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13 November 2012

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Dear David,

RESPONSE TO SUBSIDENCE RELATED COMMENTS ON LONGWALLS 4 AND 5 AND MG6, 7, 8 PT3A MODIFICATION APPLICATION

As requested, please find herein our response to comments listed in the spreadsheet that you provided by email. This report has been updated to include subsidence monitoring from the end of Longwall 4 and a revised interpretation of the geological stratigraphy at Borehole NRE GW01 (GW01).

The report is structured to provide a background to SCT Operations Pty Ltd's (SCT's) commission, an overview of subsidence results available at the end of Longwall 4 and groundwater monitoring from GW01 located near Cataract Creek, and then responses to particular issues raised based on these results. There are several issues that are raised repeatedly in various submissions and these issues are addressed collectively in the response presented.

1. BACKGROUND

Over the past three months, SCT has been commissioned by Gurjarat NRE Coking Coal Limited (NRE) to assess the anticipated subsidence related impacts of proposed longwall mining in the Wongawilli Seam at NRE No.1 Colliery and to assist with guiding the development of strategies to monitor and manage these impacts. Site inspections of relevant sections of Cataract Creek, Cataract River, Lizard Creek, Wallandoola Creek and various tributaries have been conducted as part of this review together with inspections of the general surface terrain above both the proposed Wonga East and Wonga West mining areas. The comments presented in this letter report are based on our review of the available data, observations made during the site inspections, and our assessment of these results in the context of experience at other sites.

NRE has recently completed mining Longwall 4 in the Wongawilli Seam in an area called Wonga East. In this area, the Bulli Seam was previously mined using pillar extraction techniques (early to mid 1900's) and the Balgownie Seam was extracted using longwall mining techniques (between 1970 and 1982). Subsidence data was not collected for mining in the Bulli Seam, but about 1m of subsidence is considered likely to have occurred based on the extraction geometries and experience at other similar sites. The results of subsidence monitoring above the Balgownie Seam longwall panels are of high quality and provide insight into the nature of subsidence above multi-seam mining operations.

Subsidence monitoring data and deep groundwater monitoring data from GW01 has become available since the completion of Longwall 4 and this data is included in this report. These results provide a basis for initial comment on the various submissions presented.

2. Overview of Subsidence Movements Observed

Figure 1 shows the layout of subsidence monitoring lines above Longwall 4 reproduced from a plan prepared by Southern Cross Consulting Surveyors.

Figure 2 shows a plan of the subsidence lines superimposed onto a 1:25,000 topographic series map and their position relative to previous mining in the Bulli Seam, Balgownie Seam, and Longwall 4 in the Wongawilli Seam. The longwall face positions at the time of the various resurveys and at the completion of the panel on 21 September 2012 are also shown.

Figure 3 shows the subsidence monitored on both the southern and northern cross-lines when Longwall 4 was in the positions indicated in Figure 1. Subsidence on the southern cross-line was substantially complete on 9 July 2012 with maximum subsidence of approximately 1.3m in the centre of the panel, maximum tilt of approximately 30mm/m, and maximum strain of approximately 5mm/m (allowing for peg spacing variations from a standard 1/20th overburden depth).

Figure 4 shows the subsidence monitored on the central longitudinal line at various stages of longwall retreat. Maximum subsidence is 1.3-1.4m. Maximum tilt is approximately 25mm/m at the start of the panel and 15mm/m over the longwall face. Maximum strain is approximately 3mm/m.

2.1 Discussion of Subsidence Monitoring Results

The subsidence monitoring over Longwall 4 has been two dimensional (level and peg to peg distance) rather than three dimensional. The available monitoring data is therefore not suitable to determine far-field horizontal movements or movements in a downslope direction associated with valley closure. The data nevertheless provides insight into multi-seam subsidence effects. SCT has recommended the surveying be upgraded to full three dimensional subsidence monitoring in future and be extended to include more detail of valley closure movements. It is understood that this upgrade is planned.

