The Effects of Mining Subsidence on Rockbars in the Waratah Rivulet at Metropolitan Colliery

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Summary

Metropolitan Colliery is currently longwall mining below a section of Waratah Rivulet in the Woronora water supply catchment. The effects of mining subsidence on the quantity and quality of water and the ecological integrity of the rivulet are of interest to the Sydney Catchment Authority. The colliery has undertaken a significant program of work aimed to assess the likely impact of mining on the rivulet. The program includes subsidence monitoring, instrumentation to monitor the effects of mining subsidence on rockbars, flow and water quality monitoring and monitoring of vegetation, aquatic ecology and archaeological sites.

This paper describes the results of subsidence and rockbar monitoring up to the completion of Longwalls 9 and 10.

1. Introduction

Coal mining commenced at Metropolitan Colliery in 1886 and has continued under various owners since then. It mines a 3.2-3.5m high section of the Bulli Seam at overburden depths of approximately 500m using the longwall method of mining. Longwall mining started in 1995. Since then ten longwall panels have been mined.
The longwall panel widths have gradually increased in width as mining has progressed, but are relatively narrow compared to other mining operations on the South Coast. They are also narrow compared to overburden depth. In Longwalls 1-7 the extracted void was nominally 125m wide. The panel width increased to 140m in Longwalls 8-10, and is 162m in Longwall 11. The chain pillars have remained 35m wide (measured rib to rib). Longwall 9 started in September 2002, Longwall 10 started in September 2003 and Longwall 11 started in June 2004.

The Waratah Rivulet is one of the main tributaries of the Woronora Reservoir and flows over the current mining area of Metropolitan Colliery. Sydney Catchment Authority (SCA) and other government agencies are interested in the effects of mining subsidence on the quantity and quality of water in the Waratah Rivulet and the ecological integrity of the area. Helensburgh Coal Pty Ltd (HCPL), the owners of the colliery commissioned SCT Operations Pty Ltd to undertake measurements and install monitoring instrumentations at two rock bars on the Waratah Rivulet known as WRS1 and WRS3 and to report on the results of monitoring these instruments and other subsidence monitoring as Longwalls 9 and 10 have mined past these sites.

Figure 1 shows the location of the longwall panels at Metropolitan Colliery plotted on a 1:25000 topographic series map of the area. The location of the subsidence lines and the two rockbar monitoring sites on the Waratah Rivulet, WRS1 and WRS3, are also shown.

The results presented herein relate to subsidence monitoring on:

- D Line, the main cross line that crosses all the previous panels.

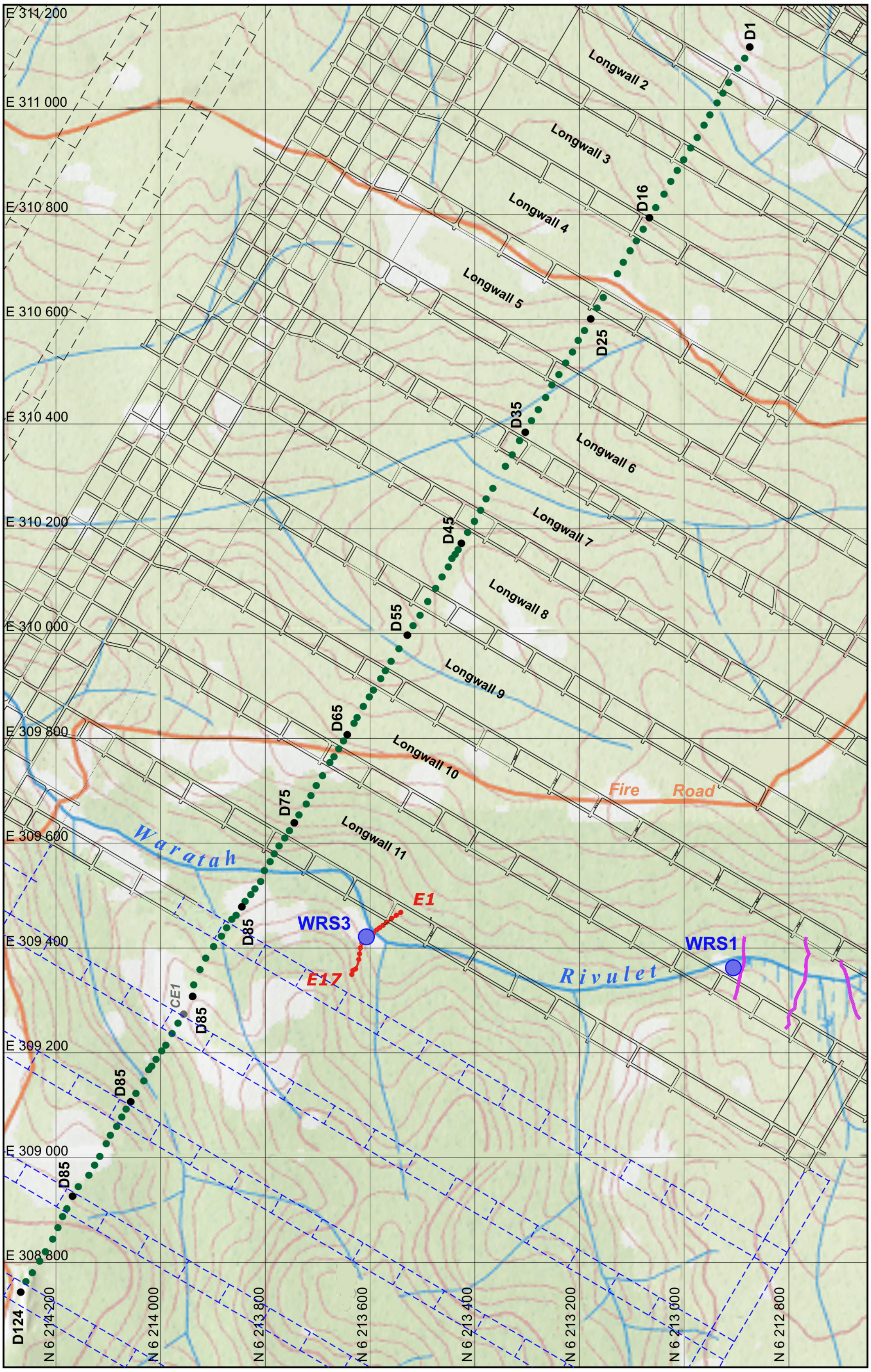

Figure 1 Site plan showing subsidence lines and WRS1 and WRS3.

- E Line, a short line that crosses in the vicinity of WRS3.
- Three short lines in the vicinity of WRS1 and upstream named Lines 1, 2 and 3.

And rockbar monitoring on WRS1 and WRS3, including:

- Replacement and ongoing monitoring of an extensometer, stresscell and water levels at WRS1 (after the previous instruments were sheared off by subsidence movements when Longwall 10 approached the site).
- Installation and monitoring of an extensometer, stresscell and water levels in nine boreholes at WRS3.

