-4.1	11.6	-4.6	-13.7	2.6	9.4	7.2	11.7	-1.9	9.2	5.2	2.3
1948	-3.0	-2.7	-4.1	2.8	3.6	-4.7	0.9	-4.4	-7.6	6.1	4.6	-5.5	-1.2
1949	-7.3	2.0	5.6	1.2	-5.8	-12.0	-1.7	-4.4	2.0	5.4	-6.0	7.7	-1.1
1950	5.1	17.6	17.6	16.8	7.6	26.9	21.1	12.3	6.9	17.1	12.5	23.0	15.4
1951	16.5	9.6	-1.4	-1.3	-6.6	5.0	-8.2	-0.5	-7.0	-8.0	-3.4	-3.0	-0.7
1952	-9.2	-7.9	0.2	-8.8	6.0	7.4	3.5	-3.7	-3.4	1.8	-0.7	-12.6	-2.3
1953	2.2	-6.0	-5.8	-0.5	-31.9	-2.3	-1.0	-17.2	-13.0	-0.1	-2.0	-4.0	-6.8
1954	6.0	-3.6	-0.9	6.9	4.4	-1.5	4.2	10.4	4.5	1.8	3.9	12.8	4.1
1955	-5.4	15.2	2.9	-3.0	13.1	16.4	19.2	14.9	14.1	15.2	15.1	9.3	10.6
1956	11.3	12.4	9.4	11.1	17.9	12.3	12.6	11.0	0.2	18.3	1.9	10.3	10.7
1957	5.6	-2.2	-0.9	1.2	-12.2	-2.3	0.9	-9.5	-10.6	-1.3	-11.9	-3.5	-3.9
1958	-16.8	-6.9	-1.4	1.2	-8.2	0.2	2.2	7.8	-3.4	-1.9	-4.7	-6.5	-3.2
1959	-8.7	-14.0	8.4	3.6	2.8	-6.3	-5.0	-5.0	0.2	4.2	11.1	8.2	0.0
1960	0.3	-2.2	5.6	7.8	5.2	-2.3	4.8	6.6	6.9	-0.7	7.2	6.7	3.8
1961	-2.5	6.3	-20.9	9.4	1.3	-3.1	2.2	0.1	0.8	-5.0	7.2	13.8	0.8
1962	17.0	5.3	-1.4	1.2	12.3	5.0	-0.4	4.6	5.1	10.3	5.2	0.6	5.4
1963	9.4	3.0	7.3	6.1	2.8	-9.6	-1.0	-2.4	-5.2	-12.9	-9.3	-11.6	-2.0