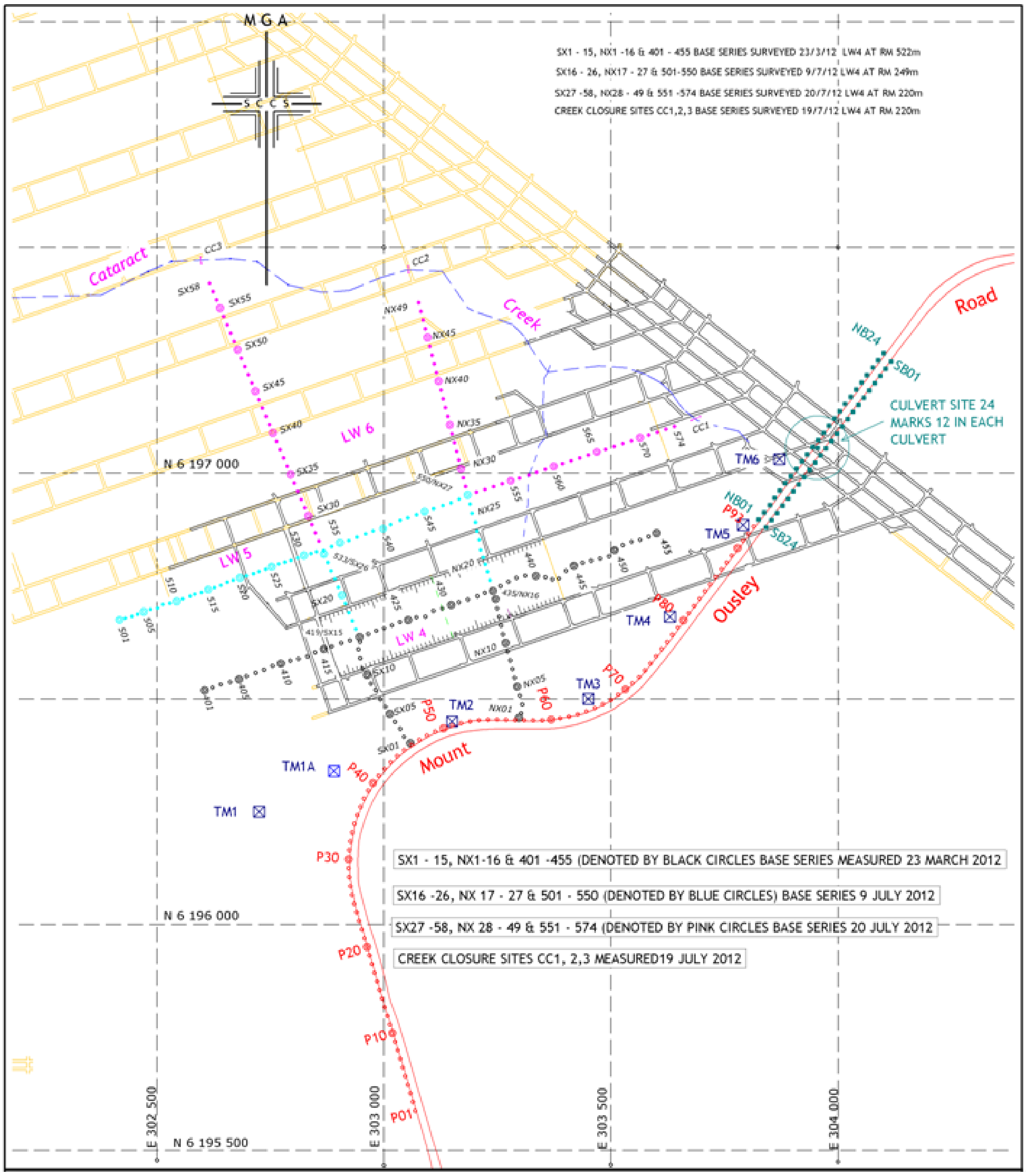

Figure 1: Plan showing location of survey monitoring pegs above Longwall 4 (reproduced from figure provided by Southern Cross Consulting Surveyors).

