LONGWALL MINING BENEATH THE PACIFIC HIGHWAY
MOONEE COLLIERY – AN OVERVIEW

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ABSTRACT

Since 1997 Moonee Colliery has operated a longwall extraction system in the Great Northern Seam of the Newcastle coal measures. This seam is overlain by 35-40 metres of massive conglomerate at a depth of 150 metres. This paper is an overview of the work carried out at Moonee Colliery during extraction of the first six longwalls, both underground and on the surface. Processes which have been used to control the risks during longwall extraction are discussed. As the measured subsidence to date indicates that the remaining chain pillars isolated in the supercritical goaf are still stable, it is anticipated that full subsidence of 0.7 – 1.0 metre will at some stage be realised in the future.

INTRODUCTION

Moonee Colliery is situated in the Newcastle coalfields of New South Wales located in the Catherine Hill Bay area which is approximately 160km north of Sydney and 30km south of Newcastle. It is located in the Swansea-Entrance Mine Subsidence District.

Figure 1 – Location of Moonee Colliery in the Newcastle Coalfield. (Source: Wyong Coal Joint Venture, C.O.A.L)

It commenced operations shortly after World War II mining the Wallarah seam, initially for domestic markets and later for export. It was initially a bord and pillar operation and when the
reserves of the Wallarah seam were exhausted the mine relocated into the underlying Great Northern Seam. This was uneconomic prior to the introduction of longwall systems, principally due to the claystone, which forms the immediate roof below the massive conglomerate strata. The mine was placed on care and maintenance in 1993 and then re-established as a longwall operation in 1996. During the life of longwall blocks 1 to 4a, the mine was operated as part of the Wallarah Coal Joint Venture. Current production level of the mine is approximately 1.5 million tonnes with a workforce of 110.

Moonee operates a 90 metre wide (block) DBT longwall face. It is narrow face due to mine subsidence restrictions of mining under the Pacific Highway. The depth of cover ranges from 100 to 160 metres with the roof above the Great Northern Seam comprising the Teralba Conglomerate member, which is around 40 metres of thickness over LW1 – LW4a.

This paper is broken into two parts.

1. UNDERGROUND

Looks at the operations carried out underground since startup and in particular at the processes that have been employed to manage the problem of windblast from goaf falls.

2. SURFACE

Looks at the predicted and actual subsidence due to longwall mining and the processes that have been used to prevent or reduce the effects of underground mining on surface infrastructure, namely the Pacific Highway, a 33Kv power transmission line, a petrol station and a weighbridge.

GEOLOGY

The rock sequence in the Catherine Hill Bay Area marks the transition from coal-bearing Permian strata (250-270 Ma) to barren fluvial Triassic sediments. In particular the Moon Island Beach Subgroup of the Newcastle Coal Measures (Late Permian), together with the basal units of the Triassic Narrabeen Group outcrop in the Catherine Hill Bay area (Ziolkowski 1978, pp3-8).
The Newcastle Coal Measures are located adjacent to the New England Fold Belt, which was the dominant source of sediment to the Sydney basin throughout the Permian. Deformation and uplift of the New England Fold Belt in the late Early Permian led to the transformation of the Sydney Basin into a foreland basin. Erosion of the active New England Fold Belt led to deposition of sediments into this basin. The large volume of sediments eroding from the topographically active New England Fold Belt led to a prolonged regressive sequence of deposition forming the Newcastle Coal Measures. During deposition of the Moon Island Beach Subgroup sequence, braided channels migrated compacting the adjacent peat, which was less dense than the channel deposits (Hawley and Brunton, pp47-52, 1995).

A generalised stratigraphic sequence of the Moon Island Beach Subgroup is given in Figure 4. Constituent components include coal, conglomerate, sandstone, shale and rocks of pyroclastic origin that are of variable grain size up to coarse and are termed ‘tuff’. The Moon Island Beach Subgroup includes three (3) major Coal Members – the Fassifern, Great Northern and Wallarah seams all of which are currently worked at various mines throughout the Lake Macquarie region.