2. Subsidence Monitoring

In this section, the subsidence monitoring undertaken at Metropolitan Colliery is analysed to show the general nature of subsidence movements at the colliery and the specific subsidence behaviour at various locations along the Waratah Rivulet.

2.1 D Line

D Line is the main cross-line used to monitor subsidence behaviour at Metropolitan Colliery. It starts over Longwall 1 and has been extended across all the longwall panels. Subsidence monitoring on this line initially comprised level and strain monitoring, but was upgraded to three dimensional monitoring in April 2002 during mining of Longwall 8. Figure 2 shows a summary of the subsidence movements measured on D Line since the commencement of longwall mining. The topography and longwall panel locations are shown on each of the plots for reference purposes as these both have a significant influence on the subsidence measured. The individual subsidence components are discussed separately in the following sections.

2.1.1 Vertical Subsidence

Figure 2a shows the vertical subsidence profiles measured at or near the completion of each longwall panel. These subsidence profiles are typical of a mining geometry where the individual panels are narrow relative to mining depth. There is no evidence of individual chain pillars in the subsidence profile. The onset of vertical subsidence is controlled by the edge of the longwall mining area. Full subsidence does not develop for 2.5-3 panels out from the solid, unmined coal.

A characteristic of the overburden behaviour in circumstances of narrow panels at depth is that the overburden strata bridges across individual panels and the overall magnitude of the subsidence is controlled by elastic compression of the chain pillars and the strata above and below the chain pillars (Mills 1998). As a result, full subsidence does not develop until many adjacent panels have been mined. In effect, subsidence occurs in response to the "super-panel" effect of multiple panels, rather than in response to individual panels.

It is well recognised that individual longwall panels cause significant disturbance within the overburden strata immediately above the extracted coal seam, but the height of this disturbance is limited to within 200-250m (approximately 1-1.6 times panel width, Mills & O'Grady 1998) of the coal seam. The upper 250-300m of overburden strata at Metropolitan Colliery is likely to remain substantially intact. The upper strata subsides gradually across multiple panels, but this movement is accommodated through small shear movements on multiple bedding planes. One implication of this behaviour is that the vertical permeability of the upper overburden strata is unlikely to be affected by mining subsidence. On this basis, ingress of surface water into the mine is considered most unlikely.

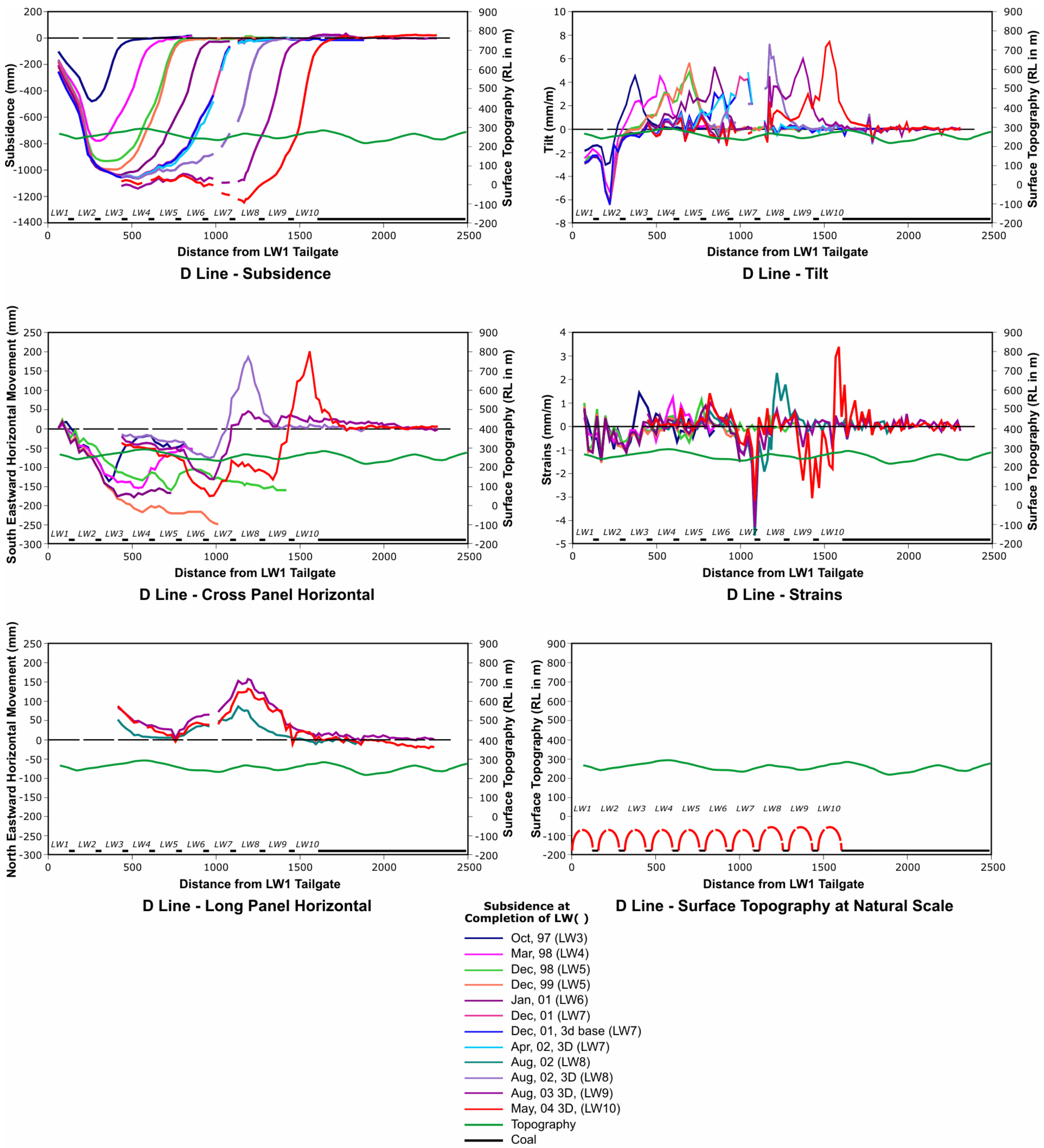

Figure 2 Summary of subsidence movements on D Line.

Figure 3 shows the vertical subsidence profiles measured at the completion of each longwall panel plotted relative to the goaf edge (solid edge of the mined out area). These profiles are essentially similar in nature, particularly over the solid goaf edge.

Goaf edge subsidence is remarkably uniform at about 70mm. It is difficult to resolve angle of draw because of survey error over such long lines, but in most of the profiles the subsidence has reduced to less than 20mm within 60-70m of the goaf edge giving an effective angle of draw of about 7°.

