HANCOCK PROSPECTING PTY LTD

Alpha Coal Project Environmental Impact Statement

G | Groundwater

HANCOCK PROSPECTING PTY LTD

ALPHA COAL PROJECT

GROUNDWATER TECHNICAL REPORT

September 2010

JBT01-005-021

RECORD OF ISSUE

File Name	Description	Issued to:	Date Issued	Method of Delivery
JBT01-005-021	Draft 1	URS	26/7/2010	email
JBT01-005-021	Draft 2	URS	16/8/2010	email
JBT01-005-021	Draft 3	URS	1/9/2010	email
JBT01-005-021	Final	URS	14/9/2010	email

TABLE OF CONTENTS

SECTION **PAGE**

List of Abbreviations

Executive Summary

LIST OF TABLES

LIST OF FIGURES – WITHIN REPORT

LIST OF FIGURES – END OF REPORT

LIST OF APPENDICES

LIST OF ABBREVIATIONS USED IN REPORT

Abbreviation	Term
AHD	Australian Height Datum
AMD	Acid and Metalliferous Drainage
ANZECC	Australia and New Zealand Environment Conservation Council
AS/NZS	Australian Standards/New Zealand Standards
BOM	Bureau of Meteorology
BPO	Barcaldine Post Office
CHPP	Coal Handling and Preparation Plant
CRD	Cumulative rainfall departure
DERM	QLD Department of Environment and Resource Management
e.g.	for example
EA	Environmental Authority
EC	Electrical conductivity (µS/cm)
EIS	Environmental Impact Statement
EM Plan	Environmental Management Plan
EP Act	Environmental Protection Act 1994
ERA	Environmentally Relevant Activity
ERE	Endangered Regional Ecosystems
EVs	Environmental Values
Fm	Formation
GAB	Great Artesian Basin
GDE	Groundwater dependent ecosystem
i.e.	that is,
LOM	Life of Mine
MDL	Mining Development Licence
ML	Mining Lease
MLA	Mining Lease Application
NAF	Non Acid Forming
No.	Number
PAF	Potentially Acid Forming
PFS	Pre-Feasibility Study
pH	Measure of acidity (<7) or alkalinity (>7) of a sample.
RE	Regional Ecosystems
RL	Reduced level (relative height compared to Australian Height Datum)
RRM	Rainfall Residual Mass
SEIS	Supplementary Environmental Impact Statement
SPT	Standard penetration test
TDS	Total dissolved solids
TSF	Tailings Storage Facility
VWP	Vibrating Wire Piezometer
WRP	Water Resource (Burdekin Basin) Plan
Units of Measurement and Symbols	
%	percent
µS/cm	microsiemens per centimetre

Abbreviation	Term
^0C	degrees Celsius
K	Hydraulic Conductivity
km	Kilometre(s)
km^2	Square kilometre
L	litres
L/s	litres per second
m	metre
M	Million or mega
m/d	metres per day
m/s	metres per second
m^2	square metres
m^3	cubic metres
m AHD	meters Australian Height Datum
mg/L	milligrams per litre
ML	million litres or megalitre
mm	millimeter
mm/day	millimetres per day
Mtpa	million tonnes per annum
S	Storage Coefficient
t	tonnes
T	Transmissivity (m^2/day)

EXECUTIVE SUMMARY

Introduction

The Alpha Coal Project (Mine) (the Project) is located in the Galilee Basin, Queensland, Australia. The project is 130 km south-west of Clermont and approximately 360 km south-west of Mackay. The nearest residential area to the Project is the township of Alpha, located approximately 50 km south of the Project (Figure 1). Access to the mining lease is from the Hobartville Road north off the Capricorn Highway at Alpha.

Coal is to be mined by draglines, shovels and trucks, and processed on site. At the Project site the coal will be mined, washed and conveyed to a train load-out facility where it will be transported more than 400 kilometre (km) to the east coast of Australia to the port facility at Abbot Point for export.

The Project is a 30 million tonnes per annum (Mtpa) open cut thermal coal mine and targets the C and D Seams in the Upper Permian coal measures of the Galilee Basin, Queensland, Australia.

The scope of work is provided in Section 2.0, and the methodology for undertaking the study is provided in Section 3.0.

Legislative Background

The legislative background to the Project is discussed in Section 4.0.

The Water Act 2000 (Water Act) is the key piece of legislation that regulates the interference with, and extraction of, groundwater in Queensland. The Project is located within the Highlands declared subartesian area, where authority is required to take or interfere with subartesian groundwater for any purpose other than stock or domestic use.

Other legislation which relates to groundwater in the Project area includes:

- The Environmental Protection (Water) Policy 2009 (EPP (Water)), which applies to all water in Queensland, and provides a framework for defining the environmental value of water and guidelines for water quality. The policy aims to protect water to designated environmental values;
- Sustainable Planning Act 2009, which promotes development based on the concept of ecological sustainability;
- Environmental Protection Act (1994) (EP Act), which promotes ecologically sustainable development, and has the stated objective “to protect Queensland’s environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends”; and
- The Project is also located with the area covered by the Water Resource (Burdekin Basin) Plan 2007 (WRP). The western boundary of the WRP in the Project area is the Great Dividing Range. The WRP has no direct bearing on groundwater in the Project area.

Climatic Data

Regional and site climatic data is presented in Section 5.0. Data obtained from the SILO Data Drill facility indicates that:

- Average annual site rainfall is approximately 535 mm and is highest in the wet summer season months between November and February and lowest during the dry months of winter;

- Average annual site evaporation (class A pan) is approximately 2 290 mm and is highest in summer and lowest in winter; and,
- Average evaporation is in excess of average rainfall during every month of the year, resulting in a significant rainfall deficit at site for every month of the year, under average conditions.

Stratigraphy/ Hydrostratigraphy

The stratigraphy and hydrostratigraphy of the site is presented in Section 6.0.

The Project is located within the Galilee Basin, a sequence of Late Carboniferous to Middle Triassic sedimentary rocks overlying Late Devonian to Early Carboniferous sedimentary and volcanic rocks of the Drummond Basin.

Late Permian, coal-bearing strata of the Galilee Basin sub-crop are found in a linear, north-trending Belt in the central portion of the exposed section of the Basin and are essentially flat lying (dip generally <1º to the west). No major, regional scale fold and fault structures have been identified in regional mapping of the Project area.

Permian sedimentary deposits at site comprise the Bandanna Formation and the underlying Colinlea Sandstone, and these units contain both economic and sub-economic coal seams. The coal seams are named alphabetically A through F, with the A seam being uppermost. There are two major coal seams that will be the target of mining within the deposit; the C seam and D seam, which vary in thickness from 3 m to 6 m in the area to be mined. Geologically the boundary between the Bandanna Formation and the underlying Colinlea Sandstone is taken to be an interval above the C coal seam at which sedimentation style changes from increasingly argillaceous (i.e. becoming more clayey with depth) to increasingly arenaceous (i.e. becoming more sandy with depth).

From a groundwater perspective, major hydrostratigraphic boundaries occur within the MLA at the base of weathering, beyond which groundwater is often encountered under confined conditions in the B-C and C-D sands and B and C coal seams, and also at the base of the D coal seam. The sandstone unit directly below the D coal seam and above the E coal seam (D-E Sandstone) will be the major target of aquifer depressurisation, and the overlying sandstone (B-C sandstone, C-D sandstone, and C and D coal seams) will need to be locally dewatered in order for mining to occur safely.

Below the D-E sandstone the Colinlea sandstone coarsens with increasing depth. The sub-E sandstone (between the E and F coal seams) and sub-F sandstone (below the F coal seam, and to the base of the Colinlea Sandstone) are regarded as containing significant groundwater resources, and will likely be the target of make-good bores for existing groundwater users whose bores are materially impacted by mining.

Existing Surface Water Environment

The existing surface water environment is described in Section 8.0

The major surface water drainage feature through the Alpha MLA is Lagoon Creek, which drains from south to north through the MLA. The catchment area for Lagoon Creek above the Alpha MLA is approximately 1 470 km^2. Major systems, which drain the site from west to east toward Lagoon Creek (i.e. from the eastern foothills of the Great Dividing Range), include Spring Creek and Sandy Creek. Drainage from the east of the MLA occurs from a low unnamed range that comprises the outcrop of the Colinlea Sandstone and underlying Joe Joe Formation (refer Section 6-2 for site geology). Drainage from this range is to the west toward Lagoon Creek, and to the east (at the eastern margin of the MLA) toward Native Companion Creek.

At the confluence of Lagoon Creek and Sandy Creek the drainage system continues north (as Sandy Creek) until joining the Belyando River, which in turn drains to the Suttor River, and ultimately to the Burdekin River.

Other surface water features include:

- An area of palustrine wetland, which is interpreted to be a perennial water feature, and which will be monitored to establish whether the feature is groundwater dependent. This is discussed further in Section 9.8.2; and
- The location of registered springs as defined by Springs of Queensland[1]. The nearest of these springs to the boundary of the Alpha MLA is spring reference no. 405, which is located just over 40 km from the boundary of the MLA.

Existing Groundwater Environment

The existing groundwater environment is described in Section 9.0.

Previous and current investigations within the Alpha MLA area into groundwater occurrence, yield, and hydraulic properties are discussed in Sections 9.1 to 9.3. Review of data from site monitoring bores indicates that groundwater flows from south-south-west to north-north-east, i.e. toward Lagoon Creek which is interpreted to be a regional discharge area. Baseflow to Lagoon Creek has not been observed, and bores drilled adjacent to Lagoon Creek first strike water that occurs under confined conditions. However, groundwater is noted to occur close to surface to the north of the MLA (on the Forrester property) and it is judged as likely that groundwater baseflow to the surface water system occurs to the north of the MLA.

Section 9.4 discusses existing groundwater users. Within a range of 20 km of the boundary of the MLA there are 112 groundwater bores that are existing, abandoned but useable, or proposed. Groundwater quality is unsuitable for potable use on the basis of concentrations of metals and metalloids, but is judged to be suitable for stock watering. The number of operable groundwater bores within a 20 km radius of the MLA suggests that groundwater is a resource of some value in the region.

Conceptual Groundwater Model – Pre-Mining

The pre-mining conceptual groundwater model is summarised as:

- Groundwater occurs beneath the MLA in coal seam and sandstone (interburden and floor) aquifers. The sandstone aquifers, which occur between and below the coal seams, are the major groundwater sources;
- The sandstone aquifers become cleaner (greater quartz content) and coarser with increasing depth;
- The coal seams confine the underlying sandstone aquifers. This is of greatest significance where the D coal seam confines the underlying D-E sandstone. Seepage modelling predicts that, if the D-E sandstone is not depressurized, the upward pressure from groundwater will exceed the weight of overlying material (i.e. weight balance would be exceeded), causing the

[1] Springs of Queensland version 4.0, Aug 2005, http://www.epa.qld.gov.au/wetlandinfo/site/factsfigures/springs.html

floor of the mine to heave (plus groundwater ingress through floor). Therefore, depressurisation of the D-E sands will be required to allow mining to proceed safely to depth;

- Groundwater occurrence in the units overlying the Permian deposits (Tertiary sediments and Quaternary alluvium) is sporadic, and the units are not regarded as significant regional aquifers; and
- Recharge occurs in topographically elevated areas and flows down gradient (i.e. as a subdued reflection of topography) toward Lagoon Creek. In the area to be mined the groundwater flow direction is to the north-north-east, and the gradient is shallow (approximately 1:1 000).

Groundwater in the Permian Bandanna Formation and Colinlea Sandstone is encountered under confined conditions, even adjacent to Lagoon Creek. This suggests that groundwater does not necessarily discharge to Lagoon Creek under average conditions, but may reach surface e.g. if structures such as joints or faults exist that allow upward movement of water.

Impact of the Proposed Operation on Groundwater

Potential impacts from the mine on the groundwater environment are discussed in Section 10.0. In summary these include:

Water Level Impacts

Modelling undertaken to date indicates that the D-E sandstone (unit occurring directly below the D seam, which is the deepest coal seam targeted by mining) will require depressurisation to allow mining to proceed safely to depth. Mine dewatering and the presence of mine infrastructure have the potential to impact on:

- Groundwater levels;
- Groundwater flow direction;
- Groundwater chemistry; and,
- Recharge and discharge mechanisms.

Mine dewatering operations therefore have the potential to impact the stated environmental values (EV's) of agriculture (stock watering) maintenance of baseflow to the surface water system (which could potentially impact groundwater dependent ecosystems (GDE's), and these features may have EV's of cultural or spiritual values).

Water Quality Impacts

Mine infrastructure that has the potential to impact groundwater quality includes:

- Tailings storage facility (TSF);
- Landfill;
- Coal Handling and Preparation Plant (CHPP);
- Waste Rock Dump;
- Train Load-out facility; and
- Environmental dams.

Conceptual Groundwater Model – Post Mining

The post-mining conceptual groundwater model is presented in Section 10.9 and includes:

- A drawdown cone will develop around the open pit that will extend preferentially north and south (along strike) and to the west, but will be of limited extent in the east as the aquifers outcrop to the east and in this area the aquifers will be locally dewatered;
- Groundwater will flow into the pit through the pit wall, from the Tertiary sediments (where water occurs), the sediments of the B-C and C-D sands and C and D coal seams;
- Groundwater will flow through the pit floor from the underlying D-E sandstone aquifer. Seepage modelling predicts that the majority of groundwater reporting to the floor of the pit will be derived from the D-E sandstone, and not from underlying sandstone units (sub-E sands, sub-F sands). However, induced flow from underlying aquifers will be considered in the proposed regional groundwater model, which will include the impacts of adjacent mining operations;
- A water table will be developed over time in the in-pit waste dump, though a drainage layer will be installed at the base of the internal dump to limit pressure build-up (i.e. for geotechnical stability), and this is expected to limit the extent to which a watertable will develop. Sources of water will include direct rainfall infiltration, and inflow from the D-E sandstone that will underlie the in-pit dump;
- Rehabilitation (and maintenance to counter settlement) of the surface of the in-pit dump will be required to limit the potential for rainfall infiltration (via capping, revegetation, and/or grading of the surface to encourage runoff and limit surface ponding); and
- The cone of depression will extend within the hanging wall to the west, but it is predicted that drawdown will not influence water levels in the GAB. The outcrop of the Rewan Formation (Fm), like the Joe-Joe Formation, is expected to provide a physical limit to the extent of groundwater level drawdown.

Groundwater Monitoring and Mitigation Measures

Groundwater monitoring requirements and potential mitigation measures are presented and discussed in Section 11. In summary these include:

- Requirements for groundwater investigations and monitoring for the TSF;
- Investigations (bore survey) and monitoring to allow assessment of water level and water quality impacts on existing groundwater users; and
- Groundwater level and quality monitoring up gradient and down-gradient of other mine infrastructure, including:
  - Landfill;
  - CHPP;
  - Waste Rock Dump;
  - Train Load-out facility;
  - Tailings Storage Facility;
  - Environmental dams; and
  - Sewage treatment plant.

1.0 INTRODUCTION

The Project is located in the Galilee Basin, Queensland, Australia. The project is 130 km south-west of Clermont and approximately 360 km south-west of Mackay. The nearest residential area to the Project is the township of Alpha, located approximately 50 km south of the Project (Refer Figure 1). Access to the mining lease is from the Hobartville Road north off the Capricorn Highway at Alpha.

Coal is to be mined using draglines, shovels and trucks. The coal will be washed on site and then conveyed to a train load-out facility where it will be transported more than 400 km to the east coast of Australia to the port facility at Abbot Point for export.

The Project is a 30 Mtpa open cut thermal coal mine to target the C and D Seams in the Upper Permian coal measures of the Galilee Basin.

2.0 SCOPE OF WORK

The scope of work included conducting hydrogeological investigations in order to collate and assess sufficient data in order to prepare a report to satisfy the Terms of Reference (TOR) for the Environmental Impact Study (EIS) in respect to groundwater resources. The investigations included:

- A description of the geology of the Project area, with particular reference to the physical and chemical properties of surface and sub-surface materials and geological structures within the proposed areas of disturbance;
- A review of the quality, quantity and significance of groundwater resources within and adjacent to the Project area. The review included a survey of existing groundwater supply facilities (bores, wells, or excavations). The information gathered for analysis included:
  - location and type of facilities;
  - pumping parameters;
  - drawdown and recharge at normal pumping rates; and
  - seasonal variations (where records exist) of groundwater levels.
- A description of the nature of the aquifers, including:
  - aquifer type - such as confined, unconfined;
  - depth to and thickness of the aquifer and transmissivity of the aquifer;
  - potential for aquifer interconnectivity;
  - depth to groundwater level and seasonal changes in levels, including response to existing extraction;
  - groundwater flow directions (defined from groundwater level contours);
  - interaction with surface water;
  - existing and possible sources of recharge; and
  - vulnerability to pollution.
- Specification of the major ionic species present in the groundwater, pH, electrical conductivity and total dissolved solids.

- Description of the environmental values of the groundwater of the affected area, in terms of:
  - values identified in the EPP (Water);
  - sustainability, including both quality and quantity; and
  - physical integrity, fluvial processes and morphology of groundwater resources.
- Assessment of the potential environmental harm caused by the Project to local groundwater resources;
- Proposed management options to monitor and mitigate these effects. In particular, proposed methods and the feasibility of those methods to 'make-good' any adverse affects on the groundwater resources utilised by adjacent landholders;
- Description of the expected response of the groundwater resource to the progression and finally cessation of the Project, particularly in relation to the recharge potential of aquifers affected by mining;
- An assessment of the options for the beneficial use of surplus water from dewatering of the mine pit over the life of the project, including the potential for irrigation or recharge to mitigate the impacts on areas containing vegetation with conservation value;
- An assessment was undertaken of the impact of the Project on the local ground water regime caused by any land disturbance; and
- Description of the development of a network of observation points which would satisfactorily monitor groundwater resources both before and after commencement of operations should be developed.

3.0 METHODOLOGY

The groundwater investigation has been undertaken using a phased approach, which included:

- Review of existing data, prior phases of groundwater investigations, and other EIS reports that may be influenced by groundwater (e.g. surface water studies, cultural heritage studies, waste management studies);
- Review the regulatory framework as it relates to groundwater, including discussions with the Department of Environment and Resource Management (DERM) as required;
- Field work, including siting and construction of groundwater monitoring bores, installation of data loggers (water level monitoring, rain gauges), undertake hydrocensus (bore survey);
- Prepare baseline description of the groundwater environment (description of aquifer types, groundwater levels, groundwater flow directions, recharge and discharge mechanisms, water quality, sustainable yield);
- Prepare a description of the environmental values of groundwater in the region;
- Assess mine dewatering requirements;
- Assess the impacts of the operation on the groundwater resource in terms of groundwater levels, groundwater quality, and groundwater environmental values (i.e. impacts on existing groundwater users and the environment);
- Undertake assessment of the final void for prediction of water levels and long-term water quality (in terms of salinity);

- Develop a conceptual groundwater model to describe the groundwater environment pre-mining, and the groundwater environment post-mining; and
- Develop monitoring and mitigation strategies input into the Environmental Management Plan (EMP).

4.0 LEGISLATIVE BACKGROUND

4.1 Water Act 2000

4.1.1 General Outline

The Water Act 2000 (Water Act) is the key piece of legislation that regulates the interference with, and extraction of, groundwater in Queensland.

Section 19 of the Water Act states that "all rights to the use, flow and control of all water in Queensland are vested in the State," and Section 808 makes it an offence to take, supply, or interfere with water without authority.

Section 20 of the Act lists a number of cases where, despite section 19, taking of water without water entitlement is authorised. With respect to sections 19 and 20:

- Artesian water is not mentioned in section 20, therefore authority is always required to take or interfere with artesian water. There is no known artesian water within the Alpha MLA; and
- Section 19(6) states that a person may take or interfere with subartesian water[1] unless:
  - a moratorium notice, or water resource plan declaration, limits or alters the water that may be taken or interfered with; or,
  - a regulation under section 1046 of the Act regulates the taking or interfering with water. Section 1046 of the Water Act is concerned with the regulation of declared subartesian areas.

The following comments apply with respect to declared subartesian areas (subartesian areas):

- Schedule 11 of the *Water Regulation 2002* lists current subartesian areas. The schedule also lists the bores types (e.g. stock or domestic) for which a water entitlement or permit is not required, and the bore types which are not assessable (i.e. for which a development permit is not required for bore drilling and construction).
- For bore types not listed in schedule 11 of the *Water Regulation 2002* (e.g. bore types such as irrigation, water supply excluding stock and domestic, mine dewatering etc), authority is required to take or interfere with water, and a development permit is required for bore drilling and construction. Authority to take or interfere with groundwater may be in the form of:
  - A Permit to Take Water, which is applicable if the activity is of a temporary nature and has a reasonably foreseeable conclusion date. A Permit to Take Water is appropriate to activities such as running pumping tests (e.g. to obtain aquifer properties) obtaining water supply for exploration drilling, or relatively short-term construction activities (in the order of 12 months or so); or

[1] The Water Act 2000 defines subartesian water as "water that occur naturally in, or is introduced artificially into, an aquifer, which if tapped by a bore, would not flow naturally to the surface"

- A Water Licence, where the take or interference with groundwater is of a longer-term nature. The definition of "reasonably foreseeable conclusion date" is not set and so requires interpretation by DERM, but experience suggests that activities expected to last for several years or more (or where the impacts of the activity may be of long-term duration) would be expected to be licensed. In recent years DERM have begun making a more formal distinction between the purpose for which water is taken or interfered with, and this has resulted in two broad classes of water licence that are applied to mining projects. There is no difference in the application process for these types of licence, but the purpose of the licence (as stated on the water licence application) will determine the way in which the application is assessed and eventually managed (if the licence is granted). The two types of licence are:

  i. Dewatering Licence, which is required for dewatering of an open-cut or underground mine void. Mine dewatering covers active dewatering (e.g. via bores), or passive dewatering (e.g. where water drains to a pit or underground void under gravity drainage and is removed via sump pumps); and

  ii. Water supply licence. This type of licence is applicable where, for example, the bore is to be drilled and constructed to provide a long-term water supply, rather than for dewatering purposes. A water supply licence will be assessed by DERM on the basis of sustainability of the water supply, and impacts on existing groundwater users and the environment.

4.1.2 Implications for the Project

The applicability of the various sections of the Act (as outlined above) to the project is discussed below. In some cases the interpretation presented is based on discussions with DERM groundwater licensing and management personnel in Rockhampton. Where this is the case the interpretation will be acknowledged.

The Alpha MLA is located near the border of two subartesian areas, the Great Artesian Basin (GAB) subartesian area, and the Highlands subartesian area. The boundary between the two subartesian areas is shown on Figure 2. As can be seen from Figure 2 the Alpha MLA is located entirely within the Highlands subartesian area, and the edge of the area disturbed by mining is approximately 16 km from the management boundary of the GAB.

The GAB declared subartesian area does not impact the project in a legislative sense as the project is located within the boundary of the Highlands declared subartesian area. This boundary is shown on Figure 2 merely to highlight the location of the project with respect to the GAB.

The Alpha MLA is located entirely within the Highlands subartesian area, and this has the following implications for the project, with respect to groundwater:

- Authority is currently not required for bore construction or water take from subartesian stock or domestic bores. DERM also currently allow the drilling and construction of standpipe groundwater monitoring bores without a requirement for development permits (so long as a licensed water bore driller is used). DERM assume that small diameter groundwater monitoring bores will not be used for water extraction, with the exception of the relatively small volumes to be removed for groundwater sampling. Authority is required to take or interfere with groundwater for any other purpose, including mine water supply bores and mine dewatering bores;

- DERM have advised that the project will require a dewatering license for dewatering of the mine. With respect to the assessment and conditions of a dewatering licence, it has been determined through discussions with DERM that:
  - Assessment of environmental impacts will be undertaken via the EIS process, and via the process that results in awarding of an Environmental Authority (EA) to the Project;
  - Measures for monitoring, assessing, reporting, and mitigating any environmental impacts from mine dewatering will be conditioned via the Project's EA, and not the water licence;
  - Should the Project be awarded an EA, a dewatering licence would need to follow suit to allow dewatering to occur, however a dewatering licence would not be awarded without an EA;
  - A dewatering licence would not limit the volume of water that could be removed for dewatering purposes, and the water removed via mine dewatering could be utilised as a component of the Project's water supply; and,
  - The rights of existing groundwater users will still be protected under the provisions of the Water Act, but it is DERM's advice that "make-good", or alternate water supply agreements should be in place with existing groundwater users within the area of impact of the Project before a dewatering licence is issued, although existing groundwater users are ultimately afforded protection under the Water Act, this should not replace negotiated alternate water supply agreements between the Project and existing groundwater users.

4.2 Sustainable Planning Act 2009

The stated purpose of the Sustainable Planning Act 2009 is to seek to achieve ecological sustainability by:

(a) managing the process by which development takes place, including ensuring the process is accountable, effective and efficient and delivers sustainable outcomes; and

(b) managing the effects of development on the environment, including managing the use of premises; and

(c) continuing the coordination and integration of planning at the local, regional and State levels.

As stated in the section above relating to the Water Act, a water take in Queensland requires both an authority to take water (via a permit, licence, or stated exemption from either), as well as assessment as to whether a development permit is required to construct the physical works (e.g. a water bore) from which the water is to be taken.

The Sustainable Planning Act provides the mechanism (via the Integrated Development Assessment System, or IDAS), via which assessment of a proposed development is undertaken, and under which a Development Permit is granted.

The Project will require Development Permits for all groundwater bores that are drilled and constructed within the MLA, for purposes other than stock or domestic use, or construction of groundwater monitoring bores.

4.3 Water Resource (Burdekin Basin) Plan 2007

The Alpha MLA is located within the boundary of the Water Resource (Burdekin Basin) Plan (WRP). The WRP applies to the following water in the WRP area:

(a) water in a watercourse or lake;

(b) water in springs not connected to:

i. artesian water; or

ii. subartesian water connected to artesian water; and,

(c) overland flow water, other than water in springs connected to:

iii. artesian water; or

iv. subartesian water connected to artesian water.

The WRP does not specifically apply to groundwater though it is a requirement that the WRP consider the management and water supply requirements of existing groundwater schemes within the WRP area (e.g. the Giru Benefited Groundwater Area, and the Lower Burdekin delta groundwater system).

There are no groundwater systems in the Project area that are specifically mentioned in the WRP, therefore, the WRP plan has no bearing on groundwater in the Alpha MLA area. Legislative requirements relating to taking or interfering with groundwater in the Alpha MLA area are covered by the broad requirements of the Water Act, and the specific requirements of the Highlands subartesian area.

4.4 Environmental Protection Act 1994

The Environmental Protection Act 1994 (EP Act) promotes ecologically sustainable development, and has the stated objective “to protect Queensland’s environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends”.

Under the EP Act all persons have a general environmental duty, which is stated under section 319 as “a person must not carry out any activity that causes, or is likely to cause, environmental harm unless the person takes all reasonable and practicable measures to prevent or minimise the harm.”

Section 320 of the EP Act makes it a requirement to notify the administering authority (DERM) that serious or material environmental harm has occurred. However, the requirements under Section 320 do not apply if the harm is authorised under an environmental authority (EA). Therefore the project’s EA will specify the nature and extent of any authorised environmental harm, though any serious or material environmental harm resulting from the Project, that is not authorised under the EA, would still need to be reported under section 320.

4.5 Environmental Protection (Water) Policy 2009

4.5.1 General Outline

The Environmental Protection (Water) Policy 2009 (EPP (Water)) applies to all water in Queensland, and provides a framework for defining the environmental value of water and guidelines for water quality. The policy aims to protect water to the designated environmental value.

Environmental values (EV's) of specific waters to be protected or enhanced are defined in schedule 1 of the EPP (Water). No rivers in the Burdekin Basin catchment are specifically defined in schedule 1, therefore the EV's for waters in the area of the Alpha MLA are defined under section 6(2) of the EPP (Water) for all other waters in Queensland. Under section 6(2) of the EPP (Water) current EV's include:

(a) for high ecological value waters[2]—the biological integrity of an aquatic ecosystem that is effectively unmodified or highly valued;

(b) for slightly disturbed waters[3]—the biological integrity of an aquatic ecosystem that has effectively unmodified biological indicators, but slightly modified physical, chemical or other indicators;

(c) for moderately disturbed waters[4]—the biological integrity of an aquatic ecosystem that is adversely affected by human activity to a relatively small but measurable degree;

(d) for highly disturbed waters[5]—the biological integrity of an aquatic ecosystem that is measurably degraded and of lower ecological value than waters mentioned in paragraphs (a) to (c);

(e) for waters that may be used for producing aquatic foods for human consumption—the suitability of the water for producing the foods for human consumption;

(f) for waters that may be used for aquaculture—the suitability of the water for aquacultural use;

(g) for waters that may be used for agricultural purposes—the suitability of the water for agricultural purposes;

(h) for waters that may be used for recreation or aesthetic purposes, the suitability of the water for—

   i. primary recreational use; or

   ii. secondary recreational use; or

   iii. visual recreational use;

(i) for waters that may be used for drinking water—the suitability of the water for supply as drinking water;

(j) for waters that may be used for industrial purposes—the suitability of the water for industrial use; and

(k) the cultural and spiritual values of the water.

---

2 high ecological value waters means waters in which the biological integrity of the water is effectively unmodified or highly valued

3 slightly disturbed waters means waters that have the biological integrity of high ecological value waters with slightly modified physical or chemical indicators but effectively unmodified biological indicators

4 moderately disturbed waters means waters in which the biological integrity of the water is adversely affected by human activity to a relatively small but measurable degree.

5 highly disturbed waters means waters that are significantly degraded by human activity and have lower ecological value than high ecological value waters or slightly or moderately disturbed waters.

4.5.2 Implications for the project

For the purpose of the EIS groundwater and surface water is assessed to have the following EV's:

- *Agricultural purposes* - groundwater in the project area is used relatively extensively as stock watering supply, based on current usage patterns, groundwater has an environmental value of agricultural purposes, specifically watering of beef cattle and horses.
- *Cultural and spiritual values* – permanent or semi-permanent surface water features that are maintained to some degree by groundwater flow may have cultural significance in an area where surface water is normally ephemeral. These aspects are described further in the Cultural Heritage report, and specific surface water features are discussed in Sections 8.0 and 11.4.
- *Surface water features that may receive baseflow from groundwater (and may therefore contain groundwater dependent ecosystems)* – The local area around the proposed mine has been farmed since the 1800's and has been cleared and used for agriculture, predominantly beef cattle grazing. These farming practices modify the landscape, affecting the volume and rate of runoff, the flow characteristics of the creeks, and the recharge to groundwater. As such, the aquatic ecosystems of the area have been modified, and will have the biological integrity of modified aquatic ecosystems.

  Water available to ecosystems may include a mix of groundwater with soil water (unsaturated zone) and surface water. Groundwater Dependant Ecosystems (GDEs) are ecosystems which have their species composition and natural ecological processes determined in part by groundwater. The groundwater parameters that sustain GDEs are flux, level, pressure and quality, with dependence potentially being a function of one or all of these factors.

  Springs are known to occur approximately 40 km north of the MLA boundary, but no springs are known to occur on site. A palustrine wetland (Figure 5) occurs on Lagoon Creek within the MLA boundary. It is believed that the wetland was deepened in the 1970's to improve its suitability as a stock water supply and is considered to be perennial, but it has not been established whether groundwater plays a role in maintaining the wetland.

As discussed in Section 9.9.5, while groundwater in the area may be potable in some instances based on TDS values, groundwater can be above drinking water guideline values for metals and metalloids, and generally is not be suitable for drinking water consumption without complex treatment. For this reason groundwater in the area is not assessed to have an environmental value of drinking water.

5.0 CLIMATIC DATA

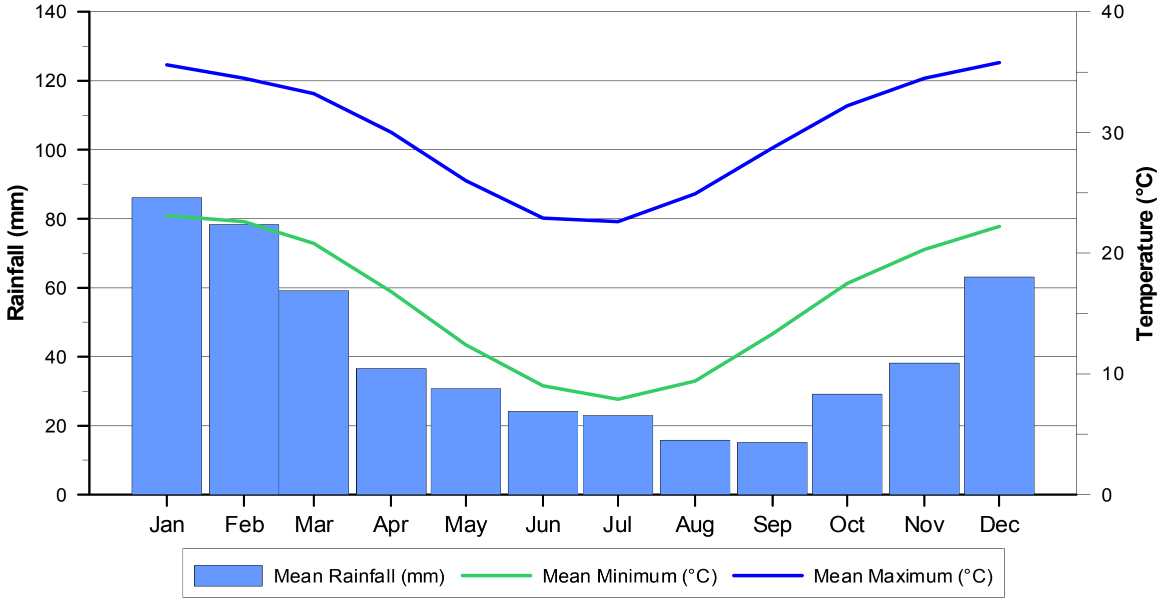
5.1 Regional Climate Data – Barcaldine BOM Station

This climatic description of the region in which the Project site is located has been compiled using the regional data collected by Australian Bureau of Meteorology (BOM) (http://www.bom.gov.au). Rainfall and temperature data is sourced from the BOM station at Barcaldine Post Office (Station 036007), located approximately 138 km west of the project site. Recording of data at Barcaldine Post Office has been occurring from 1886 to present.

Data trends indicate that mean annual rainfall for the region is approximately 499 millimetres (mm). Figure 5-1 shows that rainfall is highly seasonal, with the dry season peaking between August and September, and the wet season peaking from December through to February.

The coldest mean daily temperatures occur in July (8ºC), with November to January having a mean maximum temperature of 35.3ºC (Refer Figure 5-1).

