BICKHAM COAL COMPANY PTY LTD

PROPOSED BICKHAM SOUTH BULK SAMPLE
GROUNDWATER MANAGEMENT

PETER DUNDON AND ASSOCIATES PTY LTD

17TH OCTOBER 2002

TABLE OF CONTENTS

TABLES

FIGURES

1 INTRODUCTION

Bickham Coal Company Pty Ltd has been investigating a coal resource in Exploration Licences EL5888 and EL5306, approximately 10 km south of Murrurundi, known as the Bickham South Coal Project. The open cut resource lies on the eastern side of the New England Highway, and occupies an area of approximately 2.25 km by 0.7 km. The resource under investigation is totally within land owned by Bickham Coal Company Pty Ltd, and is situated on the western side of the Pages River, a major tributary of the Hunter River (**Figure 1**).

The coal deposit comprises a number of coal seams within the Greta Coal Measures, and is situated in the very northern part of the Hunter Valley Coal Field.

As part of the ongoing investigations, Bickham Coal Company Pty Ltd plans to extract approximately 25,000 tonnes of coal from a bulk sample site as shown in **Figure 2**. This bulk sample will entail the removal of 330,000 cubic metres of overburden. This report on groundwater management issues has been prepared in support of the Development Application for the bulk sample proposal.

The bulk sample pit will extend below the water table, and it will be necessary to control water inflows to the pit during extraction of the bulk sample. Impacts of these measures on the groundwater resources and the surface water resources need to be assessed. Options for use or disposal of groundwater extracted during the bulk sample recovery, as well as the assessment of potential impacts, are also addressed. Finally, the ongoing management of groundwater in the bulk sample pit following completion of the bulk sample extraction is also addressed in this report.

2 DESCRIPTION OF EXISTING ENVIRONMENT

2.1 Climate

2.1.1 Rainfall

The nearest long-term Bureau of Meteorology rain gauging stations to the Bickham South Project are those listed in **Table 1**.

Table 1: Bureau of Meteorology Stations

Station No.	Location	Latitude	Longitude
61051	Murrurundi PO (20km NW of Bickham)	31.7631 S	150.8361 E
210061	Pages River (Bickham) (5km NNW)	31.8119 S	150.9242 E
55252	Willow Tree (Temi) (30km NW)	31.7214 S	150.7844 E
61079	Wingen (Muralla) (2km W)	31.8697 S	150.8797 E

Analysis of the daily rainfall data since 1877 (ie. 125 years) from the nearest meteorological station at Muralla Homestead, 2.5 km west of the Bickham South Project, provides the following key characteristics shown in **Table 2**.

Table 2: Long Term Rainfall Data for Wingen (Muralla) Station 61079[1]

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean (mm)	83.9	76.8	63.5	47.5	46.2	53.0	48.5	47.8	50.5	61.0	62.3	75.6	716.6
Median Decile 1	11.7	6.5	5.3	5.6	7.9	11.1	11.9	11.5	11.6	15.6	12.8	20.0	466.4
Median Decile 5	70.6	56.5	46.0	38.3	34.1	45.6	43.4	40.6	42.2	50.9	57.5	62.4	711.9
Median Decile 9	176.2	167.8	147.8	102.7	108.9	112.8	105.7	102.7	96.2	124.5	123.3	142.1	938.0
Highest Monthly	310.4	449.4	220.8	201.0	195.0	222.3	171.9	200.1	196.2	163.7	161.2	216.6	
Lowest Monthly	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.6	2.5	
Highest Recorded Daily	123.7	143.5	107.7	74.4	124.5	88.6	68.8	94.7	129.5	75.0	95.3	96.0	
Mean No of Raindays	6.9	6.1	5.7	5.5	6.1	7.3	6.7	6.7	6.4	6.9	6.5	6.8	77.8

The annual rainfall at the Muralla site exhibits a moderate seasonal pattern with the highest median rainfalls occurring between November and February, and lower rainfall between March and September-October. No evaporation data is available from the Muralla meteorological station.

2.1.2 Evapotranspiration

The nearest meteorological station for which evaporation records are available is Scone, approximately 25 km south of Bickham. Average annual pan evaporation at Scone (Station 061069) is 1606 mm[1], which exceeds the average annual precipitation at Muralla by almost 900 mm. It is likely that average daily evaporation exceeds average daily precipitation in most months of the year.

[1] From Bureau of Meteorology – daily rainfall data for Station 61079.

2.2 Groundwater

2.2.1 Geology

The target coal seams of the proposed Bickham South mine are part of an outlier of the Greta Coal Measures, which lie within the Bickham Formation and are located in the lowest section of the Late Permian Newcastle Coal Measures. They are located stratigraphically above the Lower Permian Koogah Formation and below the Upper Permian Singleton Super Group (Tamworth 1:250,000 geological map sheet).

There are seven coal seams of the Greta Coal Measures in the Bickham outlier, of which two seams, "E" and "G" are believed to contain about 80% of the coal resources. Conglomerates overlie the Coal Measures and minor bands of conglomerate are found between the coal seams. Generally, the coal seams are interbedded with sandstone, siltstone and claystone. The seams are low in sulphur, with the exception of Seam "A". However, significant iron content in ash from seams "E" and "G" necessitates additional testing of the coal to ensure market acceptance.