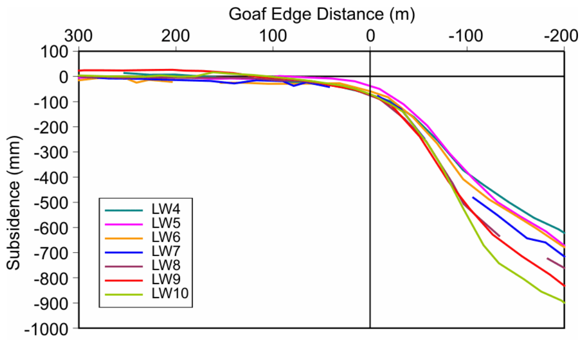

Figure 3 Vertical subsidence profiles over longwall goaf edge.

The magnitude of maximum vertical subsidence measured on D Line is increasing with each additional panel mined. There are two effects working together to produce this increase. The first relates to the increasing panel width which has the effect of generating more vertical load on the chain pillars and therefore greater elastic compression. The second effect is a geometric effect. Longwalls 3-5 were relatively short in comparison to the other panels and full subsidence was not able to be developed in these panels because of the influence of the end abutments. In the later panels, the inbye end of the panels is too remote to prevent full subsidence at D Line. Nevertheless, it will take 5 or 6 panels in total before the width of the “super-panel” is sufficient for full subsidence to have developed.

It is quite likely that D Line does not experience full subsidence that might be occurring further to the south because of its relatively close proximity to the outbye end of the panels. However, the results from D Line are more than sufficient to give a good indication of the overburden behaviour.

2.1.2 Cross-Panel Horizontal Movements

Figure 2b shows the cross-panel horizontal movements measured and inferred for D Line.

Cross-panel movements have only been measured directly since the introduction of three dimensional surveying in April 2002 with the first results becoming available in August 2002. The results prior to this have been determined by integrating the strains measured between pegs. Unfortunately survey errors and movements that occur across the line (which are not measured by peg to peg strain measurements) contribute to significant errors in the calculation of horizontal movements by this method. Although the three dimensional movements are now being measured, the initial movements on many of the pegs are not present in the measurements, so it will take several more longwall panels before a full profile of cross-panel horizontal movement has developed.

The three most recent profiles of cross panel horizontal movement give a good indication of the general horizontal subsidence behaviour. The horizontal movement profiles from Longwalls 8 and 10 indicate peak horizontal movements of about 200mm, some 60m, or 0.3 times depth, from the goaf edge. This behaviour is typical of subsidence behaviour measured at other sites.

The profile from Longwall 9 is different to the profiles from both the adjacent longwall panels. This difference is considered to be a result of the direction of slope of the surface topography. The peak movement toward the goaf is approximately 40mm, but this peak occurs at the same location as the peak from Longwall 8. Horizontal movement of 30mm to the east occurred at a point 60m from the goaf edge. In the section of subsidence line between pegs D45 and D55 (where the peak from Longwall 9 should be), the surface terrain slopes to the north-west whereas the surface terrain in the equivalent locations on the adjacent longwalls slopes in the opposite direction to the south-east.

This data suggests that downslope movement is approximately 80mm superimposed on general movement over the goaf edge of 110mm. It should be recognised that:

1. The magnitude of downslope movement is likely to be slope dependent and may increase in sections of steeper terrain.
2. Generalised horizontal movements comprise two components that add together to give higher horizontal movement near the start of the panel and reduced movement near the end of the panel.

2.1.3 Long-Panel Horizontal Movement

Figure 2c shows the long-panel horizontal movements measured on the section of D Line monitored in three dimensions. Peak long panel movement is 150mm in the direction of mining, which is also the downslope direction at the point where the peak occurs. The peak is located on a broad ridge that slopes north-east. The peak has remained in essentially the same location even though the goaf edge has moved, suggesting that the horizontal movement in this area is a consequence of the topography rather than a mining geometry effect.

Allowing for approximately 80mm of downslope movement, the background long panel movement of approximately 70mm in the direction of mining would be consistent with experience at other sites.

2.1.4 Tilt

Figure 2d shows a summary of the tilts measured along D Line. The tilt is calculated as the differential subsidence divided by the length across which it occurs.

The background systematic tilt appears to be about 6mm/m. The peak tilts measured so far are 7.5mm/m, and these have a component of downslope movement associated with them. These tilts are consistent with the 7.2mm/m that would be calculated based on general subsidence experience in the Southern Coalfield (Holla 1992).

2.1.5 Strain

Figure 2e shows a summary of the horizontal strains measured along D Line. The strains are measured directly in the early part of the subsidence line and calculated as the cross-panel component of differential horizontal movements between adjacent pegs in the section of the line monitored in three dimensions. Two peaks of tensile strain (2.3mm/m and 3.4mm/m) developed at approximately 50m from the goaf edge over Longwalls 8 and 10. These peaks appear to be located close to the top of slopes dipping in the direction of mining. Two compressive strain peaks (3.1mm/m and 4.7mm/m) developed at the goaf edge over Longwalls 7 and 9. These peaks appear to be located close to the bottom of valleys. Strains otherwise appear to be generally less than 1mm/m.

General experience from elsewhere in the Southern Coalfield (Holla 1992) indicates peak strains of 1mm/m in tension and 2mm/m in compression would be expected for the panel geometry and depth at Metropolitan Colliery. This general experience would suggest that the higher peak strains observed are a likely to be a consequence of downslope movement resulting in additional stretching near the top of ridges and compression movements in the valleys (also known as valley convergence).

The compressive strains observed on D Line close to the bottom of valleys would be expected to be sufficient to cause failure, and therefore fracturing, of intact rock strata. Fracturing of intact rock has been observed at various locations along the length of undermined sections of stream channels consistent with the strain levels observed on D Line.

2.1.6 Longwall Panels at Natural Scale

Figure 2f shows a cross-section along D Line plotted at natural scale (vertical and horizontal scales the same). The zones of large scale downward movement within the overburden strata expected on the basis of extensometer monitoring at Clarence Colliery (Mills & O'Grady 1998) are also plotted.

The benefits of the relatively narrow longwall panels (narrow relative to depth) can be seen. There is a significant zone of essentially intact strata above the zones of large downward movements. Strata within this upper zone is disturbed only by shear movements along bedding planes. Vertical permeability through this upper zone is unlikely to be greatly affected by mining.

2.2 E Line

E Line runs across the Waratah Rivulet at WRS3 in a direction perpendicular to F Line as shown in Figure 1. The subsidence movements on E Line have been monitored in three dimensions and although relatively modest at this stage are expected to increase as a result of future mining.

Figure 4 shows a summary of these movements as Longwall 10 passed in line with WRS3 and then again at the completion of Longwall 10. WRS3 is located approximately 270m from the goaf edge of Longwall 10.