The Great Northern Seam worked at Moonee Colliery is a high volatile low sulfur medium ash thermal coal, which is used for power generation. The seam is mined at Moonee to a height of around 3.1 metres of a total seam thickness of up to 4.5 metres. Overlying the Great Northern Seam is the Catherine Hill Bay formation. This ranges in thickness from zero, where the Great Northern Coal and Wallarah Coal merge, to over 60 metres.
In the roof of Moonee Colliery, the Booragul Tuff member forms the immediate roof of the working seam, which is termed the ‘claystone’ roof and measures up to 700mm in thickness. Above this immediate claystone roof is the Teralba Conglomerate, which is up to 40 metres in thickness and thins rapidly to the eastern side of the proposed mining area. The Teralba conglomerate is composed of conglomerate, sandstone and some mudstone. Chert and quartzite pebbles predominate and are rounded and sub rounded and generally less than 25mm in diameter but range up to 150mm. Bedding ranges from massive to well bedded with generally extensive cross bedding. The compressive strength of the conglomerate averages around 45 MPa and exhibits tensile strength around 8 Mpa. Roof support requirements in the roadway development at Moonee Colliery dictate that sufficient roof coal is left to support the overlying claystone and at the same time leave up to 0.5 metre of coal in the floor to minimise the incidence of heave of the floor which contains bentonitic clays. Thus the working height in development is restricted to around 2.8 metres. The longwall itself cuts up to a height of around 3.1 metres leaving some 300mm of roof coal to temporarily support the claystone on the longwall face as it retreats.
LONGWALL PROPOSAL

Prior to reopening in 1996 as a longwall operation, a feasibility study was undertaken, which was based around the following criteria:

• Annual production to be 1.2 Mta

• Development driveage to be by continuous miners specifically equipped to enable installation of the roof support system as recommended from detailed geotechnical investigations i.e. roof support set as close to the face as possible.

• Extraction by longwall methods

• Consideration to be given to the likely impact of surface subsidence

• Capital cost to be consistent with the relatively limited size of the resource.

The layout design stage of feasibility study was preceded by a comprehensive suite of geotechnical investigations, which included the determination of rock properties for the inclusion in numerical modelling of both roof and pillar behaviour. A key objective of this modelling was to determine a suitable chain pillar width that ensured tailgate stability under the influence of the abutment load of the previously extracted wall.

Moonee Colliery commissioned Strata Control Technology Pty Ltd (SCT) to provide an assessment of the surface subsidence expected during mining of Longwalls 1 – 4. Subsidence estimates were based on previous subsidence monitoring at the neighbouring Wallarah Colliery and elsewhere in the southern Lake Macquarie area where the behaviour of pillars on claystone strata was known.

A list was prepared of man made surface structures that may eventually be affected by the proposed extraction and an opinion sought from the Mine Subsidence Board as to their eligibility for compensation. The list indicated that:

• The Pacific Highway

• 33kV Power Line

• The Big T Petrol Station

were all eligible for compensation.
ASSESSMENT OF ALTERNATIVE OPTIONS

To address the concerns regarding surface subsidence, a working party consisting of representatives of the Department of Mineral Resources, Roads and Traffic Authority, Mine Subsidence Board and the mine owners was formed, with Coal Operations Australia Ltd. asked to consider a number of alternative extraction layouts.

Three (3) options were considered:

1. 50m void with 25m chain pillars
2. 100m void with 35m chain pillars
3. 200m void with 45m chain pillars

Table 1 highlights the subsidence implications of each option:

SUBSIDENCE IMPLICATIONS

<table>
<thead>
<tr>
<th>Mode of subsidence</th>
<th>50m Void</th>
<th>100m void</th>
<th>200m void</th>
</tr>
</thead>
<tbody>
<tr>
<td>controlled</td>
<td>Pillar controlled</td>
<td>Pillar controlled</td>
<td>Caving</td>
</tr>
<tr>
<td>Subsidence (mm)</td>
<td>Initial</td>
<td>600-800</td>
<td>700-1000</td>
</tr>
<tr>
<td></td>
<td>Ongoing</td>
<td>50-100</td>
<td>40-80</td>
</tr>
<tr>
<td>Strains (mm/m)</td>
<td>Tensile</td>
<td>2.2</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Strains</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Severity of Impact</td>
<td>Initial</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Ongoing</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

N.B “Initial” in this context refers to the subsidence that can be expected as the panels are extracted
“Ongoing” in this context refers to subsidence that may continue for some time after the panels have been extracted

