

DENDROBIUM MINE: FROM PAPER TO PRODUCTION

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INTRODUCTION

In July 2000, BHP Billiton Illawarra Coal announced its intention to conduct a feasibility study into establishing a new mine in Mt Kembla, New South Wales. The mine was needed to replace a specific grade of coal currently being supplied from the Company's Elouera Colliery. The Dendrobium Mine Project (incorporating the mine and the associated infrastructure), having undergone a Commission of Enquiry, was given approval by the Department of Planning in November 2001 and by the BHP Billiton Board of Directors immediately thereafter. The Dendrobium Mine became an official entity on December 23, 2001 by a redistribution of Kemira, Mt. Kembla and Elouera Mine holdings.

The project and the mine were named for the Dendrobium, a genus of orchid native to the area, the name of the parish in which the mine holdings are located and, for many years, the name given to the area of coal to the north west of the Wongawilli and Nebo workings.

The Dendrobium Project has been seen as a benchmark in a number of areas including community consultation. This paper, while referring to a range of areas, will predominantly focus on the planning of the mine, the mining and engineering challenges and successes the mine has achieved to date, and some of the learnings from undertaking to create a new underground coal mine on the Illawarra escarpment.

BACKGROUND

BHP Billiton's Illawarra Coal Holdings (and previously BHP (AIS Steel Pty Ltd)) has owned and managed many underground coal mines in the Illawarra area since the operations at the steelworks at Port Kembla began in the late 1920s.

Attrition of coal reserves along the escarpment has seen the majority of BHP Billiton's mines close or merge with neighbouring mines to obtain synergies in infrastructure and access. Prior to Dendrobium, BHP Billiton's last new mine openings were the Cordeaux and Tower Mines in the late 1970s.

BHP Billiton Illawarra Coal currently operates the Appin, Elouera and West Cliff Mines, with Appin and West Cliff mining the No.1, or Bulli, Seam, and Elouera mining the No.3, or Wongawilli, Seam. These mines produce premium coking coal for the steel making industry and it is a blend of the Bulli and Wongawilli Coals that produces the best product.

Elouera Colliery (created from the Wongawilli and Nebo Collieries) dates back to 1927 and has mined extensively by both pillar extraction and more recently by longwall extraction. Large faults to the north of the current mining area restrict further development and has forced the Company to look to an alternate source for the Wongawilli Seam product to meet the blending needs of the Bulli Seam mines. Elouera supplies about 20 - 30% of the Steelworks coal (approximately 1 Mt per annum of clean coking coal)

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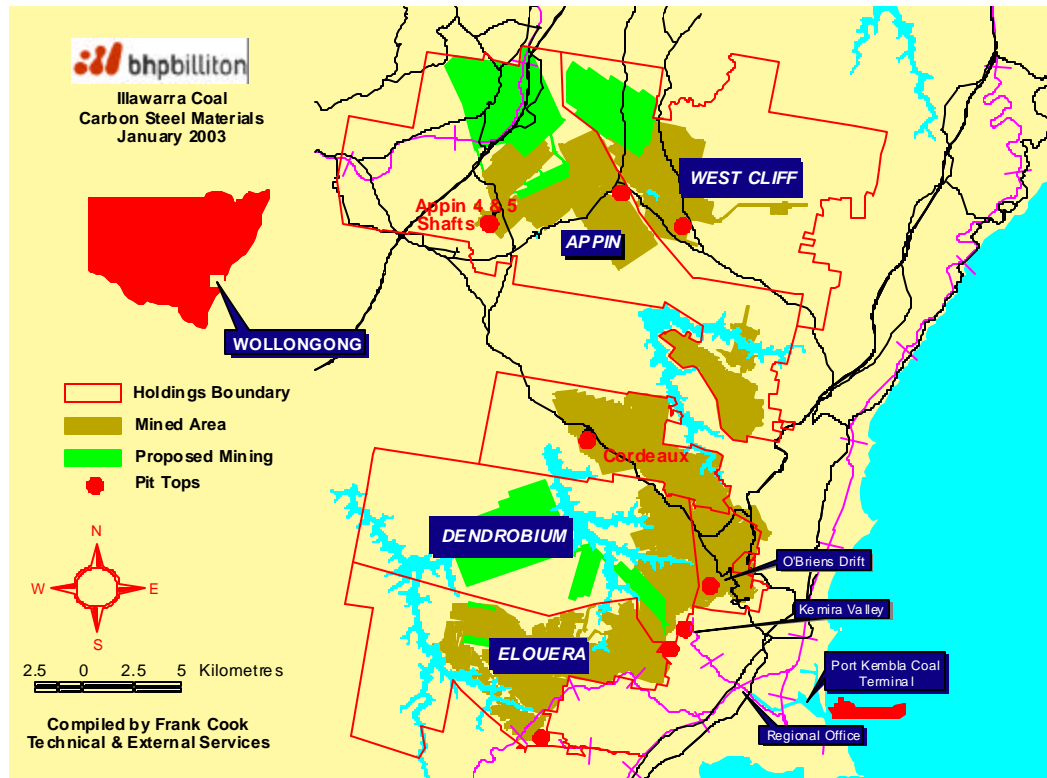


Fig 1 - Illawarra Coal, Mining and Infrastructure Layout

The concept and pre-feasibility studies for the Dendrobium Project investigated alternate sources for the Wongawilli Seam-type coal as well as alternative steel making opportunities that would reduce the need for this type of coal in the blend. The alternative steel technologies were not viable. The Wongawilli Seam is of similar reflectance to the Bulli Seam Coals (approximately 1.23%) but of higher vitrinite. At 80% vitrinite the Wongawilli Seam is among the highest ranked coals in Australia. The Wongawilli coal is also an order of magnitude lower in phosphorous (0.007%) than the Bulli Seam coals of Appin and West Cliff. Although similarly ranked coals were available from several sources in Queensland, those coals did not have similarly low phosphorous levels to compensate for the Bulli Seam in the blend. Sourcing coal from a remote source rather than locally also significantly impacted the Steelworks viability due to transport and handling charges as well as infrastructure upgrades required at the port.

The recommendation of the pre-feasibility was to pursue to development of a locally sourced Wongawilli Seam product. The Nebo Portal of Elouera Colliery (formerly the pit top for the Nebo Colliery) was chosen as the surface location of the new mine as it provided existing infrastructure and reasonable access to the resource.

The area of coal available to the Dendrobium Mine lies within the Wongawilli Seam of the Illawarra Coal Measures. Access to the larger reserves away from the escarpment is via a relatively narrow corridor of coal bounded to the south by Elouera's Nebo workings, to the north-east by the abandoned Kemira Colliery and vertically above by the abandoned Mt Kembla workings in the Bulli Seam.

The scope of the total Dendrobium Project incorporates:

- The development of the new Dendrobium Mine (including the upgrade to the old Nebo Colliery surface facilities as the Dendrobium Pit Top);
- The establishment of a 150,000 tonne raw coal stockpile in the adjacent Kemira Valley;
- Coal handling facilities in Kemira Valley for stockpile reclamation and train loading;
- Upgrade to the existing rail link between the Kemira Valley and the coal washery located within the Steelworks site;

- Upgrade to the coal washery for increased tonnage and a move to wash only Dendrobium Coal;
- Establishment of a Coal Drier at the washery to reduce the moisture content of the finer Wongawilli Coal;
- Management of the West Cliff emplacement area to receive Dendrobium coal wash (the Elouera emplacement area will discontinue with the closure of Elouera).

Following BHP Billiton Board Approval in December 2001, work commenced on the new mine site in February 2002, tunnels commenced underground on 28th May 2002 and longwall production is targeted to commence in late 2004.