The area of interest is truncated in the north by a bend of Pages River and the seam strikes to the southwest for some 2.5km, at which point igneous intrusions start to impact on coal quality. Within the open pit area, the seams dip to the northwest at about 15^0 to 25^0, and are projected to extend beyond the expected maximum economic depth of open pit mining.

The coal has been moderately to highly weathered in places, and frequently intruded by intrusive structures. There is evidence that the coal may have been burnt in the upper sections.

Coal was discovered in the area in the late 1800s, and underground mining occurred over about 30 years early in the 20^{th} century.

2.2.2 Groundwater Occurrence

Groundwater occurs generally throughout the area. Most exploration boreholes drilled on the coal deposit have encountered groundwater. Permeabilities are generally low to moderate, but occasional reasonably high rates of water inflow have been reported during drilling.

The coal measures are not generally considered significant aquifers, but moderate permeability is sometimes encountered in the coal seams, and at times in the sandstones and siltstones within the interburden sediments. Localised aquifers may also occur in alluvium associated with Pages River and its tributaries, but there is not an extensive floodplain developed in this area, and the alluvial aquifers are expected to be of limited importance.

A search of the Department of Land and Water Conservation database of registered groundwater bores in the vicinity of the Bickham coal deposit identified only two (2) registered bores within 5km of the project area; and a further forty (40) between 5 and 10 km from the project, mostly in and around the towns of Wingen and Blandford.

The identified registered bores/wells within 5km of the Bickham project site are listed in **Table 3**.

Table 3: Registered Bore Locations within 5 km of the Bickham South Project

DLWC Borehole No.	Latitude	Longitude	Depth (M)	Intended Use	Salinity
GWO54347	31^{O}47'49"	150^{O}57'40"	8.0	Domestic/Stock	Unknown
GWO61258	31^{O}51'05"	150^{O}54'19"	85.3	Domestic/Stock	Good Stock

The first listed bore in **Table 3** is a well dug in 1930. The second is a bore drilled in 1985. Locations are shown on **Figure 1**.

It is acknowledged that other bores may exist within the project vicinity that are currently in use, but are either not registered or are not yet listed in the DLWC database. There are a number of shallow bores/wells on the Bickham property itself. They are believed to be very shallow, and designed to intercept shallow near-surface flow in the thin veneer of alluvium-colluvium overlying the basement rocks.

2.2.3 Groundwater Quality

The groundwater quality is often variable in the coal measures of the Hunter Coalfield, with saline groundwater sometimes encountered in the coal seam aquifers. However, in the Bickham area, all groundwater encountered in the investigation drillholes is of potable quality. The results of the groundwater investigations carried out on the project site are discussed in more detail in the next section of the report.

The total dissolved solids (TDS) content of groundwater samples collected from bores on and near the coal deposit ranged from 154 to 996 mg/L, with a mean value of 580 mg/L. pH values ranged from 6.83 to 8.28, except for one sample which reported a pH of 4.56.

The low pH sample was obtained from bore BCWM071A, which is a piezometer monitoring the G seam of the coal deposit. It is uncharacteristic of the G seam quality, which in other bores revealed pH values ranging from 7.69 to 8.23. Piezometer BCWM71A is being re-sampled to verify the result.

3 GROUNDWATER INVESTIGATIONS

3.1 Summary

A series of piezometers were installed, to enable separate sampling, testing and monitoring of the principal coal seams, and the overburden and interburden sediments, within the deposit, downdip from the deposit, and along strike to the north-east and the southwest.

Some were installed in existing exploration drill-holes that had not yet been backfilled. However, in most cases, new bores were specifically drilled for the piezometer installations, when it was found that existing holes had collapsed or were obstructed. Each piezometer was designed with a screen at a specific depth interval, sealed above and below, to enable the specific screened zone to be separately sampled and tested.

A hydraulic testing program was carried out, comprising either slug tests or short duration pumping tests, to determine aquifer permeabilities.

Water samples were collected from each piezometer, and submitted to a laboratory for comprehensive analysis of the major inorganic parameters, nutrients, and a heavy metal screening analysis.

An assessment of the likely dewatering requirements of the bulk sample program was carried out using an analytical approach[2].

3.2 Piezometer Installation

Fourteen piezometers were installed, at eight sites. Completion details are listed in **Table 4**. Locations of all piezometers are shown on **Figure 3**.

The piezometers were designed to allow separate monitoring, sampling and testing of aquifers in the main coal seams, as well as in the overburden and interburden sediments, and were installed in locations that were within the coal deposit, as well as down dip and along strike to the north-east and south-west.

Also listed in **Table 4** are five uncased exploration drillholes that have been retained as open hole monitoring bores.

An Application for a Bore Licence under Part 5 of the Water Act 1912, has been submitted to the DLWC for the piezometers.

[2] It is proposed to set up a numerical groundwater model of the project area for assessment of impacts of the full-scale coal project.