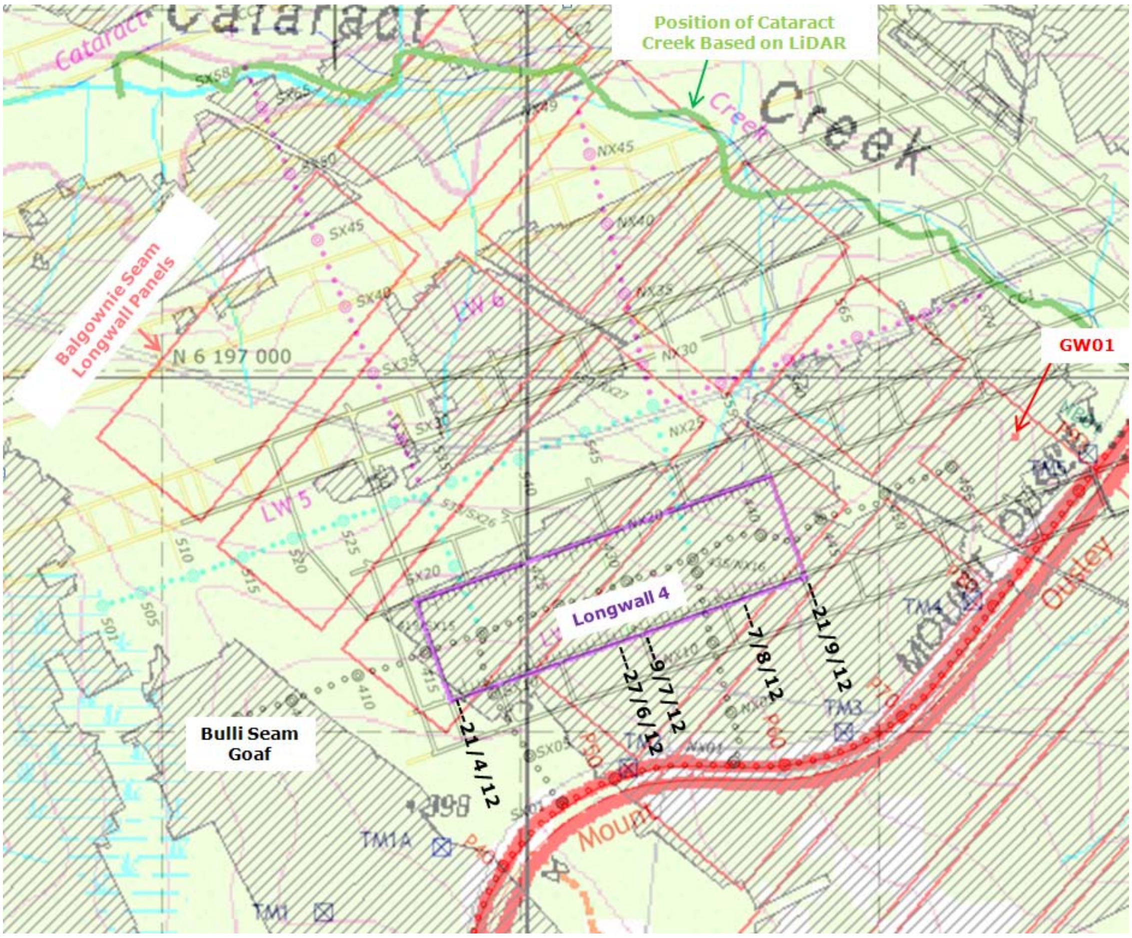

Figure 2: Site plan showing location of subsidence lines and previous mining activity superimposed onto a 1:25,000 topographic series map (with alignment of Cataract Creek adjusted using LiDAR measurements).

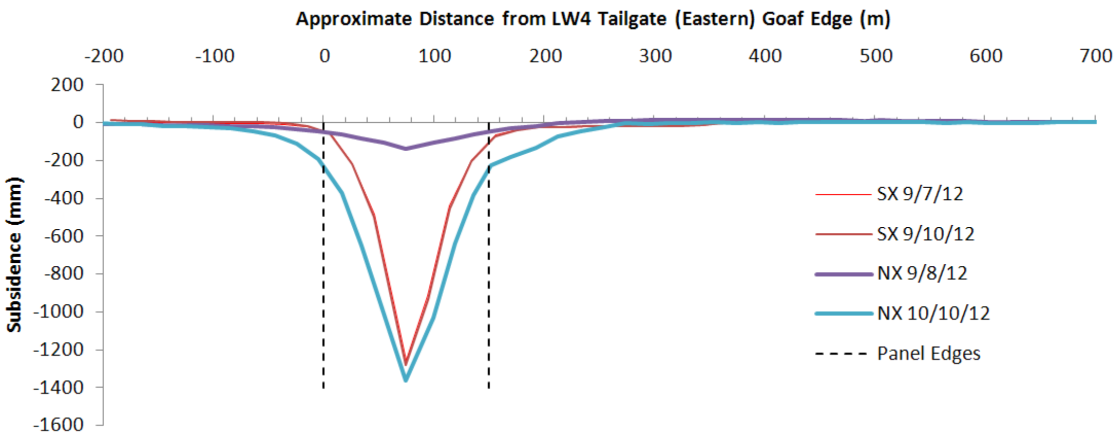

Figure 3: Subsidence measured on SX and NX cross-lines above Longwall 4.

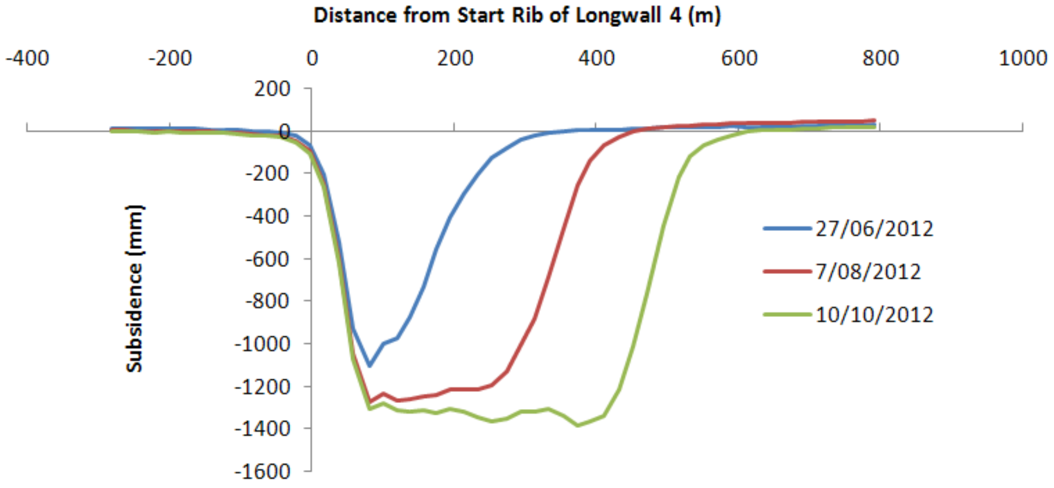

Figure 4: Subsidence measured on longitudinal line above Longwall 4.

The subsidence monitoring above Longwall 4 has several characteristics that are of particular interest in the context of multi-seam mining and the potential for future mining in Wonga East.