FEASIBILITY STUDY DOCUMENT

BHP Billiton Capital Investment System

The Dendrobium Project was evaluated using BHP Billiton's Capital Investment System of review based on the Investment Modules for Concept Study, Pre-feasibility Study, Feasibility Study and Execution Phase. Each module sets out the requirements for analysis and the level of detail and accuracy for both technical and financial assessment. The Feasibility Study comprises 21 chapters which are required to be addressed:

- Executive Summary and Recommendations;
- Strategy;
- Market Analysis;
- Risk (Business and Safety);
- Geology and Mineral Resources;
- Mining;
- Mineral (Coal) Processing;
- Infrastructure;
- Human Resources;
- Project Execution;
- Asset Management;
- Information Management;
- Safety;
- Environment;
- External Relations;
- Capital Costs;
- Operating Costs;
- Ownership, Legal, Contractual and Finance;
- Financial Analysis;
- Project Status and Reviews; and
- Work Plan to next decision.

The Capital Investment System also requires the use of "Peer Review Teams" and "Tollgate Reviews". The Peer Review Teams comprise internal Company subject experts who are charged with reviewing a project for both the technical and financial evaluation methodologies and also the deliverables from the project. The Tollgate Reviews are an opportunity for the Peer Review Team to evaluate the progress of the Project Study.

More specifically, the purpose of the tollgate process is to ensure:

- That critical decision and project parameters are addressed prior to committing funds, and
- Each project meets the strategic, technical and investment requirements of BHP Billiton;

The Tollgating process incorporates a progressive review of project development and facilitates:

- Utilisation of appropriate expertise from other areas of the Company, or from external sources, to enhance project delivery;
- Re-assessment of project deliverables/financial criteria for investment in the light of changes in external circumstances, such as market conditions, and
- Cessation of a project subject to requests for more risk management work.

Ultimately, at the conclusion of the Feasibility Study, the Peer Review Team's endorsement and recommendations are required before a project can be submitted for funding by the Company.

Dendrobium underwent a number of Peer Reviews on every aspect of the project utilising varying groups of reviewers. The mining and mine engineering reviews for the project were held in November 2000, February 2001 and June 2001, prior to final tollgate.

Mining And Mine Engineering Study Scopes

During the previous stages of the Dendrobium Project, a mine plan had been conceived and evaluated to a standard sufficient to allow the Dendrobium Mine option to be chosen over other options discussed earlier. The task of the Feasibility Study is to take the selected option, in this case a new mine and associated infrastructure, develop the option from a technical perspective and also to address all of the issues presented within the chapters outlined above. The Feasibility Study is required to be evaluated to a +/- 10 - 15% range for both capital and operating costs prior to project sanction.

The scope of the Mining study included:

- Mine Planning;
- Critical Safety Risk Review of Mine Plan and Operations;
- Mine and Production Scheduling;
- Portal Construction and Drivage of Mine Access Tunnels;
- Ventilation Design;
- Shaft Construction;
- Main Fan Selection;
- Gas Drainage;
- Roadway Development;
- Hydrology - inrush prevention and prediction, mitigation of mine water accumulation risk;
- Subsidence;
- Strata Control;
- Management Plans - Statutory and Critical Risk;
- Mine Operating Costs; and
- Underground "issues" not otherwise covered.

The scope of the Mine Engineering study included:

- Mine Services - compressed air, fresh water supply, underground power distribution;
- Surface Conveyor and interaction with Kemira Valley Coal Handling Facilities;
- Pit Top Facilities and Building works program;
- Surface Power Substations and distribution;
- Mine Equipment Requirements
 - Mining Equipment - Development and Longwall;
 - Underground Conveyor System;
 - Internal company availability, new equipment requirements, equipment sizing.

The scope of this paper precludes an in depth analysis of all of these topics, although each one has required significant work in designing the mine and bringing it to production level. The intent is to look at some of the more critical issues that have affected the implementation of the operations to date.

MINE PLANNING AND OPERATIONS

Mine Planning

As previously identified, the pre-feasibility mine plan was designed sufficiently robust from a mining engineering perspective to allow evaluation as a viable mine plan.

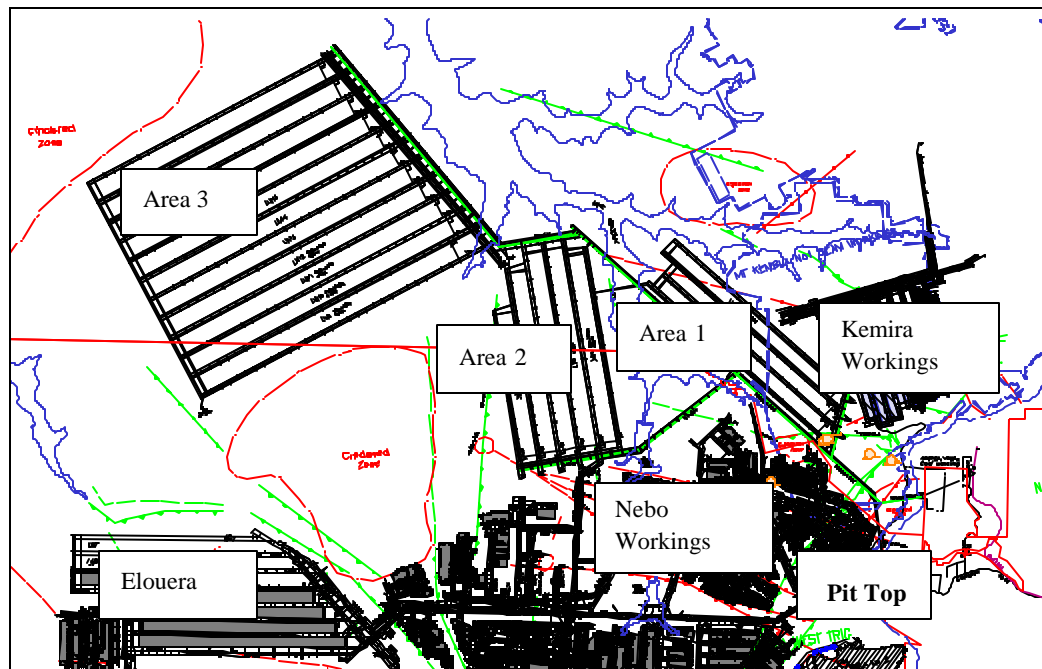


Fig 2 - Dendrobium Mine Plan November 2000

Figure 2 shows the Dendrobium Mine Plan effectively as it was at the commencement of the feasibility. The key physical constraints on the mine geometry are:

- Surrounding colliery workings of Kemira, Elouera (Nebo) and Mt Kembla Collieries;
- Cordeaux Dam and storage;
- Igneous Intrusions - Nepheline Syenite Intrusion (between Elouera longwalls and Dendrobium Area 3), Cordeaux Crinanite (a basalt like intrusion which will restrict Area 2); a large intrusion to the north west of Area 3; and a sill and dyke structure to the north of Area 1 which bisects the Kemira workings and Area 3; and
- Structures - large (approx 10m) fault to the west of Area 2; fault clusters close to the escarpment in Area 1.

A significant difficulty experienced during the mine planning process was that the review of previous exploration data, had not been completed and an active exploration program of boreholes and surface seismic was being conducted as part of the feasibility study. The upside was no doubt improved knowledge of the holding and greater confidence in the end result. The downside, for the mine planning and scheduling process, was the constant "truncations" to the mining areas caused by identification of significant structures.