Figure 4a shows vertical subsidence is essentially zero consistent with the location of the site relative to the active mining. However, it is noted that the reference level for this survey is linked into F Line so there is some uncertainty in this survey that will be resolved when the next survey is conducted.

Figure 4b shows that there was very little closure at the site when the longwall face passed the site, but closure increased to approximately 60mm by the time Longwall 10 finished. The movement appears to have occurred predominantly on the goaf side of the rockbar over a 40m interval in the area where cracking has been observed.

Figure 4c shows that there has also been long-panel movement of approximately 40mm in the direction of mining. Movement is greatest on the goaf side of the rockbar, but there is approximately 20mm of movement in the direction on mining on the other side of the rockbar as well.

Figures 4d indicates that the ground tilt at the site is insignificant.

Figure 4e indicates slight compressive strains with a localised tensile peak at a point 55m from Peg E1 were observed in December 2003 when the longwall face was adjacent to the site. It is likely that the tensile peak is associated with localised buckling and the onset of perceptible fracturing. This fracturing was first observed by SCT personnel on 10 February 2004. It is predominantly over-ride shear fracturing and appears to be localised in a relatively small area on the eastern bank of the river channel.

The second resurvey at the completion of mining indicates that there is a broad zone of compression strains extending along most of the eastern 80m of the subsidence line. The peak compressive strains approach 1.8mm/m. Strains of this magnitude are consistent with perceptible fracturing.

Figure 4f shows the surface topography drawn at natural scale. The grades are relatively gentle over the section of the river channel where the subsidence line is located.

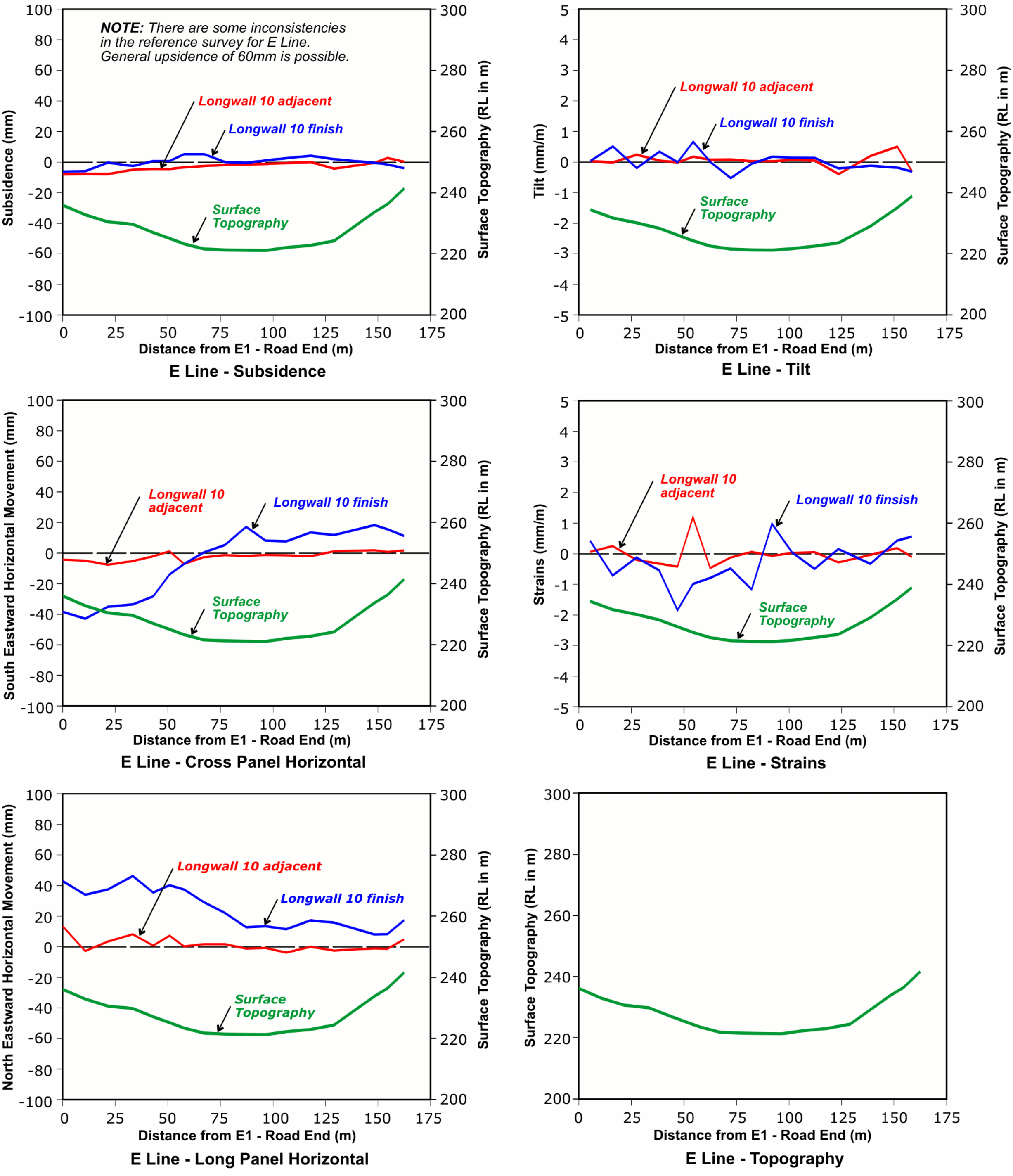

Figure 4 E Line subsidence.

2.3 Subsidence Monitoring in the Vicinity of WRS1

There are three subsidence lines in the vicinity of WRS1 and immediately upstream. The locations of these lines are shown in Figure 1 and are then reproduced in more detail in Figure 5. They are referred to as Lines 1 to 3.

2.3.1 Line 1 – Lower End of Flat Rock Swamp

When Longwall 9 was complete, subsidence was less than 30mm and probably close to the resolution of the measurement system. When Longwall 10 was mined, the vertical subsidence increased over the longwall goaf as would be expected. However, subsidence does not develop as quickly with distance from the goaf edge as it does on D Line. Line 1 is located at the corner of Longwall 10 and therefore the overburden strata is able to bridge across the corner of the panel, thereby reducing the subsidence. When subsequent longwall panels are mined, this corner effect will disappear and a full abutment profile is expected to develop off the end of the panel.

Longwall 10 commenced on 3 August 2003. By the time that the first resurvey on Line 1 for Longwall 10 was completed on 19 January 2004, the longwall had retreated almost 900m and subsidence movements at Line 1 were essentially complete.

Horizontal closure of approximately 100mm was observed across the river channel. This closure is concentrated at one location under the river channels. The western side of the river channel also moved some 150mm north relative to the eastern side.

2.3.2 Line 2 – Upstream of WRS1

Line 2 is located approximately 120m upstream of WRS1.

When Longwall 9 was mined, there were some small horizontal movements typically less than 100mm and the vertical subsidence was less than about 20mm.