Figure 5-1: Climograph for Barcaldine Post Office (1886 – 2009)



5.2 Rainfall and Evaporation – SILO Data

As the available climate data is only available from a weather station some 138 km from site, the Department of Environment and Resource Management (DERM) Silo Data Drill facility data was used to obtain synthetic climatic data for the centre of the MLA. The Data Drill accesses grids of data interpolated from surrounding Bureau of Meteorology (BOM) point observations. The interpolations are calculated by splining and kriging techniques. The data in the Data Drill are therefore all synthetic, although they have been derived from surrounding observed values. The key advantage of using the Data Drill is that rainfall and other climate data can be derived for any location throughout Australia, the data is continuous and can be provided for an extended period generally in excess of 100 years.

Averaged monthly SILO data for the period 1950 to 2009 is shown below in Figure 5-2. The data indicates that:

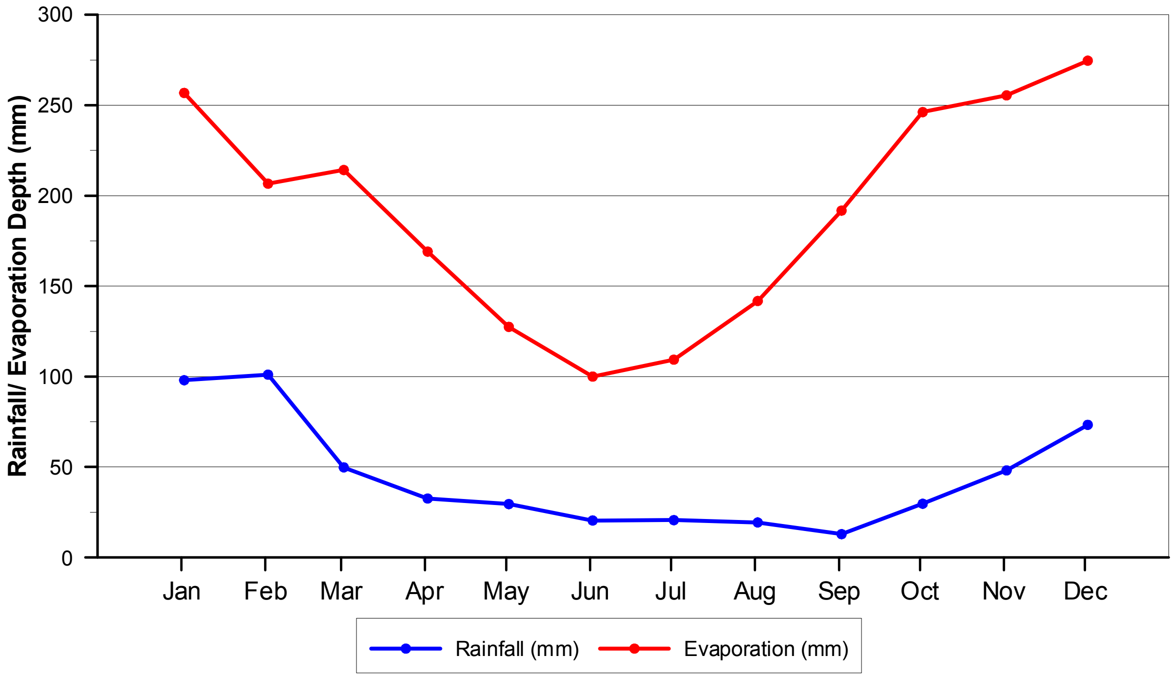
- Average annual site rainfall is approximately 535 mm and is highest in the wet summer season months between November and February and lowest during the dry months of winter;
- Average annual site evaporation (class A pan) is approximately 2,290 mm and is highest in summer and lowest in winter; and,
- Average evaporation is in excess of average rainfall during every month of the year, resulting in a significant rainfall deficit at site for every month of the year, under average conditions.

For the purpose of groundwater analysis the monthly rainfall data was analysed to produce a Rainfall Residual Mass (RRM) curve.

The RRM is calculated by subtracting the long-term average monthly rainfall (535 mm average annual rainfall divided by 12 equals 44.6 mm average monthly rainfall) from the synthetic monthly rainfall, to provide a monthly "departure" from average conditions. If the monthly rainfall is above average the resulting rainfall departure number is positive, whereas if rainfall is below average, the number is negative. The monthly rainfall departures are summed cumulatively to provide the RRM. A number of below-average rainfall months will result in a falling RRM curve, while a number of above average rainfall months will result in a rising RRM curve. The RRM curve is used routinely in groundwater investigations due to the strong correlation in many locations between the RRM and groundwater level trends, especially for shallow aquifers. Analysis of the RRM curve is useful as it allows analysis of rising or falling trends in groundwater levels against long-term climatic data, i.e. it allows for consideration of factors such as long-term drought periods in assessing groundwater level response, allowing impacts from mining to be assessed against underlying groundwater level trends.

Figure 3 shows the calculated RRM curve plotted against monthly rainfall from January 1980 to February 2010.

Figure 5-2: Monthly Rainfall and Evaporation Data from SILO Datadrill



Rainfall data is also being collected from site from two tipping-bucket rain gauges that have been in operation since mid-December 2009. Site rainfall data, compared to SILO data over the same period of data collection, is shown graphically in Figure 4. A comparison between data collected from site, and synthetic data from SILO Data Drill, is shown in Table 5-1.

From Figure 4 it can be seen that the SILO synthetic rainfall data under-predicted the magnitude of a rainfall event on 31 January as well as other high magnitude events. From Table 5-1 it can be seen that rainfall over the period of comparison (19 Dec 2009 to 31 March 2010) was relatively similar between sites – the difference is that the SILO data applied smaller rainfall depths but over a greater number of days.

It should be noted that average annual rainfall at site is approximately 535 mm (based on SILO data), so the 2009-2010 wet season rainfall was relatively significant.

SILO data is regarded as suitable for site use for design purposes, as the data is generated from long-term records from the three closest rainfall stations to site (Barcaldine, Clermont, and Emerald). However, the discrepancies noted above highlight the need to collect data from a climate station installed at site.

Table 5-1: Rainfall comparison – 19 Dec 2009 to 31 March 2010

	SILO Data Drill	AVP-13	AVP-01
Rain days	56	39	43
Total Rainfall (mm)	543.7	563.6	558.2

6.0 STRATIGRAPHY/ HYDROSTRATIGRAPHY

6.1 Regional Geology overview

The Project is located within the Galilee Basin (Figure 6-1), a sequence of Late Carboniferous to Middle Triassic sedimentary rocks overlying Late Devonian to Early Carboniferous sedimentary and volcanic rocks of the Drummond Basin.

The rocks of the Galilee Basin are of similar age to those of the Bowen Basin (Late Permian) which are exposed to the east of the Drummond Basin. The Bowen and Galilee Basins are separated along a north-trending structural ridge between Anakie and Springsure, referred to as the Springsure Shelf. Much of the western portion of the Galilee Basin is interpreted as occurring beneath Mesozoic sediments of the Eromanga Basin. The Anakie Inlier comprises older Palaeozoic rocks.

Late Permian, coal-bearing strata of the Galilee Basin sub-crop are found in a linear, north-trending Belt in the central portion of the exposed section of the Basin and are essentially flat lying (dip generally <1° to the west). No major, regional scale fold and fault structures have been identified in regional mapping of the Project area.

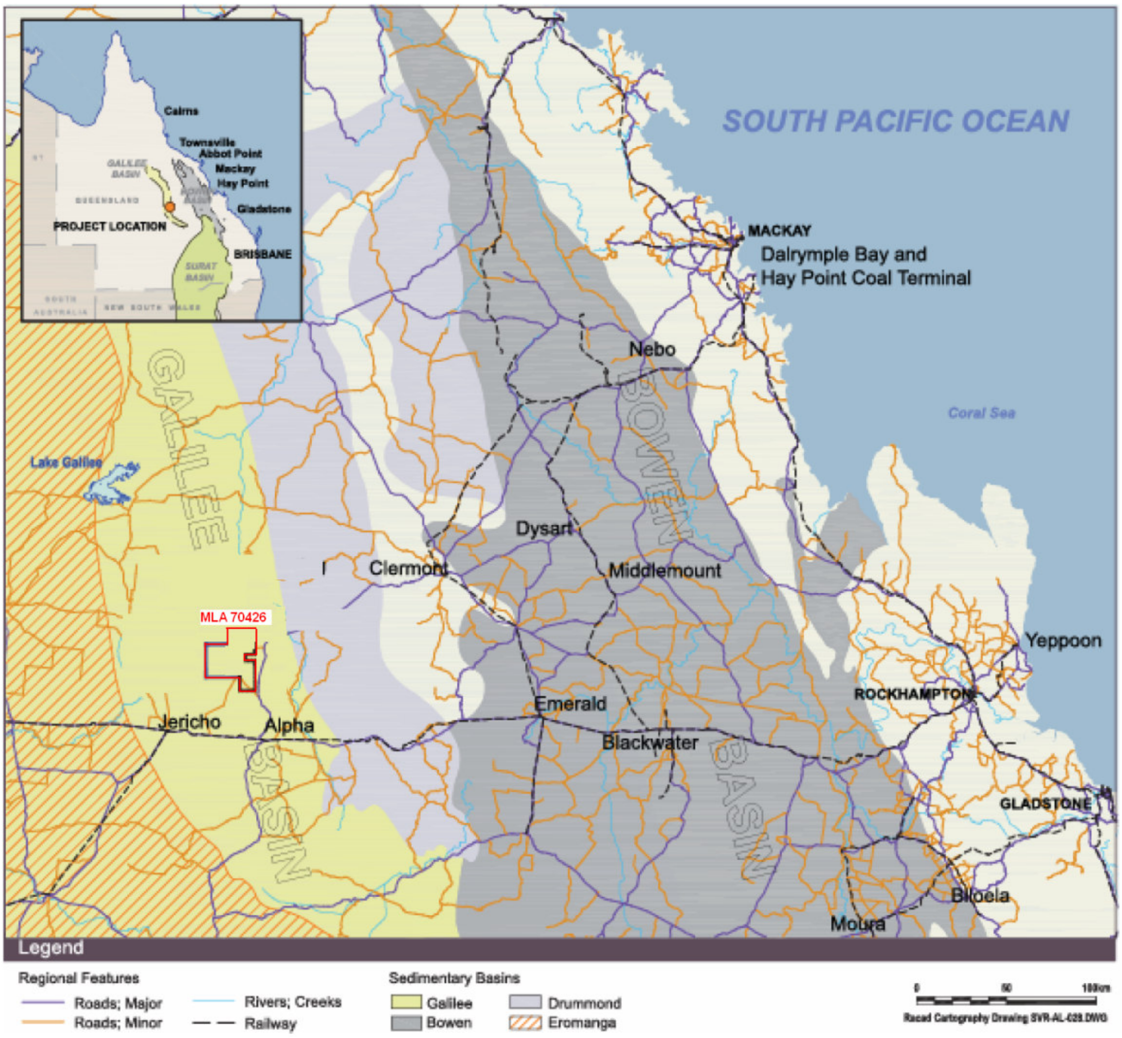


Figure 6-1: Location of Geological Basins

6.2 Stratigraphy/Hydrostratigraphy of the Project Site

Figure 6-2 (below) shows a typical east-west cross section across the deposit.

6.2.1 Cainozoic

In the Tertiary sediments above the base of weathering, water is encountered only sporadically, and the Tertiary sediments are not regarded as comprising a significant groundwater resource. Quaternary alluvium associated with current surface water drainage systems may contain localised occurrences of groundwater, especially following wet season rainfall, but the alluvium is not extensive or continuous, with limited effective storage. It is therefore not regarded as a significant groundwater resource.

6.2.2 Rewan Formation

The Cainozoic unconformably overlies the Rewan Formation and Permian Sequence. Drilling shows the contact to undulate. The Rewan Formation occurs only in the far west of MDL333 and

MDL285, where it subcrops under Cainozoic cover. The Rewan Formation comprises typical green to brown-purple siltstone and fine grained sandstone. The base of the Rewan Formation is located some 30 to 50 m above the uppermost A seam coal ply.

6.2.3 Permian Sediments

Permian sedimentary deposits at site comprise the Bandanna Formation and the underlying Colinlea Sandstone, and these units contain both economic and sub-economic coal seams. The coal seams are named alphabetically A through F, with the A seam being uppermost. There are two major coal seams that will be the target of mining within the deposit; the C seam and D seam, which vary in thickness from 3 m to 6 m in the area to be mined. The overlying A and B coal seams will not be the target of mining by the Project, as the western limit of the proposed open cut does not extend to include these seams (Figure 6-2).

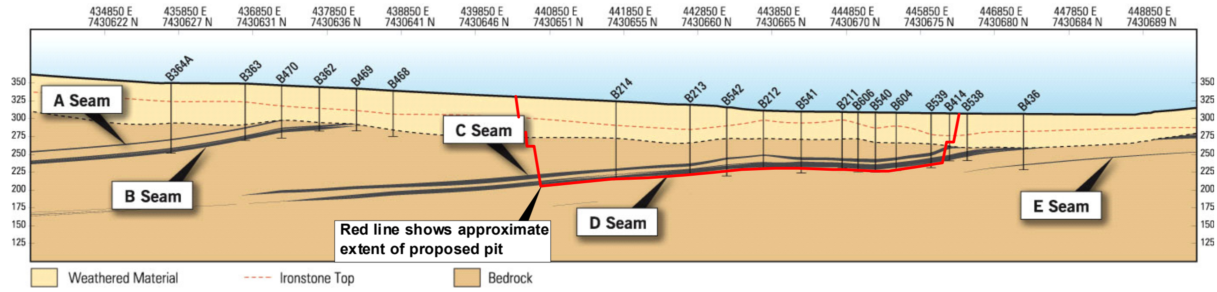


Figure 6-2: Geological W-E cross-section through project area (Source: Hancock)

Geologically the boundary between the Bandanna Formation and the underlying Colinlea Sandstone is taken to be an interval above the C coal seam at which sedimentation style changes from increasingly argillaceous (i.e. becoming more clayey with depth) to increasingly arenaceous (i.e. becoming more sandy with depth). Therefore the Bandanna Formation hosts the A and B coal seams, while the Colinlea Sandstone hosts the target C and D coal seams.

From a groundwater perspective, major hydrostratigraphic boundaries occur within the MLA at the base of weathering, beyond which groundwater is often encountered under confined conditions in the B-C and C-D sands and B and C coal seams, and also at the base of the D coal seam. It has been observed during exploration drilling that groundwater inflows are relatively low until the D coal seam is drilled through, at which point higher rates of groundwater flow are often encountered. The sandstone unit directly below the D coal seam and above the E coal seam (D-E Sandstone) will be the major target of aquifer depressurisation, and the overlying sandstone (B-C sandstone, C-D sandstone, and C and D coal seams) will need to be locally dewatered in order for mining to occur safely.

Below the D-E sandstone the Colinlea sandstone coarsens with increasing depth. The sub-E sandstone (between the E and F coal seams) and sub-F sandstone (below the F coal seam, and to the base of the Colinlea Sandstone) are regarded as containing significant groundwater resources, though seepage modelling undertaken to date (refer Section 10.1.2) indicate that the sub-E and sub-F sandstones will not require active depressurisation.

The Colinlea Sandstone is in turn underlain by sediments of the Joe Joe Formation. The Jericho 1:250 000 scale geological map describes the Joe Joe Formation as “mudstone, labile sandstone, siltstone, shale” and on this basis the Joe Joe Formation is interpreted to be a confining unit below the Colinlea Sandstone aquifer.

The stratigraphy of the Galilee Basin in the Alpha area is described in Table 6-1 below.

Table 6-1: Site Stratigraphy

Age	Stratigraphic unit		Lithology	Thickness	Aquifer Type
Quaternary			Alluvium	15 - 20 m	Unconfined
Tertiary			Argillaceous sandstones and clays	40 m	Unconfined
Unconformity					
Triassic	Clematis Sandstone		Quartz sandstone, minor siltstone and mudstone	140 m	Confined aquifer – GAB aquifer, occurs to west of MLA
	Rewan Formation/ Dunda beds		Green-grey mudstone, siltstone and labile sandstone – Rewan Fm grades into Dunda beds below Clematis Sandstone	175 m	Confining unit – base of hydrogeological GAB – occurs to the west of the MLA
Late Permian	Bandanna Formation		Sandstone	10 - 30 m	Unconfined to semi-confined
			Coal – A Seam	1 – 2.5 m	Unconfined to semi-confined
			A-B Sandstone - Labile sandstone, siltstone and mudstone	10 m	Unconfined to semi-confined
			Coal – B Seam	6 - 8 m	Unconfined to semi-confined
Early Permian	Colinlea Sandstone		B-C Sandstone - Labile sandstone, siltstone and mudstone	70 - 90 m	Semi-confined to confined
			Coal – C Seam – target coal seam	2 - 3 m	Confined
			C-D Sandstone – Labile sandstone, siltstone and mudstone	5 - 20 m	Confined aquifer
			Coal – D Seam – target coal seam	4.5 – 6 m	Confines underlying D-E sandstone
			D-E Sandstone	15 m	Confined aquifer
			Coal – E Seam – dirty coal/ carbonaceous shale – generally considered uneconomic	0.1 – 0.4 m	Leaky confining layer
			Sub-E sandstone, labile sandstone, siltstone and mudstone	15 - 20 m	Confined aquifer
			Coal Seam F. Localised thick geological section, no working section	0.5 – 5 m	
			Labile sandstone, siltstone and mudstone	Unknown	
Early Permian	Joe Joe Formation		Labile and quartz sandstone	Transition to Joe Joe Formation	
Unconformity					
Early Carbonaceous	Drummond Basin				

6.3 Geological structures

No major regional scale fold and fault structures have been identified to date in regional geology of the Project area (Salva, 2010). For geological modelling of the coal resources no faults or intrusions have been included. This is because there is no evidence of intrusive activity and major faulting appears to be absent.

6.4 Relationship to the GAB

The lower boundary of the hydrogeological GAB (outcrop of Rewan Fm) occurs approximately 10 - 15 km west of the western limit of mining.

In order for the Project to impact on the water resources of the GAB, drawdown from the operation would need to transfer against the vertical hydraulic conductivity of the Rewan Formation aquitard, which is taken to be approximately 175 m thick in the area to the west of the MLA. The vertical hydraulic conductivity of the Rewan Formation is taken to be in the order of 1.2×10^{-8} to 1.2×10^{-9} m/s (1×10^{-4} to 1×10^{-3} m/day), based on calibrated values for GAB confining units from an early phase of GAB groundwater modelling.[6]

The potential for the Project to impact the groundwater resources of the GAB is regarded as remote, as drawdown would be required to transfer through approximately 175 m of aquitard with a maximum vertical hydraulic conductivity of 1×10^{-4} to 1×10^{-3} m/day. However, the potential is to be investigated as a component of the regional groundwater modelling study, which will be supplemental to this report.

7.0 TOPOGRAPHY

The broad topographical setting of the catchment at the Project site consists of flat to undulating topography, with a range of 305 – 330 m above sea level. Hills and tertiary sand plains create higher relief on the western and eastern margins (formed by bordering mountains/hills of the Great Dividing Range to the west and Drummond Range to the east). These rises ascend approximately 70 m above the plains. Lagoon Creek is the central topographical feature, comprising of incised drainage profiles, formed within a broad floodplain.

8.0 EXISTING SURFACE WATER ENVIRONMENT

The major surface water drainage feature through the Alpha MLA is Lagoon Creek, which drains from south to north through the MLA (Figure 5). Major systems, which drain the site from west to east toward Lagoon Creek (i.e. from the eastern foothills of the Great Dividing Range) include Spring Creek and Sandy Creek. Drainage from the east of the MLA occurs from a low unnamed range that comprises the outcrop of the Colinlea Sandstone and underlying Joe Joe Formation (refer Section 6-2 for site geology). Drainage from this range is to the west toward Lagoon Creek, and to the east (at the eastern margin of the MLA) toward Native Companion Creek.

[6] Audibert, M. (1976) Progress Report on the Great Artesian Basin Hydrogeological Study 1972 – 1974. Bureau of Mineral Resources, Geology and Geophysics, Record 1976/5

At the confluence of Lagoon Creek and Sandy Creek the drainage system continues north (as Sandy Creek) until joining the Belyando River, which in turn drains to the Suttor River, and ultimately to the Burdekin River.

Other surface water features shown on Figure 5 include:

- an area of palustrine wetland, which is interpreted to be a perennial water feature, and which will be monitored to establish whether the feature is groundwater dependent. This is discussed further in Section 11.4; and,
- the location of registered springs as defined by Springs of Queensland[7]. The nearest of these springs to the boundary of the Alpha MLA is spring reference no. 405, which is located just over 40 km from the boundary of the MLA.

9.0 EXISTING GROUNDWATER ENVIRONMENT

9.1 Summary of Previous Investigations

Prior to the current phase of groundwater investigations there have been at least three phases of groundwater investigation undertaken on the parcel of land now described as MLA 70426. These phases of investigation include:

Phase 1 – Surface water, groundwater, and geotechnical investigations by Australian Groundwater Consultants (AGC) for Bridge Oil Limited, during 1982-1983. In summary, these investigations provided:

- Information from the drilling of pumping test wells and monitoring bores at four sites (TPB-1 to TPB-4);
- Information (observations and calculated hydraulic properties) from pumping tests undertaken at four sites (TPB-1 to TPB-4). Results from these pumping tests are summarised in Tables 9-1 and 9-2;
- Summary of groundwater chemistry (TDS, major and minor ions) from the four pumping test sites;
- Summary of groundwater conditions and observations for the site, including a preliminary conceptual groundwater model;
- Summary of surface water investigations, including description of the surface water system, runoff yield potential, and preliminary flood studies; and,
- Water supply potential of surface water and groundwater systems at the site.

Phase 2 – Groundwater and geotechnical investigations undertaken by Longworth & McKenzie during 1984 for Bridge Oil Limited. In summary, these investigations provided:

- Information from the drilling of pumping test wells and monitoring bores at one site, with pumping wells developed in vertically separated aquifer systems. Pumping test bores included bore W1 which was constructed within “aquifer 1” (this covers an interval including the C and D coal seams and interburden); and bore W2 which was constructed within “aquifer 2” (the sandstone aquifer between the D and E coal seams); and,

7 Springs of Queensland version 4.0, Aug 2005, http://www.epa.qld.gov.au/wetlandinfo/site/factsfigures/springs.html

- Information (observations and calculated hydraulic properties) from pumping tests undertaken on bores W1 and W2.

Pumping tests undertaken by Australian Groundwater Consultants (AGC)[8] in 1983 and by Longworth & McKenzie[9] in 1984, are summarised below in Tables 9-1 and 9-2.

Phase 3 – Prefeasibility Stage Investigations undertaken by Connell Hatch

The Connell Hatch investigations did not present any new work, but provided a summary of previous investigations, and re-iterated the volume of groundwater likely to be held in storage, as calculated by the AGC investigation.

9.2 Aquifer Hydraulic Properties

Aquifer hydraulic properties have been obtained from a number of pumping tests undertaken on site during the previous groundwater investigations described above.

A description of previous pumping tests is shown in Table 9-1. The range of hydraulic properties obtained from each test is shown below in Table 9-2. The location of test bores drilled for previous investigations is shown in Figure 6.

Table 9-1: Summary of Pumping Tests

Bore	**Test Duration**	**Interval Tested**	**Pumping Rate (L/s)**	**Comments**
Testing undertaken by AGC 1983				
TPB-1	100 hr	D-E Sands	10	37 m of drawdown in pumping bore. Water level drawn down to base of top screens.
TPB-2	24 hr	D-E Sands	3.6	At a pumping rate of 10 L/s the water level dropped to the pump intake. Testing continued at 3.6 L/s. Drawdown during test was 55 m in the pumping bore.
TPB-3	100 hr	C-D Sands	10	19 m of drawdown in pumped bore. Water level almost down to top of aquifer.
TPB-4	100 hr	D-E Sands	6	44 m of drawdown in pumped bore. Water level drawn down within the aquifer.
Testing undertaken by Longworth & McKenzie 1984				
W-1	2 days	C-D Sands	0.1	Bores W-1 and W-2 were constructed at the same location, but were screened within separate aquifers. W-1 was constructed within “Aquifer 1” (C-D Aquifer of AGC reports), while W-2 was constructed within “Aquifer 2” (E Aquifer of AGC Reports) 5.5 m of drawdown in pumped bore.
W-2	15.87 days	D-E Sands	1.03	34.27 m of drawdown in pumping bore.

[8] AGC (1983) Alpha Coal Project (A to P 245C), Surface Water and Groundwater Aspects – Preliminary Evaluations. Report for Bridge Oil Limited

[9] Longworth & McKenzie (1984) Report on Geotechnical and Groundwater Investigation (1984) Area 2, ATP245C, Alpha Queensland for Bridge Oil Limited. Report Reference UGT0115/KDS/ejw

Table 9-2: Aquifer Hydraulic Properties from Pumping Tests

Pumping Test Bore	Bore Monitored	Distance from Pumped Bore (m)	Unit	Analysis Method	Transmissivity (T) (m²/day)	Aquifer thickness (m)	Hydraulic Conductivity (K)		Storage Coefficient (S)
							(m/d)	(m/s)	
AGC (1983)									
TPB1	TPB1	0	D-E Sandstone	Jacob	41.6	24	1.73	2.01E-05	-
				Jacob Late Stage	23.2	24	0.97	1.12E-05	-
				Recovery	29.1	24	1.21	1.40E-05	-
	B597	10.05	D-E Sandstone	Jacob	43.9	30	1.46	1.69E-05	4.80E-05
				Jacob Late Stage	30.4	30	1.01	1.17E-05	4.70E-04
				Recovery	29.8	30	0.99	1.15E-05	-
	B593	260	D-E Sandstone	Jacob	42.7	24	1.78	2.06E-05	3.60E-05
				Jacob Late Stage	28.4	24	1.18	1.37E-05	4.65E-05
				Recovery	28	24	1.17	1.35E-05	-
	B591	572.5	D-E Sandstone	Jacob	42	28	1.50	1.74E-05	1.26E-04
				Recovery	65.3	28	2.33	2.70E-05	-
				Average - Jacob			**1.56**	**1.80E-05**	**7.00E-05**
				Average - Jacob late stage			**1.20**	**1.39E-05**	**2.58E-04**
				Average - Recovery			**1.43**	**1.66E-05**	-
TPB2	TPB2	0	D-E Sandstone	Jacob	2.8	16	0.18	2.03E-06	-
				Recovery	4.7	16	0.29	3.40E-06	-
	B538	20.03	D-E Sandstone	Jacob	5.3	16	0.33	3.83E-06	6.60E-05
				Recovery	4	16	0.25	2.89E-06	-
				Average - Jacob			**0.25**	**2.93E-06**	**6.60E-05**
				Average - Recovery			**0.27**	**3.15E-06**	
TPB3	TPB3	0	C-D Sandstone	Recovery	6.5	20	0.33	3.76E-06	
	B506	21.35	C-D Sandstone	Jacob	5.6	20	0.28	3.24E-06	1.10E-03
				Recovery	5.4	21	0.26	2.98E-06	
				Average			**0.30**	**3.50E-06**	**1.10E-03**
TPB4	TPB4	0	D-E Sandstone	Jacob	10.3	32	0.32	3.73E-06	
				Recovery	9.8	32	0.31	3.54E-06	
	B627	32.9	D-E Sandstone	Jacob	14.8	26	0.57	6.59E-06	1.00E-05
				Recovery	18.3	26	0.70	8.15E-06	

Pumping Test Bore	Bore Monitored	Distance from Pumped Bore (m)	Unit	Analysis Method	Transmissivity (T) (m^2/day)	Aquifer thickness (m)	Hydraulic Conductivity (K)		Storage Coefficient (S)
							(m/d)	(m/s)	
	B191	370	D-E Sandstone	Jacob	16.6	30	0.55	6.40E-06	1.90E-05
				Recovery	15.9	30	0.53	6.13E-06	
				Average - Jacob			**0.48**	**5.57E-06**	**1.45E-05**
				Average - Recovery			**0.51**	**5.94E-06**	
Longworth & McKenzie (1984)									
W1	W1	0	C-D seams/interburden	Jacob early time	2.8	24	0.12	1.35E-06	
	P1/1	30	C-D seams/interburden	Jacob early time	4.3	24	0.18	2.07E-06	1.30E-03
	P3		C-D seams/interburden	Jacob early time	2.8	21	0.13	1.54E-06	8.00E-03
				Average			**0.14**	**1.66E-06**	**4.65E-03**
W2	W2	0	D-E Sandstone	Leaky aquifer analysis	4.6	21	0.22	2.54E-06	
	P1/2	30	D-E Sandstone	Leaky aquifer analysis	4.3	15	0.29	3.32E-06	3.20E-05
	P2/2	50	D-E Sandstone	Leaky aquifer analysis	4.3	15	0.29	3.32E-06	3.70E-05
				Average			**0.26**	**3.06E-06**	**3.45E-05**

9.3 Summary of Current Investigations

Groundwater investigations and analysis for the current phase of groundwater studies include:

- Vibrating wire piezometer monitoring bores have been installed at 17 sites, monitoring 46 vertical intervals (within the sub-E sandstone, D-E sandstone, C-D sandstone, B-C sandstone) – refer Figure 8 for bore locations;
- Standpipe monitoring bores have been installed at four sites (monitoring the sub-E sandstone, D-E sandstone, C-D sandstone);
- Test pumping bores have been installed at three sites. Two bores are constructed within the D-E sandstone, and one bore is constructed within the sub-E sandstone. Pumping test results will be presented in a supplementary report;
- Seepage modelling, undertaken to predict inflow rates to the pit, extent of drawdown due to passive drainage, and geotechnical requirements for mine dewatering. Results of modelling are presented in this report, but the full modelling report will be provided in a supplementary report;
- Regional three-dimensional groundwater modelling is being undertaken to provide prediction of the magnitude and extent of groundwater level impacts from Alpha and Kevin's Corner projects (cumulative impacts). The regional groundwater modelling is ongoing as it relies on input from the Kevin's Corner project. Results will form an addendum to this report and could potential be included in any supplementary EIS reporting;
- Final void modelling, to provide predictions of water levels and long-term water quality (in terms of salinity). The results of final void modelling compiled using the regional model; and
- Survey of existing groundwater facilities (bore survey) – refer Section 9.4.2.

Current investigations are discussed in further detail in subsequent sections of this report.

9.4 Existing Groundwater Users

9.4.1 DERM Groundwater Database

Figure 7 shows registered bores from the DERM groundwater database within an area of just over 20km from the boundary of MLA 70426. The DERM groundwater database has fields to indicate the status of the bores, which includes existing, proposed, abandoned and destroyed, or abandoned but still useable. The database has been filtered to exclude bores that are listed as being abandoned and destroyed, and the remaining bores are colour-coded based on whether they are listed as existing, proposed, or abandoned but still useable.

There are 176 registered groundwater bores within the area shown on Figure 7, of which 160 are listed as existing, 15 listed as abandoned but useable, and 1 listed as proposed. Within 20km of the edge of the mine pits there are 61 bores listed as existing, 2 listed as abandoned but useable, and 1 listed as proposed.

The number of groundwater bores within the vicinity of the Project indicates that groundwater is a resource of some importance in the area.

9.4.2 Bore Survey

Within the Highlands Declared Subartesian Area a development permit for bore construction, and a water entitlement (by way of licence, water permit etc) is currently not required for stock or domestic bores (Section 4). For this reason, the DERM groundwater database may not contain information on all bores in the area and it was therefore necessary to undertake a bore survey to identify the presence of bores that may be impacted by the Project.

A formal survey of bores is planned to be conducted, and the results of the survey will provide the Proponent with additional baseline data and identified monitoring points. These data will assist in compiling optimum make-good water replacement plans, should mining activities impact on neighbouring bores.

The bore survey is to be undertaken as a staged approach, which will include:

Stage 1 – Survey of existing groundwater extraction facilities within the zone of predicted impact of the proposed open cut mine. Once regional groundwater modelling is complete the zone of predicted impact may be amended. If the predicted extent of impact extends further than the properties listed below, an additional survey will be undertaken to include the potentially affected properties: The initial survey will include bores on the following properties (refer Figure 7 for property locations):

- Hobartville
- Wendouree
- Forrester
- Surbiton
- Surbiton South
- Burtle
- Kia Ora
- Spring Creek
- Tresillian
- Mentmore
- Monklands

Stage 2 – Undertake specific capacity tests on appropriate bores identified by the Stage 1 bore survey. A specific capacity test provides information on the volume of water obtained from the bore per m of drawdown. It is intended that existing bore infrastructure be utilised for the tests, as this will allow for the tests to be repeated at a later date if required. The specific capacity tests provide a baseline dataset, including information on the normal operating range of groundwater levels for each bore, which can be used to assess the degree of any impact at each site that may be attributable to the Project. The bore survey will also assist in identifying neighbouring bores that may be used as monitoring points during mining.

9.4.3 Existing Groundwater Use

Based on discussions with landholders to date, it is apparent that the main use for groundwater in the region is for stock supply. Many properties also have a "house bore" and this water is used for domestic purposes. Drinking water supplies are understood to be obtained from rainfall storage tanks.

9.4.4 Groundwater monitoring network

Groundwater monitoring bores have been constructed at a number of sites throughout the Alpha MLA, and in areas to the north of the MLA, as shown on Figure 8. Sites have been constructed as either vibrating wire piezometers, which monitor groundwater level fluctuation, or standpipe monitoring bores, which can be used for both groundwater level and groundwater quality monitoring. The existing monitoring bore network is discussed below. Additional proposed monitoring bores are discussed in Section 11.

9.4.5 Vibrating Wire Piezometers

Vibrating Wire Piezometer (VWP) monitoring bores have been constructed at 17 sites within or adjacent to the Project Mining Lease Application (MLA 70426) area, with 46 separate intervals monitored (the number of VWPs installed in each bore ranges from one to four). The location of these bores is shown on Figure 8, and the interval monitored by each bore is shown in Appendix A.

The VWP bores were constructed using the grout-in method, where the piezometers are strapped to the outside of poly pipe at locations that correspond to their planned setting depth. The poly pipe then acts as a tremmie tube, as cement-bentonite grout is pumped down the inside of the poly pipe, with the column of grout rising up the borehole and displacing the contained water. Using this method the bores are fully grouted after installation of the piezometers. This method allows the piezometers to record changes in pore pressure adjacent to the piezometer, as the grout is porous and allows transfer of pressure. As the grout does not allow vertical movement of water it is possible to monitor a number of vertical intervals within the one hole without the risk of inter-aquifer transfer of water.

At eight sites within the Project area VWP bores are monitored using data loggers, which compile daily groundwater level records. In addition, two of these sites are equipped with tipping-bucket rain gauges, with rainfall data also captured by the data loggers.

The location of all VWP bores drilled and constructed to date, as well as location of bores with data loggers and rain gauges, is shown on Figure 8.