The restricted mining areas has meant that geophysical parameters such as stress direction, roof strength variability and coal quality variations, have, for all intents and purposes, had to be dealt with as outcomes of the chosen mine layout rather than drivers of it. Area 3 is the only area with sufficient flexibility to allow optimisation against stress orientation. Figure 3 shows the principal stress directions across the mine. Mining to date has supported these stress predictions although there has been significant variability in direction and magnitude around the "pit bottom" area associated with localised structures.

Area 1 is oriented in what would normally be deemed to be the worst stress direction for both the gate roads and the longwall retreat. A mine schedule was run whereby Area 1 was bypassed and Area 2 mined first. This option was rejected based on poor financial return as the lead times and start-up costs before longwall coal were prohibitive. The alternative has been to budget for significant amounts of secondary support in the Area 1 gateroads.

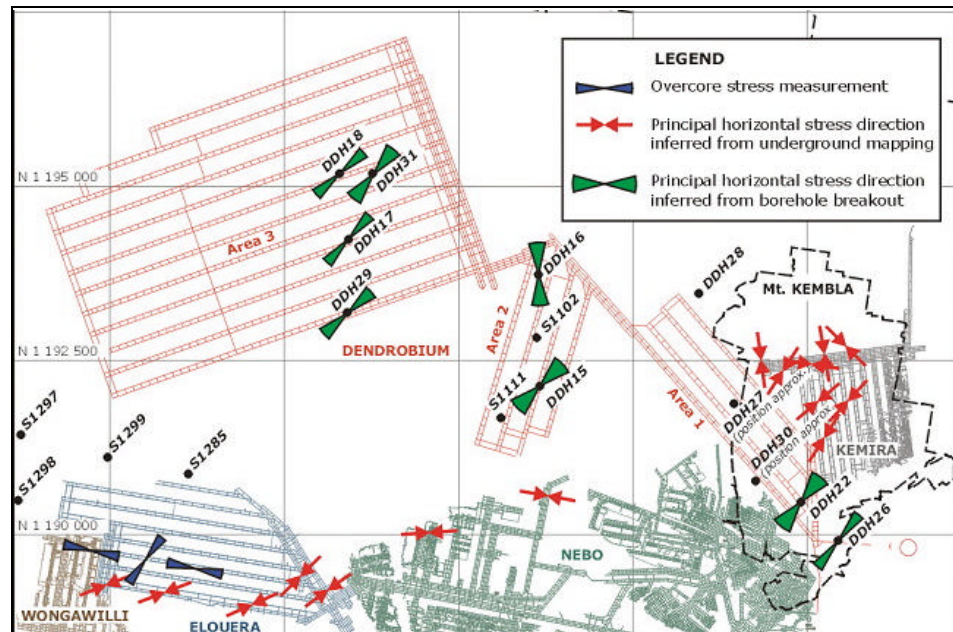


Fig 3 - Principal Horizontal S stress (source Strata Control Technology 2001)

Figure 4 shows the mine plan as it is currently being executed. Significant changes between the plan shown in figure 2 (November 2000) and this plan (August 2003) and their reasons are:

1. Portals and Drifts
 - a. Dendrobium Tunnel (Personnel and Materials) - the location of the portal has been relocated some 100m closer to the pit top to accommodate a drift section to the American Creek Seam;
 - b. Kemira Valley Tunnel (Belt Drift) - the portal for this tunnel had several options but the final location produced a tunnel which commenced approximately 60m below the Wongawilli Seam and drifted upward at 1 in 20 to intersect the seam. The orientation of the tunnel allows the main conveyor to deliver from pit bottom to the top of the stockpile rill tower.
2. Area 1 - Kemira Mains, servicing the Area 1 longwall entries, has moved away from pit bottom because the longwall takeoff points are defined by the Dam Safety Committee restrictions on mining under the Cordeaux Storage. From a cost benefit it was a fairly neutral decision although there were increased belt installation costs, the reduced overall drivage took days off the longwall start date which is the critical path for the project.
3. Area 1 - Longwall reduced from 3 x 180m blocks to 2 x 240m blocks. This saved one set of gateroads and gave a better subsidence profile for the same extraction thickness.
4. Longwall 2 truncated to the north due to dyke and sill;
5. Area 2 - no longer connected to Nebo Workings. The longwalls have each been shortened due to the presence of the Cordeaux Crinanite and a significant amount of net development drivage has been saved. The trade-off has been that an additional 20km of roadways need to be driven towards Area 2 prior to longwall 1 startup to ensure continuity going from longwall 2 to longwall 3.
6. Area 3 - exploration confidence has allowed these longwalls to be lengthened to 5200m with some reorientation to optimal stress direction.

The mine plan will no doubt continue to evolve at a micro level to accommodate geological anomalies as well as scheduling imperatives. As the plan shows, however, there is not a large discretion for significant changes to the layouts of Area 1 or Area 2.

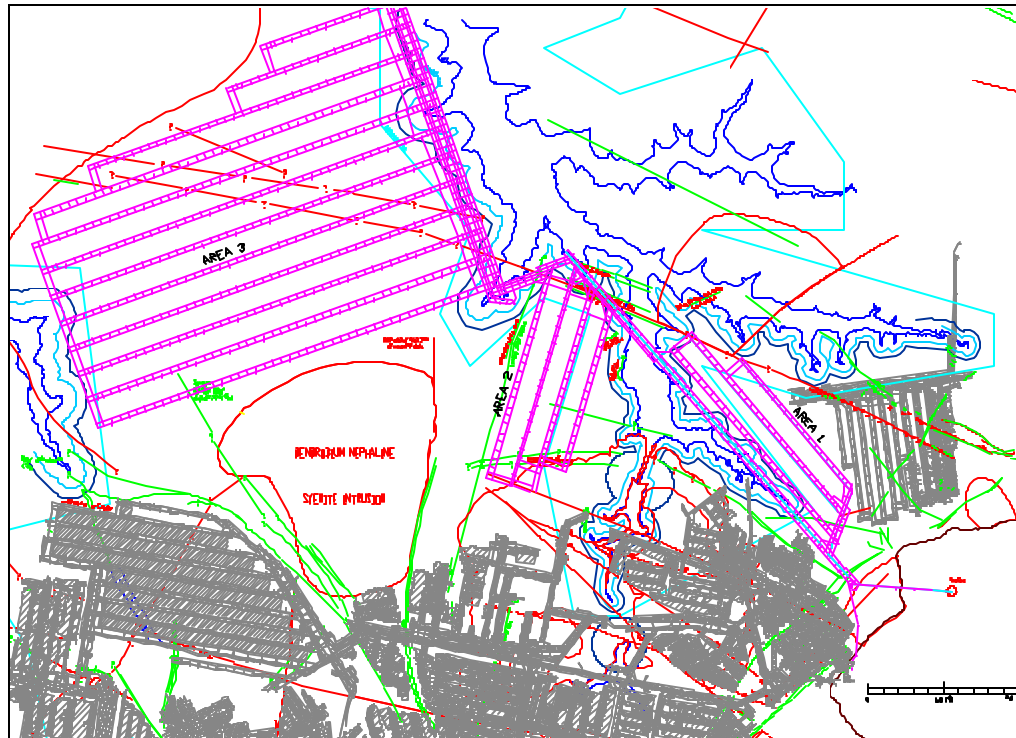


Fig 4 - Dendrobium Mine Plan - August 2003

Critical Safety Risk Review Of Mine Plan And Operations

In February 2001 the Project Team conducted a comprehensive safety risk assessment of all mine operations. The review started with the construction phase of the surface infrastructure and portals and covered all aspects of underground operations through to longwall extraction.