When Longwall 10 was mined, a vertical subsidence profile similar to those measured on D Line developed. Approximately 700mm of subsidence occurred at the eastern end of the line and effectively no subsidence was observed at the western end over the unmined area. There is a slight "hump" apparent in the subsidence profile between about 70m and 110m from the Longwall 10 goaf edge. This hump was apparent in the Longwall 9 subsidence profile and reflects the zone of upsidence associated with valley closure. The hump is offset from the river channel proper on a broad flat area. It appears to have developed in this area due to a change in direction of the river channel and reflects a tendency for zones of upsidence to cut across corners.

The horizontal movements on Line 2 show more clearly where the zone of convergence has developed. Approximately 230mm of valley closure has occurred in a 60m wide zone. The step in the horizontal movement profile at 110m suggests that about 90mm of convergence at the eastern end of the line is a result of shear movement on one or more bedding planes. There does not appear to be any upsidence associated with movement in this area, whereas the 140mm of convergence in the zone between 70m and 110m from the goaf edge occurs in an area where there is upsidence apparent in the vertical subsidence profile. This correlation would be consistent with failure (shearing and upward buckling) of near surface strata causing the hump in the subsidence profile. The convergence appears to have created an additional fracture volume of about 100mm within the top 5-10m of rock strata.

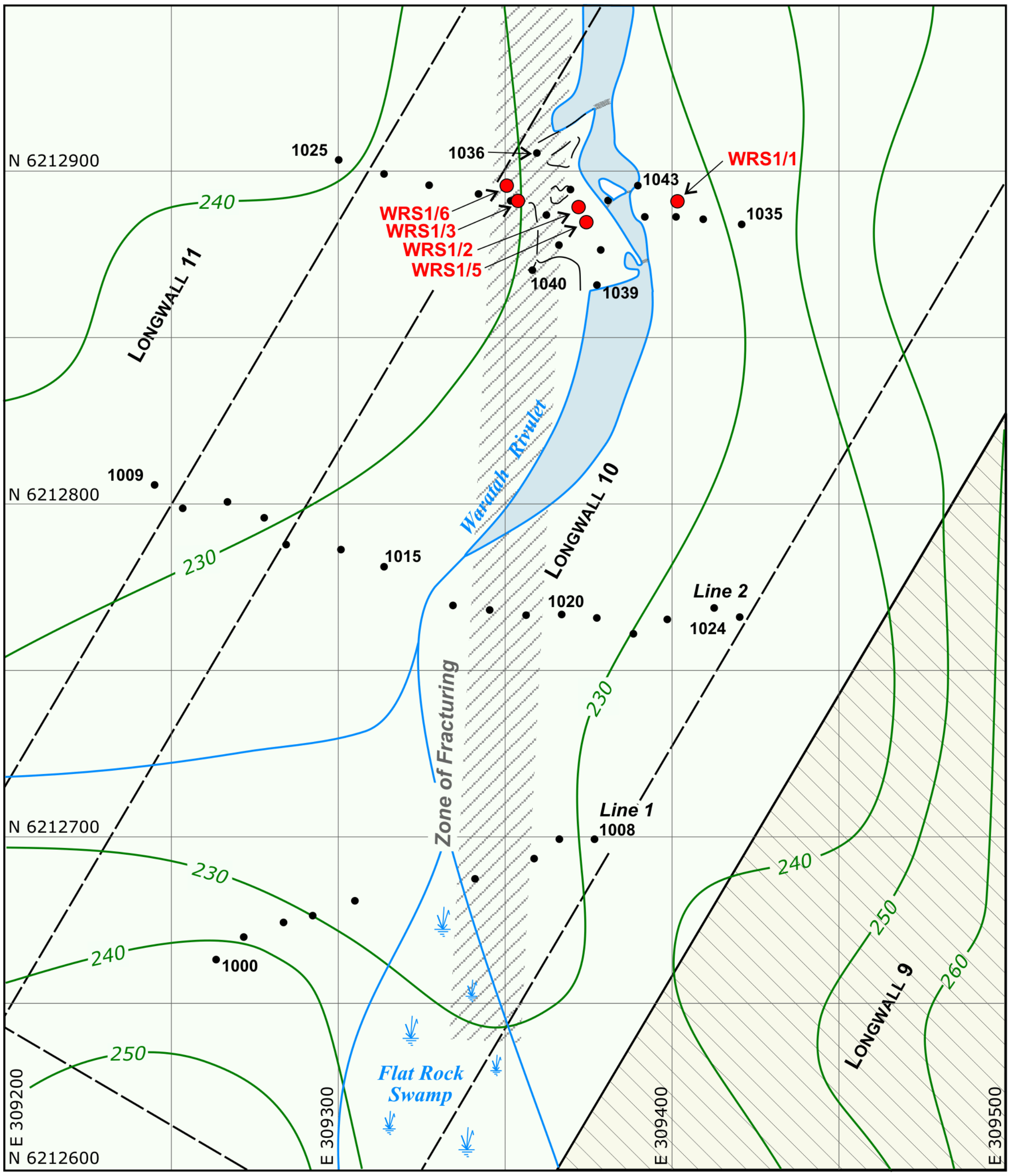

Figure 5 Plan showing location of survey marks and instrumentation boreholes at WRS1.

There appears to be general movement of the ground toward the goaf, but the absolute magnitude of this movement is not known because the surveys have not been referenced to the outside world. There has also been a relative movement of the eastern end of the line toward the south compared to the western end of the line of about 200mm.

2.3.3 Line 3 – At WRS1

Line 3 comprises one line that crosses the river channel at WRS1 and two shorter 45° lines that provide additional coverage of the area. When Longwall 9 was mined, the vertical subsidence at WRS1 was generally less than about 20mm and the upsidence was just starting to develop. As Longwall 10 has mined past the site, the upsidence has become much more pronounced in the area between -20m and +40m from the goaf edge with some 120-150mm of upsidence apparent at about 25m.

While the vertical subsidence profile developed at WRS1 is essentially similar to that measured on D Line with subsidence developing over the mined area as would be expected, the subsidence appears to develop more quickly than subsidence shown by profiles measured on D Line. The reasons for this greater rate of subsidence are not clear.

A zone of valley floor convergence is apparent as a step in the profile of eastward horizontal movement. This step occurs between +5m and +25m from the Longwall 10 goaf edge with approximately 180mm of convergence occurring across this 30m interval. This rate of convergence is equivalent to an average compressive strain of approximately 6mm/m. Failure of the rock strata in compression and development of fracturing is expected to occur at this level of strain.

The eastern end of the subsidence line appears to have moved approximately 150mm south compared to the western end, consistent with observations on the other two subsidence lines in the area.

3. WRS1 Rockbar Monitoring

Monitoring instrumentation was installed at WRS1 prior to the commencement of Longwall 9 and successfully monitored during retreat of Longwall 9.