1964	-4.0	-0.3	8.4	13.5	2.8	7.4	6.8	14.3	14.1	12.8	2.6	-3.0	6.3
1965	-4.0	1.6	2.9	-12.9	-0.3	-12.8	-22.6	-11.4	-14.2	-11.1	-17.9	1.6	-8.4
1966	-12.0	-4.1	-13.9	-7.1	-9.0	1.0	-1.0	4.0	-2.2	-2.5	-0.1	-4.0	-4.2
1967	14.6	12.9	7.8	-3.0	-3.5	6.6	1.6	5.9	5.1	-0.1	-4.0	-5.5	3.2
1968	4.1	9.6	-3.0	-3.0	14.7	12.3	7.4	0.1	-2.8	-1.9	-3.4	2.1	3.0
1969	-13.5	-6.9	1.8	-8.8	-6.6	-0.6	-6.9	-4.4	-10.6	-11.7	-0.1	3.7	-5.4
1970	-10.1	-10.7	1.8	-4.6	2.1	9.9	-5.6	4.0	12.9	10.3	19.7	17.4	3.9
1971	2.7	15.7	19.2	22.6	9.2	2.6	1.6	14.9	15.9	17.7	7.2	2.1	11.0
1972	3.7	8.2	2.4	-5.5	-16.1	-12.0	-18.6	-8.9	-14.8	-11.1	-3.4	-12.1	-7.4
1973	-3.0	-13.5	0.8	-2.1	2.8	12.3	6.1	12.3	13.5	9.7	31.6	16.9	7.3
1974	20.8	16.2	20.3	11.1	10.7	2.6	12.0	6.6	12.3	8.5	-1.4	-0.9	9.9
1975	-4.9	5.3	11.6	14.4	6.0	15.5	21.1	20.7	22.5	17.7	13.8	19.5	13.6

Table F1. Monthly Southern Oscillation Index, Australian Bureau of Meteorology

National Climate Centre												
Climate Analysis Section												
												Annual
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1976	11.8	12.9	13.2	1.2	2.1	0.2	-12.8	-12.1	-13.0	3.0	9.8	-3.0	1.1