Taking operational, financial and subsidence implications into consideration Option 2 with a 90m face, 100m void and 35m chain pillar was considered the best compromise with the layout geometry consistent with experience from FCT panels at the neighbouring Wallarah Colliery. Option 2 mined in close liaison with the Roads and Traffic Authority was seen by Coal Operations Australia Ltd as offering the best compromise to the extraction of the Moonee
Colliery resource, which would have, otherwise be sterilised in its entirety. (Mills SCT Report No. Moo09021, 1995)

WINDBLAST HISTORY

The phenomenon of Windblast appeared during the first goaf fall of LW1 which occurred after a retreat of approximately 200 metres. It was initially predicted that although the conglomerate would span the 100m voids, it would also fall in small lenticular shaped pods. However this was not the case and the conglomerate fell with an area of 20,000m$^2$ to a height of approximately 14 meters generating velocities in excess of 360km/hr and damaging ventilation appliances, water barriers, face computers and lights.

Production continued under the guidance of the Windblast Management Plan, however the fifth goaf fall in the panel, which occurred in January 1998, resulted in a windblast that knocked over and injured 6 of 19 crew who were engaged on regular maintenance. The injuries to the personnel were relatively minor in physical nature with the worst injury being a broken rib but the psychological damage done to the mine personnel as a result was extensive. The publicity received by the organisation was extensive and very negative.

![Figure 6 – Publicity from Fall # 5 LW1 (Source: Sydney Daily Telegraph Jan 22$^{nd}$ 1998)](image)

This was the first of a number of windblast crises that the mine faced in the next 12 months before the event, which resulted in the introduction of hydraulic fracturing, accompanied by real-time microseismic monitoring as part of the production process.

Controls that were put in place to manage the effects of windblast were:

- Windblast Management Plan
- Microseismic Monitoring System
- Hydraulic Fracturing Treatment

WINDBLAST MANAGEMENT PLAN

The windblast management system includes a range of measures designed to minimise the risk of injury during a windblast. They include extensive personal protective equipment i.e full-face helmets, leather jackets, knee guards and elbow guards. All personnel are attached to a rock climbing lifeline which is located on the face and in the maingate conveyor road. These
protective measures are taken at any time where more than 20 metres of goaf is standing. Refuge areas are provided for on every second longwall support and at several places at the maingate area. Any procedure that needs to be carried out in “red” zone (where more than 20 metres or 2,000 m$^2$ of goaf is standing) is covered by a detailed risk assessment and written procedures for the tasks involved. The face must be stopped before any individual is permitted to travel from the face down the maingate roadway. (Moonee Colliery WMP-01, 1998)

Figure 7 – Protective equipment to be worn in windblast zone during Red zone

Figure 8 – Windblast monitoring velocity pod (Fowler 2000, p2)
MICROSEISMIC MONITORING SYSTEM

Rock falls are usually preceded by audible cracking and bumping as the roof material breaks. Microseismic monitoring involves the use of seismic detectors (geophones) to record seismic events (cracking) associated with this breakage. This technology was initially developed to assist in the prediction of rock bursts in deep level gold mines in South Africa, and has since been applied to the prediction of outbursts and windblasts in coal mines. The microseismic monitoring system consists of an array of geophones installed in the maingate and tailgate near the face as shown in Figure 9.

The geophones are positioned at the end of 57mm diameter boreholes 10 metres into the overlying Teralba conglomerate. During rock breakage, a signal is sent back to the surface microseismic operator (a geologist) where it is processed for magnitude, frequency and location of the seismic event. The parameters form the basis of a set of criteria for the prediction of major events with which a windblast may be associated. If the criteria are met then the microseismic operator activates the strata alarm. The microseismic system was able to give sufficient warning of impending roof falls that could cause windblast in approximately 90% of cases.

Figure 9 – Typical geophone layout.(Source: Moonee Colliery 1999)

HYDRAULIC FRACTURING TREATMENT

The windblast that occurred on 30th April 1999, about a third of the way into longwall 3, was a major turning point in the history Moonee Colliery. Unusually, there was no audible warning of impending roof fall and no microseismic warning of the event. A mine deputy was blown approximately 3 metres bodily against the No.2 support and suffered multiple compound fractures of the left arm.
After this event, Dr Ken Mills of Strata Control Technology (SCT) and Dr Rob Jeffery of CSIRO Petroleum introduced hydraulic fracturing at Moonee Colliery in June 1999. Hydraulic fracturing is a well proven petroleum industry technology that is widely used to stimulate oil and gas flows.