The level of vertical subsidence is significantly higher than would be expected above a single panel of the width and depth of Longwall 4 in undisturbed strata. The 1.3-1.4m of vertical subsidence observed in the centre of the panel is well above the few centimetres of subsidence that would be expected in the centre of a similar width panel in strata that has not been disturbed by previous mining subsidence. A similar response was observed above the Balgownie Seam longwall panels where 1.4m of subsidence was observed above panels that would, for the same geometry in undisturbed strata, be expected to show less than 100mm of subsidence.

The implication of this result is that the initial Bulli Seam mining and the subsequent Balgownie Seam mining have reduced the bridging characteristics of the overburden strata so that the overburden strata is more compliant and less able to span across a single panel.

Total cumulative subsidence in the centre of Longwall 4 is estimated to be about 1m from mining the Bulli Seam, 0.5-1.3m from mining in the Balgownie Seam depending on location and 1.3-1.4m from mining in the Wongawilli Seam giving total subsidence above Longwall 4 in the range 2-3m.

A second characteristic of the cross-line subsidence measured above Longwall 4 is that the subsidence observed is tightly constrained within the plan geometry of Longwall 4, despite two seams having been mined immediately above the Wongawilli Seam mining horizon, each with their own independent extraction geometries.

The tight correlation between observed subsidence and the mined panel geometry in the deepest of three seams, indicates that the multi-seam mining may not be as significant in terms of altering the footprint of the surface subsidence as previously envisaged.

The tight correlation of subsidence footprint with the Wongawilli Seam panel geometry indicates that there has been no pillar instability (pillar run) in the Bulli Seam as a result of mining Longwall 4 and that the pillar extraction areas in the Bulli Seam above Longwall 4 are already fully subsided.

Close inspection of the extent of the goaf areas in the Bulli Seam below the northern and southern cross-lines indicates that the Bulli Seam goaf is almost coincident with both goaf edges of Longwall 4 on the alignment of the southern cross-line but extends some distance beyond the footprint of Longwall 4 on the alignment of the northern cross-line.

The broader spread of the surface subsidence profile evident in Figure 3 on the northern cross-line indicates that the Bulli Seam goaf is softening the subsidence profile slightly and slightly increasing the magnitude of subsidence in the centre of the panel.

There is no evidence of the mining geometry in the Balgownie Seam influencing the subsidence behaviour, although this may be a result of the relatively small size of the Wongawilli Seam mining footprint at the completion of Longwall 4.

The implication of these results is that although the subsidence magnitude is greater for mining in the third seam, the lateral extent of the area affected by mining does not appear to be significantly greater than for single seam mining. This outcome needs to be reviewed after further data becomes available for a wider range of pillar geometries in the overlying seams, but the initial data indicates that the surface subsidence is substantially limited to within the panel footprint in the seam that is mined.

Subsidence monitoring conducted alongside the northbound slow lane of Mount Ousley Road on P Line provides an indication of the nature of subsidence movements beyond the goaf edge in the multi-seam mining at this site. Figure 5 shows the result of subsidence measured on P Line. The magnitude of movement observed is less than 30mm, but the form of the movement is well defined in the survey results where the effective accuracy of the survey appears to be of the order of ±5mm.

The maximum subsidence on P Line is measured at peg P53, midway along, but offset from, Longwall 4. To the south, beyond the southern edge of the Balgownie Seam longwall panels, the subsidence returns to less than survey tolerance in a smooth profile with an additional 10mm or so of subsidence coincident with the overlying Bulli Seam goaf. To the north above areas of previous extraction in both the Bulli Seam and Balgownie Seam, there is additional subsidence beyond the end of Longwall 4 of 10-15mm over the Balgownie Seam longwalls.