1977	-4.0	7.7	-9.5	-9.6	-11.4	-17.7	-14.7	-12.1	-9.4	-12.9	-14.6	-10.6	-9.9
1978	-3.0	-24.4	-5.8	-7.9	16.3	5.8	6.1	1.4	0.8	-6.2	-2.0	-0.9	-1.7
1979	-4.0	6.7	-3.0	-5.5	3.6	5.8	-8.2	-5.0	1.4	-2.5	-4.7	-7.5	-1.9
1980	3.2	1.1	-8.5	-12.9	-3.5	-4.7	-1.7	1.4	-5.2	-1.9	-3.4	-0.9	-3.1
1981	2.7	-3.2	-16.6	-5.5	7.6	11.5	9.4	5.9	7.5	-5.0	2.6	4.7	1.8
1982	9.4	0.6	2.4	-3.8	-8.2	-20.1	-19.3	-23.6	-21.4	-20.2	-31.1	-21.3	-13.1
1983	-30.6	-33.3	-28.0	-17.0	6.0	-3.1	-7.6	0.1	9.9	4.2	-0.7	0.1	-8.3
1984	1.3	5.8	-5.8	2.0	-0.3	-8.7	2.2	2.7	2.0	-5.0	3.9	-1.4	-0.1
1985	-3.5	6.7	-2.0	14.4	2.8	-9.6	-2.3	8.5	0.2	-5.6	-1.4	2.1	0.9
1986	8.0	-10.7	0.8	1.2	-6.6	10.7	2.2	-7.6	-5.2	6.1	-13.9	-13.6	-2.4
1987	-6.3	-12.6	-16.6	-24.4	-21.6	-20.1	-18.6	-14.0	-11.2	-5.6	-1.4	-4.5	-13.1
1988	-1.1	-5.0	2.4	-1.3	10.0	-3.9	11.3	14.9	20.1	14.6	21.0	10.8	7.8
1989	13.2	9.1	6.7	21.0	14.7	7.4	9.4	-6.3	5.7	7.3	-2.0	-5.0	6.8
1990	-1.1	-17.3	-8.5	-0.5	13.1	1.0	5.5	-5.0	-7.6	1.8	-5.3	-2.4	-2.2
1991	5.1	0.6	-10.6	-12.9	-19.3	-5.5	-1.7	-7.6	-16.6	-12.9	-7.3	-16.7	-8.8
1992	-25.4	-9.3	-24.2	-18.7	0.5	-12.8	-6.9	1.4	0.8	-17.2	-7.3	-5.5	-10.4