During Hydraulic Fracturing Treatment, water is typically injected into a short section of borehole at sufficient pressure to overcome the stresses in the rock and the tensile strength of the rock. Once the fluid pressure rises high enough to overcome the forces holding the rock around the borehole together, a fracture is initiated and this fracture spreads laterally away from the hole and aligns itself in a direction perpendicular to the lowest stress acting in the ground. In the case of Moonee Colliery, this means that the fracture grows in the horizontal plane. (Jeffrey et al, Internal Report for C.O.A.L, 1999)

**HYDRO FRAC PROCESS**

- Advance 20 metres from previously fallen goaf

- Drill three 10.8m x 57mm diameter holes into the conglomerate roof across the face

- Grout 25mm $\bigcirc$ hydraulic hose and 6mm pressure transducer hoses into the holes obtaining full encapsulation and leaving a 1m void at the end of the hole

- Advance another 40 metres while running the hydraulic hoses and pressure transducer hoses into the goaf between the roof supports.

- Pressurise the holes with solsenic fluid to generate a frac (320 bar x 180lt/min) and then extend the frac using shearer water pump (80 bar x 470l/min)

The solsenic pressure is greater than the forces maintaining the rock integrity around the borehole and so a fracture is initiated

The consistency and greater predictability of this process compared to previous natural falls is illustrated by Figure 11, which shows a plan of the falls across an area of longwalls 1, 2 and 3. In the same area where 300m of goaf stood before a natural fall on longwall 2, hydrofracturing enables **falls which averaged less than 50m.**
Figure 11 – Comparison of fall length: pre and post hydrofrac. (Source: Moonee Colliery, 1999)

PRODUCTION DELAYS

Production delays associated with windblast equate to an average of 30.2min/8hr shift. However, production inefficiencies due to barriers and controls utilised in management of windblast have not been recorded accurately and these inefficiencies would increase this figure to a more realistic estimate of 60min/8 hr shift making the total hydrofrac/windblast delay in the order of 30% of total production time.

SITE DETAILS – MOONEE COLLIERY

Moonee Colliery commissioned Strata Control Technology to provide an assessment of the surface subsidence expected during mining of Longwalls 1 – 4. Figure 12 shows the general layout of the longwall blocks at Moonee Colliery, major geological structures and the location of major surface infrastructure identified as likely to be affected by mining induced subsidence – namely the Pacific Highway, 33Kv Power transmission line and the “Big T” petrol station.

Figure 12 – Moonee mine layout with major surface and geological features (Source: Moonee Colliery, 2001)
The longwall panels are 100m wide (void) with intermediate chain pillars 35m (rib to rib). The depth of overburden ranges from 160m at the start of Longwall 1 to 90m at the finish of Longwall 5, but is generally greater than 150m in areas where the main surface infrastructure is located. The main highway follows a topographic ridgeline that curves around the first 5 longwalls. The depth of overburden along this section of the highway ranges from 150m-160m.

The geological section in the area of interest is as follows:

- The conglomerate between the Wallarah Seam and the top of the Great Northern Seam is 35m – 40m thick.
- The Great Northern Seam is 3.7m thick. Development 2.8m Longwall 3.1m
- The claystone strata in the roof section is 0.5m – 0.7m thick: Booragul Tuff
- The immediate floor of the Great Northern Seam includes claystone strata: Awaba Tuff

**SUBSIDENCE EXPERIENCE IN FCT PANELS AT WALLARAH COLLIERY**
**A CASE STUDY**

Analysis of the subsidence behaviour over Flexi- Conveyor Train (FCT) Panels 1 – 4 at the neighbouring Wallarah Colliery, indicated that the overburden strata was able to substantially bridge across individual panels up to 100m wide without significant caving. When the total width of extraction became supercritical (after three panels where extracted), bridging was no longer possible and the resulting surface subsidence was controlled by the characteristics of the chain pillars. The subsidence occurred sufficiently gently that Welsh bords in the overlying Wallarah Seam remained stable throughout mining despite subsiding 1.1m.