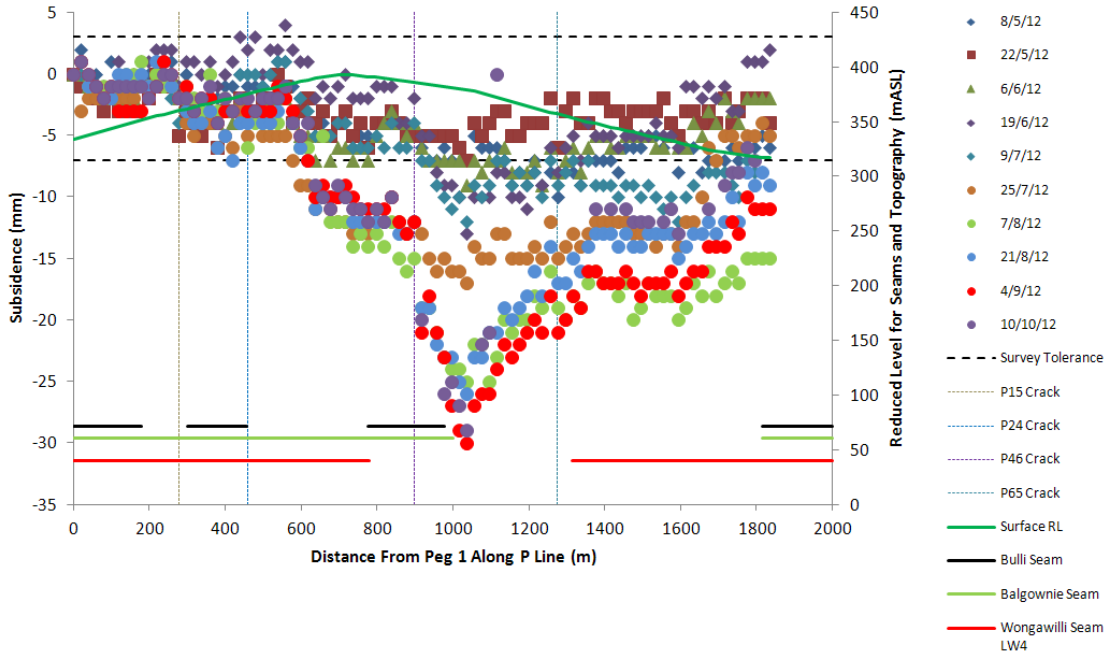

Figure 5: Subsidence measured on P Line during mining of Longwall 4.

Although there is some small additional subsidence movement beyond the goaf edge as a result of previous mining in overlying seams, the subsidence observed on P Line is small in magnitude, regular in nature, and consistent with the extraction geometries in the overlying seams. A maximum of 30mm of subsidence at 180m from the goaf edge at about 360m overburden depth is not significantly greater than the vertical subsidence that would be expected for an angle of draw of 26.5°. These measurements add further to the experience that, outside the footprint of the mined panel, the ground movements associated with multi-seam subsidence may not be significantly greater than the ground movements associated with single seam subsidence.

2.2 Valley Closure Movements Associated with Horizontal Movement in a Downslope Direction

When mining under terrain where there is some topographic relief, or where the strata is dipping relative to the surface, there is a tendency for subsiding strata to cause an outward movement of the valley sides towards topographic low points. This movement is considered to be a result of dilation of natural joints and mining induced fractures as well as dilation caused by the rotation of blocks of overburden strata as they subside differentially. The effect of these horizontal movements is to cause stretching at topographic high points and compression (valley closure) at topographic low points. These horizontal movements appear to occur substantially in response to vertical subsidence with the energy available to drive them derived from the potential energy released as the rock strata subsides or in some circumstances by release of potential energy stored as in situ stress.

Minor tensile surface cracking has been observed near the top of the hill on Mt Ousley Road during the period of mining Longwall 4 adjacent to Peg 46. This observation is consistent with general experience of mining below steep terrain and is likely to be associated with an equal amount of compression across Cataract Creek, with the movement likely to have been taken up on a horizontal shear plane at or near the base of the valley.

Despite comments in some of the submissions to the contrary, the mechanics of the processes associated with valley closure and horizontal movement in a downslope direction have been relatively well understood for some time (Mills 2001).

2.3 Disturbance to the Overburden Strata and Potential for Increased Hydraulic Conductivity

A characteristic of the reduced bridging capacity of the overburden strata and the increased subsidence that is observed above multi-seam mining operations such as Longwall 4 is increased disturbance of the subsided overburden strata and increased potential for overall increased hydraulic conductivity between the surface and the mining horizons. Such increased hydraulic conductivity is not necessary a significant issue if the main source of recharge is rainfall because, in general, only a very small percentage of total rainfall is lost into mining induced fractures in a typical bushland environment.

However, this increased vertical hydraulic conductivity may be an issue if the recharge source is a reservoir, a major creek or river, or a swamp whose flora and fauna are sensitive to the natural balance between inflow from rainfall or surface runoff and losses to the bedrock so that longer term storage of water within the swamp is affected.

Significant disturbance to the overburden strata through vertical subsidence is likely to be substantially avoided if surface features are not directly mined under because most of the vertical stretching that contributes to increased hydraulic conductivity is located directly over each longwall panel.

There is still potential for some disturbance and associated increase in the hydraulic conductivity as a result of secondary effects such as valley closure and ridgeline stretching or where aquifers or stratigraphic units with higher natural hydraulic conductivity are impacted, but these effects also tend to be much greater directly above each panel.

The valley closure impacts tend to be limited to topographic low points and are not necessarily associated with increased vertical hydraulic conductivity to the mining horizon, although the impacts may nevertheless be significant within the context of the river channel or valley infill swamp.

Subsurface mining disturbance to stratigraphic units that have naturally higher hydraulic conductivity may result in a pathway of increased hydraulic conductivity between groundwater stored in these units and the mining horizon. There is potential for the associated drawdown to extend well outside the footprint of individual longwall panels, particularly when horizontal movements that occur toward each longwall goaf result in a net volume increase of the aquifer.

The further away that a longwall panel is from a given surface feature, the less likelihood there is for significant impact on that feature. A distance equal to half the depth between the surface and the mining horizon (also referred to as an angle of draw of 26.5°) is commonly used to describe the distance outside a longwall panel where vertical subsidence becomes imperceptible for most practical purposes. This distance tends to increase with overburden depth and in the Southern Coalfield of NSW a value of 0.7 times depth (angle of draw of 35°) is commonly adopted where the overburden depth is greater than about 250m.