The purpose of this Critical Risk Assessment was:

1. Identification of critical hazards
2. Assessment of the risk of Dendrobium Mine to BHP Billiton;
3. To provide qualitative analysis of single or multiple fatality potential events and thereby identify key hard barriers for financial evaluation during the feasibility study;
4. Identification and verification that risk reduction strategies are in place to render the critical risks to an acceptable level;
5. To identify management systems which need to be developed at the mine as a matter of priority in preparation for commencement;
6. To identify any features of the mine plan which may, by their nature, be introducing significant risk to the mine where an alternative may be available;
7. To identify key risks and groups of risks to allow quantitative evaluation against Company, District, State, National, and International industry and multi-industry data;
8. Development of project Individual Risk Per Annum (IRPA);
9. Comparison of IRPA values with BHP acceptability criteria, other projects and historical probability of fatality; and
10. Documentation of management systems relating to individual risks by means of a risk register.

The primary objectives of the Critical Risk Assessment were:

1. Demonstration that the project has identified critical risks and has adopted risk reduction strategies and systems which will manage those risks ; and
2. Verification that the risk reduction strategies will be effective in managing those risks to a level which is acceptable to BHP.

The risk assessment involved both Company and Consultant representatives. An initial review identified the main categories for assessment such as gas, ventilation, inrush, fire, strata control, underground transport, rail operations, asphyxiation, single entry and emergency response. Individual sessions were then run specifically for each risk category with a targeted review group. Only the Mine Manager, OH&S Manager and the facilitator were common to every session which included between eight and fifteen people depending on the session.

This was an excellent process to undertake early in the mine design phase. In one two-week period (plus processing time), a safety roadmap was established for the construction and operations phase with comprehensive involvement from a broad group of operational and technical experts.

The key safety mining risks were targeted for further analysis by Quantitative Risk Assessment (QRA). The objectives of the QRA were:

1. Assessment of risk on a statistical basis of probability;
2. Development of IRPA data for the project;
3. Comparison of quantified risks against BHP Billiton acceptability criteria;
4. Comparison of relative risks across different projects;
5. Comparison of relative risks across different industries;
6. Comparison of relative risks before and after implementation of risk reduction strategies; and
7. Tracking of changes in the risk profile with time.

The QRA process involved:

1. Assessment of the annual probability of an initiating event based on industry statistical data eg. gas explosion from 1993-2000;
2. Analysis of the downstream events which will dictate survival or otherwise by means of an event tree;
3. Assignment of probability to after the event circumstances, decisions, survival equipment and actions;
4. Determination of outcomes (fatality or non-fatality);
5. Combination of probabilities in order to derive probability of fatality (IRPA)
6. Comparison of site IRPA value with BHP Billiton acceptability criteria.

Acquisition of suitable data was difficult in this process and deriving meaningful results which enhanced the safety of the operations is a point for further discussion. In summary, the qualitative risk assessment provided an excellent platform for the development of safety systems and the management risk at Dendrobium well into the operational phase. The quantitative risk assessment allowed the project to be evaluated against other investment options for the Company based on their relative risks to our employees and contractors.

A strong culture of risk assessment has been established at Dendrobium.

MINE PRODUCTION AND SCHEDULING

At the time that Dendrobium was being evaluated, Illawarra Coal was operating an in-house developed scheduling package based on Excel macros. Each of the mining engineers within the Group were proficient on this tool and Illawarra Coal was still evaluating an alternative commercially available scheduling package. The whole of the project through to current operations has been scheduled on this package which has proven over the years to be reliable, powerful and flexible. To ensure consistency through the implementation phase, Dendrobium is still running its schedules on this package although, like the rest of Illawarra Coal, Dendrobium has commenced using a commercial scheduling package in parallel.

Key features of the mine's schedules have been:

1. Each mine plan layout has been run on an expected best (P10), expected (P50) and expected worst (P90) case;
2. Every schedule must be accompanied by accurate notes on assumptions and strategies to allow comparison of outcomes between options (also helped as several engineers were used over the early stages of the project to assist with scheduling);
3. Longwall continuity was kept at +100 days in all scenarios for all layouts;
4. Development rates were outcomes of industry benchmarking and heavily weighted to outcomes of neighbouring mines in similar conditions. No "upside" was allowed for "new mine, fresh work force" types of intangibles. Consequently development rates were perceived as conservative;

5. Development panels modelled on Dendrobium projected advance rates irrespective of Contractor development predictions;
6. Insufficient ramp up time was allocated in the schedule for new panels/workforce starting up in confined panels with no "pit room". Dendrobium has experienced significant delays in early stages of development due to inefficiency of operations. These were not adequately allowed for in the schedule.
7. Similarly outbye tasks such as pumping and secondary support impact directly on face operations due to lack of outbye labour and the proximity of outbye and face operations. This has improved as the mining faces have progressed inbye.

PORTAL CONSTRUCTION AND DRIVAGE OF MINE ACCESS TUNNELS

The Dendrobium mine is accessed via two cross measure drift and in-seam tunnel combinations, Dendrobium Tunnel and Kemira Valley Tunnel.

Dendrobium Tunnel

To access the Dendrobium Holdings from the pit top, it was necessary to drive a tunnel in approximately a northern direction along the escarpment to skirt the old Nebo Colliery workings. Several options for the portal location and mining horizon were investigated. A drill rig was located at the extremity of the pit top bench with the intent of drilling along the tunnel orientation and proving the ground. The drill rig encountered impassable ground after 400m of drilling. No amount of grout or branching was able to progress drilling past this point. A few surface bores on the hillside above the portal added to the conclusion that at least the first 400m would be in dubious ground with the strata above the seam eroded and replaced by talus slope. Lack of access to the surface above the remainder of the tunnel due to terrain and government approvals led to the decision to drift down to the American Creek (AC) Seam, approximately 8m below the floor of the Wongawilli Seam, via a 1 in 10 drift commencing at the portal on the floor of the Wongawilli Seam.

The portal was preformed against the hillside and then forepoles were drilled in a ring around the portal. Removal of the initial material was by excavator until the roadheader could be positioned. Arches were used and shotcreted to form a smooth lining for the first 15m.

The Dendrobium Tunnel shown in Figure 5 commenced portal construction in April 2002 and went underground on June 3, 2002.



Fig 5 - Dendrobium Tunnel - June 2002

In this area the AC Seam is banded coal over about two metres of shales and is not commercially recoverable. The weathering was found only to extent to the top of the Wongawilli Seam. The interburden consists of 80 - 100Mpa sandstone and provides an excellent roof for the tunnel. The tunnel was driven to keep approximately 1m of this sandstone in the crown. Maintaining a constant downgrade over the length of the tunnel for long term water drainage meant the variations in the strata impacted on the this horizon and often large faces of sandstone slowed progress. The majority of structures in the tunnel were able to be projected from Nebo Colliery plans in the Wongawilli Seam. Development of this tunnel was by S200 roadheader and diesel ramcars.

The tunnel stayed in the lower AC horizon for some 800m before drifting back up at 1 in 10 to the floor of the No 3 seam approaching pit bottom.

Kemira Valley Tunnel (KVT)

The Kemira Valley Tunnel shown in Figure 6 connects the underground operations with the coal handling facilities in Kemira Valley and contains the mine's trunk conveyor. The portal is located on the hillside about 60m above the valley floor and allows the trunk belt to exit the mine and be delivered to the top of the 150 Kt stockpile rill tower in a single flow. Unlike the Dendrobium Tunnel, the KVT commenced from a box cut. The underground portion of the tunnel commenced on May 28, 2002 and is approximately 1150m in length. The first 900m is a cross measure drift rising at 1 in 20 and then flattens out in the Wongawilli Seam towards pit bottom.