**SUBSIDENCE OVER FCT PANELS 1 - 4**

Figure 13 shows the layout of FCT Panels 1 – 4 in the Great Northern Seam at Wallarah Colliery. Each panel is approximately 100m wide. The chain pillars between panels are 12m wide. The depth of overburden is approximately 125m. The extracted seam thickness is 3.2m. The interburden between the Great Northern Seam and the Wallarah Seam is 35m – 40m thick of which is conglomerate strata.

**Figure 13  -Layout of FCT panels 1 - 4 at Wallarah Colliery. (Source: Wallarah Colliery 2001)**
After completion of FCT 1 (February 1989), the maximum surface subsidence was approximately 52mm. Maximum subsidence increased when FCT 2 had been mined, to approximately 900mm and was greatest over the centre of combined goaf area of FCT1 and FCT 2.

When FCT 3 and FCT 4 had been mined, the combined goaf area was supercritical in width as indicated by the characteristic even subsidence profile over the centre of the panel. The maximum subsidence in the centre was approximately 1100mm.

A survey undertaken approximately 3 years after mining was completed showed only minor additional subsidence had occurred over the chain pillars during this period. Over the chain pillars, this residual subsidence ranged from 30mm to 58mm.

Horizontal strains were measured by peg to peg chainage on 10m bay lengths as the FCT panels were mined. Maximum horizontal strains of 15mm/m in tension and 10mm/m in compression were measured. These strains measurements were consistent with a downslope component of horizontal movement that has been widely observed in the Western and Southern coalfields. In these coalfields, the horizontal subsidence movements have two components: a flat terrain component and a downslope component. The flat terrain component is generally in a direction towards the goaf and the retreating face. The downslope component is movement in a downhill direction. This component tends to increase rapidly with increasing topographic slope and in steep terrain may be much greater in magnitude than the horizontal movements normally associated with flat terrain conditions.

The measurements over the FCT panels confirm that subsidence behaviour at Wallarah Colliery is similar to that observed in other coalfields. Estimates of horizontal strain are likely to be influenced significantly by surface topography. (Mills, SCT Report No. MOO1321, 1997)

**PREDICTED SUBSIDENCE FOR LONGWALL BLOCKS – MOONEE COLLIERY**

Experience in the FCT panels at Wallarah Colliery has been that the conglomerate roof strata substantially bridges across 100m wide panels. It was anticipated that similar bridging would occur across individual longwall panels at Moonee. If bridging occurs, subsidence humps above the chain pillars are not expected to be seen on the surface. Instead a general lowering of the overburden strata was expected with the final level controlled by the geometry of the chain pillars.

Subsidence above the longwalls blocks at Moonee Colliery was expected to be predominately a function of chain pillar stability. While the chain pillars remain stable, surface subsidence of the order of 100mm – 200mm would be expected from elastic compression of the chain pillars. This elastic subsidence would be expected to occur soon after mining reaches supercritical geometry. Failure of the chain pillars would be expected to cause significant additional subsidence. Timing of this additional subsidence would be a function of the bridging characteristics of the overburden strata relative to the strength characteristics of the chain pillars.

**Maximum subsidence movements expected due to longwall mining of blocks 1 - 4 is as follows:**

| Subsidence | 0.7 – 1.0m |
Tensile Strains : 2mm/m Flat Terrain
Compressive Strains : 3mm/m Flat Terrain

RISK ASSESSMENTS

A comprehensive risk assessment was carried out prior to the commencement of longwall mining. Representatives attended this from the Roads and Traffic Authority, Energy Australia, Telstra, Mines Subsidence Board, Department of Mineral Resources and management from the “Big T” petrol station.

From this came the Subsidence Management Plan for Extraction of Longwalls 1 – 4 Sept 1997, which encompassed the monitoring of survey marks, (usually galvanised steel star pickets) at regular intervals, placed along the Pacific Highway, around the Big T petrol station and on the 33Kv power transmission poles. In all, a total of 735 survey monitoring marks were required to be installed and initially surveyed. These ranged from galvanised steel star pickets (1.2m, 2.1m or 2.4m), galvanised iron nails or cats-eye reflectors.