Table 4a: Groundwater Monitoring Piezometers (depths as m below surface)

Piezometer	Piezometer Diameter	Depth Drilled (m)	Screen Interval (m depth)	Aquifer Screened	Greta E Seam (m depth)	Greta G Seam (m depth)	Water Level (m depth) 18 July 2002
DDH45	uncased	163.3	open hole		80.7 – 89.5	139.6 – 154.2	31.44
DDH46	uncased	178.3	open hole		96.0 – 105.3	156.1 – 166.5	16.89
DDH48	uncased	109.3	open hole		46.6 – 56.0	85.8 – 89.6	40.48
DDH49	uncased	110.0	open hole		22.1 – 28.5	-	-
OH038	50mm	154	87 - 107	G seam	46.2 – 56.0	87.5 – 107.4	45.88
OH056A	uncased	91	open hole				26.64
Water Bore OH056B	100mm	60	47 – 56	Broken Intrusives	Not present	72 - 80	26.65
OH057	50mm	97	52 - 71	Siltstone below F seam	20.6 – 27.0	78.8 – 88.1	36.43
OH065	50mm	91	74 - 83	G seam	16.5 – 19.5	73.5 – 82.6	55.28
WM069A	50mm	37	21 - 29	G seam & sandstone above			4.78
WM069B	50mm	15	9 - 14	Sandstone above G seam			4.81
WM070A	50mm	211	193 – 205	G Seam			1.26
WM070B	50mm	140	133 – 139	E seam			1.62
WM070C	50mm	40	34 – 39	Bickham Formation			3.23
WM071A	50mm	166	146 – 160	G seam			22.59
WM071B	50mm	35	30 – 34	A seam			13.87
WM071C	50mm	97	86 – 94	E seam			20.24
WM072	50mm	142	137 – 141	Sandstone above A seam			1.30
WM073A	50mm	140	128 – 139	A seam & siltstone below			2.42
WM073B	uncased	43	open hole				?dry

Table 4b: Groundwater Monitoring Piezometers (depths as m AHD)

Piezometer	Elevation of Lip of Monument (m AHD)	Depth Drilled (m AHD)	Screen Interval (m AHD)	Aquifer Screened	Greta E Seam Location (m AHD)	Greta G Seam Location (m AHD)	Water Level (m AHD) 18 July 2002
DDH45	469.02	305.7	open hole				437.58
DDH46	451.92	273.6	open hole				435.03
DDH48	488.55	379.3	open hole				448.07
DDH49	443.26	333.3	open hole				-
OH038	494.095	339.3	407.1 – 387.1	G seam	447.11 – 437.24	405.72 – 385.87	448.22
OH056A	463.972	373.0	open hole				437.33
Water Bore OH056B	464.420	373.0	418.0 – 409.0	Broken intrusives	Not present	393.0 – 385.0	437.77
OH057	424.509	326.8	372.5 – 353.5	Siltstone below F seam	403.9 – 397.5	345.7 – 336.4	388.08
OH065	432.146	341.1	358.1 – 349.1	G seam	415.6 – 412.6	358.6 – 349.5	376.87
WM069A	380.144	343.1	359.1 – 351.1	G seam & sandstone above			375.36
WM069B	380.184	365.2	371.2 – 366.2	Sandstone above G seam			375.37
WM070A	384.523	173.5	191.5 – 179.5	G seam			383.26
WM070B	384.614	244.6	251.6 – 245.6	E seam			382.99
WM070C	384.065	344.1	350.1 – 345.1	Bickham Formation			380.84
WM071A	454.534	288.5	308.5 – 294.5	G seam			431.94
WM071B	454.278	419.3	442.3 – 420.3	A seam			440.41
WM071C	454.130	357.1	368.1 – 360.1	E seam			433.89
WM072	443.670	301.7	306.7 – 302.7	Sandstone above A seam			340.67
WM073A	451.528	311.5	323.5 – 312.5	A seam & siltstone below			449.11
WM073B	?		open hole				?dry

Bore logs for the piezometers are presented in **Figures 4** to **18**.

3.3 Groundwater Levels

Groundwater levels are being monitored in all piezometers, as well as in the uncased monitoring bores, on a monthly basis.

Hydrographs of the monitoring bores are shown at **Figures 19** to **22**.

The groundwater levels in all bores are higher than the streamflow levels in the adjacent Pages River. The relative groundwater and surface water elevations are shown on the hydrographs for piezometers BCWM069A to B and BCWM070A to C on **Figures 21** and **22**.

There is also a surface water body in the former flint clay quarry to the south-east of the deposit, which is the proposed location for disposal of the overburden from the bulk sample extraction program (**Figure 3**). The water level in the former quarry fluctuates seasonally, but was measured at around 451 mAHD in August 2002. The groundwater level in the closest bore, BCOH056B, is approximately 438 mAHD (see location on **Figure 3** and groundwater level on **Figure 22**). Thus the water level in the former clay quarry is around 15m above the water table in the vicinity.

Over the period of monitoring, some piezometers have shown a falling water level, others a rising level. No consistent pattern of seasonal recharge-discharge has yet emerged.

3.4 Hydraulic Testing

Short pumping tests were conducted on piezometers with shallow water levels, viz BCWM069A and B, BCWM070A, B and C, BCWM072 and BCWM073. A short pumping test was also carried out on the larger diameter water supply bore, BCOH065B. Falling head tests were carried out on the other piezometers.