Water level plots for all VWP bores with data loggers are shown in Figures 9 to 11. The following observations are made with respect to VWP readings:

- For the monitoring period shown in Figures 9 to 11, the data loggers were recording pressure readings at 6-hourly intervals;
- Most of the piezometer readings show diurnal variations in groundwater level. A number of trends are apparent with respect to these diurnal groundwater level variations:
  - Within an individual bore the magnitude of variation increases with depth (i.e. generally the diurnal variation is more distinct in VWPs monitoring the D-E sands interval than for overlying sediments);
  - The magnitude of variation increases to the west, e.g. compare the piezometer response for the D-E sands interval in the east of the lease area (AVP01, AVP03, AVP07, AVP10) with bores in the middle of the lease area (AVP04) and in the western part of the lease (AVP11, AVP13); and
  - For a number of bores a trend is evident (refer AVP04, VW2; AVP11, VW3; AVP13, VW3) that overprints the diurnal variation discussed above. In these cases it appears that pressures rise before significant rainfall events and reduce following rainfall.
- The interpretation at this stage is that these diurnal variations are due in part to earth tides (caused by deformation of the solid earth as it rotates within the gravitational field of the sun and moon) and barometric effects (i.e. from passing high and low pressure systems).

Barometric monitoring equipment will be installed at site. Once this occurs, data correction to remove earth tide and barometric effects will be undertaken, and updated groundwater level plots will be compiled on a regular basis.

A number of existing monitoring bores are located within the mining footprint, and will therefore be destroyed by mining. A program will be implemented once mining commences to extend the existing network, and to replace bores destroyed by mining with bores in alternative locations.

9.4.6 Standpipe Monitoring Bores

Standpipe monitoring bores have been constructed at sites shown on Figure 8. These bores will be utilised for groundwater level as well as groundwater quality monitoring. The interval screened by each standpipe monitoring bore is shown in Appendix A. The construction of additional standpipe piezometer monitoring points will be undertaken to enable groundwater level and quality monitoring to be undertaken at specific locations, as outlined in Section 11.

9.5 Potentiometric Surface and Groundwater Flow Direction

9.5.1 Water level data from Exploration Bores

Groundwater level data has been reviewed from over 250 groundwater exploration bores within MLA 70426 and the adjacent Kevin's Corner lease (MLA 70425). From this data, a potentiometric surface map has been produced (Figure 12) which must be viewed with consideration for the following:

- The water levels were measured in open exploration holes, and therefore represent a composite water level for all water-bearing intervals encountered within each borehole; and,
- Water levels are taken from recent phases of exploration drilling, but the levels have been collected over a period of approximately 1 year. Therefore the potentiometric surface contours do not represent a surface at a single moment in time.

In spite of the above limitations a general trend is evident from the data, i.e. the water level is higher in the west and lower in the east, suggesting that the composite potentiometric surface is a subdued reflection of topography (i.e. mimics topography), with groundwater flowing towards Lagoon Creek.

9.5.2 Water Level Monitoring Bores

A number of VWP bores were installed during the 2009 exploration drilling program (as discussed above in Section 9.5.2), and these bores generally targeted the sandstone aquifer below the D seam (i.e. D-E sandstone interval, within the Colinlea Sandstone) as well as sandstone unit above the D seam (typically C-D sands, within the Bandanna Formation). Figure 13 shows the potentiometric surface of the D-E sands aquifer (i.e. upper Colinlea Sandstone aquifer) for readings taken in December 2009. Water pressures are higher in the west and southwest of the lease area and lower in the east toward Lagoon Creek. This indicates that the potentiometric surface of the D-E sandstone (Colinlea Sandstone) follows the same general trend as shown in Figure 12 for the potentiometric surface generated from exploration drilling data.

9.6 Groundwater Recharge

9.6.1 Background on Groundwater Recharge

Groundwater recharge is a difficult area of study. One method of estimating recharge is to compare long-term groundwater level trends from bore hydrographs to the rainfall residual mass curve (discussed in Section 5.2), and to then undertake an analysis known as cumulative rainfall departure (CRD). The aim of the analysis is to provide an indication of the intensity of rainfall required for recharge to occur, as it is recognised that not all rainfall events result in recharge. One reason for this is that the hydraulic conductivity of unsaturated material is low relative to the hydraulic conductivity of the same material when saturated. For rainfall events below a particular intensity water recharge is restricted due to:

- Rainfall run off via the surface drainage system;
- Lost through evapotranspiration (resulting in no deep drainage); or
- Infiltrates to shallow depth until encountering low permeability layers, at which point the water is directed down topographic gradient as interflow (below the ground surface but above the regional water table) until being removed via plant roots, evaporation, or discharge to surface water drainage features.

A study of recharge rates to GAB intake beds was undertaken by Kellett et al, (2003). In line with the process described above, it was concluded that rainfall events in excess of 200 mm in a month in the area of the intake beds is required before marked recharge events will occur. The study also concluded that recharge could be described under three distinct recharge processes, as summarised in Table 9-3.

Table 9-3: Recharge Process of the Great Artesian Basin Intake Beds (Kellett et al 2003)

Process	**Recharge Rate (mm/year)**	**Description**
Diffuse rainfall	Up to 3 mm	A relatively low rate of recharge that occurs over a wide area of the intake beds in response to average rainfall conditions. Recharge rates for diffuse rainfall range from < 1mm to ~3mm/year, up to 10 mm/year in localised areas.
Preferred pathway flow	0.5 to 28.2	Preferred pathway flow is regarded as the dominant recharge mechanism for GAB intake beds. The study concluded that rainfall events in the order of 200mm per month or more are required for preferred pathway flow to be initiated. An important aspect of this process is that the regolith becomes saturated during periods of high magnitude rainfall, and once this occurs "preferred pathway flow" can occur though fissures, joints, or other more permeable pathways.
River leakage	up to 30	Localised recharge zones where rivers cross subcrops of intake beds. Rivers may alternate between recharge and discharge conditions along different stream reaches, or seasonally.

Recharge process at the Project site are discussed below, with reference to the recharge processes described above, and observations from site.

9.6.2 Groundwater Recharge – Project Area

a) Observations from Site

Eight vibrating wire piezometer sites have had data loggers fitted since December 2009, and two automated rain gauges are installed at two of these sites (refer Figure 8 for bore locations, and Figures 9 to 11 for VWP hydrographs). It is noted in Kellett et al (2003) that marked GAB recharge events are generally associated with monthly rainfall totals in excess of 200 mm, and the rainfall near Alpha (Barcaldine Bureau of Meteorology (BOM) weather station) recorded:

- 172.6 mm in December 2009;
- 271.2 mm in January 2010; and
- 209.3 mm in February 2010.

Therefore, the 2009/2010 wet season represented a potentially significant groundwater recharge event.

A review of VWP hydrographs (Figures 9 - 11) does not indicate an obvious increase in groundwater levels that could be interpreted as aquifer recharge in response to wet season rainfall, in spite of significant rainfall recorded at site over the 2009/2010 wet season. The hydrographs also display a confined response (to barometric effects and earth tides, as discussed in section 9.5.2).

Therefore it is interpreted that groundwater occurs under confined conditions in the western area of the MLA, as well as in the area immediately west of Lagoon Creek, potentially becoming unconfined to the east of Lagoon Creek in the outcrop area of the Colinlea Sandstone.

Geotechnical drilling undertaken in the area to the east of Lagoon Creek at the out-of-pit Tailings Storage Facility site (described in more detail in Section 10.2) encountered weathered rock (Colinlea Sandstone) at shallow depths of between 1 and 5 m. Hydraulic conductivity testing of the unsaturated weathered rock indicated very low hydraulic conductivity values (in the range of 10^{-7} to 10^{-8} m/s), and also found occurrence of (perched) groundwater in shallow unconsolidated sands lenses above weathered rock. These results tend to support the conclusion that even under above average rainfall conditions infiltration is limited in this area of Colinlea Sandstone outcrop, at least not until enough rainfall had occurred that the rock profile becomes saturated, which will then allow infiltration to occur more readily via the higher saturated hydraulic conductivity of the rock.

Analysis of site geology and available groundwater data, therefore, suggests two potential recharge mechanisms at site, as summarised below.

b) Recharge Mechanism 1 – Direct Recharge to Outcrop Areas

Figure 6 shows the geology of the project area. From this figure it can be seen that the Colinlea Sandstone outcrops in the eastern area of the Project MLA, and as described above weathered Colinlea Sandstone occurs at shallow depth between the area of outcrop and Lagoon Creek. Therefore, one possible recharge mechanism is via direct rainfall recharge to aquifer units in areas where they outcrop or subcrop (once sufficient rainfall has occurred to increase infiltration). This is the same mechanism by which recharge is assumed to occur within groundwater intake beds of the GAB. The main aquifer that underlies the project area is the sandstone units of the Colinlea Sandstone. The base of the Colinlea Sandstone is, for the purpose of this groundwater study, the eastern-most extent of Colinlea Sandstone outcrop (Figure 6). The top of the Colinlea Sandstone for the purpose of groundwater studies is taken to be the base of the D coal seam, and the D floor subcrop line is also shown on Figure 6. Recharge may therefore occur in this zone from either rainfall recharge or from downward leakage from Lagoon Creek following flow events in the creek. In this recharge model, groundwater recharge enters the Colinlea Sandstone within this outcrop/subcrop area and flows down-dip (i.e. generally westward).

c) Recharge Mechanism 2 – Diffuse recharge along the Great Dividing Range

Figure 1 shows the location of the Great Dividing Range relative to the MLA. The second recharge mechanism that has been considered is that recharge occurs in topographically elevated areas and flows down gradient (i.e. as a subdued reflection of topography) toward surface water drainage features in lower-lying areas. The major surface water drainage feature in the Project area is Lagoon Creek (Figure 5). The name Lagoon Creek is suggestive of at least semi-permanent surface water features that may receive some component of base flow from the groundwater system.

9.6.3 Proposed Recharge Mechanisms

The potentiometric surface contours presented as Figures 12 and 13 tend to support the second type of recharge mechanism, at least for the shallow aquifer system in the vicinity of the Project site.

If this is the case, a groundwater divide (i.e. representing a point at which some groundwater flow is to the west, and some flow is to the east) may exist for the Colinlea Sandstone to the west of the Project site. If this recharge mechanism is dominant, recharge from the area of Colinlea Sandstone outcrop and subcrop may not be as regionally significant as recharge that occurs to the west of the site, as the area to the west of the site represents a much greater surface area in which recharge could occur. However, it is possible that recharge as described by mechanism 1 may be important for deeper units within the Colinlea Sandstone aquifer.

The above interpretation is complicated by the fact that the coal units and interburden aquifers outcrop in the area of Lagoon Creek, and hydraulic testing data suggests that shallow units to the east are confined to semi-confined. Therefore, depending on surface water levels in Lagoon Creek, it is possible that the interburden aquifers are periodically recharged by Lagoon Creek (i.e. under flood conditions) and that the groundwater flow potential may be reversed under some conditions. However, under "average" dry conditions, it is considered most likely that groundwater recharge occurs to the west of the site, and that groundwater flow will be from elevated topographic areas toward Lagoon Creek. The following observations support the 2nd type of recharge mechanism:

- Groundwater flow direction in the western part of the MLA is from south-south-west to north-north-east, i.e. from a recharge area in the west to a discharge area at Lagoon Creek;
- Groundwater samples from bores within the Project MLA plot within the relatively mature or stagnant portion of a Piper (tri-linear) hydrochemistry plot (refer Section 9.9.4, Figure 18), which tends to support the observation that recharge is occurring at distance from site; and,
- Groundwater springs occur to the north of the MLA, but to the west of Lagoon Creek, indicating groundwater flow from topographically elevated areas in west toward Lagoon Creek.

The implications of the Project with respect to groundwater recharge are discussed in Section 10.3.

9.7 Groundwater Discharge

9.7.1 General

Groundwater flow contours indicate a groundwater flow direction from topographically elevated areas to the west of site, to the north-north east and toward Lagoon Creek. While groundwater level data is not yet available for the area to the east of Lagoon Creek, it is judged as likely that the potentiometric surface observed to the west of Lagoon Creek will be mirrored on the eastern side of the creek, i.e. the potentiometric contours will vee up Lagoon Creek, indicating a potential for groundwater discharge to the Lagoon Creek system.

However, groundwater in the Permian Bandanna Formation and Colinlea Sandstone (the units in which groundwater is usually first intersected) is encountered under confined conditions, even adjacent to Lagoon Creek. Analysis of groundwater levels (refer Section 9.5, Figure 13) indicates that the confined water level (potentiometric surface) is approximately 8 to 10 m from surface in areas adjacent to Lagoon Creek, and the Lagoon Creek alluvium is interpreted to be in the order of 15 to 20 m deep in central area of the creek (AGC, 1983). Therefore there may be a potential for groundwater to discharge to the bed sands of Lagoon Creek, but it may be that actual discharge only occurs if structures are present (e.g. faults, sand lenses, or joints) that allow the upward movement of groundwater to occur.

9.7.2 Areas of potential groundwater discharge

Within the region where the MLA is sited, potential for groundwater discharge has been identified in the following areas:

1. Discharge to the bed sands of Lagoon Creek, via the mechanisms described above.
2. Discharge to an area of palustrine wetland on Lagoon Creek. The area of palustrine wetland is shown on Figure 5, and has been identified in the surface water ecology report (Volume 2, Section 11 of this EIS). The feature is understood to be ephemeral, but is known to have been deepened by dredging, possibly in the 1980's. It is not currently possible to prove or disprove that the feature is groundwater dependent based on available data, so the feature will require further investigation (via construction of groundwater monitoring bores, monitoring of water levels in the surface water feature, and water quality analysis). This is described further in Section 11.4.
3. Groundwater springs. A number of springs have been identified on the Forrester property (Figure 5), with the closest spring being approximately 40 km north of MLA 70426 boundary. Discussions with the landholder indicate that, for at least one bore; the groundwater level is close to the surface in the area where other springs occur. The springs appear to line up in a north-south direction, and occur on the western side of Lagoon Creek. This is consistent with the interpretation that groundwater flow direction is from south-south-west to north-north-east (i.e. from recharge sources in the west to a discharge area at Lagoon Creek and that these are recharge springs). It is intended that the springs be investigated as part of the groundwater facilities survey (bore survey) that is discussed in Section 9.4.2.

9.8 Groundwater Yield

9.8.1 Review of Air-Lift Yield Data

Information on groundwater yield is available from the DERM groundwater database as well as site exploration drilling, where air lift yields are routinely measured at the end of the hole using a 90° v-notch weir. Most exploration bores extend below the D coal seam into the D-E sandstone. Therefore the air-lift yield figures presented below can be assumed to be based on inflows from the entire Permian sequence down to the top 5 – 10 metres of the D-E sandstone (where drilling is generally discontinued). The weathered overburden material, comprising the Tertiary sediments and weathered Permian sandstones, is generally cased off at the start of drilling, so it assumed that no water is reporting to the bore from the weathered Permian and overlying Tertiary sediments.

Figure 14 shows bore yield classes for data obtained from the DERM groundwater database. The data shows that of the 119 bores for which data was available (in the area covered by Figure 14):

- 46 (38%) recorded a yield less than 1 L/s
- 39 (33%) recorded a yield between 1 and < 2.5 L/s
- 21 (18%) recorded a yield between 2.5 and < 5 L/s
- 7 (6%) recorded a yield between 5 and < 10 L/s
- 6 (5%) recorded a yield in excess of 10 L/s

Figure 15 shows bore yield classes for data obtained from air-lift testing of site exploration boreholes. The data shows that of the 457 bores for which data was available (in the area covered by Figure 15):

- 263 (57%) recorded a yield less than 1 L/s
- 141 (31%) recorded a yield between 1 and < 2 L/s
- 45 (10%) recorded a yield between 2 and < 5 L/s
- 8 (2%) recorded a yield between greater than 5 L/s

The data from the DERM groundwater database and exploration drilling suggests that the majority of the bores in the area will yield < 2 L/s. However, high yielding bores (10 L/s or more) are known across the area, as discussed below. It should be noted that the data set does not include information on holes that were dry, so the data may be skewed towards an assumption of relatively high yields.

9.8.2 Pumping Test Data

Data is available on groundwater yield from a number of pumping tests undertaken at site (Section 9.2).

For the AGC phase of testing (AGC, 1983), four pumping tests were undertaken, and it was initially programmed that all tests would be undertaken at 10 L/s for a period of 100 hours. Test results are summarised in Table 9-1, but in summary:

- Bore TPB-1 was tested at a rate of 10 L/s for 100 hours. During this time, the water level was drawn down to the top of the bore screens (37 m drawdown)

- Bore TPB-2 (D-E sandstone) was initially pumped at a rate of 10 L/s, but the water level dropped to the level of the pump intake, and the test was discontinued. A new test was run for 24 hours at a rate of 3.6 L/s, which resulted in 55 m of drawdown in the pumping bore.
- Bore TPB-3 (C-D sandstone) was pumped at a rate of 10 L/s for 100 hours, for 19 m drawdown in the pumped bore. The water level was drawn down almost to the top of the aquifer
- Bore TPB-4 (D-E sandstone) was pumped at a rate of 6 L/s for 100 hours, resulting in 44 m of drawdown in the pumped bore, with the water level drawn down below the top of the aquifer

For the Longworth & McKenzie phase of testing (Longworth & McKenzie 1984):

- Bore W1 (C-D sandstone) was pumped at a rate of 0.1 L/s for 2 days, resulting in 5.5 m drawdown in the pumped bore; and,
- Bore W2 (D-E sandstone) was pumped at a rate of 1 L/s for 15.87 days, resulting in 34.27 m of drawdown in the pumped bore.

The results indicate that relatively high initial yields in the bores tested resulted in water level drawdown to the top of, or within, the aquifer, and on this basis it is concluded that the high initial pumping rates would not be sustainable in the long term.

9.8.3 Sustainable Yield

The concept of sustainable yield is much-debated, and the definition may change to reflect the requirements or circumstances of a particular area. Sustainable yield is defined by the Department of Environment, Heritage, Water and the Arts[1] as *"the groundwater extraction regime, measured over a specified planning timeframe that allows acceptable levels of stress and protects dependent economic, social, and environmental values".*

Kellett et al (2003) provide an equation for the sustainable yield of aquifer management zones of the GAB, and it is useful to introduce this concept as this type of calculation, or something similar, is likely to form the basis of DERM's decision-making in relation to water allocation. The equation for sustainable yield is given as (Kellett et al 2003):

Equation1: Sustainable Yield = Recharge Flux – Outflow – Environmental Flow ± Vertical Leakage.

The terms on the right-hand side of the equation are described briefly in Table 9-4 below.

[1] http://www.environment.gov.au/water/publications/environmental/groundwater/annex-a.html

Table 9-4: Description of Terms in Sustainable Yield Calculation

Recharge Flux	Recharge entering the groundwater system, as discussed above in Section 9.6
Outflow	Refers to the volume of water that must be allowed to leave the recharge areas in order to maintain water levels in down-gradient areas. This term is of significance in the GAB as it accounts for the volume of water that must be allowed to flow from recharge areas to meet pressure recovery targets for down-gradient areas (from which groundwater extraction may also be occurring). For the Alpha Coal Project (Mine) area, it is assumed that this term would be interpreted to represent a volume that must be in excess of the volume of water currently used by landholders, as well as the volume of any water allocation (i.e. water licence) sought by the project for long-term water supply. In other words, there must be water left to flow out of the system after taking account of water extraction from bores, environmental flows, and vertical leakage (these last two terms are discussed below).
Environmental Flows	Groundwater flows that are required to maintain the health of groundwater dependant ecosystems (GDE's). One area of potential GDE has been identified to date in the project area (an area of palustrine wetland located on Lagoon Creek). This area of potential GDE is shown on Figure 5.
Vertical Leakage	Refers to the volume of water leaking into the aquifer from units above or below, as well as water leaking out of the aquifer to units above or below. Leakage into the aquifer is a positive value; leakage from the aquifer to neighbouring units is a negative value.

- Based on recharge of between 3 and 5 mm/year, and applied over the area of the Project MLA (648 km^2), groundwater recharge is calculated to be in the order of 1 900 to 3 200 ML/year. Based on the lack of response of monitoring bores to significant wet season recharge, it is concluded that recharge rates are likely to be at the lower end of the range proposed above.
- Requirements for mine dewatering will be greater than recharge, therefore the mine will impact groundwater levels (Section 10).
- As mine dewatering requirements will be in excess of recharge, the operation will not be applying for a water licence for groundwater supply. However, the Project will require a mine dewatering licence to allow mining to proceed safely to depth.

9.9 Groundwater Quality

9.9.1 Summary Data from DERM Groundwater Database

Figure 7 shows bores from the DERM groundwater database within an area of just over 20 km from the boundary of MLA 70426. There are 176 registered groundwater bores within the area shown on Figure 7. Of these, 90 bores have some groundwater chemistry data, and a number of bores have multiple samples. Table 9-5 summarises a number of water quality parameters from the DERM database, and shows the minimum and maximum values recorded, as well as mean and median values. Water quality guideline levels for drinking water and stock use are provided in the table to allow comparison against these standards.

The data indicates that the Total Dissolved Solids (TDS) of groundwater in the region is dominated by sodium and chloride. Other main parameters that contribute to the TDS (in order of decreasing concentration) include bicarbonate, silica, sulphate, magnesium, potassium, and calcium.

Table 9-5: Summary Water Quality Data from DERM Groundwater Database

Parameter	Unit	No. of Samples	Min	Max	Mean	Median	Water Quality Standard		
							Drinking*		Stock**
pH	pH units	312	4.8	8.5	7.27	7.20	(a)	6.5-8.5	
EC	µS/cm	312	180	22,700	2,034	1,480			
TDS	mg/L	313	88	14,211	1,204	829	500		4,000(a)
Sodium	mg/L	313	23	4,860	328	215	180		
Potassium	mg/L	289	0.2	52	11	10			
Calcium	mg/L	305	0.1	380	40	30			1,000
Magnesium	mg/L	305	0.5	496	42	30			
Chloride	mg/L	312	10	7,700	544	333	250		
Sulphate	mg/L	304	0	980	60.3	37	500	250	1,000
Carbonate	mg/L	278	0	14	0.7	0.2			
Bicarbonate	mg/L	299	12	964	174	171			
Fluoride	mg/L	294	0	11	0.4	0.22	1.5		2
Aluminium	mg/L	101	0	0.11	0.025	0.01	(a)	1	5
Copper	mg/L	100	0	0.1	0.02	0.01	2	1	1
Zinc	mg/L	125	0	4	0.24	0.03	3		20
Silica	mg/L	254	1	7,575	81	61			

*Australian Drinking Water Guidelines (ADWG 2004) Health-based Aesthetics-based

**ANZECC water quality guidelines (Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000, National Water Quality Management Strategy. Volume 4 – Primary Industries.

(a) Insufficient data to set threshold

9.9.2 Groundwater Salinity – DERM and Site Exploration Data

Figure 16 shows water quality data (Electrical Conductivity (EC)) data from the DERM groundwater database, presented as a range of EC classes. The rationale for using EC data, rather than TDS data is:

- There are more data points available within the DERM dataset for EC than there are for TDS; and
- Water quality data from the project's exploration drilling program is collected as EC rather than TDS.

Beneficial use categories are generally based on TDS values, and a number of beneficial use limits that are applicable to current groundwater use in the region (potable use and stock water) are shown below in Table 9-6. The TDS limits for each beneficial use have been converted to equivalent EC value. The method used was to divide average TDS (from Table 9-5 = 1 204 mg/L) by average EC (2 034 µS/cm) to obtain a local conversion factor of 0.59. The conversion factor is applied as follows:

EC (µS/cm) x 0.59 = TDS (mg/L)

TDS (mg/L) / 0.59 = EC (µS/cm)

Table 9-6: Groundwater Beneficial Use Classes

Beneficial Use	Limit		Source
	TDS (mg/L)	EC (µS/cm)*	
Potable	1 000	1 700	Australian Drinking Water Guidelines 2004[2]. TDS > 1 000 mg/L rated as "unacceptable" for potable use. It should be noted that the guidelines are taste-based criteria, and many people may not be willing to drink water with a salinity of 1 000 mg/L. The guidelines state that salinity of < 500 mg/L would be regarded as "good"
Beef cattle/ horses	4 000	6 800	ANZECC Guidelines 2000[3]. Limit for beef cattle/ horses where no adverse effects are expected
Sheep	10 000	17 000	ANZECC Guidelines (2000). Limit for sheep where there may be initial reluctance to drink, but stock should adapt without loss of production adverse effects are expected

* EC value obtained for site by dividing TDS by 0.59

Figure 16 shows salinity yield classes for registered groundwater bores based on the beneficial use classes outlined in Table 9-6. There are 89 individual bores shown on Figure 16, but for some bores there are multiple EC values recorded for each site. In order to obtain a single representative value for each site, the value was calculated as either an average of all values, or as

[2] Australian Drinking Water Guidelines 2004. National Water Quality Management Strategy.

[3] ANZECC 2000 Water Quality Guidelines – Chapter 4 - Primary Industries.

the latest recorded value. The decision as to which method to apply was made on a case-by-case basis, but the aim was always to obtain a value that was representative of the dataset.

The data indicates that out of the 89 bores shown on Figure 16:

- 52 bores (58%) indicate a beneficial use[4] of potable supply;
- 76 bores (85%) indicate a beneficial use of livestock drinking supply for beef cattle/horses (i.e. this number also includes those bores for which potable quality is indicated);
- 86 bores (97%) indicate a beneficial use of livestock drinking supply for sheep; and,
- 3 bores (~3%) indicate a salinity (EC) value that precluded use for domestic or stock supply.

Figure 17 shows water quality data from exploration bores on the Alpha and adjacent Kevin's Corner leases. The data indicates that out of the 221 bores shown on Figure 17:

- 119 bores (54%) indicate a beneficial use of potable supply;
- 206 bores (93%) indicate a beneficial use of livestock drinking supply for beef cattle/horses;
- 220 bores (99%) indicate a beneficial use of livestock drinking supply for sheep; and,
- 1 bore (< 1%) indicate a salinity (EC) value that precluded use for domestic or stock supply.

9.9.3 Groundwater pH – DERM and Site Data

As shown in Table 9-5, groundwater samples from the DERM groundwater database indicate a groundwater pH range from 4.8 to 8.5, with a mean of 7.27 and median of 7.20.

Analysis of field pH data from the site exploration drilling program indicates a range of groundwater pH from 4.90 to 13.23, with a mean of 8.50 and median of 8.42. A natural pH value of 13.23 does seem very high, though it is noted that of the 221 field water quality samples taken from site, 11 (5%) recorded field pH values greater than 10.0.

In summary both sources of data (DERM groundwater database and site exploration drilling data) show that, on average, groundwater pH is mildly alkaline to alkaline.

The ANZECC water quality guidelines (ANZECC 2000) set guideline limits for groundwater of between 6 and 8.5 for groundwater. This range is based on limiting corrosion and fouling of pumping, irrigation and stock watering systems.

The Australian Drinking Water Guidelines (ADWG 2004) suggest limits of 6.5 to 8.5 based on limiting corrosion, scale, and taste problems. While noting that values <4 and >11 may cause adverse health effects, the guidelines state that there is insufficient data to set guideline limits based on health.

9.9.4 Laboratory Analysis - Site Data

Water quality analyses from previous and current groundwater testing programs have been reviewed against drinking water and stock watering standards, and summary tables are presented in Appendix B. In summary the analyses indicate that:

- Groundwater is, in some cases above drinking water guideline levels for:

[4] Beneficial use is based only on EC data. Other water quality factors (such as metal concentrations) may make the water unsuitable for uses such as potable supply without further treatment. It would always be recommended that bore water be tested via laboratory drinking water analysis prior to use as potable supply.

  - TDS (aesthetic based standard)
  - Sodium and Chloride (aesthetic based standard)
  - Sulphate (health standard, one sample)
  - Fluoride (health standard)
  - Aluminium (aesthetic standard)
  - Arsenic (health standard, one sample)
  - Lead (health standard, one sample)
  - Manganese (health and aesthetic standards)
  - Nickel (health standard)
  - Selenium (health standard)
- Groundwater is, in some cases, above guideline levels (for beef cattle) for:
  - TDS
  - Fluoride
  - Aluminium
  - Selenium

Water quality has also been characterised by being plotted on a piper tri-linear (Piper) graph (Figure 18). The results indicate that groundwater is of a sodium chloride type. All groundwater plots within the relatively mature or stagnant portion of the plot, which tends to support the observation that recharge is occurring at distance from site.

9.9.5 Groundwater Beneficial Use

The beneficial use of groundwater at the Project area is considered in terms of salinity, pH, major and minor ions, and metals.

Based on the review of salinity and pH data presented above in Sections 9.9.1 to 9.9.4, it is concluded that:

- In terms of salinity (EC) the beneficial use for groundwater in the region ranges from potable to stock water supply, with 85% of bores in the DERM dataset and 93% of bores in the site dataset indicating groundwater salinity suitable for consumption by beef cattle and horses, which is the primary stock use to which groundwater is put in the Project area;
- In terms of pH, groundwater is judged to be suitable for general use purposes, though samples from both the DERM and site databases indicate that groundwater occurs outside the range of 6.0 to 8.5. In some cases this may limit the use to which groundwater is put, for example it may result in corrosion or scale problems for pumps and reticulation systems, or unsuitability for drinking supply;
- In spite of the TDS considerations outlined above, groundwater samples were above health-based guideline levels[5] for sulphate, fluoride, arsenic, lead, manganese, nickel, and selenium, and above aesthetic-based guideline levels for sodium, chloride, and aluminium; and

[5] Australian Drinking Water Guidelines, 2004 National Water Quality Management Strategy.

- For stock watering purposes (beef cattle) a number of groundwater samples were above guideline levels for TDS, fluoride, aluminium, and selenium.

In summary, groundwater beneficial use should not be based on salinity or pH based criteria alone. Groundwater could not be considered to have a beneficial use of drinking water without testing of individual bores to confirm suitability for potable use, or treatment to a potable standard.

On this basis, the primary beneficial use for groundwater is judged to be stock watering.

9.10 Conceptual Groundwater Model – Pre-Mining

A pre-mining conceptual groundwater model is presented as Figure 19. Based on the information presented in previous sections, the pre-mining conceptual groundwater model is summarised as:

- Groundwater occurs beneath the MLA in coal seam and sandstone (interburden and floor) aquifers. The sandstone aquifers, which occur between and below the coal seams, are the major groundwater sources;
- The sandstone aquifers become cleaner (greater quartz content) and coarser with increasing depth;
- The coal seams confine the underlying sandstone aquifers. This is of greatest significance where the D coal seam confines the underlying D-E sandstone. Seepage modelling predicts that, if the D-E sandstone is not depressurised, the upward pressure from groundwater will exceed the weight of overlying material (i.e. weight balance would be exceeded), causing the floor of the mine to heave (plus groundwater ingress through floor). Therefore, depressurisation of the D-E sands will be required to allow mining to proceed safely to depth;
- Groundwater occurrence in the units overlying the Permian deposits (Tertiary sediments and Quaternary alluvium) is sporadic, and the units are not regarded as significant regional aquifers;
- Recharge occurs in topographically elevated areas and flows down gradient (i.e. as a subdued reflection of topography) toward Lagoon Creek. In the area to be mined the groundwater flow direction (on the western side of Lagoon Creek) is to the north-north-east, and the gradient is shallow (approximately 1:1 000); and
- Groundwater in the Permian Bandanna Formation and Colinlea Sandstone is encountered under confined conditions, even adjacent to Lagoon Creek. This suggests that groundwater does not necessarily discharge to Lagoon Creek under average conditions, but may reach surface e.g. if structures such as joints or faults exist that allow upward movement of water.

10.0 IMPACT OF THE PROPOSED OPERATION ON GROUNDWATER

10.1 Mine Dewatering Requirements

10.1.1 Introduction

Mining will occur below the regional water table and it will be necessary to dewater the mine (i.e. remove groundwater) in advance of operations to allow mining to occur safely to the intended depth. Mine dewatering will be required for geotechnical reasons (i.e. to depressurise behind the pit walls and below the floor of the mine, to prevent slope failure and floor heave) and for operational reasons (to prevent uncontrolled inflows to the mine, which would result in wet digging, equipment wear, and potential safety considerations). Mine dewatering has the potential to impact on:

- Groundwater levels;
- Groundwater flow direction;
- Groundwater chemistry; and
- Recharge and discharge mechanisms.

The following sections discuss the studies undertaken to predict the dewatering requirements of the operation, in order that impacts resulting from mine dewatering may be assessed.

Studies to date have included:

- Pit seepage modelling, which investigated the water level impacts from passive drainage to the pit (i.e. for a scenario with no advance dewatering bores) and the geotechnical stability implications of not undertaking advance dewatering via bores. A conclusion of the modelling study was that depressurisation of the D-E sandstone would be required to prevent floor heave and instability at the toe of the batters;
- Analytical modelling to assess pumping requirements to reduce groundwater pressures in the D-E sandstone to below the base of the D coal seam over a 12-month period prior to commencement of mining; and,
- Three-dimensional regional groundwater modelling to assess the long-term groundwater impacts of the operation, including final void modelling studies. This modelling is ongoing, and will be finalised once additional information regarding adjacent mining activities have been included, to allow for an assessment of cumulative impacts. The results of the modelling will be made available as an addendum to this technical report and possible in response to supplementary EIS requests.

10.1.2 Pit Seepage Modelling

a) Introduction

Groundwater seepage modelling has been undertaken to provide input to studies for the test pit, and also to provide input to geotechnical studies. Modelling was undertaken using SEEP/W[6],

[6] SEEP/W 2007 - Geo-Slope International Pty Ltd.

which is a finite-element model capable of modelling groundwater movement and pressure distribution within porous materials such as soil and rock. SEEP/W has been used in this study to compute the rate and extent of change to the phreatic surface, seepage face development, pore pressure distribution, and inflow rates through the sides and floor of the test pit, as well as a pit developed in the western highwall area.

Summary results from the seepage modelling are presented below.

b) Model Setup

The seepage model was developed based on an east-west section, through the location of the test pit that extends to the eastern boundary of MLA 70426. The location of each model section (Sections A-A' for the test pit model, and B-B' for the model in which the western highwall pit is developed) is shown on Figure 20. Detail and identification of individual units for the section in the test pit area (section A-A') is shown in Figure 21. The stratigraphy shown in Figure 21 extends to the west and the units are mined at greater depth as they extend down-dip (refer Figure 19).

The use of two-dimensional slice models for prediction of the phreatic surface shape and inflow rates is regarded as valid when the model is constructed along a groundwater flow line, so that there is no flow (or minimal flow) through the sides of the model. This is generally the case with open pits as a stage is reached where flow toward the pit dominates over the pre-existing groundwater flow direction.