Far-field horizontal movements, valley closure movements, and lateral drawdown within the deep groundwater system are recognised to have potential to extend beyond the limits of vertical subsidence, but these effects do not generally have a significant impact.

3. Overview of Piezometer Monitoring Results From GW01

GW01 was recently drilled some 220m southwest of where Mt Ousley Road crosses Cataract Creek (see Figure 2). The hole is located in an area where the Bulli Seam has previously been mined and above a 150m long by 190m wide longwall goaf in the Balgownie Seam. The hole was drilled to a depth of 170.1m and terminated in the Scarborough Sandstone. Numerous fractures were observed within the overburden strata during drilling and subsequently when the borehole was inspected with a down-hole camera and geophysically logged.

A string of eight vibrating wire piezometers was installed in GW01. Figure 6 shows the profile of the pore pressures measured in this hole soon after the instruments were installed and at several times since then. This profile is plotted alongside the stratigraphy inferred from chip logging during drilling and geophysical logging once the hole was completed. The collar of this borehole is at RL318m.

A hydrostatic pressure gradient is plotted from 24m below the surface, the elevation of the standing water level in the hole observed during much of the drilling. A hydrostatic pressure gradient represents the rate of increase in water pressure that would be expected in a connected body of water where there is no vertical flow, such as might be observed in the ocean for instance. A pore pressure gradient that is reduced below hydrostatic is indicative of a downward flow, although the rate is also dependent on the hydraulic conductivity of the strata.

Initial readings from the piezometers were available on 27 September 2012, approximately a week after Longwall 4 finished. Within the resolution of the instruments there does not appear to be much change in the upper part of the profile since the piezometers were installed on 27 September 2012. However, there does appear to have been ongoing drawdown of 3-6m below 60m and drawdown of 15m at 165m so that the piezometric pressure at this level is close to fully depressurised.

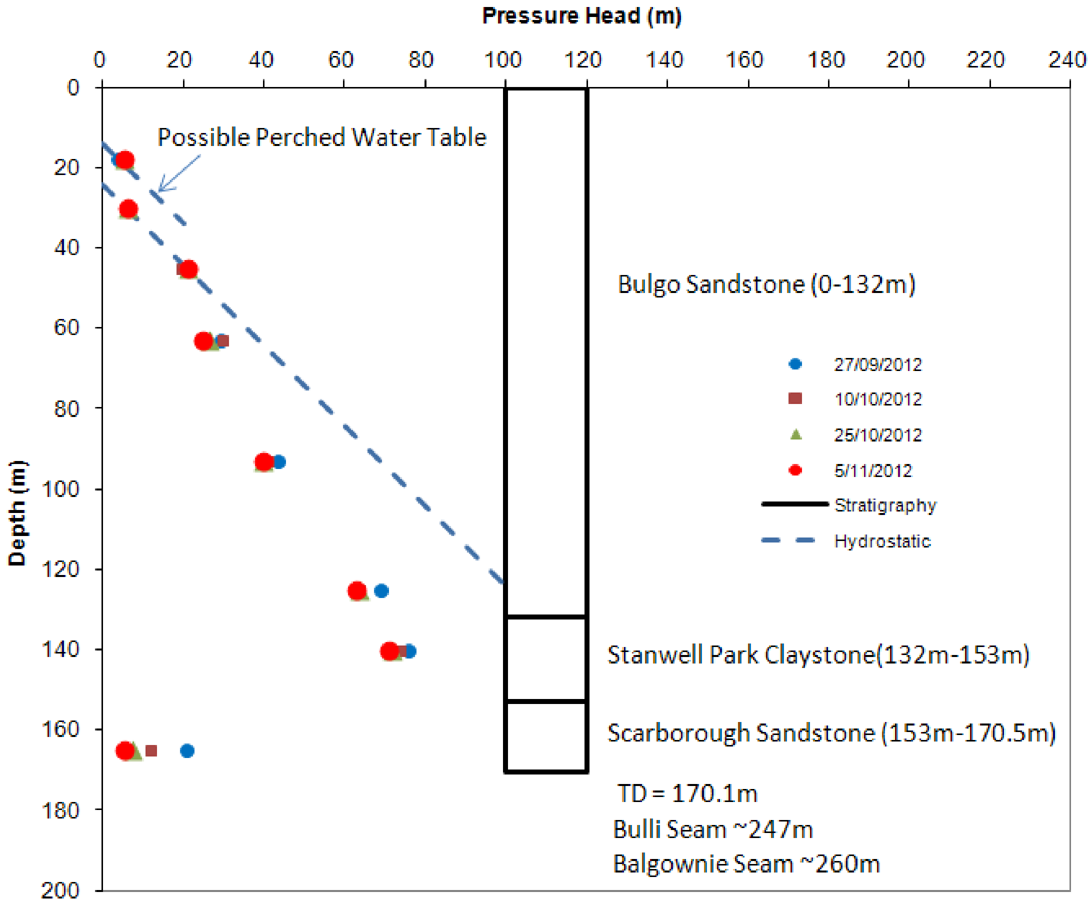

Figure 6: Pore pressure profile measured in Borehole NRE GW01 since the completion of Longwall 4.