The primary purpose of the tests was to determine permeability values for the different aquifers in the sequence. The pump used was a low capacity sampling pump, which was not suitable for long term pumping. The pumping tests were therefore of limited duration, ranging up to 3 hours maximum.

Results of the hydraulic testing are detailed in **Table 5**.

Table 5: Hydraulic Testing Results

Bore	Screened Interval	Hydrogeological Unit	Type of Test	Pumping Rate (m^3/d)	Transmissivity (m^2/d)	Average Hydraulic Conductivity		Comments
						m/sec	m/day	
BCOH038	87-107m	G seam	Slug			8.7×10^{-7}	0.075	Early time data
						1.4×10^{-7}	0.012	Late time data
DDH048	0-109m open hole	E and G seams and sediments in between	Slug			4.2×10^{-8}	0.0036	
BCOH056a	0-91m open hole	Broken Intrusives	Slug			1.9×10^{-6}	0.17	
BCOH056b	47-56m	Broken intrusives	Pumping Test	60 m^3/day	180		17	Early time data
					55		5.0	Late time data
BCOH057	52-71m	Siltstone below F seam	Slug #1			8.4×10^{-6}	0.72	
			Slug #2			3.2×10^{-6}	0.27	Early time data
						1.4×10^{-6}	0.12	Late time data
BCOH065	74-83m	G seam	Slug			2.3×10^{-6}	0.20	
BCWM069a	21-29m	G seam and sandstone above	Pumping Test	30 m^3/day	110		14	Storativity of 0.014 determined from observations on BCWM069b
BCWM069b	9-14m	Sandstone above G seam	Pumping Test	60 m^3/day	140		28	Storativity of 0.038 determined from observations on BCWM069a
BCWM070a	193-205m	G seam	Pumping Test	27 m^3/day	0.3		0.025	Early time data
					4.1		0.30	Late time data
BCWM070b	133-139m							
BCWM070c	34-39m	Bickham Formation	Pumping Test	30 m^3/day	0.6		0.13	
BCWM071a	146-160m	G seam	Slug			1.5×10^{-6}	0.13	
BCWM071b	30-34m	A seam	Slug			7.5×10^{-7}	0.065	
BCWM071c	86-94m	E seam	Slug			9.2×10^{-8}	0.0079	
BCWM072	137-141m	Sandstone above A seam	Pumping Test	30 m^3/day	5.0		1.2	Early time data
					1.9		0.47	Late time data
BCWM073	128-139m	A seam and siltstone below	Pumping Test	60 m^3/day	70		6.6	

Table 5 shows a wide range of permeabilities on the site. Permeabilities are generally moderate to low in the coal seams and interburden sediments within the region of the coal deposit which is under consideration for mining.

However, higher permeability values were determined for the G seam and the sandstone immediately above it in bores BCWM069A and B. These bores are located adjacent to Pages River to the north-east of the deposit. The permeabilities determined in these two bores were an order of magnitude higher than those determined for the G seam and the overburden sediments at sites within the possible mining area. The higher permeabilities at the BCWM069 site suggest that there may be enhanced permeability associated with a fault zone or similar geological structure in that vicinity.

Higher permeability values were also determined from the water supply bore BCOH56B, which intersected an aquifer in broken intrusives.

Based on the results of the hydraulic testing, inspection of typical core samples, and experience from other sites in the Hunter Coalfield, the following representative permeability values for the various hydrogeological units in the vicinity of the bulk sample pit are considered appropriate:

Table 6: Representative Aquifer Hydraulic Properties

Aquifer	Hydraulic Conductivity	Storativity	Specific Yield	Lithology(ies)
Bickham Formation	0.1 m/d	0.001	0.05	Sandstones and siltstones
A Seam, and A Seam roof and floor sediments	0.1 – 5 m/d	0.0001	0.05	Coal seams, with predominantly sandstones and siltstones in roof and floor
Interburden Sediments	0.1 m/d	0.0001	0.005	Sandstones/siltstones with clay/shale interbeds, and occasional thin coal seams
Coal (principally E and G Seams)	0.2 m/d	0.0001	0.05	Predominantly coal
G Seam Floor Sediments	0.001 m/d	0.0001	0.005	Sandstones/siltstones with clay/shale interbeds, and occasional thin coal seams
Broken Intrusives	5 – 10 m/d	0.0001	0.05	Fractured fine-grained intrusives

3.5 Water Sampling and Analysis

Water samples were collected from all piezometers, after first purging the bores of water to remove any residual drilling fluids, and to ensure that the samples collected were truly representative of the groundwater and not partially contaminated by rainwater.

The samples were submitted to Australian Laboratory Services (ALS) for analysis of the physical properties (conductivity, TDS and pH), concentrations of the major dissolved cations and anions, nutrients, and a screening analysis for dissolved metals. The results are presented in **Table 7**.