Based on previous groundwater testing in the area of the test pit, previous investigations have regarded the C-D interval (i.e. the interval comprising the C coal seam, D coal seam, and C-D sandstone) as a single, hydraulically connected groundwater unit. Furthermore, it has been assumed that coal seams and interburden are hydraulically connected, in part based on the observation that all groundwater units (e.g. C-D sands, D-E sands) have similar groundwater levels (AGC, 1983).

It has also been observed from recent programs of exploration drilling that the D coal seam acts as a confining unit to the underlying D-E sandstone, as the most significant groundwater inflows during drilling are often encountered once the D Seam is drilled though, and water levels then rise to a level above the seam. Furthermore, groundwater monitoring data indicates that pressures are only similar for all groundwater units in the east of the site, near Lagoon Creek. In the western part of the lease groundwater pressures are different within different groundwater units.

The main purpose of this phase of modelling in the area of the test pit and western high wall was to:

- Make prediction of inflows for a range of scenarios where the pit is developed to a level above the D coal seam. For these scenarios properties such as volumetric water content (i.e. drainable yield, and hydraulic conductivity of the various intervals were varied to enable review of the impacts on inflow rates and pore pressure distribution, particularly for cases where the D seam acts as a confining unit to underlying aquifer units;
- Review pressure distribution in the pit walls and floor for all scenarios; and,
- Draw conclusions as to whether depressurisation would be required to maintain geotechnical stability as mining progresses to depth.

c) Results and Discussion

- For scenarios where the hydraulic conductivity of the D-E aquifer and sub-E aquifer were higher than the hydraulic conductivity of the C-D sands, inflow through the pit floor was the dominant groundwater inflow mechanism;
- For scenarios where the hydraulic properties of the C-D sands and underlying sands were similar, inflows through the pit wall were of a similar magnitude to inflows through the floor;
- For scenarios where the hydraulic conductivity of the D seam was low (i.e. simulating vertical hydraulic conductivity that is one order of magnitude lower than horizontal hydraulic conductivity), pressures below the D seam were higher than the weight of overlying material (i.e. upward groundwater pressure exceeded weight balance). Under this scenario, floor heave could result if the D-E seam is not depressurised in advance of mining;
- Pressure distribution plots also indicate highest pressures near the toe of the pit crest, particularly for cases where the hydraulic conductivity of the D seam is low;
- For scenarios where the dominant inflow mechanism is through the floor of the pit, flow vector analysis indicates that the area of greatest inflow is the floor/wall area at the toe of the pit crest;
- For the range of scenarios tested, inflow rates for a 1m width of pit wall (2 sides) and floor (100m open excavation) ranged from 2.26 x 10^{-2} to 6.34 x 10^{-2} L/s during the first 12 months following mining to full depth. While this isn't a large number on a per metre basis, if multiplied over a strike length of 24km the range of predicted inflow rates is in the order of 540 to 1,500 L/s. Over the same strike length, evaporation (assuming 24,000 m strike length, 100m open pit floor, 10m seepage face on each wall, 2.3m per year evaporation) is calculated at approximately 210 L/s;
- The inflow rates are significantly higher than the rates calculated for aquifer pumping from analytical modelling (refer Section 10.1.3 below). This is interpreted to be because the analytical model assumes an available drawdown under confined aquifer conditions, whereas the seepage model assumes that inflow is from unconfined storage, i.e. water is released from the pore spaces of the coal seams and interburden. The seepage model also considers inflow from all saturated groundwater units, whereas the analytical model assumes depressurisation of only the D-E sandstone;
- The modelling assumes uniform aquifer properties for each scenario, whereas the reality will be that aquifer properties will vary across the lease. Therefore it could be expected that some areas produce more water than others, whereas some areas may produce almost no water at all. A scenario where some areas produce no water has not been factored into the above volume calculations; and,
- Modelling has not yet been undertaken for scenarios where the pit is fully developed from east to west (including representation of internal dumps). Inflow rates could be expected to be lower for initial pit development than the range presented above.

10.1.3 Analytical Modelling

a) Introduction

Analytical modelling was undertaken using the program Winflow (Version 3.32, Environmental Simulations Inc.). Winflow is Windows-based analytical model that simulates two-dimensional steady-state and transient groundwater flow.

The modelling was undertaken as a quick means to demonstrate the drawdown impacts from advance dewatering undertaken when the aquifers are under confined conditions (i.e. prior to opening of the pits). Modelling was undertaken using the Theis solution (Theis, 1935) which is used to calculate transient drawdown in confined aquifers.

Analytical models are subject to a number of simplifying assumptions, including:

- The aquifer is of infinite areal extent;
- The aquifer is confined. When using the Theis solution, the aquifer is always confined, even when the water level falls below the top of the aquifer;
- The wells fully penetrate the aquifer, and groundwater flow is horizontal;
- The aquifer is homogenous and isotropic;
- The base and top of the aquifer are horizontal and fixed at a given elevation; and,
- The volume of water stored in the well is minimal and can be ignored.

Of the assumptions listed above, one that obviously does not hold true is that the aquifer is of infinite aerial extent. In practice, this assumption means that the cone of depression can extend unimpeded to a distance that is determined by the aquifer hydraulic parameters (transmissivity and storage coefficient) and pumping rate. At the Alpha Coal Project (Mine) site, the aquifers subcrop to the east, and this will limit propagation of drawdown. Once an aquifer boundary is reached the rate of drawdown at the boundary will increase as the cone of depression reflects back upon itself. This will result in a requirement to decrease pumping rate to maintain available drawdown in the pumping bores.

Another key model assumption is that the aquifer is confined, even when the water level falls below the top of the aquifer. In reality, the aquifer storage property will change from confined storage coefficient to unconfined storage coefficient (specific yield) when the water level falls below the top of the aquifer.

b) Model Setup

Modelling was undertaken as follows:

- Two models were set up, one model assumed aquifer transmissivity (T) of 45 m^2/day, the other an aquifer transmissivity of 6 m^2/day. These values are at the upper and lower end of transmissivity values calculated from pumping tests undertaken on bores screened within the D-E sands aquifer (refer Table 9-2);
- Storage coefficient for both cases was assumed to be 6 x 10^{-5} (i.e. confined storage conditions);
- Lines of bores were placed at the western limit of each of the pits (Pits A, B, C, D);

- The models were run for a period of 12 months. The intent was to calculate the pumping volume required to lower groundwater pressures below the base of the D seam in the western part of the lease (i.e. at the limit of the western highwall); and
- No recharge was applied over the 12-month period, as application of recharge is not possible in Winflow for transient modelling. This limits the applicability of model results to long time periods (i.e. in excess of 12 months).

c) Results

Results of modelling are shown in Figure 22. In summary:

For Transmissivity of 45 m^2/day

- For an aquifer transmissivity of 45 m^2/day, drawdown beneath the western highwall to a level that corresponds approximately with the base of D seam was achieved at a combined pumping rate for all bores and for all four pits of 260 L/s;
- After 12 months drawdown of between 70 and 90 metres is observed at the eastern boundary of the pits (refer Figure 22). At times beyond 12 months, drawdown to the east will reach the eastern subcrop limits of the aquifers, and it is likely that drawdown rates to the east will increase in this area. This will limit the pumping rate required for depressurisation;
- Drawdown (to the 5 m drawdown contour line) had extended over 30 km from the edge of the pit; and
- Short-term pumping rates for bores in areas of high aquifer transmissivity are likely to be in the order of 8-10 L/s, as these rates have been observed from 100-hour pumping tests on site (refer Section 9.1). However for all pumping tests undertaken on site to date, pumping has drawn the water level down to the top of the aquifer at some stage during the test. This suggests that long-term pumping rates will be lower, and may be in the order of 3 L/s or even less.

For Transmissivity of 6 m^2/day

- For an aquifer transmissivity of 6 m^2/day, drawdown beneath the western highwall to a level that corresponds approximately with the base of D seam was achieved at a combined pumping rate for all bores and for all four pits of 90 L/s;
- The cone of depression is steeper and less extensive than for the higher transmissivity case (refer Figure 22). This tends to indicate that a number of lines of bores may be required (i.e. on the intermediate highwalls) to achieve aquifer depressurisation to base of D seam for all areas of the pits;
- Drawdown to the 5m drawdown contour line had extended approximately 14 km from the edge of the pit;
- Long-term pumping rates from bores in areas of low aquifer transmissivity are likely to be in the order of 1-2 L/s.

d) Discussion

- Analytical modelling predicts that pumping rates in the range of 90 – 260 L/s would be required to depressurise the D-E sands aquifer to a level below the D coal seam (i.e. to remove the confined component of aquifer storage);
- The results from analytical modelling indicate that pumping rates will be variable, depending on variations in transmissivity. Variations in storage coefficient will also play a significant role in aquifer drawdown rates, though variability for this parameter has not been investigated for this phase of modelling, as the aim was to demonstrate the impacts of changes in transmissivity values under confined conditions that are known to exist at site;
- Once the pits are opened up in the east, the aquifer will become locally unconfined, and this will limit drawdown in the east, as water will begin to be removed from aquifer specific yield rather than confined pressure storage;
- Drawdown to the 5 m drawdown contour is predicted by analytical modelling to extend to between 14 km (low T scenario) to ~ 30 km (high T scenario). In practice, analytical models tend to over predict the lateral extent of drawdown due to the assumption of uniform K and infinite later extent of the aquifer. The results presented from analytical modelling should therefore be viewed as a worse-case scenario, subject to revision by the more detailed regional numerical modelling to be conducted;
- For the purpose of this report it is assumed that the extent of drawdown to 5 m will extend to a distance of 20 km from the edge of the pit;
- Analytical models are simplistic, and there are aspects of the site (aquifer boundaries, recharge, etc) that will need to be considered through use of a regional groundwater model. A regional groundwater model is being developed, and results will be presented as an addendum to this report and provided if any supplementary data is required for the EIS;
- It should be noted that analytical calculations assume that the aquifer remains confined, even when water levels are drawn down below the top of the aquifer (as noted in the assumptions presented in Section 10.1.3.1). In practice, the drawdown rate will slow down when drawdown reaches the top of the aquifer as water will start to be removed from the aquifer, rather than just removing water from confined storage (i.e. reducing aquifer pressure). Therefore the calculations presented above consider only pumping rates required to depressurise the aquifer to the base of D seam.

10.1.4 Management of Water from Mine Dewatering Operations

Water supply requirements of the mining operation will be up to 11 000 ML/year. The majority of this water will be provided via a pipeline, with water from mine dewatering to provide a relatively minor component of the overall Project water requirements.

Modelling undertaken to date predicts that mine dewatering requirements will never exceed 11 000 ML/year, therefore:

- It is anticipated that all groundwater obtained from mine dewatering will be utilised as a component of the mine water supply; and
- Generally there will be no requirement to discharge groundwater obtained via mine dewatering to the surface water environment. Any requirement for release would be managed via the mine water management system.

Out-of-pit dewatering water will be considered clean (ambient quality) water, and can therefore be stored in the raw water dam.

Dewatering water obtained from pumping of pit sumps will be considered "dirty" mine affected water, and will be stored in the mine water dams. Sizing of dams will, therefore, need to consider wet season storage requirements against average and short-term water consumption requirements of the Project.

10.2 Impacts from Mine Infrastructure

10.2.1 Tailings Storage Facility

a) Geology/Hydrogeology

The proposed out-of-pit tailings storage facility (TSF) is located to the east of Lagoon Creek (Figure 23). The site is located immediately west of an outcrop area of Colinlea sandstone, and to the east of the subcrop line of the D coal seam (refer Figure 6), which is taken for the purpose of this report to be the upper boundary of the Colinlea Sandstone.

Geotechnical drilling data (Douglas Partners, 2010) indicates that the site is underlain by weathered sandstone and siltstone with a relatively thin veneer (several metres) of sand and clayey silt. The majority of these sediments are derived from in-situ weathering of the underlying sandstone and siltstone, which is interpreted to be Colinlea Sandstone. The drilling logs and test pit logs indicate that:

- Test pits were dug to refusal at depths up to 2.5 m;
- Auger holes were drilled to depths up to 5.5 m, to refusal of the standard penetration test (SPT) equipment in weathered rock;
- A number of test pits recorded the presence of weathered conglomerate at depths up to 2.5 m, and one test pit recorded wet gravel from 1.2 to 1.6 m depth; and
- Falling head permeability tests were undertaken on 6 boreholes within the footprint of the TSF. The bores were drilled to depths of between 2.5 and 5.5 m, and screened within weathered rock. Analysis of the slug tests returned hydraulic conductivity (K) values from 1.53×10^{-7} m/s to 2.31×10^{-8} m/s. These are low values for a rock described as a fine sandstone, and it is

possible that the values represent the unsaturated K of the sandstone as the bores were dry when drilled.

The horizontal K of the rock underlying the TSF may have a similar value to that returned from pumping tests in the Colinlea Sandstone (D-E sands), where K values ranged from 1.5 x 10^{-6} m/s to 2.7 x 10^{-5} m/s. The vertical K of sediments is often in the region of one order of magnitude lower than the horizontal K, so it may be reasonable to expect vertical K values could be in the order of 1 x 10^{-7} to 1 x 10^{-6} m/s. It is the vertical K of the rock that controls the downward leakage of leachate.

10.2.2 Potential Groundwater Impacts

If the TSF were unlined, the postulated scenario for migration of leachate from the facility would include:

- Downward leakage through surficial sediments (silty sands derived from weathering of the underlying Colinlea Sandstone) until reaching lower permeability weathered sandstones and siltstones;
- Lateral migration through the surficial sediments, particularly weathered conglomerates and sands/gravels;
- Movement of leachate down-gradient at shallow depth toward Lagoon Creek where it would discharge to the Lagoon Creek alluvium;
- Over time, the weathered rock profile would become saturated, and the hydraulic conductivity of the rock underlying the TSF could be expected to become higher by several orders of magnitude (from low values in the range of 10^{-7} to 10^{-8} m/s observed from testing of unsaturated rock, to 10^{-6} or 10^{-5} m/s values (horizontal K) observed from pumping tests undertaken on the same formation under saturated conditions. Vertical K could be expected to be one order of magnitude lower than saturated horizontal K;
- Therefore, movement of leachate away from the facility would be preferentially via shallow subsurface flow toward Lagoon Creek, in addition to deeper downward infiltration through the saturated rock underlying the TSF; and
- Deeper leakage would be expected to be drawn toward the pit, as dewatering activities will create a cone of depression, and it is interpreted that groundwater flow lines will be from the area of the TSF toward the pits.

The scenario described above is considered unacceptable (EP Act) as the Colinlea Sandstone is an important regional aquifer. In addition, the proposed location of the TSF is in the lower part of the Colinlea Sandstone (sub-E, sub-F sandstone), which is likely to be the target for drilling of make-good water supply bores. Therefore any contamination of the aquifer would be deemed counter productive and thus unacceptable.

a) TSF Design and Monitoring Requirements

Design of the TSF would need to be undertaken to limit the potential for leakage from the facility, with a means of intercepting any leakage prior to leachate reaching the Lagoon Creek alluvium. The current proposed design (Parsons Brinckerhoff, 2010) of the TSF includes:

- A fully lined footprint;
- An under drainage systems atop of the liner; and

- Drainage transported directly to a decant system (which will reduce the head above the liner).

Investigation and monitoring requirements and commitments are outlined in Section 11.1.

10.2.3 Other Facilities

The majority of mine infrastructure will be located to the east of Lagoon Creek, where geotechnical investigations (Douglas Partners, 2010) have shown that, in general, weathered rock (Colinlea Sandstone) occurs at shallow depths of one to five metres. Therefore the potential contamination issues for all infrastructure areas (artificial recharge) are similar to those identified above for the TSF.

The areas that will be the subject of further investigation, including installation of groundwater monitoring bores, include:

- Landfill;
- CHPP;
- Waste Rock Dump;
- Train Load-out facility; and
- Environmental dams.

Groundwater investigation, monitoring, and reporting commitments are presented in Section 11.2.

10.3 Impact on Recharge

The impact of the operation on recharge is dependent on which recharge model is assumed (i.e. either recharge mechanism 1 or 2, or a combination of both), as presented in Section 9.6.2.

Recharge mechanism 1 assumes direct recharge in the outcrop areas of the Colinlea Sandstone. The following observations are made with respect to impacts of the Project on this recharge mechanism:

- The outcrop and subcrop area of the Colinlea Sandstone is taken to be the area between the outcrop of Colinlea Sandstone to the east, and the subcrop area of D Seam floor to the west. These features are shown on Figure 24, which also shows the location of site infrastructure relative to the features described above;
- Within the MLA 70426 boundary the total area between Colinlea Sandstone outcrop and D seam floor subcrop is approximately 175 km^2;
- The maximum potential area covered by the TSF for example (as shown in Figure 24) is approximately 19 km^2;
- Taking the example of the impact of the TSF on recharge (i.e. due to the removal of recharge potential under the footprint of the TSF), the TSF occupies approximately 11% of the potential recharge area between Colinlea Sandstone outcrop and D seam subcrop, within the area of MLA 70426; and
- In a regional context (i.e. taking into account Colinlea Sandstone outcrop areas beyond the MLA), the impact of the TSF on groundwater recharge is judged to be insignificant.

Recharge mechanism 2 assumes recharge to the west of the operation, either as recharge in the area of the Great Dividing Range, or as diffuse downward recharge over a wider area. In any case, the operation would not have a significant impact on recharge if this mechanism is dominant as recharge will be occurring outside the footprint of mining. However if this recharge mechanism is dominant then the Project will have more of an impact on groundwater discharge, as discussed below.

10.4 Impact on Discharge

It is interpreted that regional groundwater flow is from topographically elevated areas toward Lagoon Creek (i.e. recharge mechanism 2, as discussed above and in Section 9.6.2, is dominant), and it is possible that groundwater discharges to Lagoon Creek under some conditions within MLA 70426, or more regularly to the north of the MLA as the potentiometric surface approaches ground level.

The presence of the open cut mine will result in a cone of depression that will alter groundwater flow directions towards the pit (Figure 22) and will reduce the groundwater level in the vicinity of Lagoon Creek, effectively removing the potential for groundwater discharge to Lagoon Creek in the vicinity of the operation (refer conceptual groundwater model – post mining, Figure 25). The magnitude and extent of drawdown beneath Lagoon Creek, and potential for impact on GDE's, will be further considered as part of regional groundwater modelling.

A regional groundwater model is being developed, and results will be presented as an addendum to this report and provided if any supplementary data is required for the EIS.

10.5 Impact on Existing Groundwater Users

Based on results of seepage and analytical modelling undertaken to date, it is concluded that groundwater level impacts of 5 m or greater may be experienced at distances up to 20 km from the open pit. The effects will not be concentric, for example drawdown will be limited to the east of the MLA as the Colinlea Sandstone aquifer terminates against the Joe Joe Formation (a regional confining layer), and to the west against the Rewan Fm. It is, therefore, interpreted that drawdown will be elongated along strike (i.e. north-south).

The bore survey will assist in establishing the operating water level of bores, and the degree of material interference that will be experienced at each bore (i.e. available drawdown at each bore is considered as the depth of water over the pump intake, and should be considered for both standing water level (pump not operating) and the dynamic water level (pump operating). A drawdown of 5 m would not be significant if an additional 100 m of drawdown were available over the pump intake, but would be significant if only 10 m of additional drawdown were available.

Results from regional groundwater modelling will be presented as an addendum to this report. The results of modelling will be reviewed against the results of the bore survey, and will form one basis for negotiation of make-good water supply agreements with affected landholders. Assessment of impacts will also be based on monitoring of groundwater levels, so that the groundwater model is not the sole means of assessing potential impacts on existing bores.

10.6 Groundwater Quality Impacts

The Project has the potential, due to mining activities, to alter the groundwater quality within the open cut pits and below and adjacent to mine infrastructure (possible poor quality artificial recharge). The impacts are, however, limited as:

- During mining and after closure (final void), groundwater flow will be toward the pits, and the potential for contaminants to move out via the groundwater system is judged to be low; and
- Geochemical testing indicates that the materials disturbed and exposed during mining are non-acid forming or have low potential for acid-forming.

10.7 Final Void

The current mine plan includes a final void which will remain at the western limit of mining at LOM. Modelling of the final void will be undertaken to make prediction of:

- Average final void water level and maximum water level under a range of climatic conditions;
- Long-term water quality (in terms of salinity) within the final void;
- Decant potential and risk;
- Final groundwater drawdown cone (zone of influence); and
- Long term impacts on surface water systems.

The results of modelling will be presented as an addendum to this report and provided if any supplementary data is required for the EIS.

10.8 Cumulative Impacts

In addition to the Alpha Coal Project (Mine), which is the subject of this EIS, there are additional projects that have the potential to impact groundwater resources, and the cumulative impact of these projects must be assessed. The projects include:

- Kevin’s Corner Project, which is a proposed 30 Mtpa open cut and underground coal mine, being developed by Hancock Galilee Pty Ltd (HGPL). The Kevin’s Corner project is located on MLA 70425, immediately north and adjoining MLA 70426; and
- Waratah Galilee Coal Mine, which is a proposed 25 Mtpa open cut coal mine being developed by Waratah Coal Inc. The proposed mine is located 13 km west and 35 km north of the township of Alpha.

The Kevin’s Corner project is to be simulated within the regional groundwater model that will be developed and reported as an addendum to this hydrogeological technical report.

The regional groundwater model will consider the cumulative impacts (i.e. drawdown in groundwater levels) of the Alpha and Kevin’s Corner projects with respect to:

- Drawdown in the area between the mining operations (i.e. where the cones of depression from each operation overlap);
- The extent of drawdown along geological strike (i.e. to the north and south of the Alpha and Kevin’s Corner mines) as well as to the east and west of the operations (where the extent of drawdown is anticipated to be limited by hydrogeological boundaries);

- Cumulative impacts on registered recharge springs to the north of the Kevin's Corner MLA (refer Figure 5 for locations);
- Impacts on existing groundwater users; and
- Definition of a final zone of influence (i.e. at completion of both projects, following rebound of groundwater levels to a pseudo steady-state for the aquifers that are dewatered or depressurised by the mine, and for deeper aquifers that are expected to the be the target of bores drilled under make-good water supply agreements).

No details are known of the dewatering requirements of the Waratah Galilee Coal Mine, therefore the regional groundwater model will present drawdown contours for the area of the proposed mine.

10.9 Conceptual Groundwater Model – Post Mining

Elements of the conceptual groundwater model (post mining) are shown in Figure 25.

Predictions relating to the post-mining groundwater regime may need to be revised once regional groundwater modelling has been undertaken (supplemental to this report), but based on modelling undertaken to date, and professional judgement, the following post-mining conceptual groundwater model is proposed:

- A drawdown cone will develop around the open pit that will extend preferentially north and south (along strike) and to the west, but will be of limited extent in the east as the aquifers outcrop to the east and in this area the aquifers will be locally dewatered (Figure 22);
- Groundwater will flow into the pit through the pit wall, from the Tertiary sediments (where water occurs), the sediments of the B-C and C-D sands, and C and D coal seams;
- Groundwater will flow up through the pit floor from the underlying D-E sandstone aquifer. Seepage modelling predicts that the majority of groundwater reporting to the floor of the pit will be derived from the D-E sandstone, and not from underlying sandstone units (sub-E sands, sub-F sands). However, induced flow from underlying aquifers will be considered in the regional groundwater model;
- A water table will be developed over time in the in-pit waste dump, though a drainage layer will be installed at the base of the internal dump to limit pressure build-up (i.e. for geotechnical stability), and this is expected to limit the extent to which a watertable will develop. Sources of water will include direct rainfall infiltration, and inflow from the D-E sandstone that will underlie the in-pit dump;
- Rehabilitation (and maintenance to counter settlement) of the surface of the in-pit dump will be required to limit the potential for rainfall infiltration (via capping, revegetation, and/or grading of the surface to encourage runoff and limit surface ponding);
- Water quality monitoring of runoff will be required, should runoff be in the direction of Lagoon Creek. If runoff water quality is above trigger levels for the parameters outlined below in Section 11, water must be collected and diverted toward the final void. It should be noted that trigger levels will be set at a later date, subject to commitments outlined in the EMP; and
- The cone of depression will extend to the west, but it is predicted that drawdown will not influence water levels in the GAB. The outcrop of the Rewan Fm, like the Joe-Joe Formation, is expected to provide a physical limit to the extent of groundwater level drawdown.

11.0 GROUNDWATER MONITORING AND MITIGATION MEASURES

11.1 Tailings Storage Facility

Groundwater investigations that would be undertaken prior to final design of the TSF include:

- Drilling and construction of nested groundwater monitoring bores up-gradient of the TSF, as well as down-gradient in the area of the downstream toe dam of the TSF, to establish the depth at which water is intersected, and the depth to which groundwater will rise in the bore. The nested sites would comprise a deep bore screened in saturated sediments, and a shallow bore that would be drilled dry initially (onto first low permeable layer), but would be monitored for appearance of horizontal seepage water migration that could be indicative of leakage from the TSF;
- Hydraulic testing on monitoring bores to test the saturated hydraulic conductivity of the material underlying the TSF;
- Seepage modelling to make predictions of the potential for the TSF, as designed, to leak leachate to the shallow groundwater system and ultimately toward Lagoon Creek. Seepage modelling would be used to predict a hydraulic conductivity of liner material that would limit leakage from the TSF to levels deemed acceptable;
- Monthly water level monitoring and monthly groundwater quality monitoring from bores to establish baseline levels prior to development of the facility. Based on available information from the waste management strategy (EIS Volume 2, Section 16) the major potential contaminants are expected to include sulphate, elevated EC/TDS, decreased alkalinity and pH. If the seepage is acidic this may result in mobilisation of metals, most likely aluminium, iron and manganese, though other metals/metalloids to be monitored should include cadmium, copper, lead, nickel, selenium, and zinc;
- The suite of parameters to be tested will include:
  - Field parameters – pH and EC;
  - Major/minor ions, including total dissolved solids (TDS), calcium, magnesium, potassium, sodium, chloride, sulphate, alkalinity (hydroxide, carbonate, bicarbonate, total), fluoride;
  - Metals/metalloids, including aluminium, arsenic, boron, cadmium, copper, iron, lead, mercury, manganese, molybdenum, nickel, selenium, silver, zinc;
  - For bores down gradient of workshops , fuel depot and explosives storage, monitoring will include Total Petroleum Hydrocarbons (TPH), nutrients (total N, NO_x, ammonia, phosphorous); and
  - It is anticipated that the parameter list would be modified once the TSF is operational, and the nature of liquid generated by the TSF becomes apparent.
- Undertaking of an electromagnetic (EM) survey on the down gradient side of the TSF to establish baseline conditions, prior to operation of the TSF. The purpose of the EM survey is to establish baseline EM conductivity conditions prior to emplacement of tailings, so that repeat EM surveys may be used to establish conditions of leakage from the TSF.

Ongoing monitoring and investigations will include:

- Undertaking a repeat EM survey within 12 months of commencement of tailings emplacement, to test whether leakage of leachate from the TSF is occurring;

- Leak detection monitoring adjacent to the landfill;
- Monthly water level and quarterly water quality monitoring for the suite of parameters outlined above;
- Annual reporting of water level and water quality results; and
- Notification to the regulating authority within one month of receiving water quality analysis results, should any parameters tested exceed agreed trigger levels.

Should trigger levels be exceeded, investigations will be undertaken to establish:

- Whether actual environmental harm has occurred;
- Immediate measures that should be taken to reduce the potential for environmental harm; and,
- Long-term mitigation measures required to address any existing contamination, and to prevent recurrence of contamination. This may include for example:
  - Undertaking further EM surveys to establish the location of contaminant plumes;
  - Installation of a low-permeability cut-off wall; and,
  - Installation of interception trenches to collect leachate and drain to a central sump for transfer of leachate to the process water stream.

Groundwater monitoring and reporting commitments include the following:

An Environmental Monitoring Plan will be developed, which will include commitment to:

- Monitoring of groundwater levels via dedicated network of monitoring bores;
- Monitoring of groundwater quality via dedicated network of monitoring bores; and
- Monitoring commitments are provided in the Environmental Management Plan (EMP).

11.2 Other Facilities

The areas that will be the subject of further investigation, including installation of groundwater monitoring bores, include:

- Landfill;
- CHPP;
- Waste Rock Dump;
- Train Load-out facility;
- Environmental dams; and
- Sewage treatment plant.

Groundwater monitoring bores will be established up gradient and down gradient of sources of potential contaminants, and will be nested to include monitoring of saturated aquifer material, as well as shallow monitoring of unsaturated material (primarily the zone of weathered rock, which is interpreted to be the main interval along which movement of shallow groundwater would occur) to monitor for presence of shallow groundwater contamination. Figure 24 shows the location of planned mine infrastructure, with existing and proposed groundwater monitoring bores. A conceptual layout of groundwater monitoring facilities is presented in Figure 25.

- The suite of groundwater parameters to be tested will include:
  - Field parameters – pH and EC;

- Major/minor ions, including total dissolved solids (TDS), calcium, magnesium, potassium, sodium, chloride, sulphate, alkalinity (hydroxide, carbonate, bicarbonate, total), fluoride;
- Metals/metalloids, including aluminium, arsenic, boron, cadmium, copper, iron, lead, mercury, manganese, molybdenum, nickel, selenium, silver, zinc;
- TPH;
- Nutrients adjacent and down gradient of the sewage treatment facility; and
- It is anticipated that the parameter list would be modified once the TSF is operational, and the nature of liquid generated by the TSF becomes apparent.

Ongoing monitoring and investigations will include:

- Monthly water level and quarterly water quality monitoring for the suite of parameters outlined above;
- Annual reporting of water level and water quality results; and
- Notification to the regulating authority within one month of receiving water quality analysis results, should any parameters tested exceed agree trigger levels.

Should trigger levels be exceeded, investigations will be undertaken to establish:

- Whether actual environmental harm has occurred;
- Immediate measures that should be taken to reduce the potential for environmental harm; and,
- Long-term mitigation measures required to address any existing contamination, and to prevent recurrence of contamination.

11.3 Make-Good Arrangements for Existing Groundwater Users

Landholders who have groundwater supplies that are materially impacted by the operation, to a degree where groundwater is not able to be used for its pre-mining beneficial use (in terms of quality and/or quantity) will be provided with an alternate water supply of comparable extraction volume and quality. It is expected that this may include strategies such as:

- Lowering pumps within an existing borehole, or supplying pumps with a greater head capacity if required; and
- Drilling new bores to a greater depth, e.g. to intersect the sub-E sands or lower aquifers, which are not a target of dewatering by the operation and therefore will not be impacted to the degree predicted for the D-E sandstone and overlying sediments.

11.4 Impacts on Groundwater Dependent Ecosystems

The presence of groundwater dependent ecosystems within the predicted area of impact of the operation has not yet been confirmed. However, groundwater level monitoring and water quality assessment will be undertaken at the location of the palustrine wetland identified in the surface water and nature conservation reports (Volume 5 Appendices E and F of this EIS) as AQ28 to establish whether the surface water feature receives baseflow from groundwater.

Monitoring will include:

- Construction of groundwater monitoring bores adjacent to the surface water feature, to establish the depth at which water is struck, and the depth from surface to which water will rise;

- Monitoring of water levels within the wetland; and
- Water quality monitoring of both groundwater and surface water samples, to facilitate characterisation of the water in each location.

The surface water feature has been assessed in the surface water ecology report to be of low significance, and the assumption is made that the feature will be entirely affected by mining (i.e. that the feature will dry out as a result of mining). As the feature has been assessed to be of low environmental value, there are no plans to mitigate any impacts from mining, should impacts occur.

JBT Consulting Pty Ltd

John Bradley
Principal Hydrogeologist

12.0 REFERENCES

AGC (1983) Alpha Coal Project (A to P 245C), Surface Water and Groundwater Aspects – Preliminary Evaluations. Report for Bridge Oil Limited

Douglas Partners (2010)

Habermehl, M.A. & Lau, J.E. (1997) Hydrogeology of the Great Artesian Basin, Australia (map at scale 1:250,000). Australian Geological Survey Organisation, Canberra

Habermehl, M.A. (2001) Wire-line Logged Waterbores in the Great Artesian Basin. Digital Data of Logs and Waterbore Data Acquired by AGSO. Bureau or Rural Sciences Australia.

Jericho 1:250,000 Geological Map, Sheet SF55-14. Bureau of Mineral Resources, Geology and Geophysics, Canberra, ACT. First Edition 1972.

Kellett, J.R., Ransley, T.R., Coram, J., Jaycock, J., Barclay, D.F., McMahon, G.A., Foster, L.M. & Hillier, J.R. (2003). Groundwater Recharge in the Great Artesian Basin Intake Beds, Queensland. Water Sciences Program, Bureau of Rural Sciences Canberra, ACT and Water Assessment Group, Natural Resource Sciences, Department of Natural Resources and Mines, Brisbane Qld.