The pore pressure profile shown in Figure 6 is considered to be a convincing measurement of the pore pressures within the rock strata at this site following the completion of Longwall 4.

The individual point measurements are coherent with one another and consistent with experience of similar measurements at other sites. The uppermost piezometer indicates that there may be a perched water table in the surface strata as indicated by the short hydrostatic line, but the general form of the profile indicated by the other piezometers is more consistent with a hydrostatic profile below 24m.

The results indicate that there is a restriction to downward flow at a horizon between about 25m depth below the surface (RL293m) and 45m (RL273m). This restricted flow horizon may not necessarily be an aquiclude, but it is a sufficient aquitard to restrict vertical outflow to less than the recharge available. The restricted flow horizon is located stratigraphically within the top part of the Bulgo Sandstone.

Below this restricted flow horizon, the pressure gradient diverges from hydrostatic at a steady rate to about 150m deep (RL168m) consistent with a hydraulic gradient that is causing downward flow. At approximately 100-120m above the Balgownie Seam mining horizon (depth 150m and RL168m), there is a sharp reduction in pore pressure with increasing depth consistent with the top of a more hydraulically connected fracture network above the longwall goaf in the Balgownie Seam. This sharp reduction also coincides stratigraphically with the Stanwell Park Claystone which appears to be acting as a second aquitard.

The form of the pressure profile indicates the vertical flow rate is likely to be relatively insignificant by comparison with surface recharge (rainfall and lateral flow), but the magnitude of downward flow indicated by this profile depends on the hydraulic conductivity of the overburden strata.

Packer testing indicates that the hydraulic conductivity of the Bulgo Sandstone in a horizontal direction, including the restricted flow horizon, ranges from about 1.2×10^{-8}m/s to 4×10^{-6}m/s. The hydraulic conductivity of the Stanwell Park Claystone in a horizontal direction is measured as being between 3×10^{-9}m/s and 5×10^{-9}m/s. Packer testing does not provide a definitive measure of vertical hydraulic conductivity.

In due course, the response of the groundwater profile to rainfall is expected provide an indication of the rate of downward flow at this site.

4. RESPONSE TO SUBMISSIONS

There appears to be several themes within the submissions that are able to be addressed collectively.

4.1 Multi-Seam Subsidence

One theme dwells on the dangers or uncertainties associated with multi-seam mining particularly for a third level of mining. SCT is not aware of any previous mining in the Southern Coalfield where three seams have been mined directly above one another, except now from mining Longwall 4 at NRE. There has been previous multi-seam mining in three seams in the Newcastle Coalfield at Wyee and Myuna Collieries (Wallarah, Great Northern, and Fassifern Seam) and there may have been other sites in some of the older mines in the

Newcastle Coalfield. The practice of multi-seam mining is quite common in the United Kingdom where SCT are aware of at least one site where up to nine seams were mined at the same colliery. Multi-seam mining is also common in other countries such as China, Poland, Russia, and Germany.

There does not appear to be any significant practical impediment to successfully conducting multi-seam mining and managing the resulting subsidence impacts.

Although there are greater uncertainties associated with prediction of subsidence in multi-seam mining to the same level of confidence as has become customary for subsidence predictions in single seam mining operations, the greater uncertainty of prediction is not of itself necessarily of great consequence in terms of potential impacts or how they are managed. The basic mechanics of ground movement are not expected to change significantly as a result of the interaction of multiple seams. Larger subsidence movements are expected, but these are likely to be similar in form to the effects that would develop if a single seam of equivalent combined thickness was mined.

A risk based approach is an appropriate way to manage these uncertainties.

4.2 Influence of Major Geological Structures

Another theme apparent in the submissions is the concept that major geological structures such as faults and dykes will significantly influence subsidence behaviour and these features need to be avoided.

There are some examples of unusual subsidence that can be related to geological structures, mainly dykes, but these examples are relatively rare. In general, geological structures such as faults and dykes do not usually change surface subsidence behaviour.

There has been previous mining on two levels adjacent to the dyke within the Wonga East mining area. There is no evidence in the measured subsidence profiles of this feature having any influence on surface subsidence behaviour. The main influence of these structures appears to have been at seam level in the Balgownie Seam where mining through the dyke proved more difficult than stepping the longwall around the dyke.

The concept that geological fault structures may become reactivated as hydraulic pathways has been advanced in some of the submissions. In SCT's experience, there is not any very strong evidence to confirm that geological faults in the Southern Coalfield are either more conductive or less conductive than the surrounding strata or that they provide a connection between the surface and underground.

4.3 Influence of Bald Hill Claystone

The Bald Hill Claystone is recognised and accepted to have relatively low matrix permeability compared to other stratigraphic units because of its fine grained nature.

However, the fracture/joint permeability rather than the matrix permeability is recognised as likely to be the main control on overall hydraulic conductivity of stratigraphic units within the overburden strata simply because the hydraulic conductivity of the fracture network is typically much greater than the hydraulic conductivity of the matrix.