Table 7: Water Analysis Results – Bickham Groundwater

Parameter	Units	LOR	OH38	OH57	0H56B	0H65B	WM69A	WM69B	WM70A	WM70B	WM70C	WM71A	WM71B	WM71C	WM72	WM73
pH		0.01	7.94	7.89	7.14	7.69	7.99	8.08	8.23	7.94	8.28	4.56	6.83	7.76	8.16	8.10
Sodium Adsorption Ratio		0.01	0.45	0.45	0.68	0.61	1.13	0.90	1.11	0.51	2.27	2.42	1.26	1.89	0.87	0.55
Conductivity @ 25^{0}C	µS/cm	1	990	512	182	426	863	861	857	739	1050	1320	1130	1250	711	1010
TDS	mg/L	1	578	328	154	270	480	480	506	456	622	996	816	890	468	592
Calcium	mg/L	1	103	55	8	43	80	86	80	85	70	112	118	118	72	112
Magnesium	mg/L	1	59	18	5	14	38	39	37	33	43	30	35	40	32	45
Sodium	mg/L	1	23	15	10	18	49	40	48	22	98	111	60	92	37	29
Potassium	mg/L	1	20	17	17	13	14	14	17	16	11	20	18	10	13	19
Alkalinity (as $CaCO_3$)	mg/L	1	426	202	40	169	373	389	382	231	433	<1	52	111	328	304
Sulphate	mg/L	1	59	18	6	17	52	42	41	114	85	523	400	428	23	134
Chloride	mg/L	1	60	40	28	29	52	53	49	52	60	110	119	98	47	84
Aluminium	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	<0.1	<0.1	<0.1	<0.1
Arsenic	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	mg/L	0.1	0.2	<0.1	<0.1	0.1	0.2	0.2	0.3	<0.1	0.2	<0.1	<0.1	<0.1	0.1	<0.1
Barium	mg/L	0.01	0.1	0.2	0.06	0.11	0.05	0.07	0.1	0.09	0.05	0.07	0.1	0.09	0.11	0.18
Beryllium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cobalt	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	0.05	0.03	<0.01	<0.01
Chromium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/L	0.1	1.3	2.6	<0.1	1.3	1.1	1.7	0.3	1.5	0.4	3.3	10.7	2.1	1.1	3.6
Manganese	mg/L	0.01	0.09	0.04	0.03	0.28	0.05	0.09	0.02	0.29	0.04	2.29	1.35	1.81	0.07	0.16
Molybdenum	mg/L	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
Nickel	mg/L	0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.19	0.06	0.03	<0.01	<0.01
Phosphorus	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Lead	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur	mg/L	1	20	6	2	6	17	14	14	38	28	175	134	143	8	45
Silicon	mg/L	0.1	8.3	15.1	27.1	13.1	9.1	9.1	7.3	11.9	9.8	39.8	24	23.1	9.8	15.1
Strontium	mg/L	0.01	0.45	0.18	0.03	0.21	0.39	0.36	0.78	0.40	2.71	0.34	0.39	0.81	0.47	0.55
Vanadium	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.01	<0.01	<0.01	0.07	0.02	<0.01	<0.01	<0.01	0.02	<0.01	0.3	0.12	<0.01	<0.01	<0.01
Nitrate – as N	mg/L	0.01	<0.01	<0.01	0.56	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.38	<0.01	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen – as N	mg/L	0.1	0.1	0.2	<0.1	0.4	0.3	0.2	0.7	0.5	0.8	3.0	0.3	0.2	0.2	0.3
Total Phosphorus	mg/L	0.01	0.07	0.11	0.09	0.13	<0.01	<0.01	<0.01	0.05	0.02	1.53	0.02	0.09	0.07	0.10

Salinity of the groundwater samples ranged from 154 to 996 mg/L total dissolved solids (TDS). pH was generally slightly alkaline, in the range 7.0 to 8.3. However, one sample (from piezometer BCWM071A, which was screened through the G Seam) had a measured pH of 4.56. That sample also contained higher concentrations of some dissolved metals, and nutrients, as discussed below.

The hydrochemistry of the Bickham groundwater has been evaluated with the aid of Schoeller and Piper Trilinear Water Quality Diagrams, which allow a visual comparison of the relative concentrations of the major ions in solution, viz the cations calcium, magnesium, sodium and potassium, and the major anions chloride, bicarbonate and sulphate. The Schoeller diagram (**Figure 23**) is a plot of the major ion concentrations in milli-equivalents per litre. The relative concentrations give an indication of the groundwater samples in relation to the recharge and discharge points in the hydrological cycle. The Piper Trilinear diagram (**Figure 24**) comprises two triangular fields on which the relative concentrations of the cations and anions respectively are plotted, as percentage equivalents. The plotted positions of each sample in the cation and anion fields are projected onto a diamond field, allowing each sample to be represented by a single point. The plotted positions of the samples in the diamond field enable them to be assessed in relation to their proximity to the sources of recharge, and they can also allow the identification of different sources of water, and mixing of those different water sources in the flow field.

The analysis has identified three different water types in the Bickham project area. Apart from the three samples from piezometers BCWM071A, B and C, and the sample from the water supply bore BCOH056B, the groundwater generally is of similar chemical composition – typically calcium/magnesium-bicarbonate waters, suggesting an active recharge process and proximity to the source of recharge. These samples plot in a cluster on the left side of the diamond field in the Piper diagram (**Figure 24**). They also plot with a consistent shape on the Schoeller diagram (**Figure 23**).