It was intended to continue monitoring these instruments during mining of Longwall 10. However, the subsidence movements that occurred as Longwall 10 approached the site caused the instrumentation cables in the central monitoring hole (WRS1/2) to shear off and one of the two water level monitoring holes (WRS1/3) to become blocked above the ground water level. The only instrumentation that remained serviceable was the water level monitoring in WRS1/1 and the extensometer in WRS1/2.

Two new holes were drilled from 5-7 November 2003. WRS1/5 was drilled adjacent to the extensometer and stresscell hole and new instrumentation was installed in this hole on 14 November 2003 with the remote readout head on the extensometer being completed on 22 December 2003. WRS1/6 was drilled adjacent to the blocked piezometer hole WRS1/3.

By the time the holes were redrilled, the longwall face was some 250m past the site and most of the subsidence movements associated with Longwall 10 had occurred. It appears from the monitoring results and correlation with the subsidence measurements that the extensometer continued to operate throughout without any significant loss of data. The stresscell cable was severed in early October as the longwall face approached the site and was not re-established again until early November, so about one month's data was lost on the stresscell.

Water level monitoring on all the monitoring holes was re-established in early November and based on the correlation with previous measurements, the loss of data associated with the shearing was insignificant.

3.1 Extensometer Monitoring

The original extensometer in WRS1/2 had five operational anchors at 5m, 9m, 12m, 15.5m and 27.2m with a sixth anchor intended for 20m having slipped up the hole to 15.5m, effectively giving two anchors at the one location. It was initially thought that lateral shearing associated with subsidence had compromised the operation of this extensometer at the same time that the stresscell and piezometer cables were sheared off. However, it appears as though the readings obtained from the extensometer have continued to show a pattern of incremental movement that is consistent in magnitude with the surface subsidence movements.

A second, 10 anchor extensometer was installed adjacent to WRS1/2 in WRS1/5 on 14 November 2003. The anchors were located at 5m, 7m, 9m, 11m, 13m, 15m, 17m, 20m, 24m and 28.6m to give an improved coverage below the shear horizon at 6-8m apparent in the first extensometer results.

Figure 6 shows a composite of the ground dilation measured on the original extensometer in WRS1/2 and the second, adjacent extensometer installed in WRS1/5. The movements observed at the completion of Longwalls 9 and 10 are highlighted.

This result shows a generally consistent trend of increasing dilation in the upper 7-9m of the rockbar. At the completion of Longwall 9, the upper 7-9m of the rockbar had dilated some 60mm. By the completion of Longwall 10, the composite extensometer result indicates dilation of this upper 7-9m had increased to 140mm.

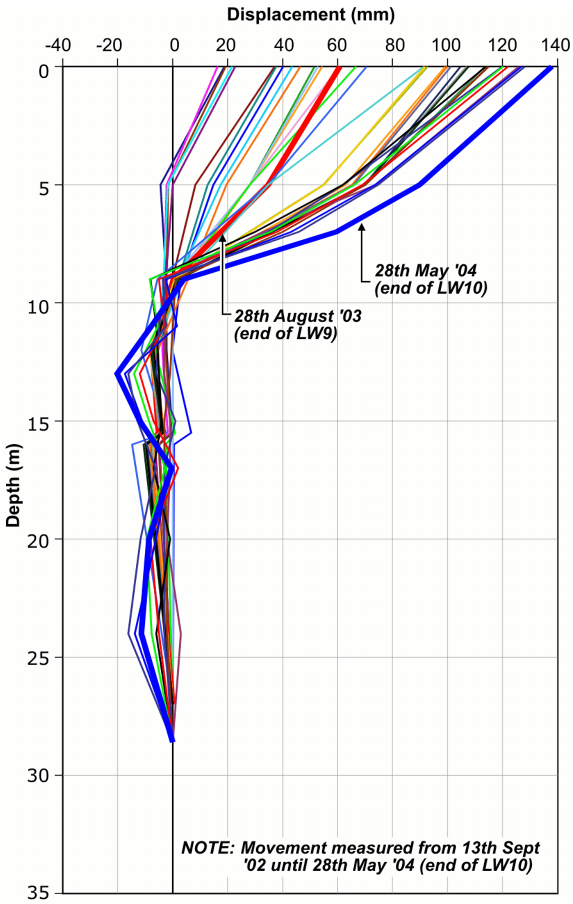

Figure 6 Composite extensometer movements measured at WRS1.

The total 140mm dilation observed at the completion of Longwall 10 is consistent with the 120-150mm of surface subsidence measurements on Line 3. This correlation gives confidence in the integrity of the composite extensometer measurement and suggests that no extensometer data has been lost as a result of having to replace the instruments.

The extensometers show no significant dilation below 9m. There is some variability in the movement of individual anchors of up to about 20mm below 9m. This variability is considered likely to be associated with instrument error and the error associated with compositing the two extensometer results. However, it is clearly apparent that dilation is occurring more or less evenly throughout the upper 9m of the rockbar.

3.2 Stresscell Monitoring

During Longwall 10, the integrity of the stresscell monitoring at WRS1 was compromised when the readout cable was sheared soon after Longwall 10 began. Only one set of readings was taken after Longwall 10 commenced (26 September 2003) and this showed no significant change from the monitoring previously reported. By the time of the next scheduled readings in October, the instrument cable had sheared off.

A replacement instrument was installed on 14 November 2003 at 10.4m deep in WRS1/5 and aligned at 0°GN. Figure 7 shows the pressure test conducted on 16 November 2003. This indicates that all gauges are operating correctly and the elastic modulus is approximately 18GPa assuming a Poisson's ratio of 0.25. These values were used in the analysis.

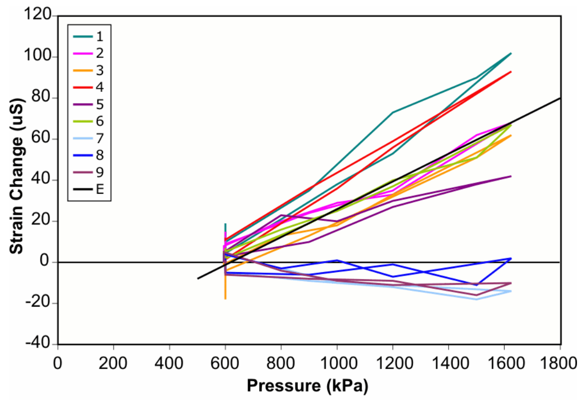

Figure 7 Pressure test for WRS1M2.