There is no evidence that SCT is aware of to indicate that the Bald Hill Claystone is somehow self-healing as a consequence of its so called "claystone" characteristics. Indeed natural joints are relatively common including joints that have remained open long enough to become infilled by mineralisation (calcite or similar) deposited by groundwater percolating through the natural fracture network within the rock mass over geological time.

Mining induced ground movements tend to increase the aperture of existing joints as well as create new fractures. The ground movements directly over each longwall panel tend to be stretching in nature and therefore, are more effective at increasing hydraulic conductivity of the rock mass than the more compressive movements that occur within the overburden strata directly above each of the chain pillars between panels.

The notion that the Bald Hill Claystone is an effective aquitard either prior to or post mining needs to be explored on a site by site basis. GW01 is collared below the base of the Bald Hill Claystone (some of which may have been excavated during road construction) so the measurements in GW01 do not provide any indication of the Bald Hill Claystone properties.

4.4 Effect of Mining on Swamps

There are recognised to be several different types of swamps and each type of swamp may be more or less vulnerable to particular types of ground disturbance. It should be recognised that any impacts to swamps are unlikely to become apparent until well after mining is complete and well after there is any capacity for the mine to make any significant change to the mining process. The concept of a Trigger Action Response Plan (TARP) as a method of protecting swamps is not credible because many of the impacts are likely to be long term and difficult to detect without extended monitoring.

In swamps that are not located across valley floors, a high level of protection is provided if the swamps are not directly mined under. Higher protection is provided with increased distance between the swamp and the edge of the nearest longwall panel.

In swamps located across topographic low points, there is potential for valley closure impacts whenever mining occurs below the slopes that lead down to the swamp, although there does appear to be some tolerance of the rock strata to valley closure before impacts become significant.

A judgement based on the significance or otherwise of individual swamps and the flora and fauna associated with them is required to be made ahead of mining. If mining is allowed to proceed directly under a swamp (or the slopes leading down to a swamp where valley closure is expected to be sufficient to have an impact) there is considered to be potential for impacts to occur, not necessarily immediately, but potentially over time as readjustments occur to accommodate changes to the balance between recharge and possible outflow through newly created fractures.

4.5 Impact Metropolitan Water Supply and Cataract Creek

Longwalls 4 and 5 are located in an area that is remote from the stored waters of Cataract Reservoir. There is not considered to be any potential for significant flow from stored waters into the mine. An increase in vertical hydraulic conductivity is expected in areas that have been directly mined under, as evidenced by the piezometric profile shown in Figure 4, but the magnitude of flow is likely to be insignificant by comparison with the volume of rainfall recharge and other natural effects such as evaporation from the surface of the reservoir.

Some impacts on water quality from tributaries to Cataract Creek are expected. There appears from the iron staining evident in the water flowing in Cataract Creek to be some ongoing impacts from previous mining that was undertaken some 30-40 years ago, so the post mining recovery appears to be relatively slow. Further mining below the tributaries to Cataract Creek is expected to increase the level of rock fracturing adjacent to these tributaries and further iron staining is expected. Such an increase is apparent in a tributary to Cataract Creek that flows from the area above Longwall 4.

The rock strata in the base of Cataract Creek does not appear to have been impacted by previous mining in the same way as rock strata in the base of watercourses located on Hawkesbury Sandstone. This difference is considered to be a result of Cataract Creek being located on the outcrop of Bald Hill Claystone and Bulgo Sandstone in the area where valley closure is likely to have occurred.

Possible explanations include:

- Valley closure or horizontal movement in a downslope direction that occurs as a result of mining subsidence may be concentrated on a horizon at the bottom of the overlying Hawkesbury Sandstone and therefore above the level of the river channel.

- Rock strata in the floor of Cataract Creek may not react to horizontal compression in the way that gives rise to fracturing and upsidence evident in watercourses located within Hawkesbury Sandstone.

Further subsidence monitoring is required to confirm the mechanism that appears to be protecting Cataract Creek, but the lack of impact from previous mining activity on the floor of Cataract Creek is recognised to be different to the behaviour typical of creeks located in Hawkesbury Sandstone.

4.6 Impact on Illawarra Escarpment and Other Rock Features

There is considered to be no potential for proposed mining of Longwall 5 to have any impact on the Illawarra Escarpment. Longwall 5 is remote from the escarpment and any far field ground movements are expected to be well below the tolerance of the escarpment or the level of other natural influences such as seasonal thermal variation.

Sandstone rock formations associated with the outcrop of Hawkesbury Sandstone are located over Longwall 5 and would be subject to horizontal compression caused by subsidence movements. There is considered to be some potential for rock falls on about 5% of the subsided length of rock formations.

If you have any queries or require further clarification of any of these issues, please do not hesitate to contact me directly.

Regards

Ken Mills
<u>Senior Geotechnical Engineer</u>

References

Mills, K.W. 2001, Observations of horizontal subsidence movement at Baal Bone Colliery', in proceedings of 5th Triennial Conference on Coal Mine Subsidence Current Practice and Issues, 2628 August 2001, Maitland NSW, pp. 99-111.