The BCWM071 samples had much lower concentrations of bicarbonate, and higher concentrations of chloride, and especially sulphate, than the other water samples. These samples plot near the top of the Piper diagram (**Figure 24**), and have a distinctly different shape on the Schoeller diagram (**Figure 23**).

The sample from the water supply bore (which was completed in an aquifer in broken intrusives) had a composition somewhat intermediate between the other types. The dominant ions in this case were sodium, chloride and bicarbonate. Sulphate concentration was low, but so too were the calcium and magnesium levels. This sample plots near the middle of the Piper diagram (**Figure 24**).

Limited sampling of water from Pages River has revealed the results listed in **Table 8**. Water samples from the piezometers closest to Pages River, viz BCWM069A and BCWM070A, are also presented in **Table 8** for comparison with the surface water quality.

Table 8 also presents the analysis results for a water sample collected from the flint clay quarry. The water quality from the nearby piezometer BCOH056B is shown for comparison.

Table 8: Surface Water Quality – Pages River and Flint Clay Quarry

Parameter	Pages River Upstream (6/6/2002)	Pages River Downstream (6/6/2002)	Piezometer BCWM069A (22/8/2002)	Piezometer BCWM070A (22/8/2002)	Flint Clay Quarry (26/7/2002)	Piezometer BCOH056B (21/8/2002)
Electrical Conductivity (µS/cm)	954	934	863	857	318	182
pH	7.6	8.3	7.99	8.23	7.5	7.14
Sulphate (mg/L)			52	42	5	6
Chloride (mg/L)			52	53	55	28
Bicarbonate (mg/L)			455	474		49
Calcium (mg/L)			80	86	9	8
Magnesium (mg/L)			38	39	7.4	5
Sodium (mg/L)			49	40	32	10
Potassium (mg/L)			14	14	16	17
Iron (mg/L)			1.1	1.7	0.06	<0.1
Cadmium (mg/L)			<0.005	<0.005	<0.01	<0.005
Lead (mg/L)			<0.01	<0.01	<0.005	<0.01
Zinc (mg/L)			<0.01	<0.01	<0.01	0.07
Nitrate-N (mg/L)	0.01	<0.01	<0.01	<0.01		0.56
TKN (mg/l)	0.12	0.11	0.3	0.7		<0.1
Total Phosphorus (mg/L)	0.045	0.024	<0.01	<0.01	<0.1	0.56
Ortho-phosphorus (mg/L)	0.032	0.017				
Ammonia-N (mg/L)	0.01	<0.01				
Suspended sdids (mg/L)	<2	<2				

It is seen from **Table 8** that the groundwater is of marginally better quality than the river water, at least in terms of salinity as indicated by the electrical conductivity. It suggests that the groundwater is not recharged from the river, but probably principally by direct infiltration of rainfall into the surficial sediments overlying the coal measures, and downward percolation to lower units in the sequence. This is consistent with the relative elevations of the surface water and groundwater, with the groundwater levels being at slightly higher elevation than the adjacent water levels in the Pages River where it passes beside the coal deposit.

Likewise, the quality of the groundwater in piezometer BCOH056B is much better that the quality of water in the nearby flint clay quarry (**Table 8**). This is consistent with them being unrelated water bodies. The very low salinity of water from BCOH056B suggests it is of very recent origin, and that the fractured intrusives are readily recharged by infiltration of rainfall. The higher salinity of water in the flint clay quarry is probably reflecting the effects of concentration by evaporation.

The source of the low pH and associated high dissolved metal concentrations in water sampled from piezometer BCWM071A is not known. The bore is located on the downdip (northwest) side of the proposed mining area. The piezometer is screened between 146 and 160m depth; this interval includes the G coal seam. The G seam is normally low in sulphur, so the result is surprising. It is not known whether there are any intrusives in the vicinity that may explain the low pH and elevated concentrations of dissolved metals.

BCWM071A is to be re-sampled, to confirm the validity of the analysis results. If confirmed, further investigation is warranted before the full-scale mining project. The water quality at this bore will not affect the bulk sample program, as it is remote from the bulk sample site, and is beyond the area of anticipated drawdown impact from the bulk sample dewatering. The bulk sample is located in an area of low salinity groundwater with alkaline pH. The anticipated water quality for the bulk sample dewatering is discussed in the next section.

4 BULK SAMPLE PROPOSAL

4.1 The Proposal

It is proposed to recover the 25,000 tonne bulk sample over a period of about six (6) months, which will involve about four (4) months for overburden stripping, and two months for coal recovery. The coal recovery will take place in several stages, as each coal seam is reached. Thus, there will be successive periods of overburden mining and coal recovery through the six month period.

The bulk sample will be mined from a box-cut to be excavated near the north-eastern end of the coal deposit, as shown on **Figure 3**. It is proposed to mine down to the base of the G seam, ie to an expected maximum depth below ground surface of 90 metres. Coal will thus be extracted from all coal seams in the deposit. The elevation of the lowest point in the bulk sample pit is expected to be approximately 350 mAHD, and will be at the south-eastern end of the pit (**Figure 25**).