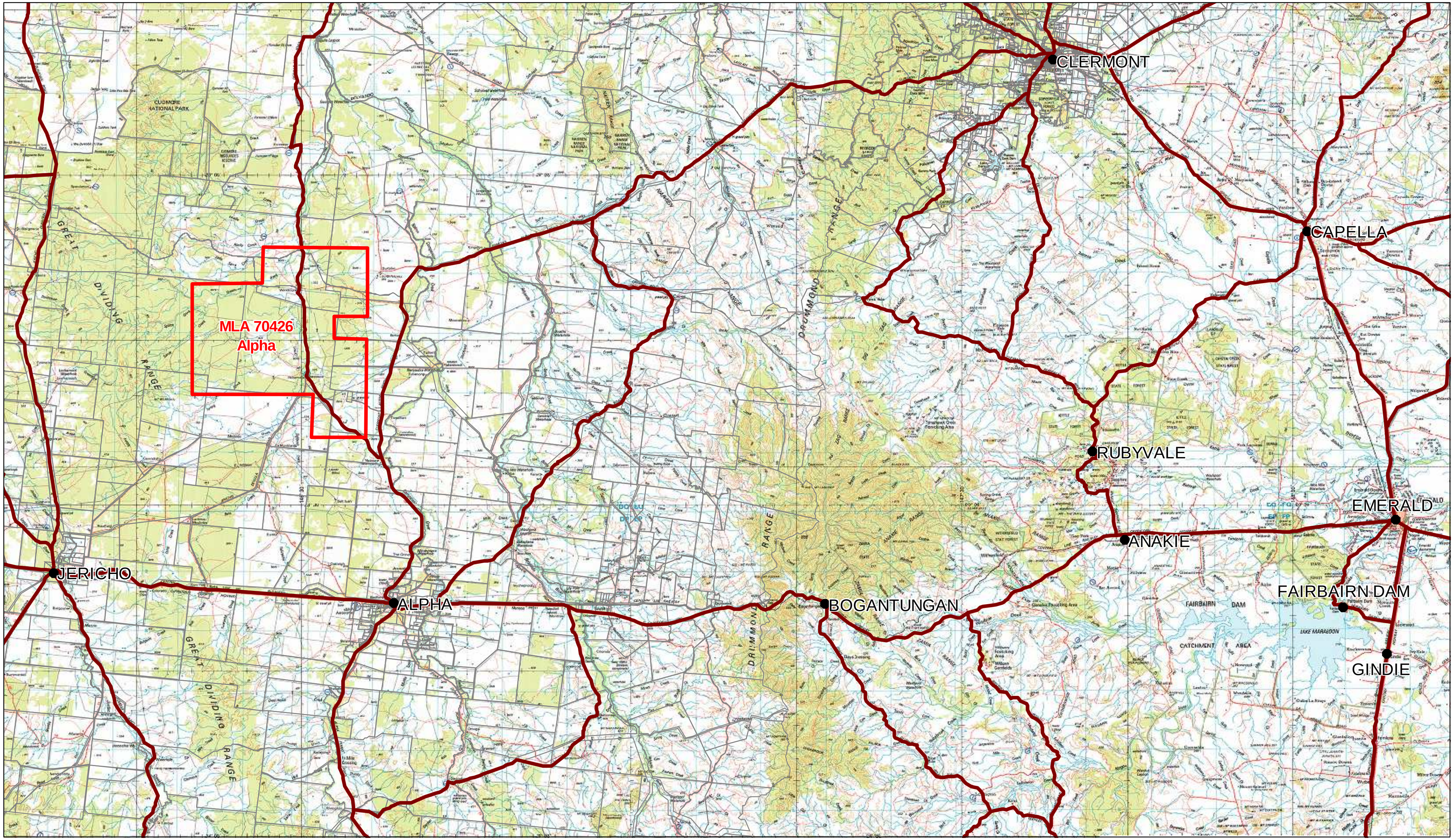
Longworth & McKenzie (1984) Report on Geotechnical and Groundwater Investigation (1984) Area 2, ATP245C, Alpha Queensland for Bridge Oil Limited. Report Reference UGT0115/KDS/ejw

Salva Resources (2010) Summary of Galilee Regional Model (GAB). Internal Project Memorandum from Salva Resources to Hancock Coal Pty Ltd, February 2010.

Water Act 2000

Water Resource (Great Artesian Basin) Plan 2006

FIGURES



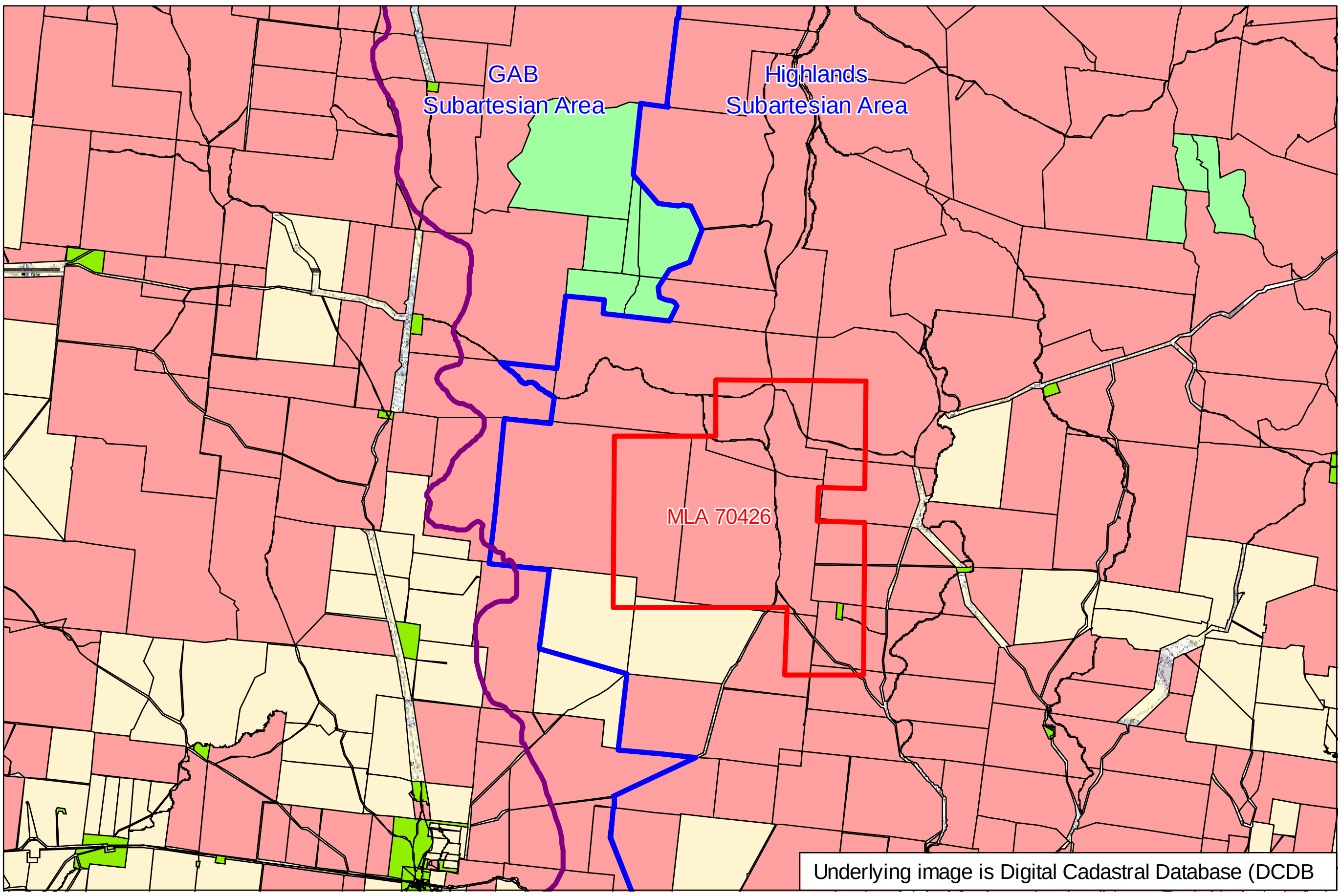
N

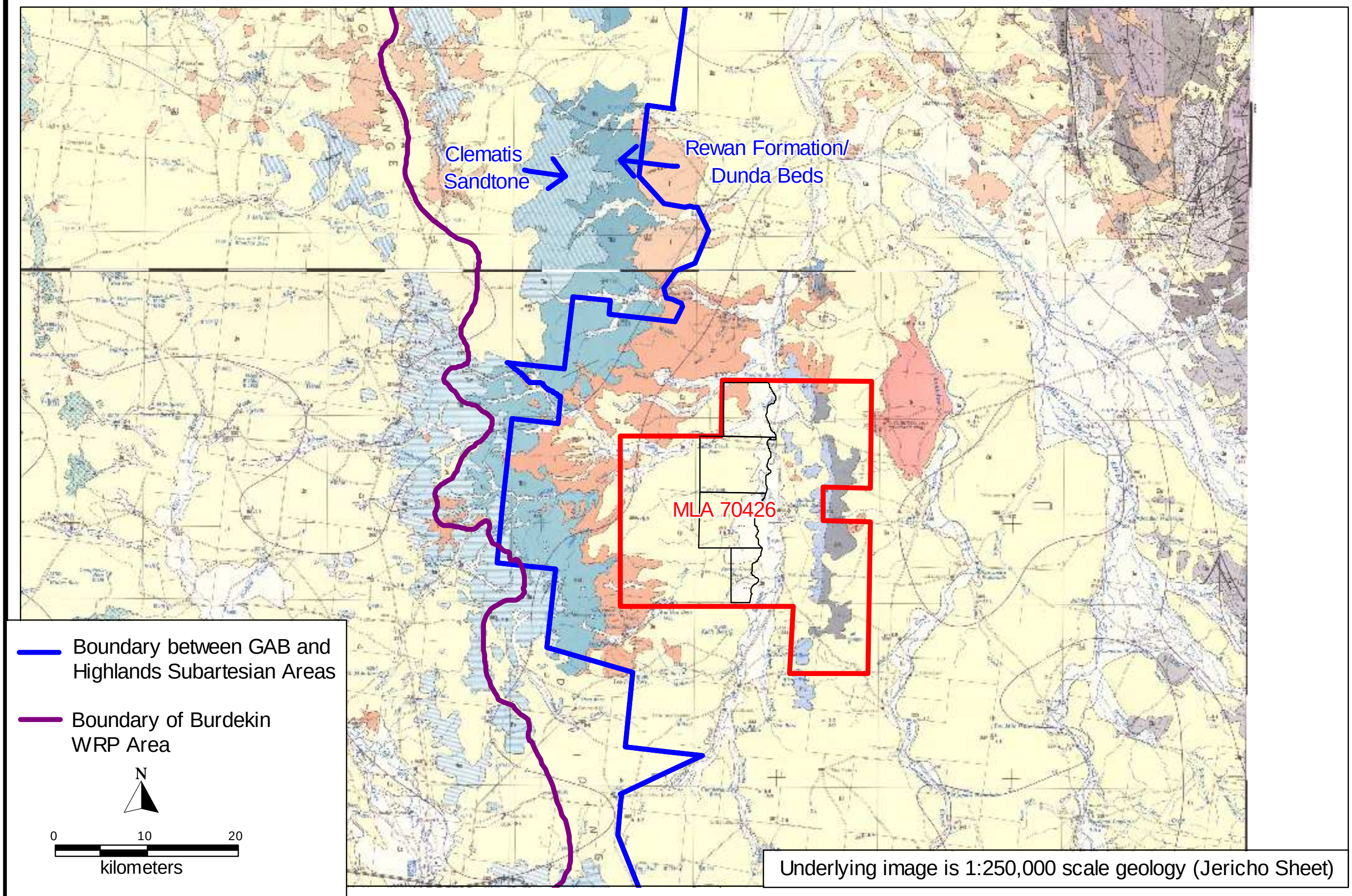
0 10 20
kilometers

CLIENT Hancock Coal Pty Ltd		PROJECT Alpha Coal Project	
DRAWN JWB	DATE August 2010	TITLE PROJECT LOCATION	
CHECKED	DATE		
SCALE 1:800:000	A4	PROJECT No JBT01-005-021	FIGURE No 1

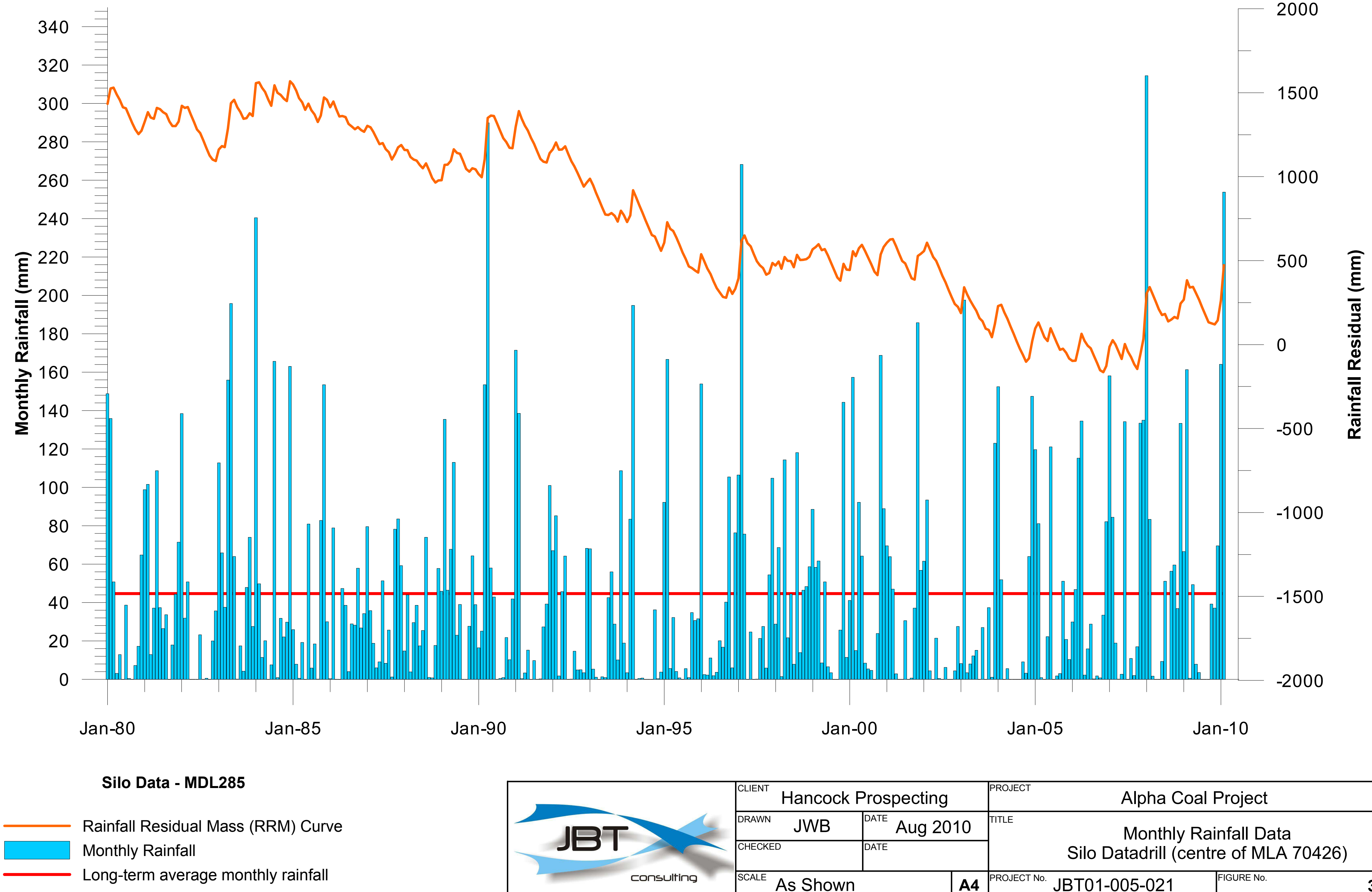
JBT consulting

C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\BFS Report





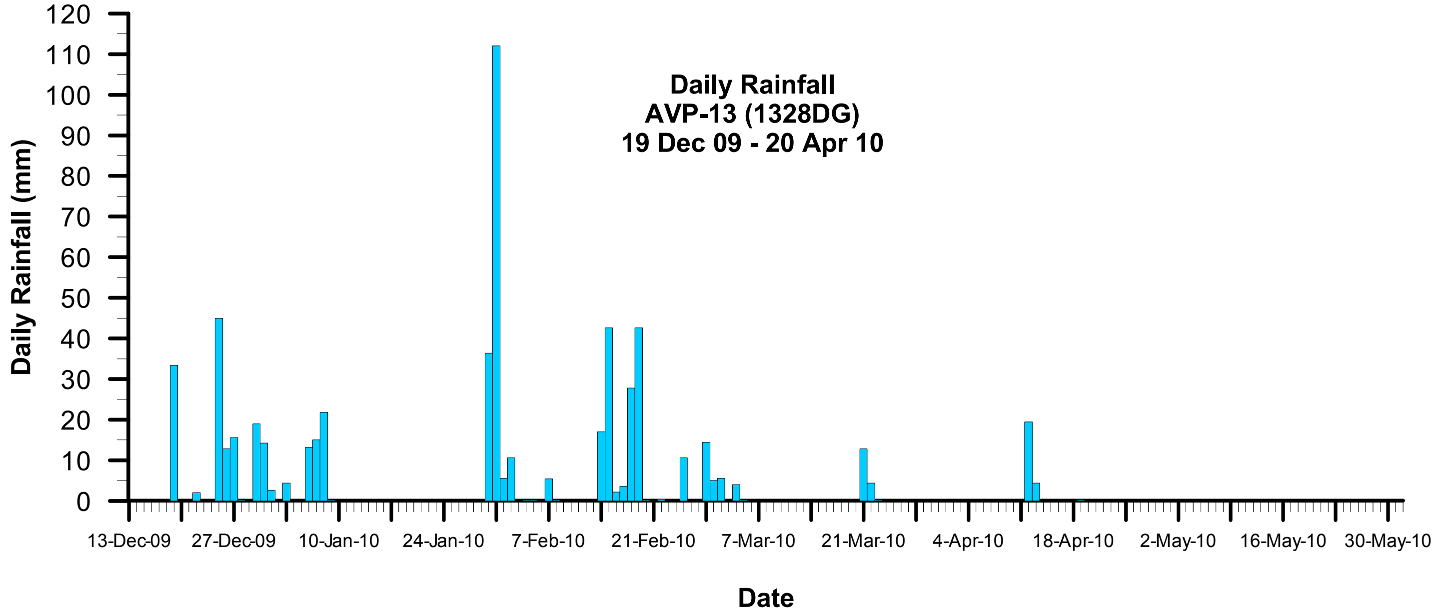
CLIENT Hancock Coal Pty Ltd			PROJECT Alpha Coal Project	
DRAWN JWB	DATE Aug 2010		TITLE Project Location with Respect to GAB Boundary	
CHECKED	DATE			
SCALE 1:800,000		A4	PROJECT No JBT01-005-021	FIGURE No 2

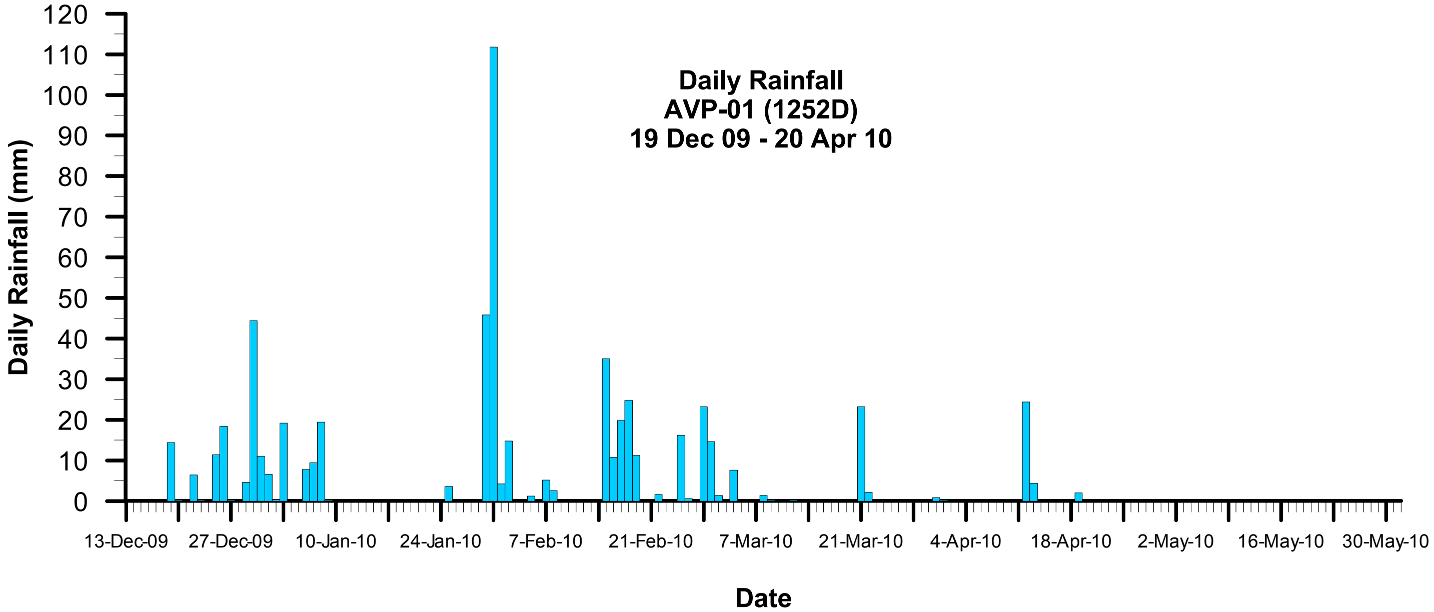


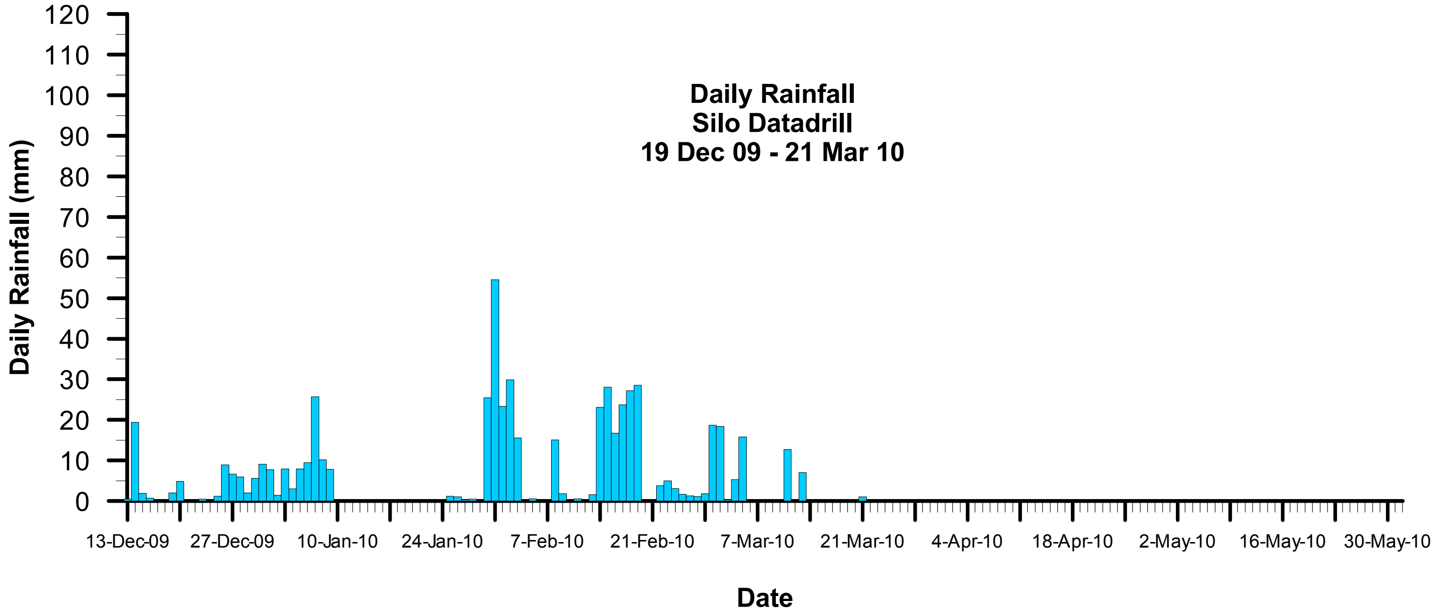
CLIENT Hancock Prospecting		PROJECT Alpha Coal Project
DRAWN JWB	DATE Aug 2010	TITLE Monthly Rainfall Data Silo Datadrill (centre of MLA 70426)
CHECKED	DATE	
SCALE As Shown	A4	PROJECT No. JBT01-005-021 FIGURE No. 3

JBT consulting

C:\Work\JBT01-005-Alpha Coal Project\Reporting\Figures\Rainfall Analysis.grf

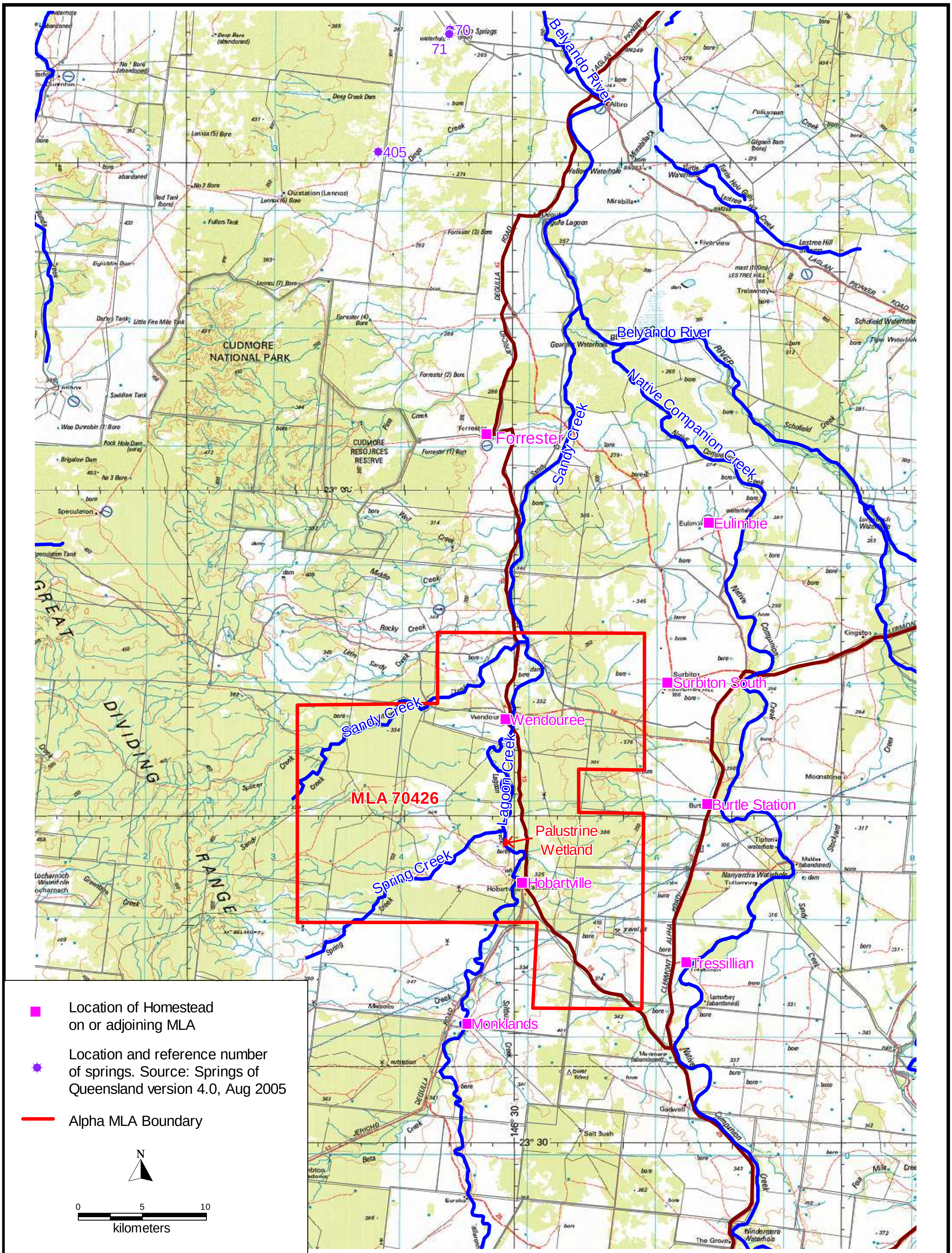






JBT consulting

CLIENT: Hancock Coal Pty Ltd		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: **Rainfall Comparison Site Rainfall vs Silo Datadrill**	
CHECKED:	DATE:		
SCALE: As Shown	**A4**	PROJECT No. JBT01-005-021	FIGURE No. 4

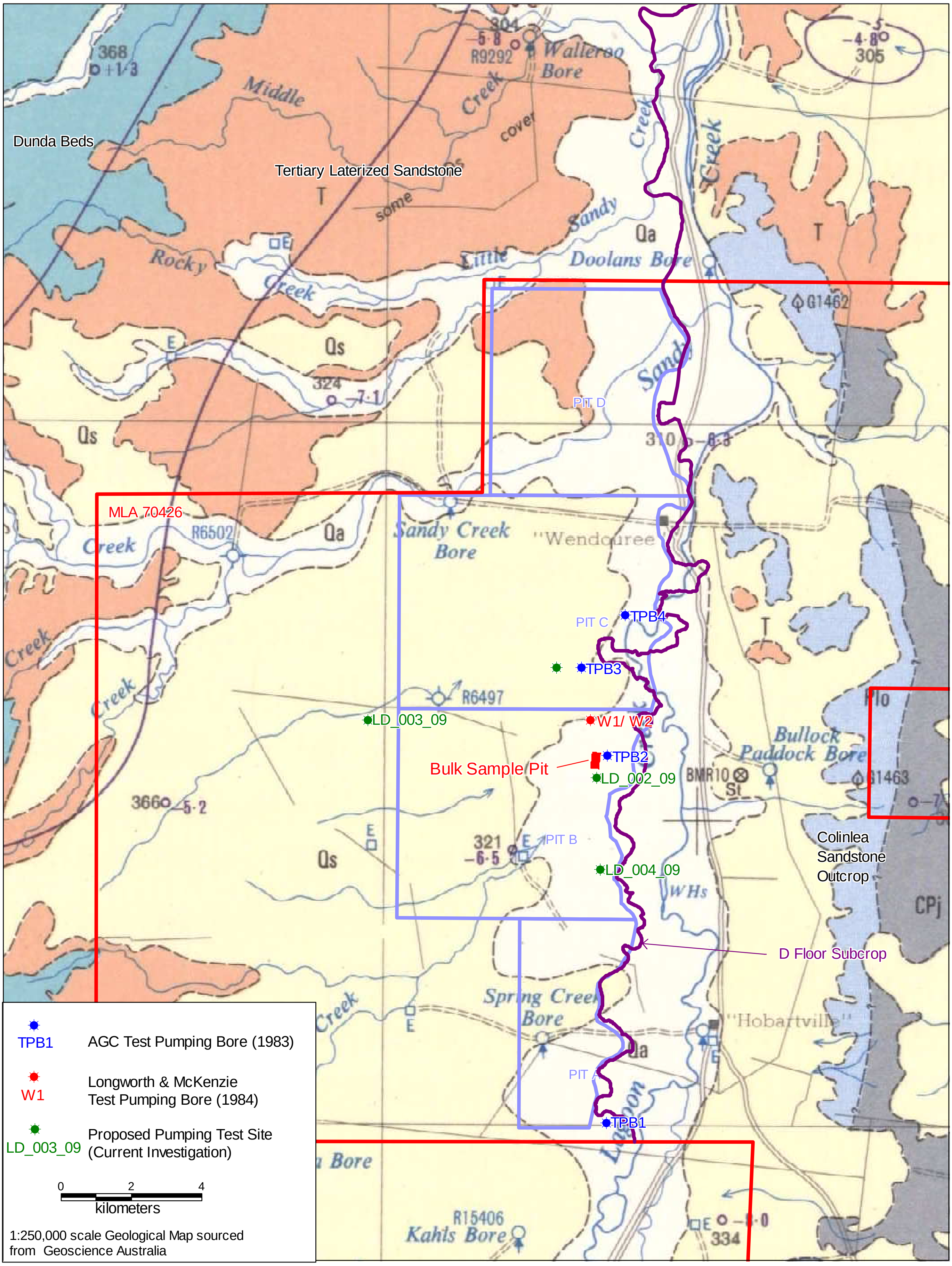


CLIENT: Hancock Coal Pty Ltd		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: Location of Surface Water Features	
CHECKED:	DATE:		
SCALE: 1:400,000	A4	PROJECT No: JBT01-005-021	FIGURE No: 5

JBT consulting

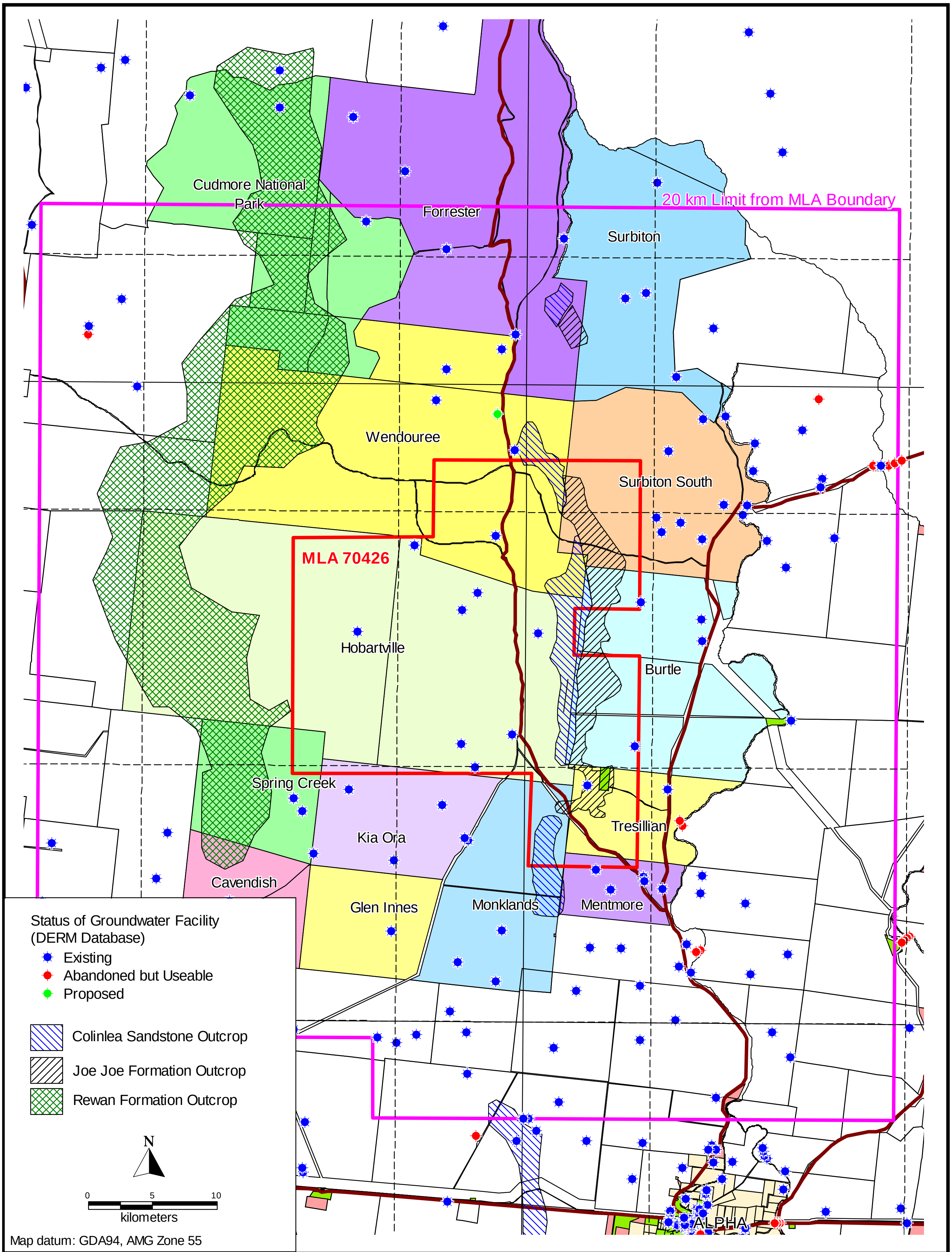
C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\Surface Water Features.WOR

GM: very hazy - can it be made clearer?