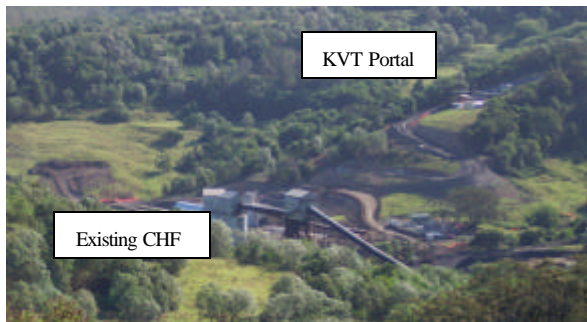


Fig 6 - Kemira Valley Works

The coal industry, especially in the Southern Coalfields, is becoming expectant of onboard bolting and positive



Fig 7 - AM 105 Roadheader - KVT July 2002

temporary roof and rib support systems. Hard rock industry roadheaders are not designed to provide this, nor are coal mining machines designed to mine sandstone tunnels. This presented a high risk area of work for the mine and also the first serious incident when an operator, supporting the roof of the KVT from the boom of the AM105 shown in Figure 7 was struck by falling rock from a greasy back on a thrust fault facing. Several attempts were made to retrofit hydraulic rams to the boom for temporary support without success.

Applying roadheader equipment and support patterns to coal measures, especially when driving cross measure, provided a long term stable roadway but presented challenges for the safe operation of the panel and support of the roof.

The two tunnels were eventually holed within the coal seam by continuous miner without further incident but having installed a significant number of additional "intermediate" bolts to ensure workers were not exposed to unsupported roof during construction.

VENTILATION DESIGN AND FAN INSTALLATION

The change to the mine plan excluding connection to Nebo in Area 2 also meant that Dendrobium would not have access to the Nebo shafts for upcast or downcast ventilation. The first step in designing the ventilation for the mine was to understand the in situ gas environment. The gas reservoir parameters used for the gas emission modelling were derived from analysis of field and laboratory testing conducted by BHPIC, Sigra, Multiphase Technologies Pty Ltd (Multiphase) and CSRIO. Geological data was provided by BHPIC.

The gas content and composition characterisation for the area was limited to 8 boreholes. Compared to normal industry practice, this is a small data set.

Using their gas emission models, GeoGAS¹ provided gas emission estimates for Areas 1, 2 and 3 of the Dendrobium Project. The gas content in Area 1 was determined to be 2 - 5 m³/t CH₄ and in Area 2 4 - 5 m³/t

¹ GeoGas Pty Ltd report to Dendrobium, July 2001

increasing in CO₂ composition (approx 30%) in the north. Area 3 presents a difficult challenge in gas environment. A dyke structure traversing the area literally splits the mining area into two zones. The Area south of the dyke indicates a gas regime of up to 6m³/t CH₄. The area immediately to the north of the dyke indicates up 17m³/t of CO₂. There appears to be little transition between the two with the dyke acting as the delineating feature.

The ventilation modelling was conducted by Australian Coal Mining Consultants Pty Ltd (ACMC) ¹.

The total development split requirements for the dilution of gas emission are determined by the greater of:

- Satisfaction of statutory auxiliary fan requirements. The minimum quantity to be available at the fan site is the sum of the open circuit capacity of each auxiliary fan operating in a panel and 30% of the open circuit capacity of the largest auxiliary fan in operation in the panel.
- Dilution of the intake emission to the last cut -through to the design basis
- Dilution of the total panel emission outbye in the return to the design basis.

These are examined independently in the following sections.

Development Ventilation Requirements

Development Face Area Gas Emission Ventilation Requirements

Auxiliary ventilation simulations were established for a twin entry 120m x 50m development panel with the return standing heading driven and the cut through (driven from the intake heading) almost holed. Permutations of 610mm and 762mm diameter fibreglass ducting and 13 m³/s and 18m³/s open circuit auxiliary fans were examined.

A face area design basis of 0.8 % CH₄ for the gas emissions predicted by GeoGAS, would require an 18m³/s open circuit auxiliary fan coupled to 610mm diameter ducting to be specified. This combination would deliver 6.3 m³/s to the face heading with the standing heading regulated to 4 m³/s. The auxiliary fan would be operating at a duty point of 13.5 m³/s at 4.3 kPa.

A minimum of 23.4 m³/s would be required at the fan site to support an 18 m³/s open circuit fan therefore 25 m³/s delivered to the last open cut through was adopted as the minimum design basis for the primary ventilation system.

Development Panel Gas Emission Ventilation Requirements

The following were used as the design basis for determination of the development panel ventilation requirements:

- General body contamination at the start of the hazardous zone of 0.25% CH₄
- General body contamination in the returns of 0.8% CH₄

Ventilation quantities were determined as being required at the last line of cutthroughs for a number of milestones in the mine's life. Between Maingate (MG)2 and MG6 this requirement increased from 40m³/s to almost 80 m³/s.

The resultant ventilation quantities were those required to manage all gas emission. It may not be possible to deliver such ventilation quantities to the working places due to excessive airflow velocities and ventilation pressure losses. Gas emission not able to be sufficiently diluted would be managed through seam gas drainage or capture.

Longwall Panel Ventilation Requirements

The following were used as the design base for determination of the longwall panel ventilation requirements:

¹ Australian Coal Mining Consultants Pty Ltd report to Dendrobium, July 2001

- Face general body contamination - 0.8% CH₄
- Longwall return general body contamination - 0.8% CH₄
- Bleed return general body contamination - 1.5% CH₄.

It was assumed that a minimum average ventilation velocity of 2 m/s is required for the control of airborne dust. Assuming a longwall airway effective cross sectional area of 15 m², a minimum longwall face ventilation quantity of 30 m³/s would be required for airborne dust control per se.

Volumes for Longwalls 2 to 6 ranged from 37 to 40 m³/s on the face and 20 to 30 m³/s for return quantities.

Ventilation Airflow Velocities

The design of ventilation systems have traditionally been undertaken with the resultant ventilation airflow velocity maximums being 2.5 m/s in belt roads, 4 m/s in intake airways road and 6 m/s in return airways. This is for reasons of minimising dust generation and pressure losses.

The use of these velocities effectively limited the Dendrobium mine intake quantity to 156 m³/s whilst the Dendrobium Tunnel and Kemira Valley Tunnel are the only intakes to the mine.

In order to mitigate against this limitation, APMC used maximum velocities as a design basis, which are generally 50% greater than those traditionally used. These are 3.8 m/s in belt roads, 6 m/s in intake airways and 9 m/s in return airways. In addition 6 m/s was used as a maximum for homotropical belt roads, being the lesser of the maximum intake roadway airflow velocity and the sum of the maximum belt road airflow velocity plus an assumed belt speed of 4.1 m/s.

Conclusions of Ventilation Modelling

Table 1 gives the pressure/quantity outcomes for a number of milestones throughout the mines life.