The overburden will be transported for disposal at a former flint clay quarry on the south-eastern side of the coal deposit. The coal will be transported by truck to the Dartbrook Coal Preparation Plant, approximately 40 km to the south of the Bickham project site.

It is proposed to leave the bulk sample pit open at completion of the bulk sample recovery program.

4.2 Groundwater Issues

The water table in the vicinity of the bulk sample pit is expected to be at an elevation of approximately 388 mAHD. The bulk sample pit is planned to extend to almost 40 m below this level. Therefore, it will be necessary to dewater the bulk sample pit to enable recovery of the coal sample. The dewatering requirements, and a recommended approach to dewatering for the bulk sample recovery, are discussed below in **Section 4.3**.

It is also expected that groundwater levels will recover after completion of mining, and a groundwater pond will develop in the base of the pit. The recovery of groundwater levels after completion, and recommendations for ongoing management of groundwater exposed in the pit void, are discussed below in **Section 4.5**. Ongoing quality impacts are assessed.

Potential interactions between the groundwater and surface water in Pages River are discussed in **Section 4.6**.

A groundwater monitoring program, both during the bulk sample phase and subsequently, is recommended in **Section 5**.

4.3 Dewatering

The surface elevations within the bulk sample pit area range from approximately 395 to 435 mAHD (**Figure 25**). The water table in that area is expected to be at around 388 mAHD. Thus mining can proceed to some depth before groundwater will be encountered.

However, in order to avoid unsatisfactory conditions in the pit, it is recommended that advance pumping be undertaken to lower the groundwater levels ahead of mining. The permeabilities are moderate to low, but inflow rates are expected to be sufficiently high that difficult mining conditions would result if water were allowed to inflow to the pit.

An analytical approach has been applied to assess the required dewatering rate for the bulk sample recovery. It has been calculated that a constant pumping rate of 1300 m^3/d (1.3 ML/d) will be required for the nominal 6 month extraction period to achieve dry pit conditions suitable for mining.

The predicted rate of drawdown resulting from pumping a total of 1300 m^3/d from bores located either side of the bulk sample pit is shown on **Figure 26**. Profiles of the drawdowns along the axes of the bulk sample pit are shown on **Figure 26**. Predicted contours of groundwater level at the conclusion of extraction of the bulk sample are shown on **Figure 27**.

It is expected that at least two dewatering bores will be required, located approximately as indicated on **Figure 26**. The dewatering bores would be equipped with pumps capable of pumping at a combined rate of up to around 1600 m^3/d, although it is likely that the sustainable pumping rates will decline as water levels are lowered, due to the available submergence declining as the aquifer becoming progressively dewatered.

It has been calculated that if it is desired to continue pumping for a prolonged period after recovery of the bulk sample, it should be possible to maintain groundwater levels below the pit floor level by pumping at a declining rate. It is estimated that the long-term steady-state pumping rate would be approximately 750 m^3/d.

The dewatering for the bulk sample extraction is expected to result in drawdowns in the water table along strike from the bulk sample pit, and in downdip areas. The contours of predicted maximum drawdown on **Figure 27** indicate drawdowns of 2m or more may occur at distances of up to 450m. Drawdowns of more than 20m will be experienced close to the pit itself. Drawdowns are predicted to be around 5m beneath Pages River where it is closest to the bulk sample pit.

Drawdowns in an updip direction (ie to the southeast) will be limited by the aquifers rising up to the water table level. Thus impacts in that direction are expected to be more restricted than in either downdip areas or along strike. Impact in the updip direction is expected to be limited to areas within about 100m of the bulk sample pit.

The dewatering is not expected to have any impact on any existing groundwater bore in the vicinity, either licensed or unlicensed.

4.4 Quality of Dewatering Discharge

The quality of the dewatering discharge is expected to be very good, and would be suitable for release to the environment if necessary. In practice, the discharge will be substantially consumed for dust suppression and other uses associated with the bulk sample recovery.

The average water quality has been assessed by taking an unweighted arithmetic average of the qualities of water samples collected from the deposit, as listed in **Table 7**. Water samples taken into account are listed in **Table 9**. The samples are listed in order of proximity to the bulk sample pit location, and the first listed samples in **Table 9** are expected to have a greater influence on the overall discharge water quality. However, it is considered appropriately conservative at this stage to use an unweighted average of all the listed samples, thereby possibly overstating the impact of the higher salinities from more distant bores, as well as the low pH water from BCWM071A. Accordingly, the actual water quality is likely to be somewhat better than calculated below.

Table 9: Assessment of Likely Dewatering Discharge Quality

Bore	TDS (mg/L)	pH
OH 057	328	7.89
OH065B	270	7.69
WM069A	480	7.99
WM069B	480	8.08
WM070A	506	8.23
WM070B	456	7.94
WM070C	622	8.28
WM071A	996	4.56
WM071B	816	6.83
WM071C	870	7.76
Averages	**582**	**7.5**

It is proposed that any surplus water be pumped to a water storage on the Mining Lease, for future mining water supply purposes or for pasture/crop irrigation.

4.5 Post-Extraction Recovery of Groundwater Levels

After recovery of the bulk sample, the dewatering pumps would be turned off, and water levels would recover. It has been calculated that 3 months after cessation of pumping, groundwater levels would have recovered to within approximately 5 m of pre-pumping levels; and after 6 months to within 3 m of pre-pumping levels.