CLIENT: Hancock Coal Pty Ltd			PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010		TITLE: **Location of Pumping Test Sites Historic and Current Investigations**	
CHECKED:	DATE:			
SCALE: 1:150,000		A4	PROJECT No: JBT01-005-021	FIGURE No: 6

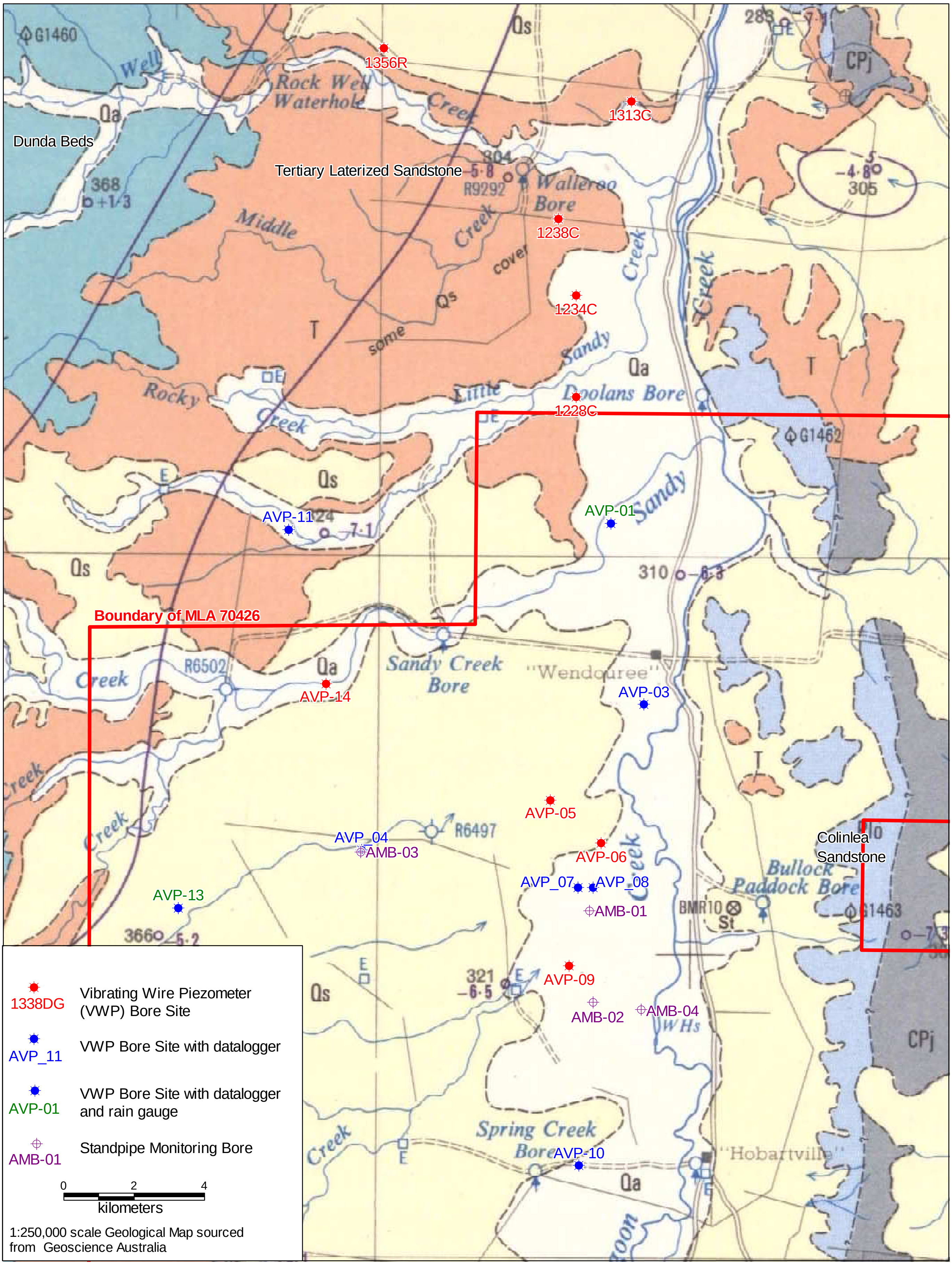
C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\Pumping Test Sites.WOR



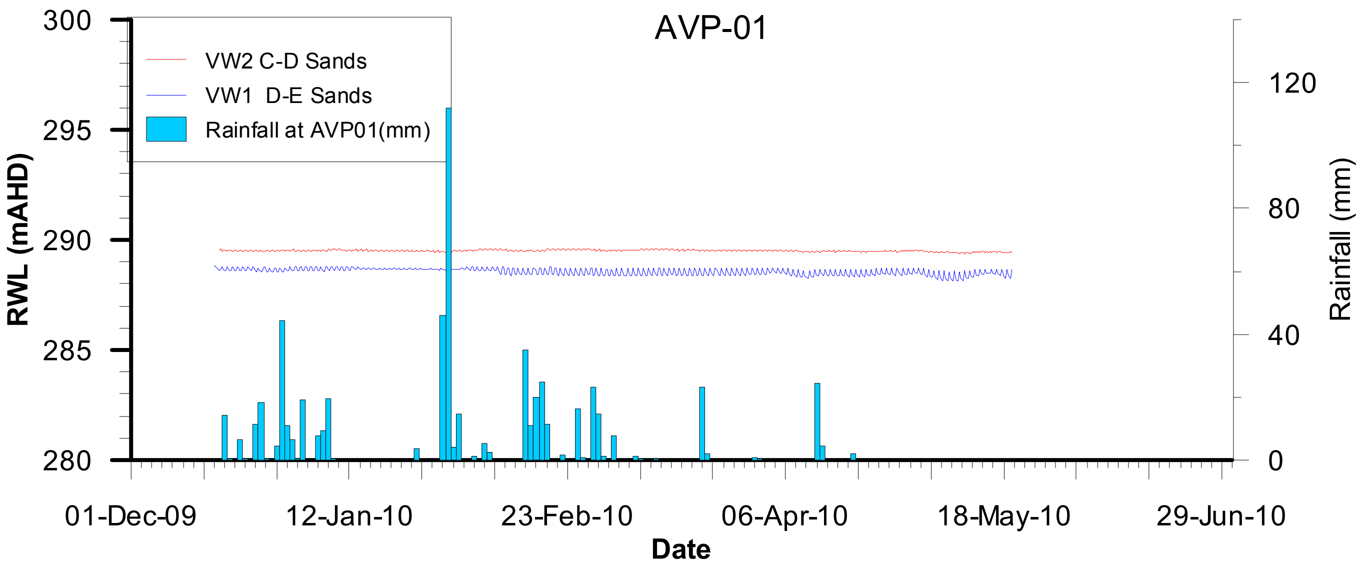
CLIENT	Hancock Coal Pty Ltd		PROJECT	Alpha Coal Project	
DRAWN JWB	DATE Aug 2010		TITLE	Location of Registered Bores from DERM Groundwater Database	
CHECKED	DATE				
SCALE 1:400,000		A4	PROJECT No JBT01-005-021		FIGURE No 7

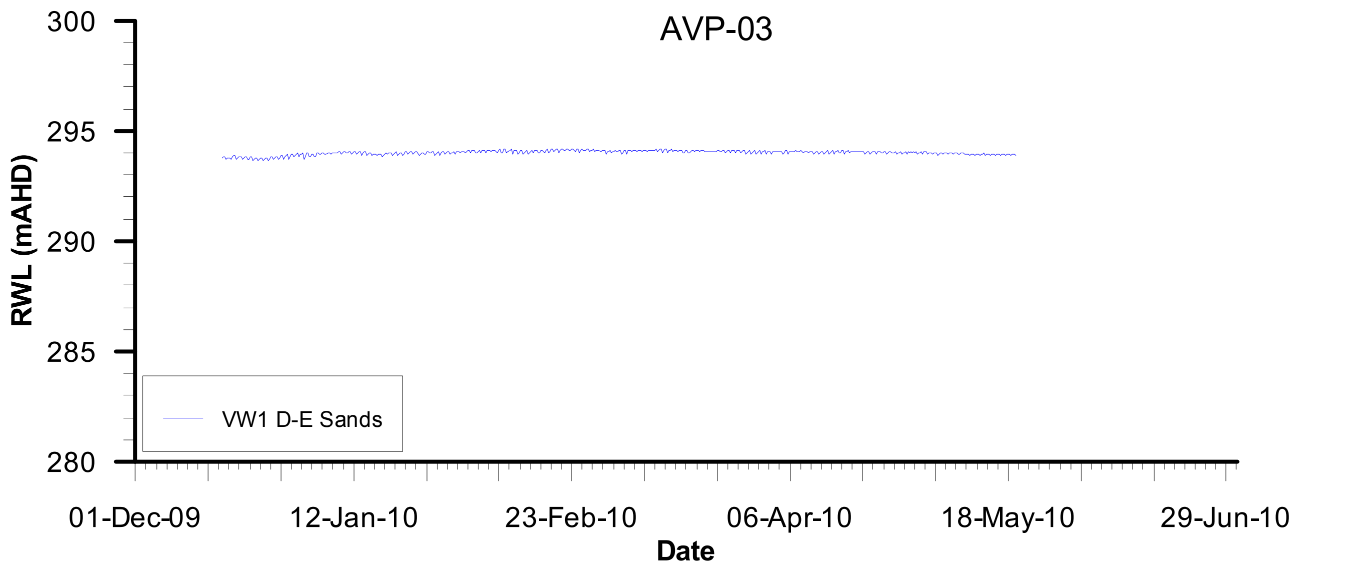
C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\MDL Locations.WOR

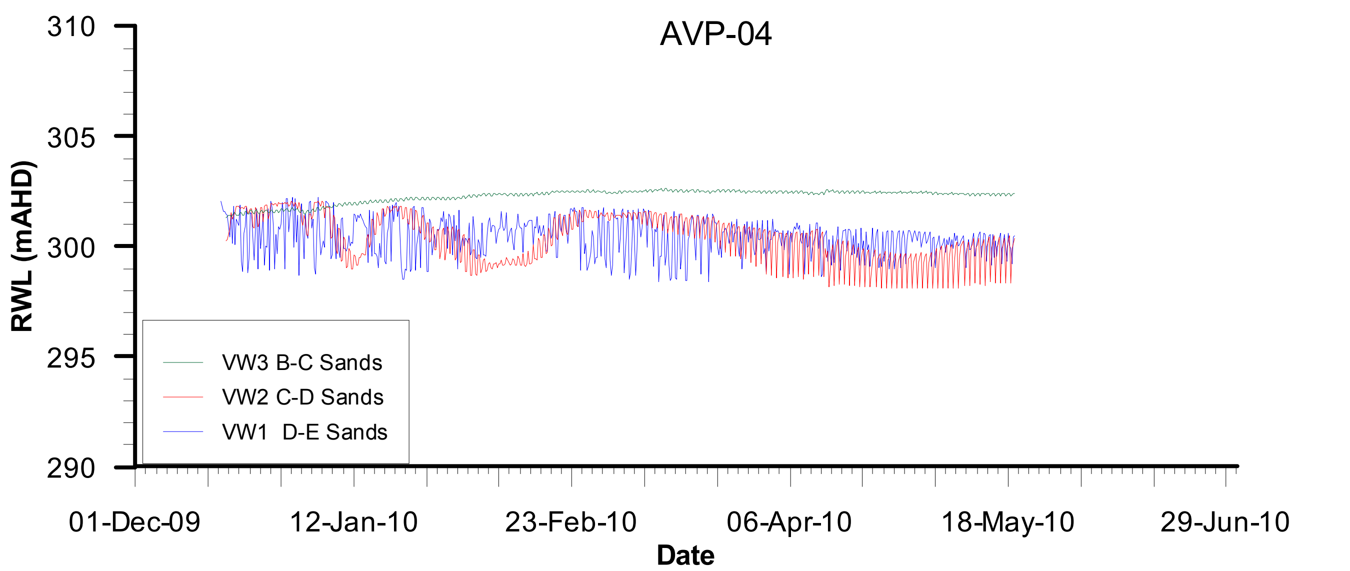
GM: very hazy - can it be made clearer?



JBT consulting	CLIENT: Hancock Coal Pty Ltd		PROJECT: Alpha Coal Project
	DRAWN: JWB	DATE: August 2010	TITLE: **Location of Groundwater Monitoring Bores**
	CHECKED:	DATE:	
	SCALE: 1:150,000	A4	PROJECT No: JBT01-005-021 — FIGURE No: 8



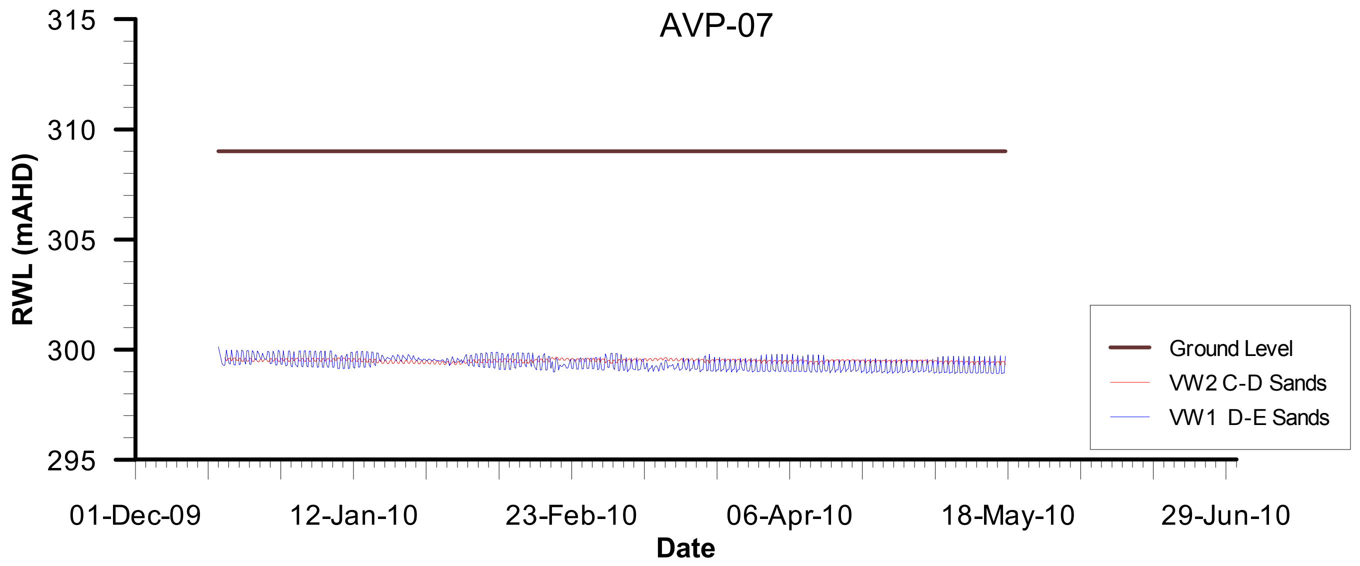


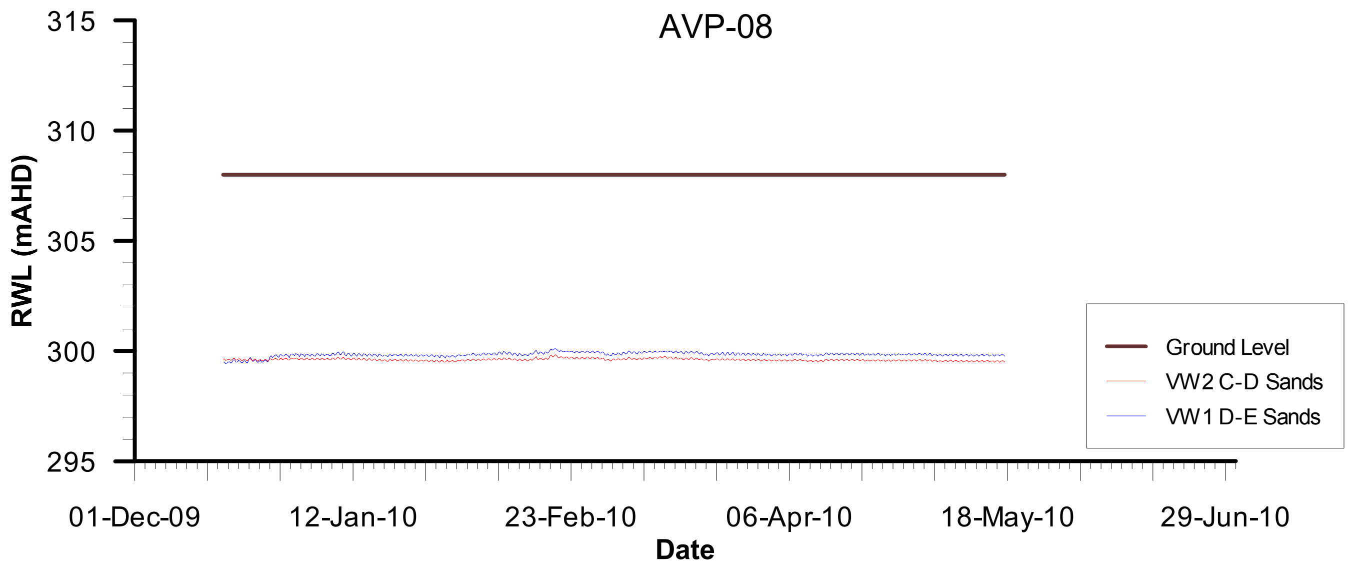


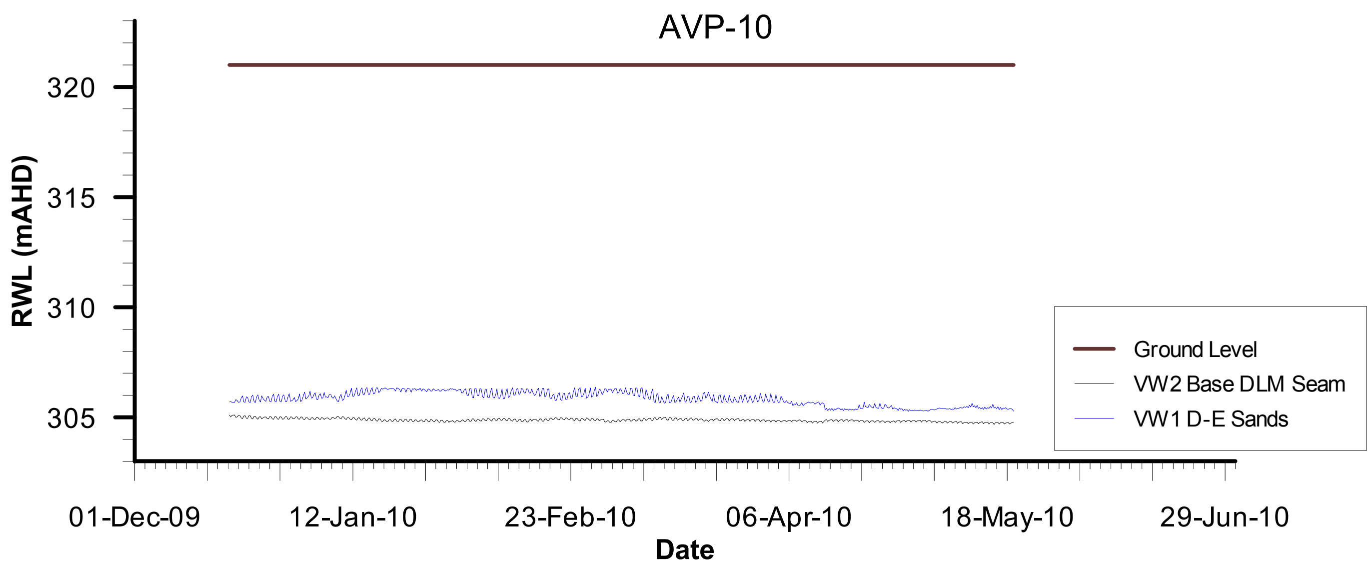
JBT consulting

CLIENT Hancock Coal Pty Limited		PROJECT Alpha Coal Project		
DRAWN JWB	DATE Aug 2010	TITLE **Reduced Water Level VWP Bores AVP01, AVP03, AVP04**		
CHECKED	DATE			
SCALE As Shown	A4	PROJECT No. JBT01-001-021	FIGURE No. 9	

C:\Work\JBT01-005-Alpha Coal Project\Bore Data\VWP Bores\Graphs\AVP01-03-04.grf

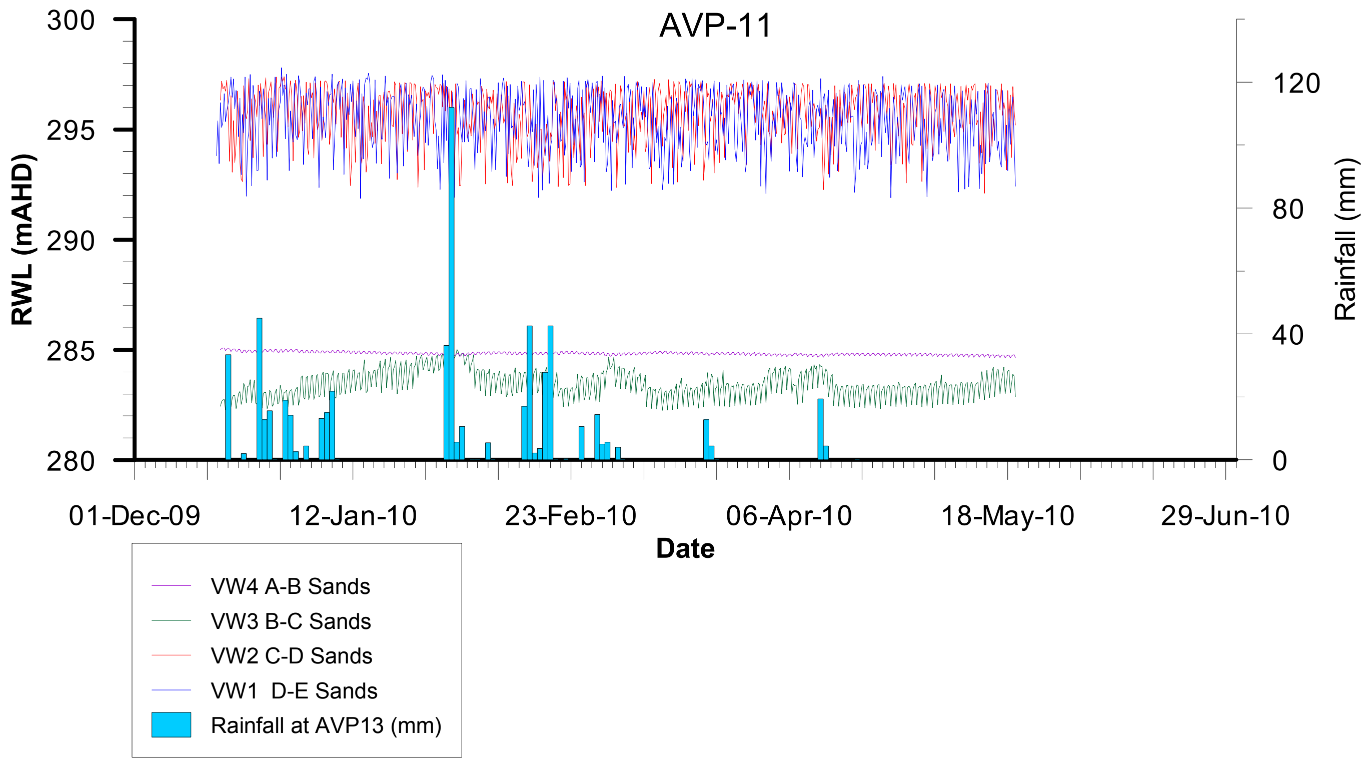


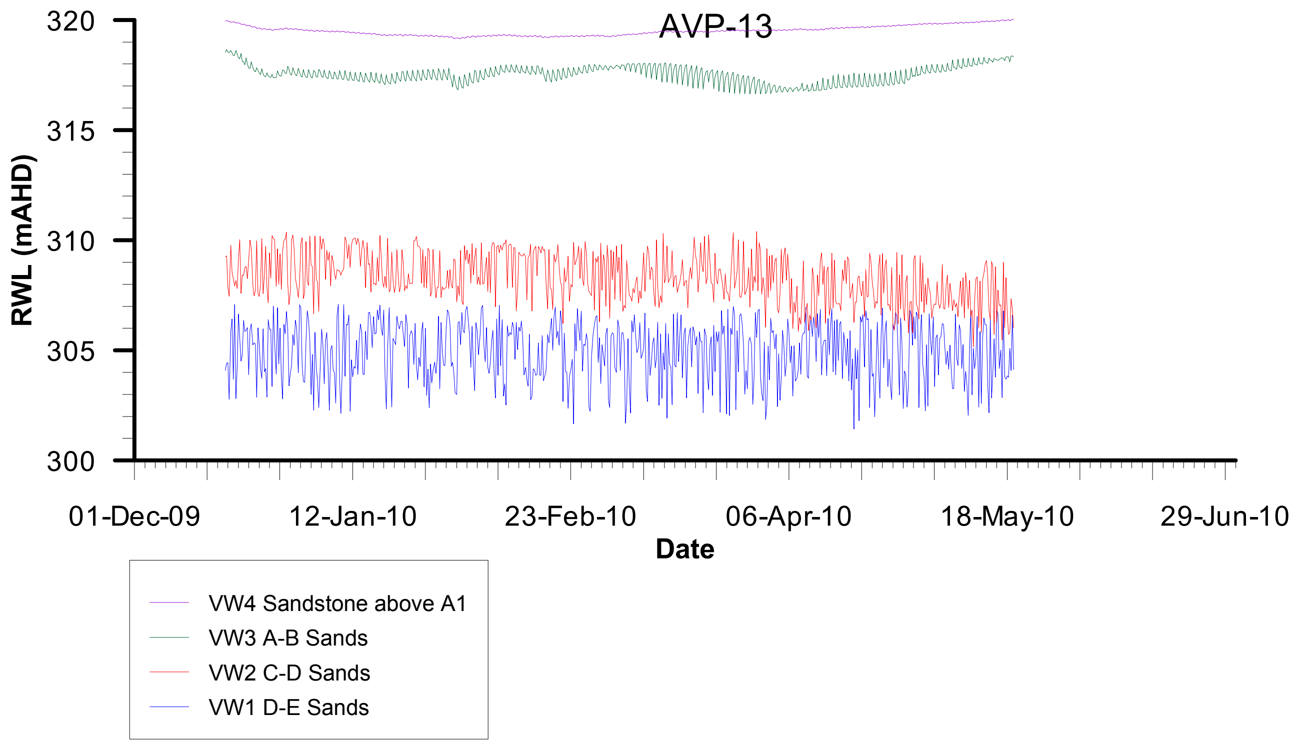




JBT consulting	CLIENT Hancock Coal Pty Limited	PROJECT Alpha Coal Project
	DRAWN JWB / DATE Aug 2010	TITLE **Reduced Water Level VWP Bores AVP07, AVP07, AVP10**
	CHECKED / DATE	
	SCALE As Shown / A4	PROJECT No. JBT01-001-021 / FIGURE No. **10**

C:\Work\JBT01-005-Alpha Coal Project\Bore Data\VWP Bores\Graphs\AVP01-03-04.grf

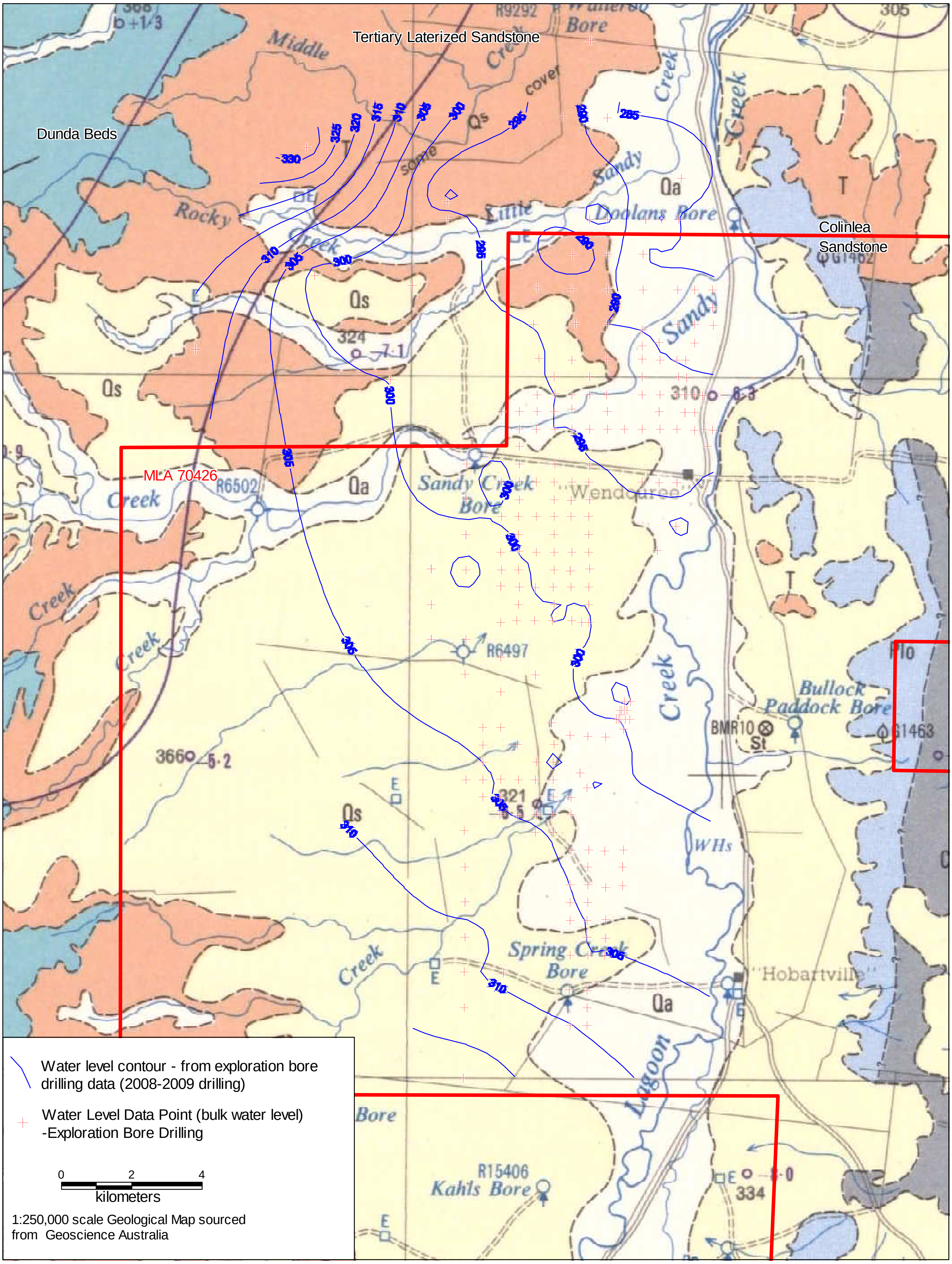




JBT consulting	CLIENT Hancock Coal Pty Limited		PROJECT Alpha Coal Project	
	DRAWN JWB	DATE Aug 2010	TITLE **Reduced Water Level VWP Bores AVP11, AVP13**	
	CHECKED	DATE		
	SCALE As Shown	A4	PROJECT No. JBT01-001-021	FIGURE No. 11

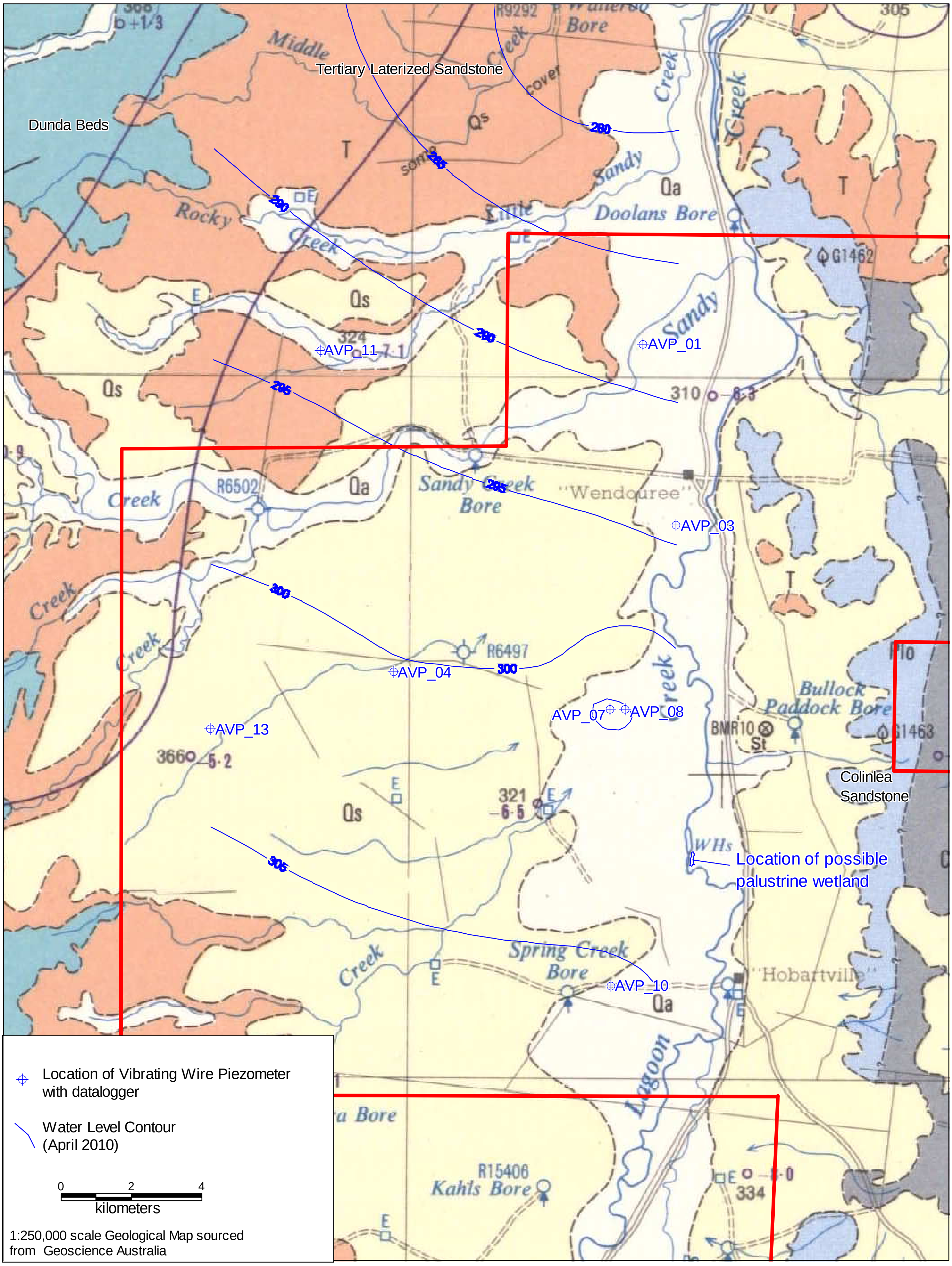
C:\Work\JBT01-005-Alpha Coal Project\Bore Data\VWP Bores\Graphs\AVP01-03-04.grf

GM: very hazy - can it be made clearer?