Table 1 – Pressure Quantity Values

Milestone	Description	Collar Ventilation Quantity	Collar Static Pressure
		m ³ /s	Pa
1	LW1 at start up, #1 shaft as upcast	190	1,396
2	LW2 at start up, #1 shaft as upcast	220	3,347
3	LW2 at start up, #1 shaft as upcast and #2 shaft as downcast	296	4,454
4	LW3 at start up, #1 shaft as downcast and #2 shaft as upcast	212	2,490
5	LW4 at start up, #1 shaft as downcast and #2 shaft as upcast	305	3,545
6	LW6 at start up, #1 shaft as downcast and #2 shaft as upcast	188	1,804
7	LW11 at start up, #1 shaft as downcast and #2 shaft as upcast	248	5,407

The conclusions of the review were as follows:

1. The results of the GeoGAS emission modelling and the APMC ventilation modelling indicate the following for development panels:
 - Face area gas emissions in all areas would be managed using an 18 m³/s open circuit auxiliary fan with 610 mm diameter ducting without the requirement for gas drainage. Where a super unit panel is to be employed, a second auxiliary fan would be required to support the second unit.
 - Gas capture and/or drainage would be required where 55 m³/s cannot be delivered to the last cut through of Area 2 development panels. Ventilation modelling indicates that this would occur in TG3 and MG3 prior to the commissioning of the #2 shaft as a down cast shaft. Prior to the commissioning of the #2 down cast shaft, the ventilation specification has allowed for 25 m³/s to be delivered to the last cut through in Area 2 gate roads. This is sufficient to dilute 62.5 l/s of intake emission and 200 l/s of return emission to the design basis.
 - Gas capture and/or drainage would be required in Area 3 for gateroad development. The ventilation specification has allowed for 50 m³/s to be delivered to the last cut through of the Area 3 gate roads. This is sufficient to dilute 125 l/s of intake emission and 400 l/s of return emission to the design basis.
 - A deviation in the actual development and extraction rates from those used in the GeoGAS gas emission modelling would result in variations in the actual compared to modelled gas emissions. If the variations were positive, additional airflow or gas drainage/capture capability would be required to meet design bases.
 - For milestone 3, increasing the airway frictional coefficients of resistance by 25% would reduce the ventilation quantities delivered to TG3 and MG3 by 15%. Increasing the resistance to leakage of the ventilation control devices by 25% would result in a 4% reduction in the ventilation quantities delivered to TG3 and MG3. Combining both variations on the design basis would result in 19% and 18% reductions in the ventilation quantities delivered to TG3 and MG3 respectively and an 8% increase in the mine resistance.
2. GeoGAS longwall extraction emission modelling (for the most southern Area 3 panel) and the APMC ventilation modelling indicated that with design bases of 0.25%, 0.8% and 1.5% CH₄ longwall intake, return and bleed general body contaminations, no post drainage would be required for longwall extraction.

The assumption that the emission estimates from LW6 represent that of successive longwall panels to the north is likely to be an optimistic one. Gas emission in excess of that which would be manageable by means of the ventilation airflow quantities would be handled through the use of post drainage.
3. Airway velocities are generally acceptable for all models with the exception of that in the Kemira Valley Tunnel during the extraction of Longwall 2 whilst Nebo Mains D heading is being mined. It is likely that some means of velocity mitigation would be required around transfer points and a conservative view would be to make provisions for the shrouding for the entire tunnel conveyor at a later date if proven required.
4. Whilst the main fan is located at the #1 shaft collar, the collar duty would vary from 190 m³/s at 1.4 kPa to 300 m³/s at 4.5 kPa. This would require 370 kW to 1.83 MW motor power capacity. Whilst the main fan is located at the #2 shaft collar, the collar duty would vary from 190 m³/s at 1.8 kPa to 250 m³/s at 5.4 kPa. This would require 471 kW to 1.86 MW motor power capacity. Motor power calculations assume an overall efficiency for the fan installation of 0.72 in converting electrical power to air power (including impeller, transmission and motor losses). As can be seen from the range of duties required, the fan or fans need to be able to perform across a wide range during the mine's life.

The successfully tendered fans are twin centrifugal Flakt-Woods fans with Variable Speed Drives (VSD) (850Kw, 690V). Installation of the VSD drives allows reduced speeds for lower duties and therefore reduced operating costs.

Because of the low duty point required during start up only one fan has been installed with the second required during the extraction of Area 1. The two fans will be installed as stand alone units with their own control systems (interlocked during twin fan operation) to allow easy relocation to the No 2 Shaft during the LW 2 - 3 changeout. The first fan shown in Figure 8 is operating well at the low duty during initial drivage although there have been some problems successfully getting the fan to perform at maximum duty during testing for full commissioning. This is as yet unresolved.



Fig 8 - Dendrobium No. 1 Fan

SHAFT CONSTRUCTION

Three types of shaft construction methods were tendered for the construction the No.1 Shaft: conventional drill and blast; raise bore; and blind bore.

The conventional method was discounted on a number of criteria including workforce exposure during construction and use of explosives in close proximity to community residences. The decision was ultimately made to construct the shaft using a blind bore method tendered by Ardent Underground Pty Ltd. This method was more expensive than the tendered raise bore methods but has significant advantages which were more attractive to Dendrobium:

1. The shaft could be sunk, lined, and allow the fan to be installed prior to holing into the shaft from the mine roadways. This effectively took the shaft off the mines critical path for longwall start up;
2. The shaft stays full of water until ready for lining and therefore there is less opportunity for the wall of the shaft (some shales and claystones) to deteriorate;
3. Under most foreseen circumstances there would be no need for any person to enter the shaft below collar level. This was a safety objective of both Dendrobium and Ardent; and
4. The shaft material did not have to be dealt with by the mine's coal flow system.

Ardent supplied a fully refurbished and newly reconfigured drill rig and purpose built drill head for the shaft. Ardent opted to drill without a pilot hole and following the completion of the 8m pre-sink, the shaft was drilled to full depth of 180m (floor of the Wongawilli Seam) at 4.25m diameter in a single pass. The method required that the shaft be maintained full of water during drilling. A small diameter steel pipe running down the inside of the drill string delivered compressed air to the bottom of the drill string above the drill head and the released compressed air bubbled up inside the drill rods creating a negative pressure. This negative pressure, couple with the hydrostatic head of the shaft water was sufficient to lift all cuttings from the hole and "float" them up the inside of the drill.

Once the shaft was completed the drill head and rods were replaced with a shotcreting frame suspended in the shaft. The frame consisted of a rotating arm, fixed stabilisers, IS lighting and video cameras. The shotcrete was then applied by an operator in a cabin adjacent to the collar who was able to watch the shotcrete being applied via the video camera while operating the crane. Approximately 15m of head was bailed from the shaft at a time exposing 15m of shaft wall for lining. On completion of this section the next 15m was bailed.

This process did initially present some technical difficulties in getting a consistent application of the product but this was rectified with different pebble sizes and different nylon staple sizes. The most significant problem arose when an aquifer was intersected at approximately 48m below collar level. The water outflow was sufficient to wash the shotcrete off during application and the operation had to be suspended pending a solution in stopping the water flow. Several options were reviewed but a desire to not allow people into the shaft forced a solution of remotely stopping the flow.

The eventual solution was ingenious. A Pro-Ram was suspended in the shaft on a makeshift frame with telescopic stabilisers. Lights and cameras were mounted on the frame to allow remote location of the drill rig and remote operation via extended hose lines. A modified 1200mm drill was drilled into the heart of the water outflow using water flushing. Polyurethane was then pumped through the drill rod into the surrounding strata until the water flow ceased. There were a number of engineering "tricks" that needed to be employed to do what sounds like a simple task. The result was that the lining was able to be continued without further complication, no-one had to enter the shaft and the shaft was successfully lined to several metres from the base.

The shaft was completed behind schedule due to some drilling and lining problems but it was still far enough ahead of underground operations to allow the fan to be installed and pre-commissioned. The fan was turned on just prior to the miner holing the bottom of the shaft.

The only injury incurred during the sinking and lining of the shaft was a cut hand to an employee handling a piece of checker-plate. The shaft project was awarded a Merit Award in BHP Billiton's annual Health Safety Environment and Community Awards in 2003.