Eventually, water levels are expected to recover fully, except possibly in the immediate vicinity of the bulk sample pit. A permanent pond will form in the base of the pit. The groundwater level in the pond may not recover fully to pre-pumping levels, due to a small net loss to evaporation as a result of the water table being exposed to the atmosphere in the pit pond.

There would be an increase in recharge due to capture of all rainfall on the pit area. However, potential losses by direct evaporation from the water surface exposed in the pit would be of similar magnitude to the amount of additional recharge received from rainfall into the pit area. Depending on the rate of evaporation from the water surface, there may be a very fine balance between the additional recharge gains, and the additional losses by way of increased evaporation. Conservatively, the overall result could be a very small net loss of up to approximately 1.5 m^3/d from the pit area, compared with the pre-extraction water balance for the pit area. This volume represents less than 10% of the additional recharge that would be received by capture of all rainfall on the pit area. It would lead to the pond level being about 0.5 m lower than in the surrounding aquifer.

This could also have a small impact on water quality in the pond itself, as the increased evaporation will lead to a slight increase in salinity of the water that resides in the pit. Salinity of the water in the pit could increase by up to 10%, ie to a TDS of around 550 mg/L, compared with the present 500 mg/L in that area. The salinity increase will be limited to the water in the pit, as groundwater levels in the pit will be slightly lower than in the surrounding rocks, due to the net loss from evaporation. Thus groundwater will flow radially towards the pit, not away from it, and the slightly more saline water will therefore be contained within the pit.

4.6 Interaction Between the Groundwater and Surface Water in Pages River

The drawdown predictions described in **Section 4.3** indicated that drawdown impacts in the aquifers beneath the Pages River would be in the order of 5 m by the completion of the 6-month bulk sample recovery program. This would cause groundwater levels to fall to 3-4 m below the stream-bed levels where the box-cut is closest to the river (**Figure 27**).

Currently, groundwater levels are above the stream-bed, and at present, there is an implied net positive gradient towards the river. If there is hydraulic connection between the groundwater and the river, there would be a net discharge of groundwater to the river system. As a result of the dewatering for the bulk sample recovery, the gradient could be reversed leading to a flow from the river to the aquifer system.

However, during drilling, the first water intersections in bores BCWM069A and B, and BCWM070A, B and C occurred at depths of 35m or greater, well below the river bed level (see bore logs in **Figures 8** to **12**). This indicates that there is no direct hydraulic connection between the river bed and the groundwater in proximity to those bores. Hydraulic connection may exist in other locations, probably along strike where the permeable zones outcrop in or beneath the riverbed. However, no evidence for direct hydraulic connection between the groundwater and the surface water is available from either the groundwater levels, or the water quality.

It is recommended, as outlined in **Section 5**, that careful monitoring of water levels, and streamflow in Pages River, be maintained during the dewatering of the bulk sample pit. The information to be gained from this monitoring will be valuable for assessing the potential impacts of a subsequent full-scale mining operation.

The groundwater is considered to be separate from the water in the old flint clay quarry, which is believed to be derived by the collection of rainfall and runoff from the catchment upslope from the quarry. The water level in the quarry appears to fluctuate seasonally, under the influence of evaporation, and may even dry up altogether during extended periods without rain.

5 RECOMMENDED MONITORING PROGRAM

It is recommended that the following monitoring program be implemented through the bulk sample extraction program:

- Accurate measurement of pumped discharges from the dewatering bores, on a weekly basis (by means of totalizing meters)
- Measurement of any pit inflows pumped from sumps in the pit, independent of the dewatering bore discharges
- Weekly measurement of pH, conductivity and TDS of the pumped discharges from dewatering bores and pit sumps
- Water levels in all piezometers,on a weekly basis
- Water sampling from all piezometers, and analysis for a broad suite of water quality parameters, three-monthly.

The groundwater monitoring program should be conducted and reviewed in conjunction with surface water monitoring.

After completion of the bulk sample extraction, the monitoring of the following should continue until the pattern of recovery has been ascertained:

- Water levels in all piezometers, on a weekly basis for the first three months, then monthly thereafter
- Water level in the pit, on a weekly basis for the first three months, then monthly thereafter
- Water sampling from all piezometers, and analysis for a broad suite of water quality parameters, three-monthly.

Once the groundwater levels have substantially recovered, the ongoing monitoring requirements could be reviewed.

The proposed bulk sample extraction program will have very little lasting impact on the groundwater system, yet it will provide an excellent opportunity to observe the response of the groundwater system to extended pumping. This will be invaluable for confirming the conceptual model of the groundwater flow system, and will allow the reliable calibration of the numerical model that will be set up for assessing the impacts of the full-scale mining operation. It will also allow the interpreted independence of the groundwater system from stream-flows in Pages River to be confirmed.

6 REFERENCES

Beckett, J, 1988. The Hunter Coalfield, and accompanying 1:100,000 geological map. Geological Survey Report No GS 1988/051, published by NSW Department of Mineral Resources.

NSW Department of Mineral Resources, 1971. Tamworth 1:250,000 geological map sheet.