CLIENT: Hancock Coal Pty Ltd		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: **Potentiometric Surface Contours (mAHD) - Exploration Bore Drilling**	
CHECKED:	DATE:		
SCALE: 1:150,000	PAGE: A4 REV.: C	PROJECT No: JBT01-005-021	FIGURE No: 12

GM: very hazy - can it be made clearer?

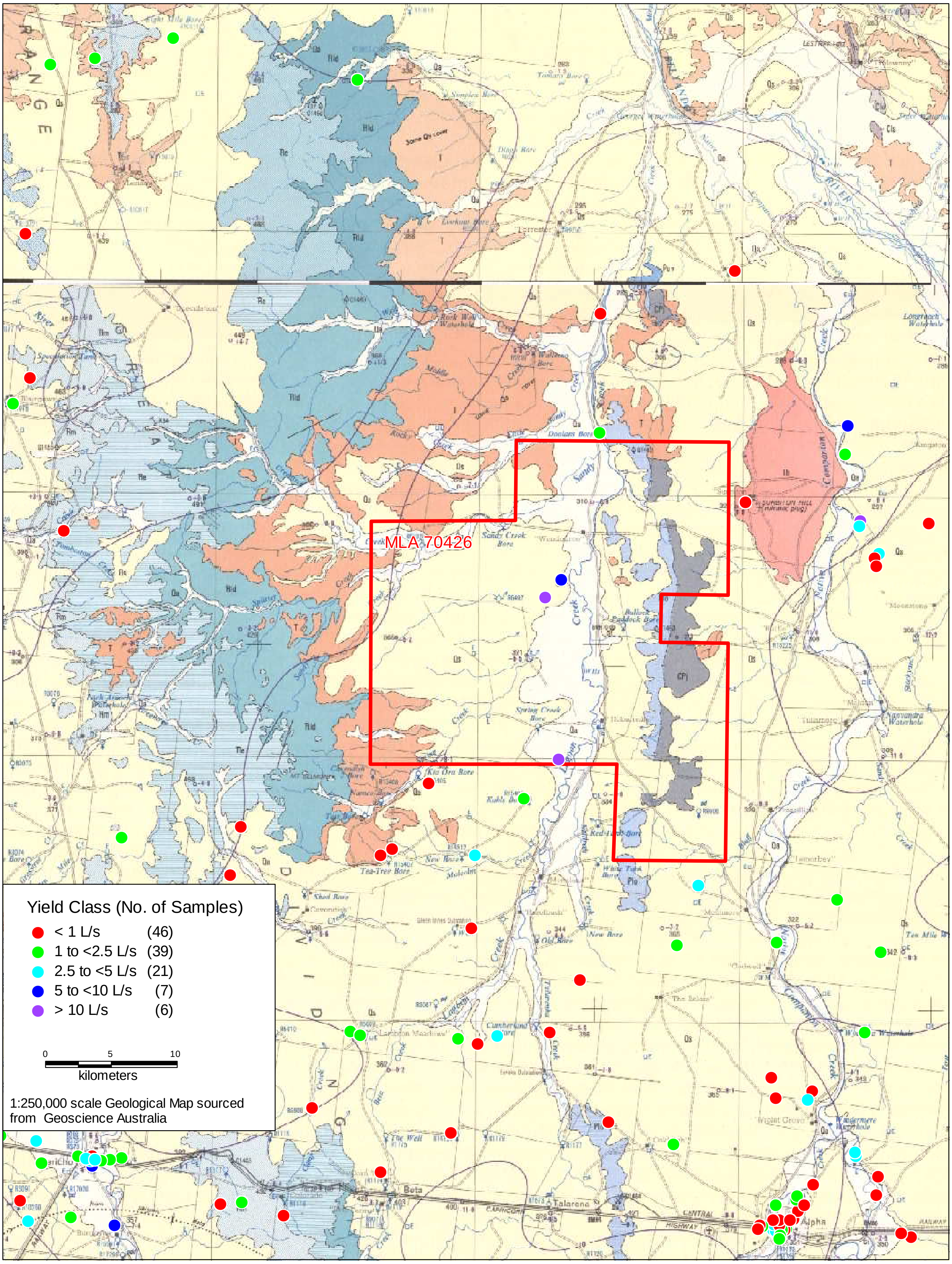


CLIENT		PROJECT
Hancock Coal Pty Ltd		Alpha Coal Project
DRAWN JWB	DATE Aug 2010	TITLE **Potentiometric Surface Contours (mAHD) - D-E Sands VWP Bores**
CHECKED	DATE	
SCALE 1:150,000	A4	PROJECT No JBT01-005-021 / FIGURE No **13**

JBT consulting

C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\Reduced Water Level.WOR

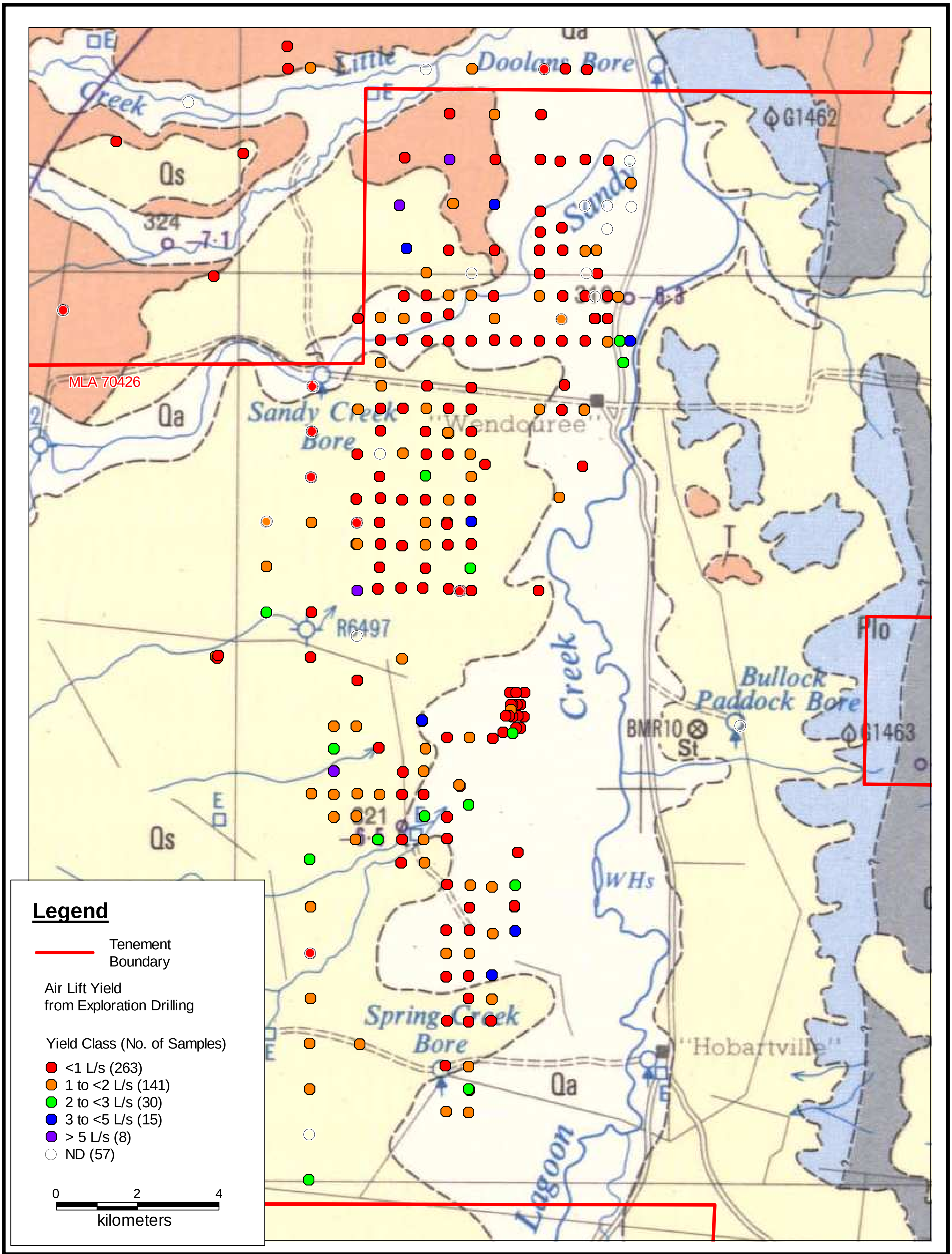
GM: very hazy - can it be made clearer?



JBT consulting	CLIENT: Hancock Coal Pty Ltd		PROJECT: Alpha Coal Project	
	DRAWN: JWB	DATE: Aug 2010	TITLE: **Bore Yield (L/s) from DERM Database**	
	CHECKED:	DATE:		
	SCALE: 1:400,000	A4	PROJECT No: JBT01-005-021	FIGURE No: **14**

C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\DERM Bore Yield.WOR

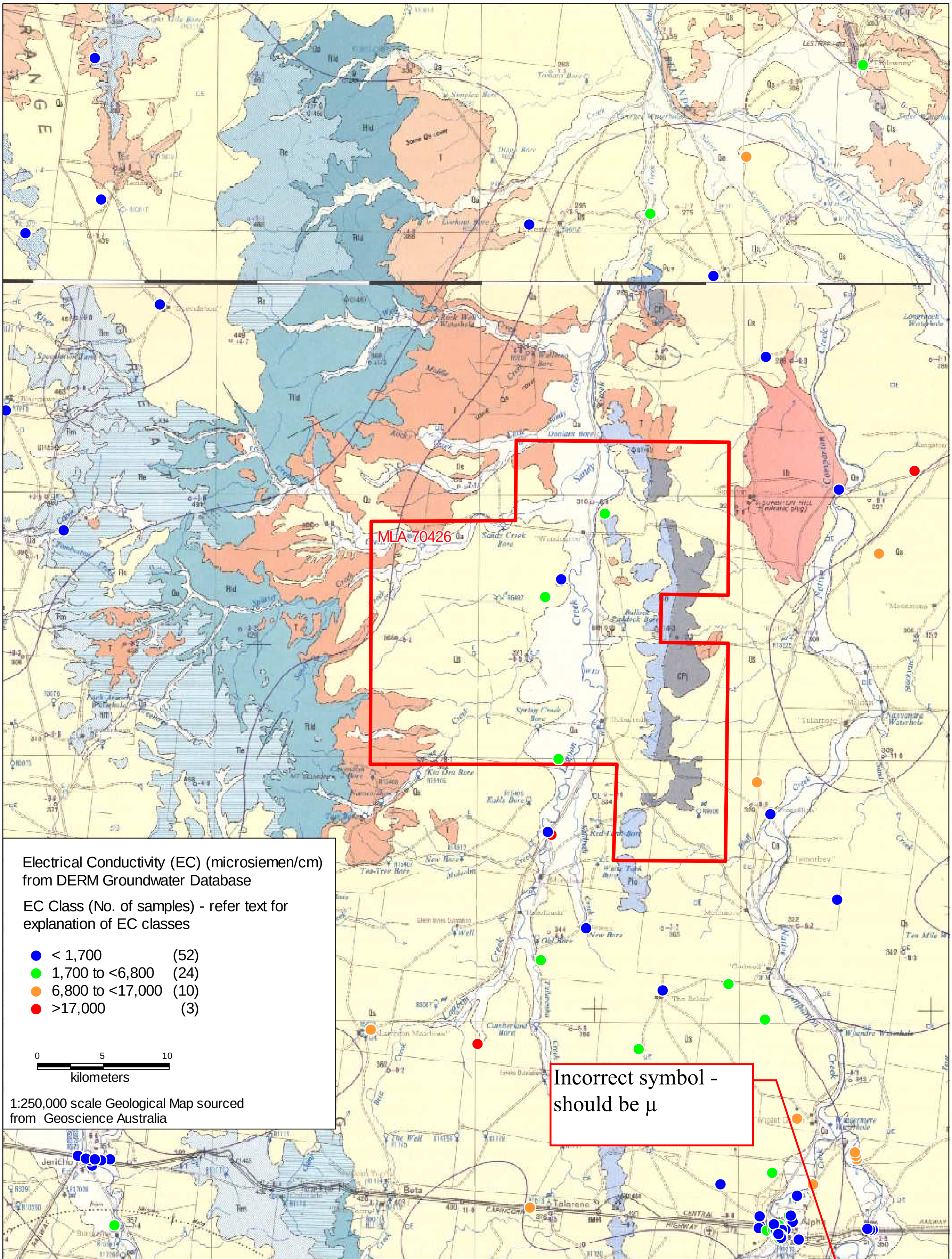
GM: very hazy - can it be made clearer?



CLIENT Hancock Coal Pty Ltd		PROJECT Alpha Coal Project	
DRAWN JWB	DATE Aug 2010	TITLE Bore Yield (L/s) from Exploration Drilling	
CHECKED	DATE		
SCALE 1:125,000	A4	PROJECT No JBT01-005-021	FIGURE No 15

JBT consulting

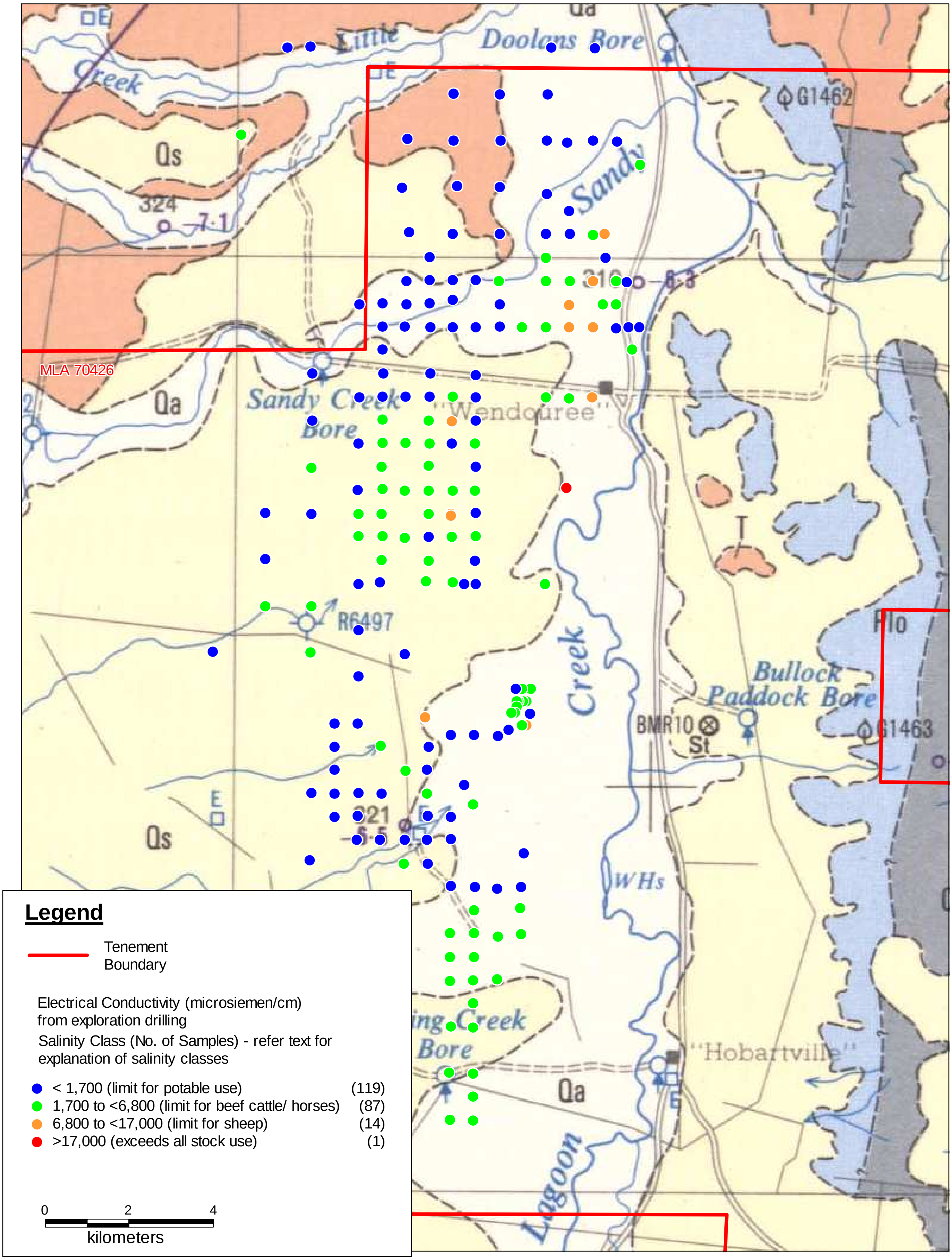
C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\Yield Class - Exploration.WOR



CLIENT		PROJECT	
Hancock Coal Pty Ltd		Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: **Electrical Conductivity (uS/cm) from DERM Groundwater Database**	
CHECKED	DATE		
SCALE: 1:400,000	A4	PROJECT No: JBT01-005-021	FIGURE No: **16**

C:\Work\JBT01-005-Alpha Coal Project\Mapinfo\DERM EC Classes.WOR

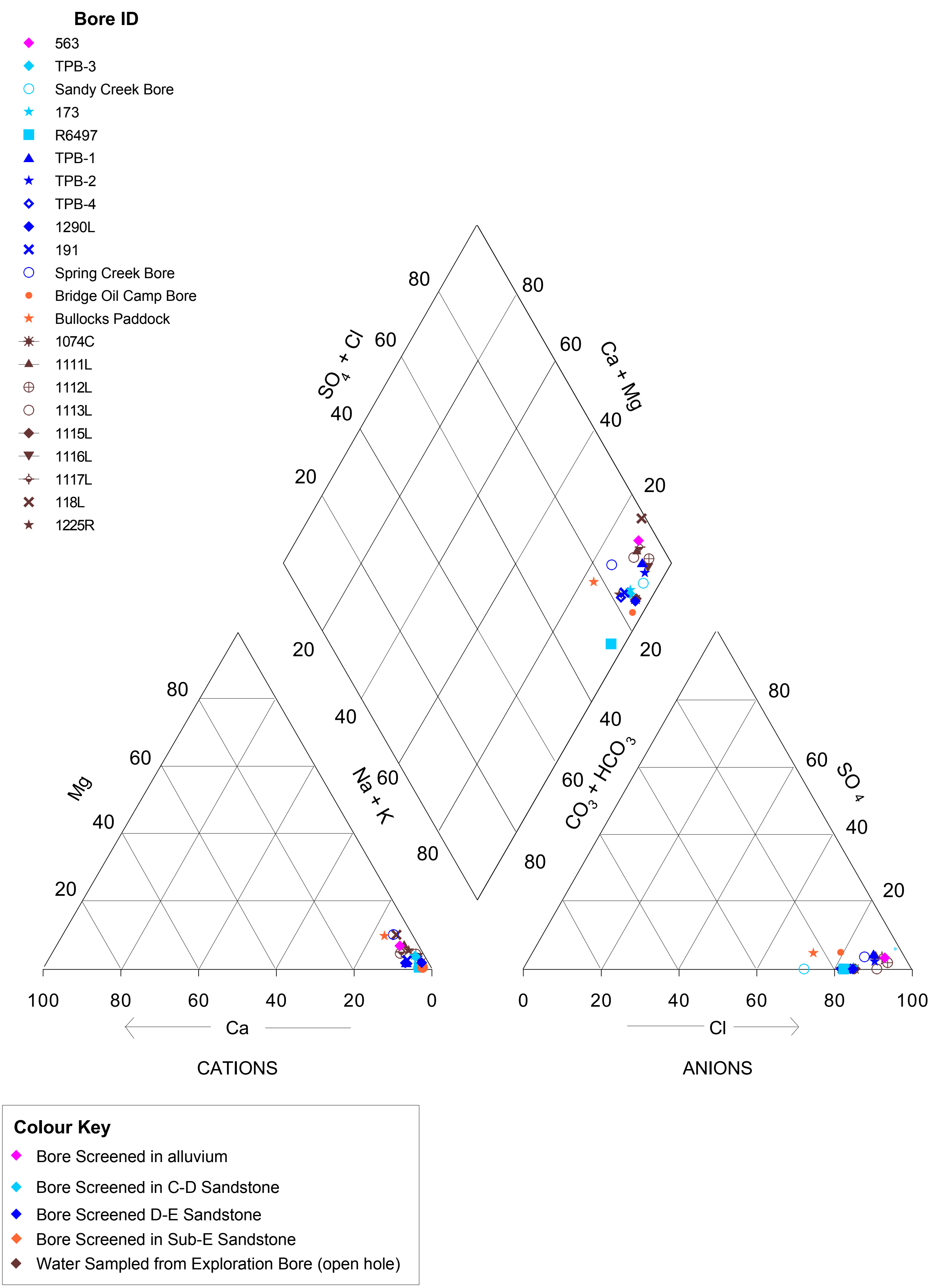
GM: very hazy - can it be made clearer?



CLIENT: Hancock Coal		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: Electrical Conductivity (uS/cm) from Exploration Drilling	
CHECKED:	DATE:		
SCALE: 1:125,000	A4	PROJECT No: JBT01-005-021	FIGURE No: 17

JBT consulting

\Work\Clermont\MapInfo\Workspace\Bore Locations for Survey.WOR



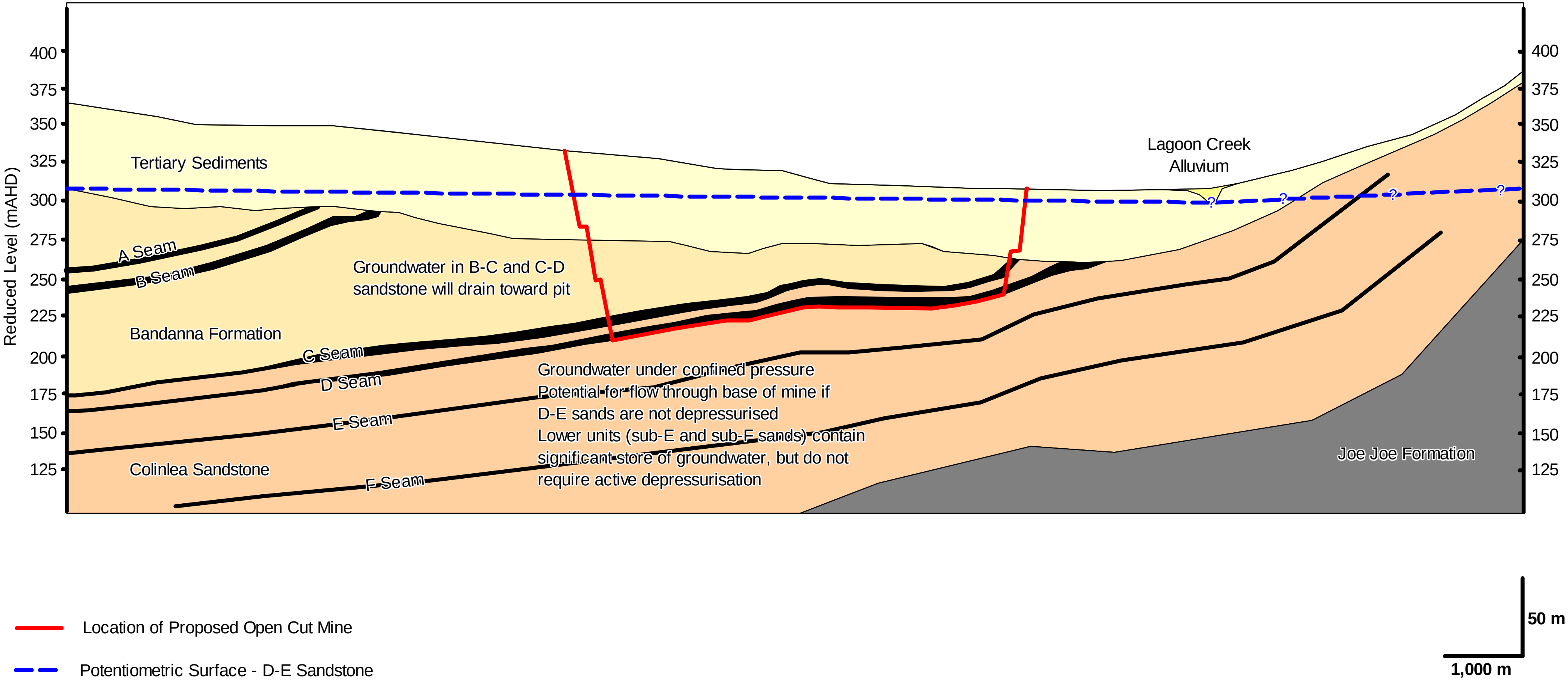
CLIENT: Hancock Coal		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: Piper Trilinear Plot Alpha Groundwater Samples	
CHECKED:	DATE:		
SCALE: As Shown	A4	PROJECT No. JBT01-007-021	FIGURE No. 18

JBT consulting

Recharge (west)
Diffuse downward recharge, predominantly in west (Great Dividing Range) where soil cover is thinnest
Vibrating wire piezometers within MLA show that the potentiometric surface of all aquifers converges in east, near Lagoon Creek. Potentiometric surface of C-D sandstone higher than potentiometric surface for D-E sandstone in west - indicates downward flow potential

Discharge
Potential for discharge to base of Lagoon Creek alluvium, but would require structural control (faults, joints) to allow groundwater discharge to base of alluvium. Groundwater occurs under confined conditions adjacent to creek

Recharge (east)
Downward recharge potential, but only under conditions where consistent rainfall saturates the rock profile. Otherwise, rainfall will runoff, or shallow infiltration will flow across weathered rock interface at shallow depth (1 to 5 m) toward Lagoon Creek alluvium

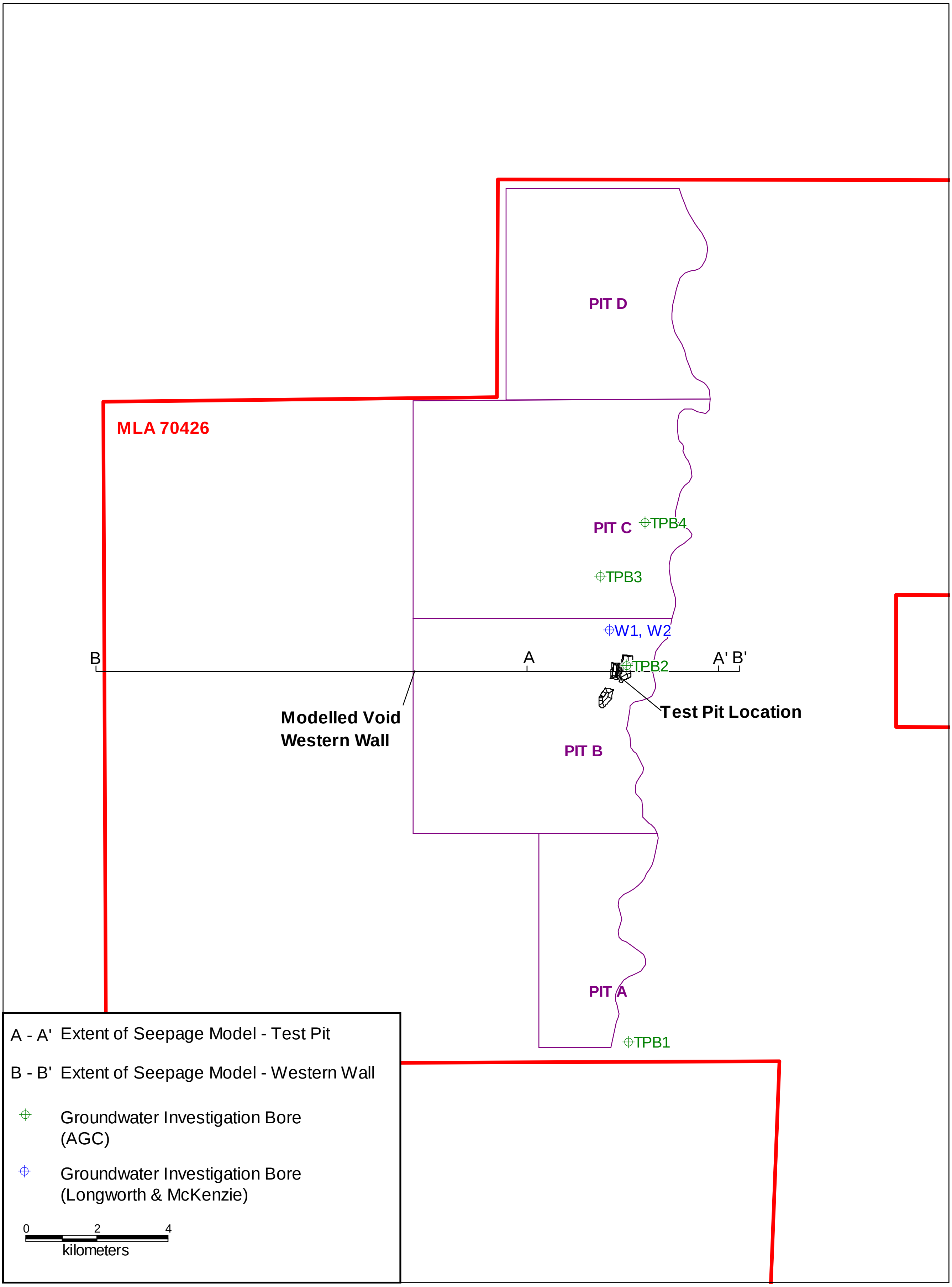


Location of Proposed Open Cut Mine

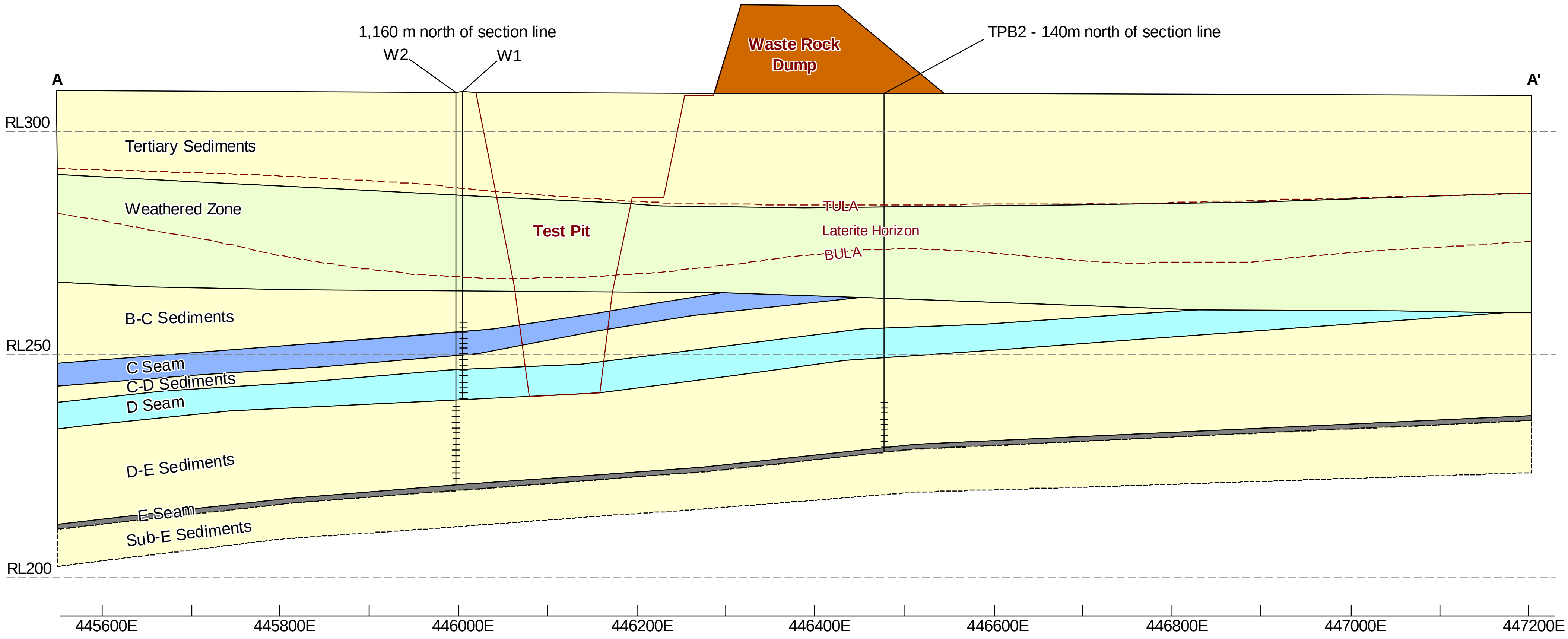
Potentiometric Surface - D-E Sandstone
Shallow gradient of ~0.001 (1m drop every 1,000 m)
Groundwater flow direction to NNE on west side of Lagoon Creek, interpreted to be NNW on eastern side of Lagoon Creek

JBT consulting

CLIENT: Hancock Coal		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: August 2010	TITLE: Conceptual Groundwater Model Pre-Mining	
CHECKED:	DATE:		
SCALE: As Shown	A4	PROJECT No: JBT01-005-021	FIGURE No: 19