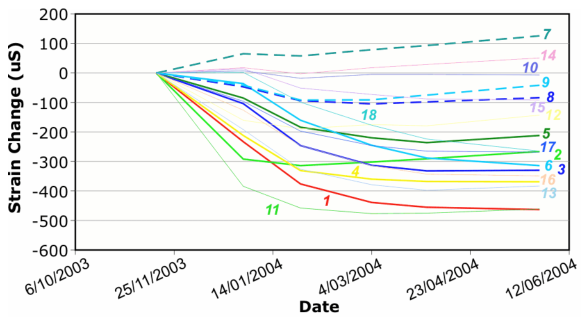

Figure 8 Strain changes measured on stress cells at WRS1.

Figure 8 shows the strain changes measured. Strain changes are occurring right from the time of installation. There is no initial settling down period, which indicates that some stress changes have occurred prior to installation of the instrument.

Figure 9 shows a plot of the stress changes that were measured since Longwall 10 was 270m past the site. This plot is incomplete as noted above, but is does indicate that all three components of stress are compressive. This behaviour is consistent with the convergence observed at the site.

The measurement itself shows an internal correlation of about 0.9 on 6 degrees of freedom. Such a result is regarded as indicative of the stress changes rather than being totally convincing.

The magnitude of the stress changes measured are of the order of 3-4MPa mainly across the river channel, but also along its length as well. In strata with a modulus of 18GPa, the stress change measured is equivalent to an average horizontal strain of the order of 0.2mm/m. The horizontal strains measured at the site are of the order of 8-10mm/m (180mm of convergence over 25m). The mismatch between the strain change measured by the stresscell at 10m below the surface and the average strain measured by subsidence surveying on the surface is indicative of:

- Some strain being missed because of the late installation of the instrument as previously discussed.
- Considerable slippage, rock failure and fracturing occurring within the rock mass.

The extensometer indicates that most of this slippage and fracturing is occurring between the surface and 9m.

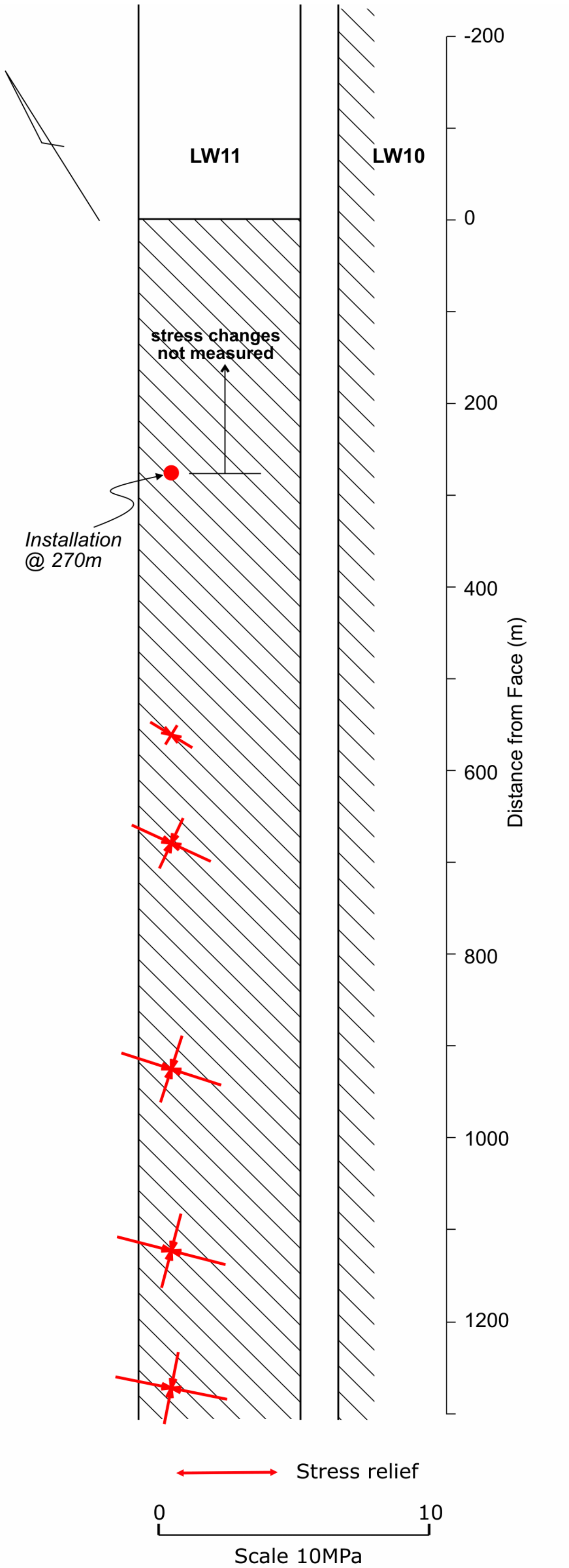

Figure 9 Stress changes and total stress plotted relative to Longwall 11.

3.3 Water Level Monitoring

The water level was monitored from time to time in three holes during mining of Longwall 10. It appears as though the groundwater levels have not changed significantly since Longwall 9 mined close to the site.

Figure 10 shows a summary of the groundwater level movements during the period of mining Longwall 10. There are fluctuations in the groundwater table as would be expected, but apart from during periods of heavy rain and high flow in the river, the water levels have remained steady across WRS1.

Figure 11 shows the monthly rainfall (based on the nearby Darkes Forest rain gauge) and average flow in the Waratah Rivulet (measured just downstream of WRS1). There appears to be a broad correlation between average monthly rainfall and river flow. The groundwater level at WRS1/01 shows a delayed response to the rainfall events.

4. WRS3 Rockbar Monitoring

Rockbar monitoring instrumentation was installed at WRS3 in October 2003. A total of 9 holes were drilled. The location of these holes is shown in Figure 12.

Two holes (WRS3/03 and WRS3/07) extend to a depth of approximately 30m. The rest are nominally 10m deep. Six of the holes are in line across WRS3 principally to measure groundwater levels, but also to allow various rockbar characterisation techniques to be trialled. A 10 anchor extensometer and stresscell have been installed in the instrumentation hole (WRS3/07). Water level recorders have been installed on the six water level holes located in line across the site (WRS3/01-06).