The main controls involved the:

• Mitigatory works to be carried out, prior to longwall mining, to the buried fuel lines around the petrol station – to replace rigid steel piping with flexible PVC plumbing.

• The placement of 33Kv conductors in sheaves to alleviate any overstressing caused by ground movement

• The regular monitoring and reporting of subsidence monitoring marks along the Pacific highway, Big T petrol station and 33Kv power transmission poles. This was done usually at end of each longwall block i.e 6 monthly.

• Visual inspections to be carried out on a daily basis, of the highway, petrol station and power transmission poles by RTA, Energy Australia, Big T management, and mine personnel.

• Implementation of a Moonee Colliery employee awareness program. As approximately 55% of the mine employees travel over the highway to and from work each day, employees were asked to report any anomalies that they observed.

BIG T SUBSIDENCE MANAGEMENT PLAN

In addition to the above controls, it became evident that the inspectorate was most concerned about undermining of the “Big T” petrol station during the second half of longwall 2.

The “Big T” is located adjacent to the Pacific Highway on the sandstone/conglomerate ridgeline, which formed the path for the highway.
Figure 14 – Site plan of Big T petrol station which was undermined (Source: Wyong Council 1998)

After an exhaustive search of council documents, a site plan of the petrol station was found showing a total of thirteen (13) steel fuel tanks buried around the site ranging from 8,000 litres to 50,000 litres and up to 2.5m in diameter.

The depth of overburden at the site is approximately 160m and there does not appear to be any geological structures in the immediate vicinity of the petrol station that are significant enough to influence subsidence behaviour.

Controls established prior to undermining:

• Initial pressure testing of tank and supply lines by Tanknology Australia to identify any faulty components.

• Replacement of faulty components and supply lines to petrol bowsers with flexible PVC piping.

• Retesting of the complete system to ensure “tight” – LW2 was not allowed to retreat to within 100m of the petrol station until the mitigatory works had been satisfactorily completed.

• Visual inspections to be carried out on a daily basis, when longwall 2 within 100m of Big T location – with any ground cracks being filled immediately to prevent the ingress of moisture and to protect the integrity of filled area.

• A daily check on stock control to ensure that the daily “dips” of underground storage tanks and the sales information from the console “add up”.

• Regular monitoring of survey monitoring marks placed around the petrol station.

In addition to the above, Moonee Colliery employed an environmental engineer to report on the current status of the site as to contamination from petroleum and its by-products.
This report showed that the site was already heavily contaminated prior to undermining. (Moonee Colliery, Big T Subsidence Management Plan, 1998)

RESULTS TO DATE

As of September 2001, six (6) longwalls have been extracted with the following results:

<table>
<thead>
<tr>
<th>Maximum Subsidence (mm)</th>
<th>LW1</th>
<th>LW2</th>
<th>LW3</th>
<th>LW4a</th>
<th>LW4b</th>
<th>LW5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway</td>
<td>35</td>
<td>83</td>
<td>100</td>
<td>105</td>
<td>108</td>
<td>112</td>
</tr>
<tr>
<td>Petrol Station</td>
<td>7</td>
<td>57</td>
<td>89</td>
<td>90</td>
<td>112</td>
<td>120</td>
</tr>
</tbody>
</table>

Max Strains 1.0mm/M

DAMAGE

The only reported damage to date has been a small (10mm wide max) crack which appeared in the road pavement towards the end of LW3 at chainage 1900, running diagonally across both northbound and south bound lanes, for approximately 30 metres. The ensuing subsidence survey showed that the area had subsided a further 40 mm from the previous survey taken at the end of the LW2. The remedial work required the closure of 1 lane (both north and south bound) for a period of 4 days. The nearby “Big T” petrol station was free of any damage associated with this highway pavement crack and only showed a further 30mm from the previous survey, also taken at the end of LW2.

Figure 15 – Location of Big T in relation to longwall mining
And direction of road cracking (Source: Moonee Colliery 1999)
DISCUSSION

Strata Control Technology Pty Ltd undertook a comprehensive review of pillar behaviour on claystone floor strata in the Southern Lake Macquarie area. Figure 16 shows the relationship of the width to height ratio of the pillars for supercritical panel geometries in the Southern Lake Macquarie area. The subsidence observed over the FCT panels at Wallarah Colliery, discussed earlier, is consistent with this data.