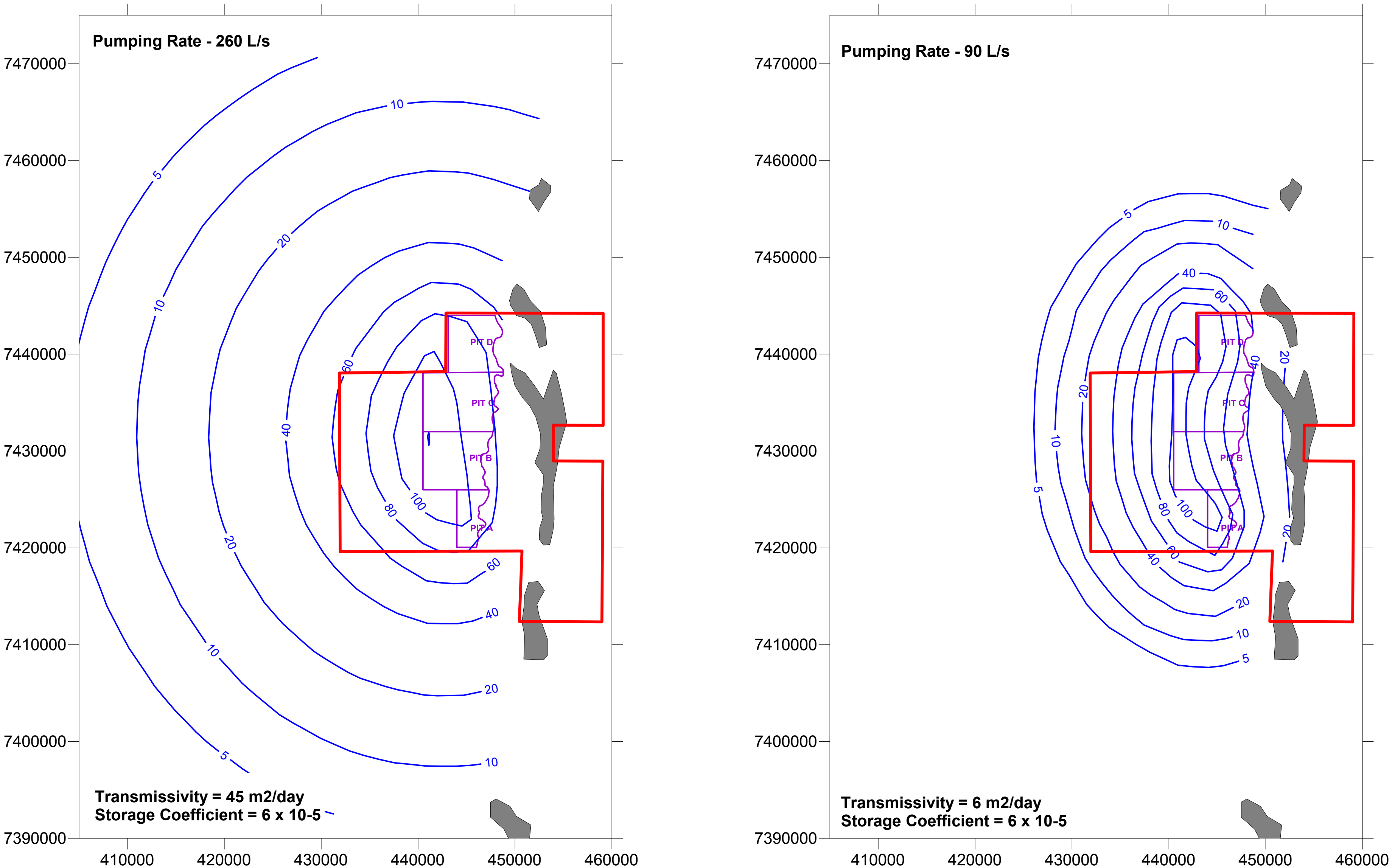


JBT consulting	CLIENT: Hancock Coal Pty Ltd		PROJECT: Alpha Coal Project
	DRAWN: JWB	DATE: Aug 2010	TITLE: SECTION LOCATIONS
	CHECKED:	DATE:	
	SCALE: 1:150,000	A4	PROJECT No: JBT01-005-021 — FIGURE No: 20



Section detail based on section provided from site geological model

JBT consulting	CLIENT Hancock Coal Pty Ltd			PROJECT Alpha Coal Project	
	DRAWN JWB	DATE Aug 2010		TITLE SECTION DETAIL TEST PIT	
	CHECKED	DATE			
	SCALE As Shown		A4	PROJECT No JBT01-005-021	FIGURE No 21



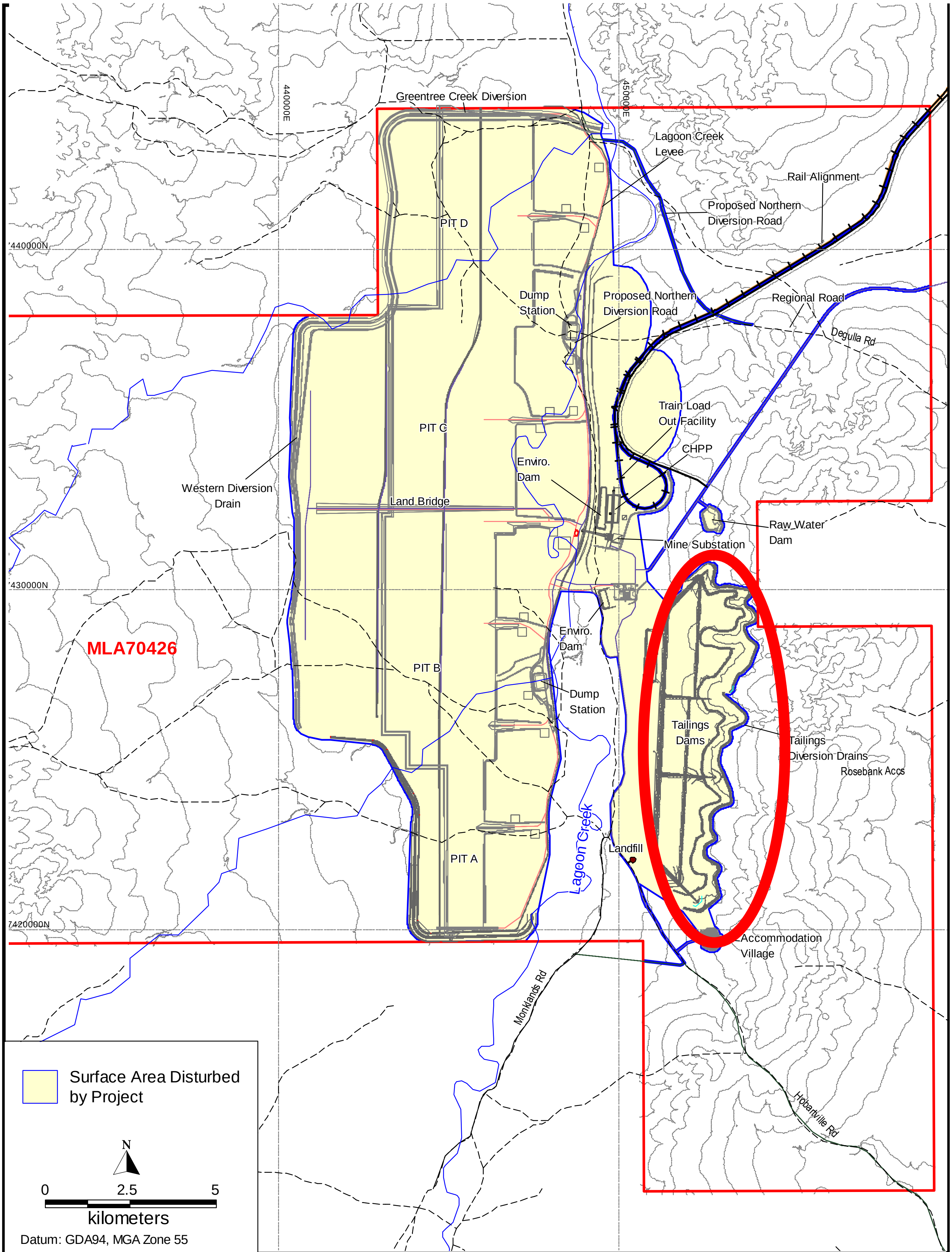
Colinlea Sandstone Outcrop

MLA Boundary

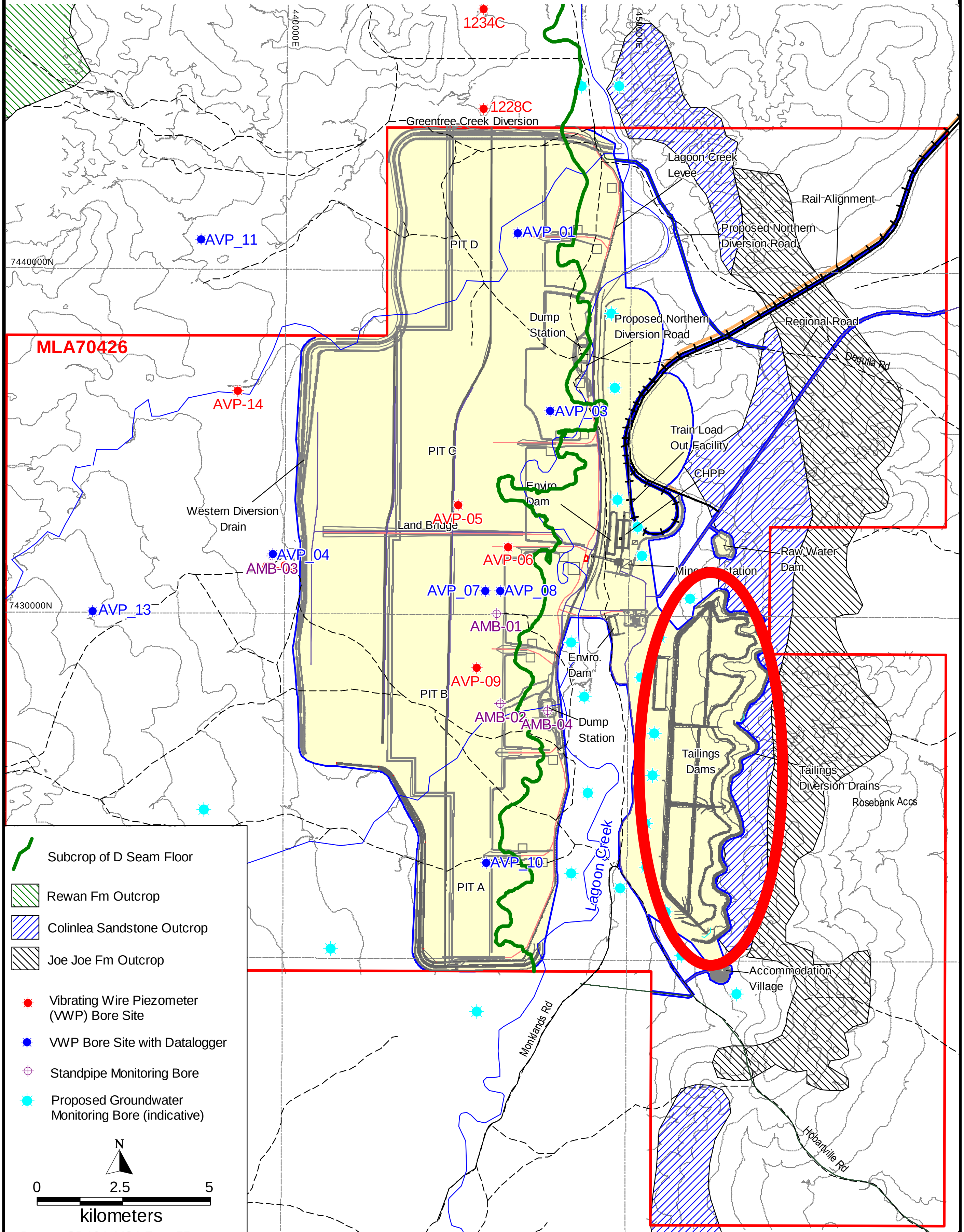
Water Level Drawdown Contours (m)
after 12 months pumping

JBT consulting

CLIENT: Hancock Coal		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: **Pit Dewatering Scenarios Effects of Varying Aquifer Transmissivity**	
CHECKED:	DATE:		
SCALE: As Shown		PROJECT No.: JBT01-005-021	FIGURE No.: 22

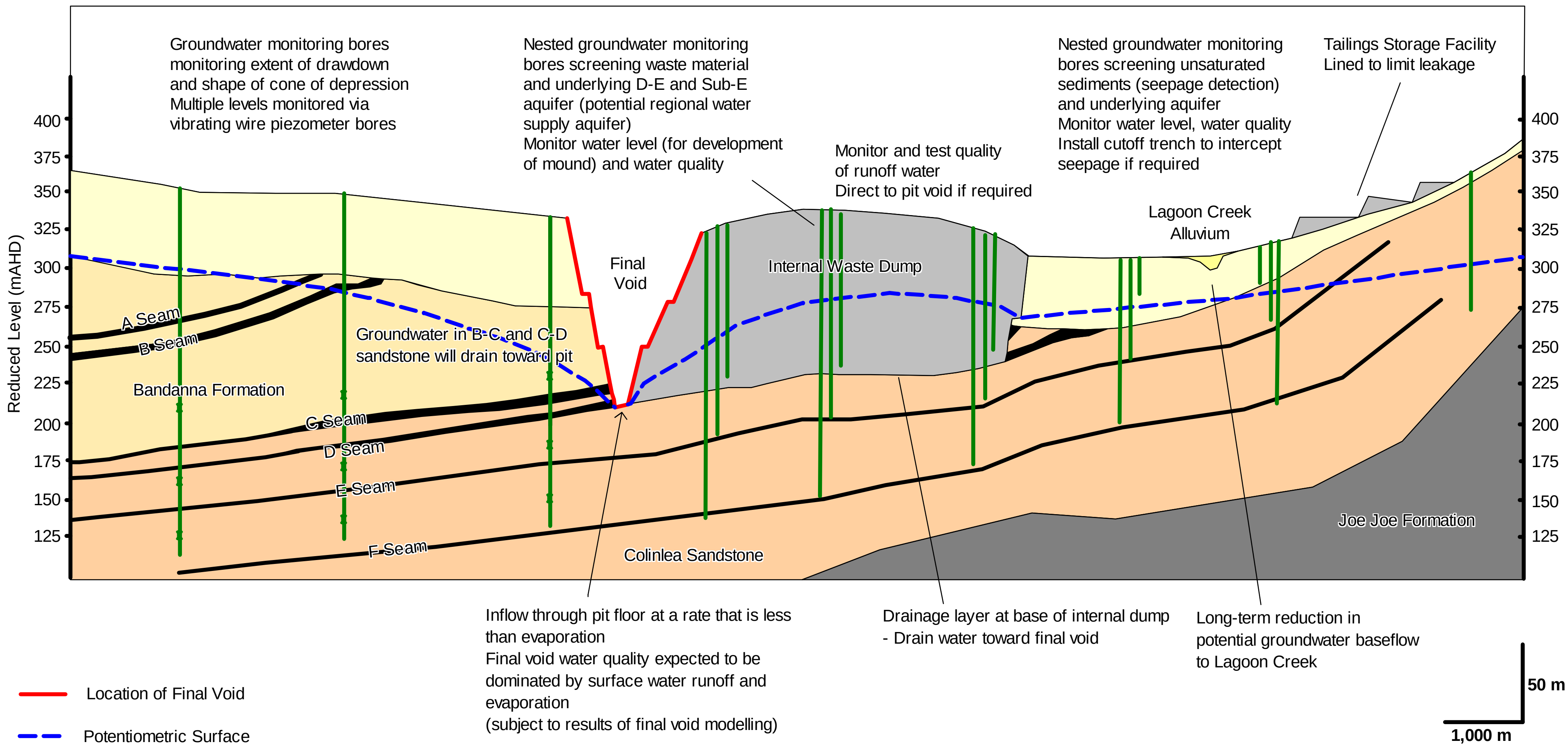


CLIENT: Hancock Coal Pty Ltd			PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010		TITLE: Site Infrastructure Layout	
CHECKED:	DATE:			
SCALE: 1:150,000		A4	PROJECT No: JBT01-007-021	FIGURE No: 23



JBT consulting

CLIENT: Hancock Coal Pty Ltd		PROJECT: Alpha Coal Project	
DRAWN: JWB	DATE: Aug 2010	TITLE: Existing and Proposed Groundwater Monitoring Bores	
CHECKED:	DATE:		
SCALE: 1:150,000	A4	PROJECT No: JBT01-007-021	FIGURE No: 24



CLIENT	Hancock Coal		PROJECT	Alpha Coal Project
DRAWN JWB	DATE August 2010		TITLE	Conceptual Groundwater Model Post-Mining
CHECKED	DATE			
SCALE As Shown	A4		PROJECT No JBT01-005-021	FIGURE No 25

JBT consulting

APPENDIX A

VIBRATING WIRE PIEZOMETER DETAILS

Appendix A - Groundwater Monitoring Bore Details

Hole ID	Monitoring Bore ID	Easting_GDA94	Northing_GDA94	Surface RL (mAHD)	Piezo No.	VWP Serial No.	Installed Depth (mbgl)	Unit Monitored	Datalogger Installed	Raingauge Installed
Vibrating Wire Piezometer Bores										
1252D	AVP-01	446725.181	7441096.55	307.89	VW2	8972	55	C-D Sandstone	Yes	Yes
1252D	AVP-01	446725.181	7441096.55	307.89	VW1	11791	77	D-E Sandstone	Yes	Yes
1262D	AVP-03	447700.515	7435935.65	303.12	VW1	8974	42.5	D-E Sandstone	Yes	
1347DG	AVP-04	439677.103	7431710.26	333.08	VW3	11792	80	B-C Sandstone	Yes	
1347DG	AVP-04	439677.103	7431710.26	333.08	VW2	11763	132	C-D Sandstone	Yes	
1347DG	AVP-04	439677.103	7431710.26	333.08	VW1	11764	143	D-E Sandstone	Yes	
1315D	AVP_05	445052.296	7433185.69	312	VW3	8970	49	CU Coal Seam		
1315D	AVP_05	445052.296	7433185.69	312	VW2	11776	65	C-D Sandstone		
1315D	AVP_05	445052.296	7433185.69	312	VW1	11793	80	D-E Sandstone		
1336D	AVP_06	446510.39	7431957.19	313	VW2	8967	48.5	C-D Sandstone		
1336D	AVP_06	446510.39	7431957.19	313	VW1	11794	70	D-E Sandstone		
1337DG	AVP-07	445862.01	7430684.68	309	VW2	8968	63.5	C-D Sandstone	Yes	
1337DG	AVP-07	445862.01	7430684.68	309	VW1	11795	79	D-E Sandstone	Yes	
1327D	AVP-08	446280.871	7430685.25	308	VW2	8975	57.5	DU Coal Seam	Yes	
1327D	AVP-08	446280.871	7430685.25	308	VW1	8625	67	D-E Sandstone	Yes	
1338DG	AVP_09	445607.245	7428456.96	316	VW2	8619	61	C-D Sandstone		
1338DG	AVP_09	445607.245	7428456.96	316	VW1	9121	73	D-E Sandstone		
1339DG	AVP-10	445920.65	7422776.91	321	VW2	8980	61	Base DLM Seam	Yes	
1339DG	AVP-10	445920.65	7422776.91	321	VW1	8622	84	D-E Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW4	11798	122	A-B Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW3	11704	165	B-C Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW2	11708	205	C-D Sandstone	Yes	
1263DG	AVP-11	437531.05	7440860.71	327	VW1	11771	218	D-E Sandstone	Yes	
1328DG	AVP-13	434456.875	7430044.11	363	VW4	11778	70	Sandstone above A1	Yes	Yes
1328DG	AVP-13	434456.875	7430044.11	363	VW3	11797	112	A-B Sandstone	Yes	Yes
1328DG	AVP-13	434456.875	7430044.11	363	VW2	11768	182	B-C Sandstone	Yes	Yes
1328DG	AVP-13	434456.875	7430044.11	363	VW1	11769	229.3	D-E Sandstone	Yes	Yes
1357D	AVP-14	438634.272	7436473.393	330.95	VW4	11777	58.5	B-C Sandstone		
1357D	AVP-14	438634.272	7436473.393	330.95	VW3	11796	108.5	B-C Sandstone		
1357D	AVP-14	438634.272	7436473.393	330.95	VW2	11765	134.5	C-D Sandstone		
1357D	AVP-14	438634.272	7436473.393	330.95	VW1	11766	149.5	D-E Sandstone		
1313C		447231.603	7453127.691	289.5	VW2	8976	45	C-D Sandstone		
1313C		447231.603	7453127.691	289.5	VW1	8977	70	D-E Sandstone		
1234C		445701.569	7447597.086	298.6	VW3	8978	45	B-C Sandstone		
1234C		445701.569	7447597.086	298.6	VW2	8621	67	C-D Sandstone		
1234C		445701.569	7447597.086	298.6	VW1	8624	98	D-E Sandstone		
1228C		445706.344	7444680.977	299.25	VW3	11727	33	B-C Sandstone		
1228C		445706.344	7444680.977	299.25	VW2	11780	64	C-D Sandstone		
1228C		445706.344	7444680.977	299.25	VW1	11799	83	D-E Sandstone		
1356R		440159.924	7454609.765	315.05	VW4	11733	71	Tertiary above A1		
1356R		440159.924	7454609.765	315.05	VW3	11709	150	B-C Sandstone		
1356R		440159.924	7454609.765	315.05	VW2	11710	180	C-D Sandstone		
1356R		440159.924	7454609.765	315.05	VW1	11711	210	E-F Sandstone		
1238C		445178.959	7449763.639	307.15	VW3	11728	40	B-C Sandstone		
1238C		445178.959	7449763.639	307.15	VW2	11781	80	C-D Sandstone		
1238C		445178.959	7449763.639	307.15	VW1	11800	105.5	D-E Sandstone		
Standpipe Monitoring Bores										
AMB-01	AMB-01	446180	7430035					D-E Sandstone		
AMB-02	AMB-02	446314	7427417					E-F Sandstone		
AMB-03	AMB-03	439653	7431658					D-E Sandstone		
AMB-04	AMB-04	447682	7427212					C-D Sandstone		

APPENDIX B

WATER QUALITY ANALYIS SUMMARY

Appendix B: Laboratory analysis results for Major Ion sampling, compared to Drinking Water and Stock Guidelines

Drinking Water Guidelines*

Bore	Date	Aquifer		pH (lab)	EC(lab)	Total Dissolved Solids	Sodium	Potassium	Calcium	Magnesium	Chloride	Sulphate as SO4 2-	Fluoride	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Hydroxide Alkalinity as CaCO3	Total Alkalinity as CaCO3
						mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
						Guideline Value											
			Health			**na/**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**500**	**1.5**	**n/a**	**n/a**	**n/a**	**n/a**
			Aesthetic	**6.5-8.5**		**500**	**180**	**n/a**	**n/a**	**n/a**	**250**	**250**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
TPB-1	1983	D-E Sandstone		8.15	2,830	1,550	529	3	28	6	828	58	0.6	1	101		102
TPB-2	1983	D-E Sandstone		7.45	3,150	1,750	619	6	11	12	945	34	0.9	1	126		127
TPB-3	1983	C-D Sandstone		7.45	1,630	930	322	6	7	7	470	1	1.5	1	120		121
TPB-4	1983	D-E Sandstone		7.65	1,320	775	267	4	15	3	370	1	1.2	1	116		117
563	1983	Alluvium		7.90	4,560	2,630	874	8	41	37	1,470	75	0.4	1	120		121
191	1983	D-E Sandstone		8.10	1,760	750	253	4	12	4	371	1	0.7	1	104		105
173	1983	C-D Sandstone		8.15	2,900	1,670	575	8	14	13	840	9	2.3	2	205		207
Sandy Creek Bore	1983	C-D Sandstone		8.15	1,280	870	297	3	8	1	361	1	1.7	2	194		196
Spring Creek Bore	1983	D-E Sandstone		7.95	1,880	1,140	403	3	14	1	582	34	0.5	1	99		100
Bridge Oil Camp Bore	1983	Sub E Sandstone		6.05	680	390	121	5	6	8	184	16	0.1	1	51		52
Bore R6497	1983	C-D Sandstone		7.80	1,410	900	316	3	6	1	438	1	1.0	1	131		132
Bullocks Paddock Bore	1983	Sub E Sandstone		6.55	430	260	77	3	6	5	109	10	0.1	1	48		49
1290L	18-May-10	D-E Sandstone		8.20	1,600	944	270	4	4	3	440	1	0.9	1	110		111
118L	9-Dec-08	Open hole - coal measures		7.70	22,000	12,980	4,400	30	180	280	7,500	670		1	149		150
1112L	9-Dec-08	Open hole - coal measures		8.20	9,600	5,664	2,900	86	50	76	3,800	110		1	309		310
1225R	9-Dec-08	Open hole - coal measures		8.30	1,600	944	260	6.3	8	9	410	1		1	129		130
1113L	9-Dec-08	Open hole - coal measures		7.40	2,900	1,711	460	7.5	26	13	710	1		1	99		100
115L	9-Dec-08	Open hole - coal measures		8.40	1,600	944	270	2.8	6	2	350	1		1	83		84
116L	9-Dec-08	Open hole - coal measures		8.20	4,300	2,537	910	12	16	18	1,300	35		1	139		140
1111L	9-Dec-08	Open hole - coal measures		8.20	8,500	5,015	1,600	14	56	67	2,200	130		1	259		260
1117L	9-Dec-08	Open hole - coal measures		7.70	4,400	2,596	780	6	40	24	1,200	67		1	110		111
1074C	9-Dec-08	Open hole - coal measures		8.90	1,800	1,062	300	4.1	5	3	410	1		1	100		101

* Australian Drinking Water Guidelines, 2004. National Water Quality Management Strategy

Value above guideline level for health

Value above guideline level for aesthetic considerations

Livestock Water Guidelines**

Bore	Date	Aquifer		pH (lab)	EC(lab)	Total Dissolved Solids	Sodium	Potassium	Calcium	Magnesium	Chloride	Sulphate as SO4 2-	Fluoride	Carbonate Alkalinity as CaCO3	Bicarbonate Alkalinity as CaCO3	Hydroxide Alkalinity as CaCO3	Total Alkalinity as CaCO3
						mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
						Guideline Value											
						4000 (a)			**1000**			**1000**	**2**				
TPB-1	1983	D-E Sandstone		8.15	2,830	1,550	529	3	28	6	828	58	0.6	1	101	-	102
TPB-2	1983	D-E Sandstone		7.45	3,150	1,750	619	6	11	12	945	34	0.9	1	126	-	127
TPB-3	1983	C-D Sandstone		7.45	1,630	930	322	6	7	7	470	1	1.5	1	120	-	121
TPB-4	1983	D-E Sandstone		7.65	1,320	775	267	4	15	3	370	1	1.2	1	116	-	117
563	1983	Alluvium		7.9	4,560	2,630	874	8	41	37	1,470	75	0.4	1	120	-	121
191	1983	D-E Sandstone		8.1	1,760	750	253	4	12	4	371	1	0.7	1	104	-	105
173	1983	C-D Sandstone		8.15	2,900	1,670	575	8	14	13	840	9	2.3	2	205	-	207
Sandy Creek Bore	1983	C-D Sandstone		8.15	1,280	870	297	3	8	1	361	1	1.7	2	194	-	196
Spring Creek Bore	1983	D-E Sandstone		7.95	1,880	1,140	403	3	14	1	582	34	0.5	1	99	-	100
Bridge Oil Camp Bore	1983	Sub E Sandstone		6.05	680	390	121	5	6	8	184	16	0.1	1	51	-	52
Bore R6497	1983	C-D Sandstone		7.8	1,410	900	316	3	6	1	438	1	1.0	1	131	-	132
Bullocks Paddock Bore	1983	Sub E Sandstone		6.55	430	260	77	3	6	5	109	10	0.1	1	48	-	49
1290L	18-May-10	D-E Sandstone		8.2	1,600	944	270	4	4	3	440	1	0.9	1	110	-	111
118L	9-Dec-08	Open hole - coal measures		7.7	22,000	12,980	4,400	30	180	280	7,500	670	-	1	149	-	150
1112L	9-Dec-08	Open hole - coal measures		8.2	9,600	5,664	2,900	86	50	76	3,800	110	-	1	309	-	310
1225R	9-Dec-08	Open hole - coal measures		8.3	1,600	944	260	6	8	9	410	1	-	1	129	-	130
1113L	9-Dec-08	Open hole - coal measures		7.4	2,900	1,711	460	8	26	13	710	1	-	1	99	-	100
115L	9-Dec-08	Open hole - coal measures		8.4	1,600	944	270	3	6	2	350	1	-	1	83	-	84
116L	9-Dec-08	Open hole - coal measures		8.2	4,300	2,537	910	12	16	18	1,300	35	-	1	139	-	140
1111L	9-Dec-08	Open hole - coal measures		8.2	8,500	5,015	1,600	14	56	67	2,200	130	-	1	259	-	260
1117L	9-Dec-08	Open hole - coal measures		7.7	4,400	2,596	780	6	40	24	1,200	67	-	1	110	-	111
1074C	9-Dec-08	Open hole - coal measures		8.9	1,800	1,062	300	4	5	3	410	1	-	1	100	-	101

**ANZECC 2000 - Austalian and New Zealand Guidelines for Fresh and Marine Water Quality

Value above guideline level

(a) No adverse effects on animals expected up to the following concentrations (mg/L):
Poultry (2000); Dairy Cattle (2,500); Beef cattle, Pigs, Horses (4,000); Sheep (5000)
Guideline value in table above set on limit for beef cattle

Appendix B: Laboratory analysis of Metals/Metalloids, compared to Drinking Water Guidelines* and Livestock Watering Guidelines**

Drinking Water Guidelines*

Bore	Date	Aquifer		Aluminium	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Vanadium	Zinc
				Total Metals																		
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
				Guideline Value(mg/L)																		
			Health	**(a)**	**0.003**	**0.007**	**0.7**	**(a)**	**4**	**0.002**	**0.05 (b)**	**-**	**2**	**(a)**	**0.01**	**0.5**	**0.001**	**0.05**	**0.02**	**0.01**	**-**	**(a)**
			Aesthetic	**1**		**-**			**-**	**-**	**-**	**-**	**1**	**0.3**	**-**	**0.1**	**-**	**-**	**-**	**-**	**-**	**3**
1290L	18-May-10	D-E Sandstone		1.1	<0.001	<0.001			0.26				0.009	3.9	<0.001	0.12	<0.0005	0.002	0.008	0.007		0.008
118L	9-Dec-08	Open hole - coal measures		0.02		<0.001	0.055	<0.001	0.63	<0.001	<0.002	0.005	0.017		<0.001	0.63	<0.0005	<0.001	0.043	0.190	0.051	0.1
1112L	9-Dec-08	Open hole - coal measures		27		<0.001	0.370	0.0024	0.17	<0.001	0.033	0.023	0.190		0.002	0.92	<0.0005	0.002	0.053	0.110	0.047	0.2
1225R	9-Dec-08	Open hole - coal measures		2.3		<0.001	0.220	<0.001	0.18	<0.001	0.005	0.002	0.029		0.002	0.14	<0.0005	0.002	0.008	0.012	0.012	0.1
1113L	9-Dec-08	Open hole - coal measures		2.3		<0.001	0.070	<0.001	0.19	<0.001	0.036	0.005	0.048		0.001	0.42	<0.0005	0.001	0.013	0.019	0.012	0.2
115L	9-Dec-08	Open hole - coal measures		0.2		<0.001	0.044	<0.001	0.16	<0.001	<0.002	<0.001	0.020		<0.001	0.06	<0.0005	<0.001	<0.001	0.012	0.006	0.1
116L	9-Dec-08	Open hole - coal measures		11		<0.001	0.170	<0.001	0.13	<0.001	0.033	0.023	0.560		<0.001	0.41	<0.0005	<0.001	0.130	0.038	0.028	0.6
1111L	9-Dec-08	Open hole - coal measures		0.3		<0.001	0.110	<0.001	0.40	<0.001	<0.002	<0.001	0.002		<0.001	0.09	<0.0005	<0.001	0.006	0.079	0.021	0.0
1117L	9-Dec-08	Open hole - coal measures		0.02		<0.001	0.097	<0.001	0.12	<0.001	<0.002	<0.001	<0.001		<0.001	0.07	<0.0005	<0.001	0.003	0.036	0.012	0.0
1074C	9-Dec-08	Open hole - coal measures		1.4		0.016	0.200	0.0015	0.12	<0.001	0.012	0.017	0.410		0.046	0.69	<0.0005	0.016	0.067	0.012	0.020	0.5

* Australian Drinking Water Guidelines, 2004. National Water Quality Management Strategy

(yellow)	Value above guideline level for health
(orange)	Value above guideline level for aesthetic considerations
(a)	Insufficient data to set a threshold
(b)	Guideline level is for hexavalent chromium - if concentration of total Cr exceeds 0.05, test separately for hexavalent chromium

Livestock Water Guidelines**

Bore	Date	Aquifer		Aluminium	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Vanadium	Zinc
				Total Metals																		
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
				Guideline Value(mg/L)																		
				5		**0.5-5 (a)**		**(b)**	**5**	**0.01**	**1**	**1**	**1**	**n/a**	**0.1**	**0.1**	**0.002**	**0.15**	**1**	**0.02**	**(b)**	**20**
1290L	18-May-10	D-E Sandstone		1.1	<0.001	<0.001			0.26				0.009	3.9	<0.001	0.12	<0.0005	0.002	0.008	0.007		0.01
118L	9-Dec-08	Open hole - coal measures		0.02		<0.001	0.06	<0.001	0.63	<0.001	<0.002	0.005	0.017		<0.001	0.63	<0.0005	<0.001	0.043	0.190	0.051	0.08
1112L	9-Dec-08	Open hole - coal measures		27		<0.001	0.37	0.00	0.17	<0.001	0.03	0.023	0.190		0.00	0.92	<0.0005	0.002	0.053	0.110	0.047	0.24
1225R	9-Dec-08	Open hole - coal measures		2.3		<0.001	0.22	<0.001	0.18	<0.001	0.00	0.002	0.029		0.00	0.14	<0.0005	0.002	0.008	0.012	0.012	0.07
1113L	9-Dec-08	Open hole - coal measures		2.3		<0.001	0.07	<0.001	0.19	<0.001	0.04	0.005	0.048		0.00	0.42	<0.0005	0.001	0.013	0.019	0.012	0.16
115L	9-Dec-08	Open hole - coal measures		0.15		<0.001	0.04	<0.001	0.16	<0.001	<0.002	<0.001	0.020		<0.001	0.06	<0.0005	<0.001	<0.001	0.012	0.006	0.11
116L	9-Dec-08	Open hole - coal measures		11		<0.001	0.17	<0.001	0.13	<0.001	0.03	0.023	0.560		<0.001	0.41	<0.0005	<0.001	0.130	0.038	0.028	0.57
1111L	9-Dec-08	Open hole - coal measures		0.27		<0.001	0.11	<0.001	0.40	<0.001	<0.002	<0.001	0.002		<0.001	0.09	<0.0005	<0.001	0.006	0.079	0.021	0.02
1117L	9-Dec-08	Open hole - coal measures		0.02		<0.001	0.10	<0.001	0.12	<0.001	<0.002	<0.001	<0.001		<0.001	0.07	<0.0005	<0.001	0.003	0.036	0.012	0.02
1074C	9-Dec-08	Open hole - coal measures		1.4		0.016	0.20	0.00	0.12	<0.001	0.01	0.017	0.410		0.046	0.69	<0.0005	0.016	0.067	0.012	0.020	0.53

*ANZECC 2000 - Austalian and New Zealand Guidelines for Fresh and Marine Water Quality

(green)	Value above guideline level
(a)	May be tolerated if not provided as a food additive, and natural levels in the diet are low
(b)	Insufficient data to set trigger level