1993	-8.2	-7.9	-8.5	-21.1	-8.2	-16.0	-10.8	-14.0	-7.6	-13.5	0.6	1.6	-9.5
1994	-1.6	0.6	-10.6	-22.8	-13.0	-10.4	-18.0	-17.2	-17.2	-14.1	-7.3	-11.6	-11.9
1995	-4.0	-2.7	3.5	-16.2	-9.0	-1.5	4.2	0.8	3.2	-1.3	1.3	-5.5	-2.3
1996	8.4	1.1	6.2	7.8	1.3	13.9	6.8	4.6	6.9	4.2	-0.1	7.2	5.7
1997	4.1	13.3	-8.5	-16.2	-22.4	-24.1	-9.5	-19.8	-14.8	-17.8	-15.2	-9.1	-11.7
1998	-23.5	-19.2	-28.5	-24.4	0.5	9.9	14.6	9.8	11.1	10.9	12.5	13.3	-1.1
1999	15.6	8.6	8.9	18.5	1.3	1.0	4.8	2.1	-0.4	9.1	13.1	12.8	8.0
2000	5.1	12.9	9.4	16.8	3.6	-5.5	-3.7	5.3	9.9	9.7	22.4	7.7	7.8
2001	8.9	11.9	6.7	0.3	-9.0	1.8	-3.0	-8.9	1.4	-1.9	7.2	-9.1	0.5
2002	2.7	7.7											

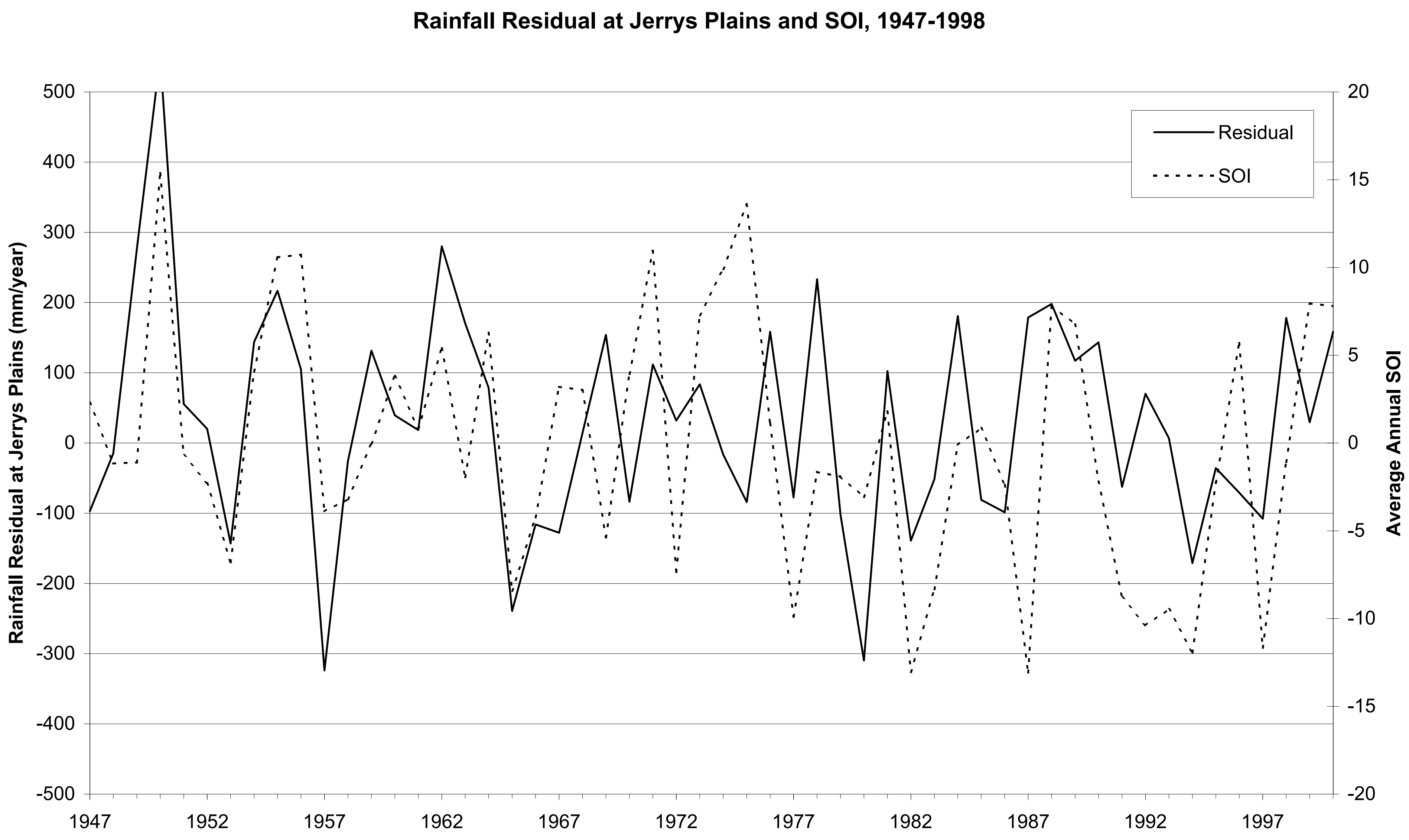

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FIGURE F1

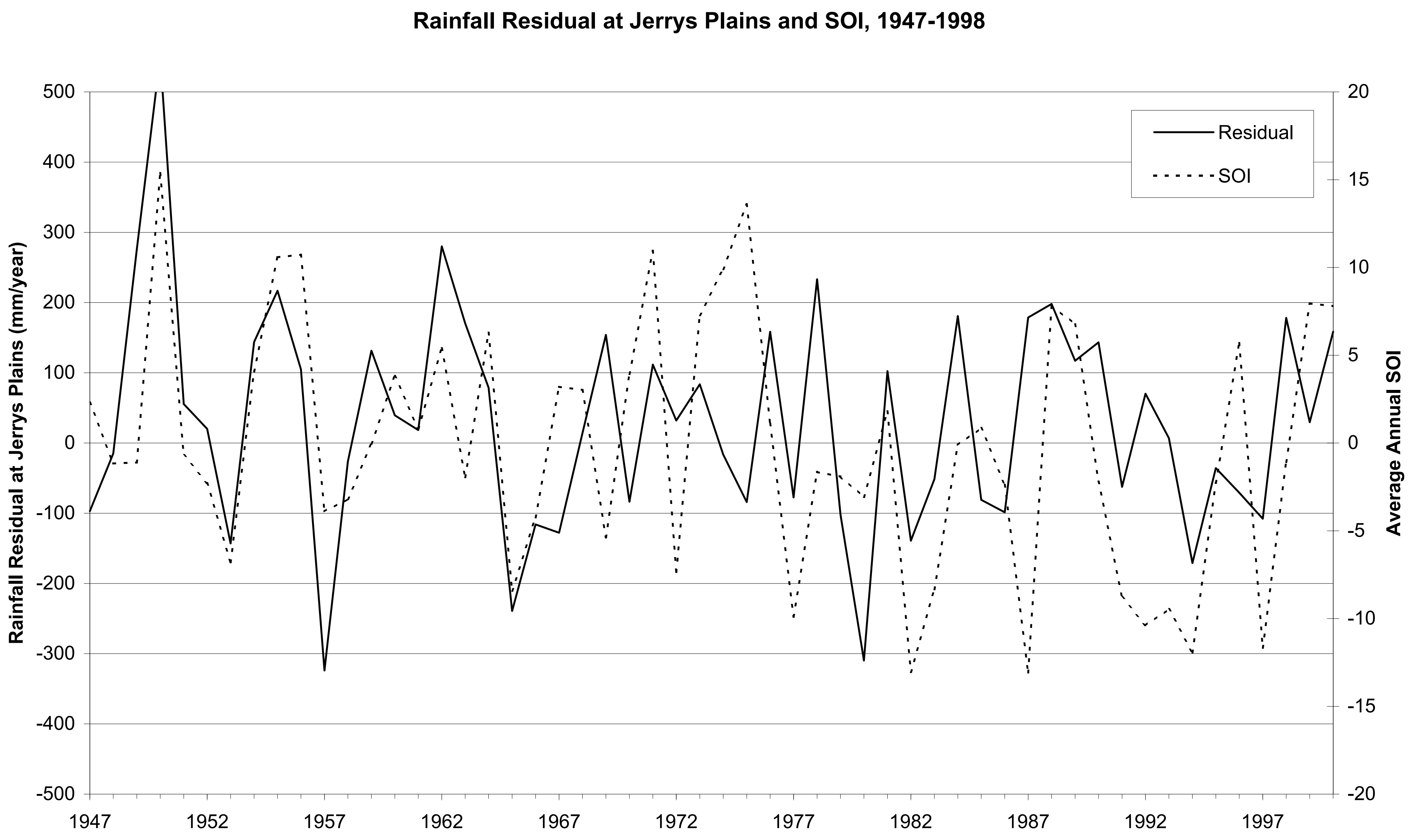
Rainfall Residual at Jerrys Plains and SOI, 1947-1998
Residual
SOI
Rainfall Residual at Jerrys Plains (mm/year)
Average Annual SOI
500
400
300
200
100
0
-100
-200
-300
-400
-500
20
15
10
5
0
-5
-10
-15
-20
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997

FIGURE F1