HYDROLOGY

There are four major sources of potential water ingress to the Dendrobium workings. These sources have inflow potential varying from the ability to create nuisance inflow requiring a pump out system to life threatening inrush potential. The four sources are:

1. Wongawilli Seam and escarpment ingress due to rain water and seam water migration (eg 3.8 l/s/km + 10l/s seam + high rain)¹;
2. Pondered stored water in the overlying Mt Kembla Bulli Seam workings;
3. Surface Stored Waters administered by the Sydney Catchment Authority and the Dam Safety Committee; and
4. Stored water against the extremity of workings in the Kemira and Nebo Wongawilli Seam workings.

Each of these sources and potentials must be evaluated based on the inflow or inrush potential of the resultant water to the mine and therefore the consequent risk to people, equipment and the operation.

Strategies must be designed to successfully mitigate both the life threatening and production hampering risks. During the Mining Peer Review process, inrush was identified as the single greatest risk to the Dendrobium personnel and operations. The Inrush Management Plan was required to be completed as part of the feasibility study prior to project approval.

The high water mark in the Nebo workings could be discerned by direct observation in Elouera. The high water mark in Mt Kembla can be inferred from a piezometer in a surface borehole located over the Mt Kembla workings. This hole had been used to successfully monitor water levels and to correlate underground measurements during research into the Kemira Colliery inundation in 1990².

The inundation at Kemira was due to a connection between the Kemira workings and the Mt Kembla flooded workings. The water level in Kemira can therefore be assumed to be consistent with the Mt Kembla water level.

Two critical components of the Inrush Management Plan are:

1. The Authority to Mine (ATM) process and document; and

¹ Seedsman Geotechnics Pty Ltd report to Dendrobium Mine July 2001

² Whittall, Peter - Hydrogeological Investigation and Analysis of a Major Inundation at Kemira Colliery, University of Wollongong Thesis, 1990.

2. Routine periodic drilling from the Dendrobium workings to the Mt Kembla workings to determine water level.

The Authority to Mine process is modelled on the Outburst ATM process used in the Illawarra No 1 Seam mines. The process requires a quorum of key people to review all relevant data and determine the extent of safe mining given the current data and then to sign off an ATM document specifying drivage configurations and distances covered under the Authority. No mining may take place without a current ATM in place in the panel.

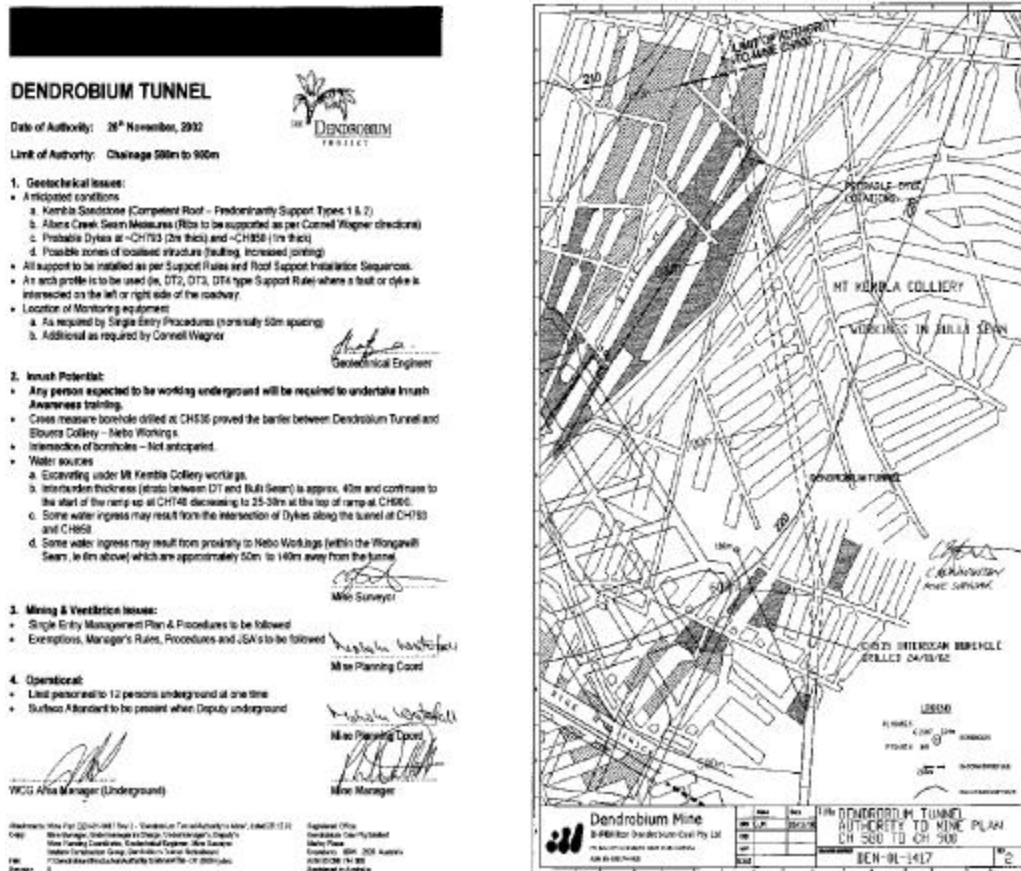


Fig 9 - Inrush Authority to Mine

The ATM is signed off by the Geotechnical Engineer, the Mine Surveyor, the Planning and Ventilation Coordinator (statutory UMIC), the Mine Manager, and the case of panels affecting the drivage contractors, by the Contractor Representative. The Management Plan allows some substitution for personnel but also specifies a minimum quorum. The Inrush Authority to Mine is shown in Figure 9

The periodic interburden drilling is designed to: routinely prove the consistency of the interburden strata and distance between the Dendrobium roadways and the overlying workings; and delineate the high water mark of the ponded water in the Mt Kembla workings. Although the Mt Kembla workings are inaccessible, Dendrobium is fortunate to have possession of original mine plans of the mine dating back to the nineteenth century. The Dendrobium Mine Surveyor has also conducted exhaustive research of colliery plans and records as well as DMR plans and records of inspection to minimise the risk of unmapped drivages from Mt Kembla or any other mine entering the Dendrobium mining area. Interviews have also been conducted with retired employees of Mt Kembla. These old mine plans have been digitised and coordinated with the current mine plans to allow more accurate drilling to hit open roadways.

All holes which intersect an open roadway in Mt Kembla are pressure tested to determine the head of water in the hole and samples of any water found are analysed to provide a fingerprint of the water sample to allow the water source to be determined.

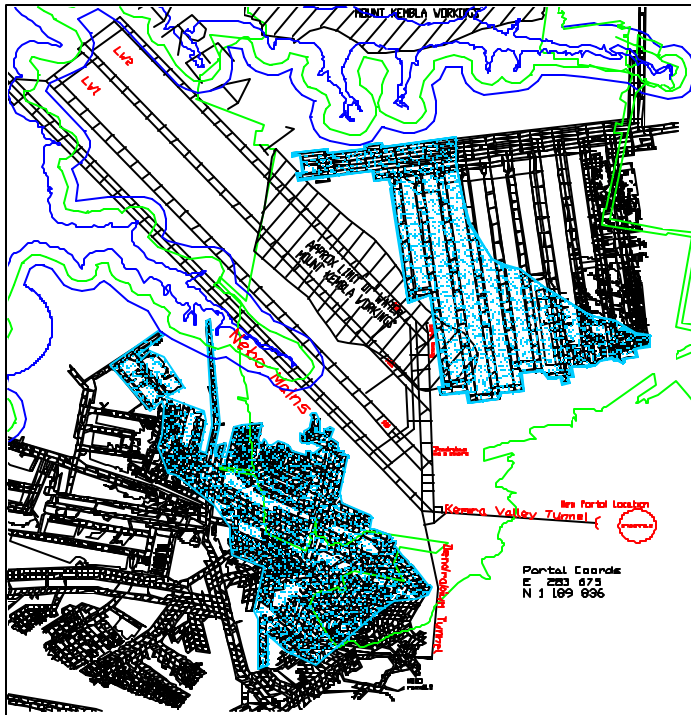


Fig 10 - Flooded Workings to 198.4m RL in Mt Kembla and Kemira Workings

A number of holes have been drilled into Mt Kembla which have indicated localised ponding in the workings but none have identified the high water mark of the main water body which is still ahead of the current workings. In December 2003 the first hole was drilled to connect with the Kemira workings and pressure testing confirmed the predicted water levels. This puts the volume of ponded water in the Mt Kembla workings at approximately 0.9Gt which will need to be drained prior to longwall extraction under the Mt Kembla workings. Figure 10 shows the position of flooded workings in the Mt Kembla and Kemira workings.