![Figure 16 – Comparison of failed pillars at Wallarah Colliery FCT panels and Longwall chain pillars at Moonee Colliery (Source: SCT Report No. MOO1713, 1999)](image)

The data presented in the above figure, suggests that subsidence in bridging conglomerate strata is governed primarily by pillar stability and pillar size. There are 2 states: stable pillars and overloaded (or failed) pillars. Surface subsidence over stable pillars is a function of elastic compression of the leave-in pillars and the surrounding strata, and is typically small i.e. less than 200mm. Once pillars become overloaded, surface subsidence is governed by the width to height ratio of the leave in pillars. There appears to be only these two (2) states, anything in between is in transition. For small pillars the transition between stability and instability occurs rapidly, in a manner of minutes to hours, and for larger pillars, more slowly over a period of months to years.

A distinction is made between seam thickness extracted and effective pillar height use in pillar strength and characteristic width to height calculations. At Moonee, the claystone band in the immediate roof is included in the calculation of effective pillar height (3.7m) but excluded from the extracted seam thickness (3.1m) because the claystone is not mined.

With the six (6) longwall blocks mined to date, the conglomerate strata immediately above the Great Northern Seam has not been able to fully span across the 100m wide voids, caving to a height of approximately 14m, creating violent windblasts, as previously discussed. The combined width for say the first two (2) longwall blocks is approximately 235m. The panel width
to depth ratio of these two panels is approximately 1.4m under the highway. While this combined panel width is almost supercritical in subsidence engineering terms, experience elsewhere suggests that first-time bridging continues until the panel width to depth ratio reaches about 2. Above this width (3 panels or more), stability is controlled entirely by pillar stability and bridging cannot occur.

The surface subsidence is expected to exist in either of two states. If the chain pillars remain stable, surface subsidence will be in the range 100-200mm. If they become overloaded, subsidence is expected to increase to 0.23 - 0.32 times the seam thickness extracted or approximately 0.7 – 1.0m. The pillars are expected to have a stability index (as defined in SCT Report ELCO437) of approximately 2.1 at 150m depth of overburden assuming an effective full seam pillar height. (Mills, SCT Report No MOO1713, 1999).

COMPENSABLE LOSS & SECTION 15B CERTIFICATION – RE THE MINING ACT

Apart from safety concerns consideration had to be given to loss of or interruption to income incurred by mine subsidence related damage to surface infrastructure. This included the:

• “Big T” petrol station
• Pacific Highway
• 33Kv power transmission line and
• An operational quarry weighbridge.

Mitigatory works were carried out on the petrol station and the power transmission line as discussed earlier, but there was no practical way, other than relocating the quarry weighbridge, to avoid a loss of income (to the quarry owner) due to the level of the weighbridge being constantly interfered with by mine subsidence.

As no Section 15B certificate had been issued for the construction of the weighbridge, some 30 years earlier, Moonee Colliery incurred the cost for relocating the weighbridge.

CONCLUSIONS

While the underground problems of managing windblast, seismic monitoring and hydraulic fracturing have been fully realised, the same cannot necessarily be said for the effects of longwall mining on surface infrastructure.

In general terms the massive conglomerate was initially expected to span the longwall blocks until the span become of a super critical nature. To date, only elastic compression of the strata has been realised with caving of the immediate goaf reaching up to a height of 14metres and causing massive windblasts.

While initial predictions for maximum subsidence were in the order of 0.7 – 1.0 metre, the restrictions caused by the falling conglomerate has offered confinement to the chain pillars stranded in the goaf and prevented such pillars from failing under a supercritical geometry.
The subsidence to date for the current geometry of the longwall blocks has been consistent with that of the chain pillars being stable. Given that both the roof and floor strata include claystone material, these chain pillars were expected to become overloaded and fail when they became isolated in the goaf in a supercritical geometry. While the current goaf geometry for longwall blocks 1 – 4a is supercritical now, it can only be argued that these chain pillars are for the time being at least stable and a period of years may be required to bring about their eventual failure. The timing of such failure may not be ideal as mine personnel, resources and expertise are far removed from the mining process when the mine has ceased operation.
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