MINE ENGINEERING

The Mine Engineering scope of study in the feasibility study incorporated all underground engineering, surface conveyor and stockpile interaction, Dendrobium pit top facilities, main ventilation fans and surface power substations.

The philosophy taken in evaluating new and second-hand components of the engineering scope was that all fixed installations such as conveyors, power supply and fixed services should be right sized with contingency for future growth and purchased new. All transitory equipment which could be made to fit the shorter term needs of the mine and cycled out as their life or applicability diminished should be sourced internally from other BHP Billiton operations where possible.

Three models were developed and applied in determining the equipment sizing for the mine. The longwall model was developed by Australian Coal Mining Consultants (ACMC) to determine maximum outputs from the longwall to achieve the mines projected tonnages. The outputs of this model were used in both the conveyor design model and also the mine scheduling package. Lastly the conveyor model outputs were used to determine stockpile parameters and design.

Conveyor System

Continental Conveyors in partnership with Walter Construction Group successfully tendered for the supply and installation of the conveyor system at Dendrobium.

The key features of the conveyor system are:

1. Trunk Belts 1800mm 4500 tph capacity (6000tph peak) with bolt on drive units. Drive units are a combination of up to four 375KW and 450KW units which can be combined and mixed and matched to down or upgrade the belts as required;
2. Gateroad belts are 1500mm 3500 tph capacity (4200 tph peak). The decision to maintain gateroad structure at 1500mm was based on ergonomics. The 1500mm is still man-handleable whereas larger structure would require all machine operation for installation and recovery;
3. System designed on Voith PKL fluid couplings with PLC controlled fluid fill to give variable speed. VVVF drives were investigated during the feasibility study but discounted because of reliability issues. The PKL couplings give creep speed for inspections and slow start up to reduce load spikes. Half speed during development only is achieved using a different gear box ratio;
4. The rill tower forms the structural support for the tail of the KVT trunk conveyor. The rill tower is required to reduce coal degradation and reduce coal dust in the Kemira Valley. The design of this structure proved to be more complex than first conceived. The final installation appears to be operating satisfactorily to date.

Overall the conveyor installations have been successful and are performing as planned. The belts have not carried longwall coal yet.

Power Supply

Dendrobium is serviced by three separate power supplies:

1. The pit top is serviced by 6.6KV via the existing site switchyard which is connect to the steelworks power supply. The switchyard was upgraded with a new transformer and all of the surface distribution boards have been replaced during construction;
2. The No 1 Shaft has its own switchyard and transformer connected to an Intergral Energy 33KV supply. The main fan runs on an 850KW 690V motor. 690V is not a common voltage and therefore the mine has purchased a spare motor and spare transformer for the site against the event of in service failure; and
3. The underground operations are supplied via Kemira Valley. The new switchyard is supplied from the Integral Energy 33KV line into two off 1500Mva transformers.

The panel transformers are 2.Mva units supplying 1000V outlets to the mining equipment. The longwall will be 3.3KV. The 2.5Mva transformers were chosen to allow longer runs on the low tension side with modelling indicating up to 1400m without a transformer advancement.

The power supply for the mine has been sized for the extraction of Area 3 (approximately 2027 at forecast extraction rates of 5 Mtpa).

Mining Equipment

The first three years of development at Dendrobium will be in strata conditions which require reasonably intensive primary support of between 6 and 8 by 2.4m fully encapsulated roof bolts as well as 1.2 to 1.8m rib bolts every metre of advance. For this reason the Project team decided to overhaul existing ABM20 machines available within Illawarra Coal rather than purchase new equipment. The available data indicates that from a roof strength and stress orientation, Area 3 will be more amenable to a 4 bolt per metre pattern and therefore a machine better suited to high speed cutting than bolting. The ABMs have been upgraded to ABM20 Mark IIIs with ABM25 conveyor and loader blade. The rib protection is essential in the Wongawilli Seam operations.

Walter Construction Group (Walter), the principle contractor at the mine, has two 12CM30 PPM machines in operation at the mine. The machine allows for changeout of the loader blade and platform area to get the machine closer to the face in poorer conditions with the trade-off of slower load out rates.

The mine has also gone with second hand shuttle cars, PJBs, Eimco 915s and EJ130, MPV, trailers, DCBs, auxiliary fans, monorail, pumps, compressors, and the TG conveyor system (which will only carry out the first tailgate development and will not be used for longwall extraction). All of the equipment has been overhauled prior to delivery to the site and is performing well.

Four new FBL loaders are currently on order as there are insufficient second hand units available.

Dendrobium Pit Top

Nebo Colliery commenced operations in 1946. The majority of buildings on the mine site date to 1948. At the commencement of the Dendrobium Project the buildings were just over 50 years old and therefore came under the NSW heritage listing. This precluded changes to the buildings unless sanctioned by the relevant government authorities and consequently presented some challenges in upgrading the 1948 facilities which serviced a pillar extraction mine with up to 500 employees to a modern pit top servicing a longwall mine with 180 employees and more service providers.

Some of the key issues were:

1. Location of an early 19th century kerosene oil shale works on the site which had to be partially excavated, investigated, mapped and covered over again for future excavation;
2. Inability to change the façade of the main bath-house office building. This led to compromises such as raising the floor in the control room to be able to see out of the windows rather than lower the window;
3. Surface services were reasonably well documented but very out of date and in need of upgrade - power supply and distribution, pipework;
4. Lack of pit top room for gear set down areas and car parking facilities;
5. The bathhouse/main office building is not located adjacent to the car parking area but rather at the back of the site which makes demarcation of personnel/visitors and heavy equipment very difficult.

In general the pit top works have gone very well although over budget. The pit top is now a functional, if tight, service area for the mine. Delivery of the longwall later this year will however stretch its capacity.

CONCLUSION

Since the Concept and Prefeasibility studies identified the establishment of a new mine in Mt Kembla as the best alternative to guarantee Illawarra's ability to supply a premium coking coal blend to the Port Kembla Steelworks and the world steel making industry, the Dendrobium Mine has set out to be a benchmark operation in all areas. As previously stated the environmental and community works, which have not been discussed in this paper, have set standards which are now being applied more broadly both within the Company and to other State significant projects. The mine, as the first new longwall mine in the district in more than 20 years, has been given the opportunity to put mining and engineering systems and practices in place from the outset which will seek to establish the mine at the forefront of the industry.

Dendrobium, however, is still a coal mine operating in a sometimes harsh underground environment. The management systems and planning prepared over the last several years is now being implemented. Some early successes such as the ventilation shaft, pit top upgrade, coal handling facilities and power supply will need to be repeated in benchmark development rates, longwall production rates and zero harm to the workforce if Dendrobium is really to transfer its paper aspirations into safety and production realities.