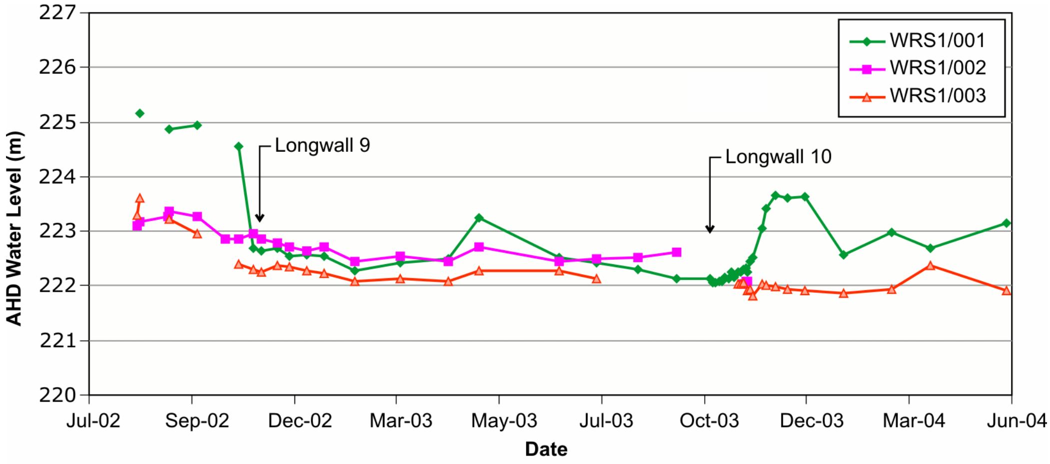

Figure 10 **Ground water levels measured at WRS1 against time.**

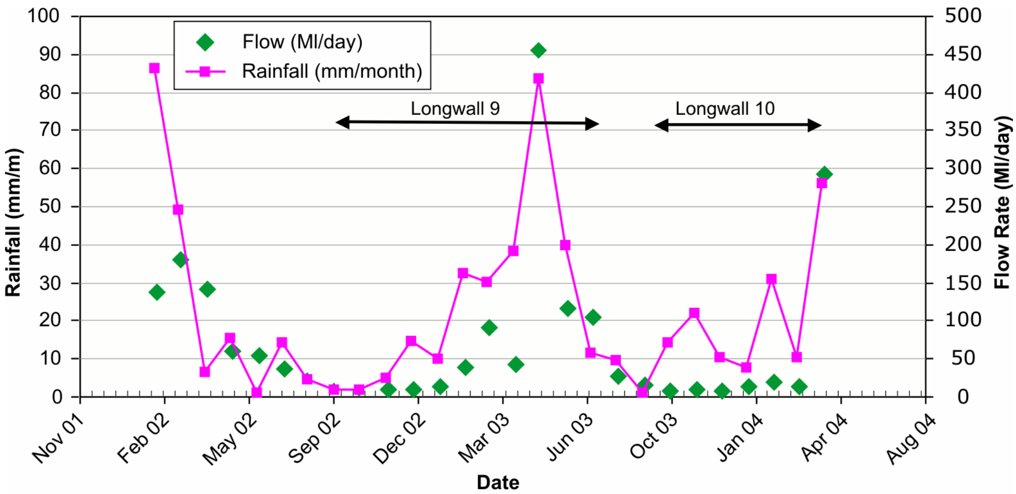

Figure 11 **Rainfall and river flows against time.**

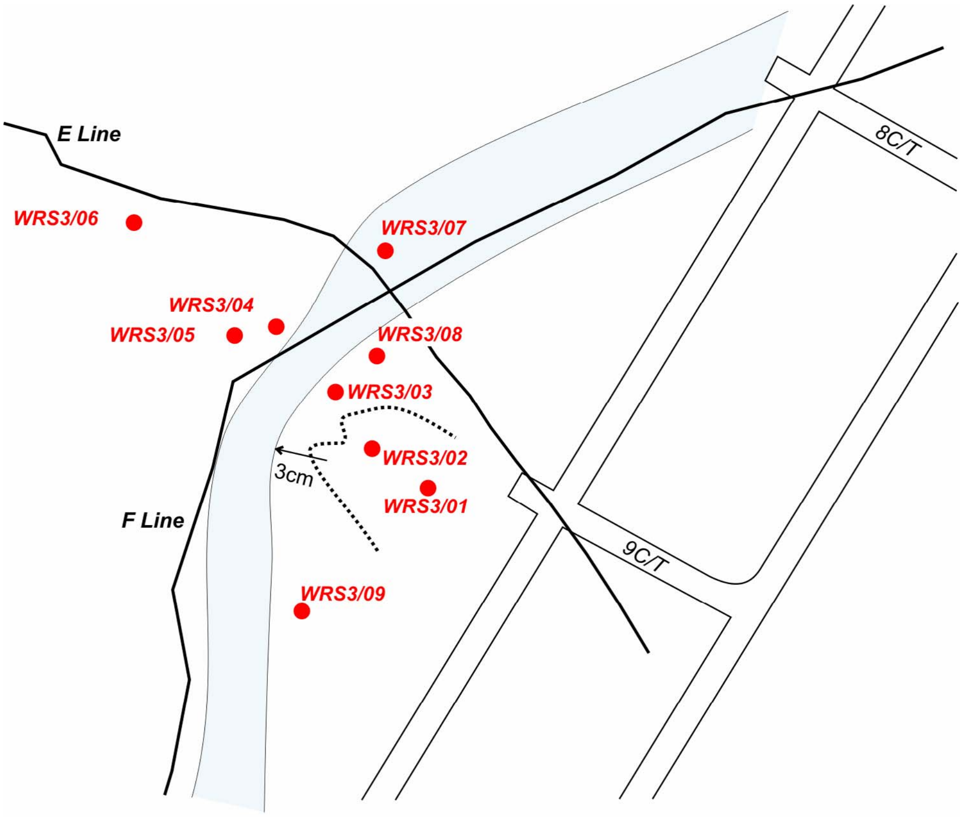

Figure 12 Borehole locations at WRS3.

There has been little change recorded at the site during mining of Longwall 10. Some perceptible cracking has been observed on the eastern side. This fracturing appears to be relatively shallow seated and involves mainly shear movements of the upper layers of rock in this area.

The monitoring instrumentation has not showed any perceptible changes since installation. The waterproof section of the extensometer was flooded when the readout cable pulled out during a storm event. The extensometer was repaired in June 2004 after Longwall 10 moved through the site. The backup manual reading system indicated that any movement that might have occurred was below the resolution of the instrument.

Water level monitoring indicates periodic fluctuations in the groundwater level consistent with rainfall events.

The boreholes have been cored to allow geotechnical logging of the core. The holes have been geophysically logged using temperature and gamma tools as part of ACARP Project C12016 to better understand pre-mining groundwater connectivity across the site.

5. Conclusions

Subsidence monitoring on D Line indicates that surface subsidence behaviour at Metropolitan is essentially consistent from one panel to the next. Subsidence profiles are typical of a mining geometry where the individual panels are narrow relative to mining depth. There is no evidence of individual chain pillars in the subsidence profile. Subsidence occurs in response to a "super panel" effect of multiple panels acting together. Vertical subsidence is controlled by proximity to the solid edge of the longwall mining area. Full subsidence does not develop for 2.5-3 panels out from the solid, unmined coal. Goaf edge subsidence is typically 60-70mm and the angle of draw is about 7°.

Subsidence monitoring indicates that surface topography has a significant influence on magnitude and direction of horizontal movements. Maximum horizontal movements of 200mm occur at a distance of about 60m (0.3 times depth) from the goaf edge.

Subsidence monitoring on the Waratah Rivulet indicates that vertical subsidence has so far been relatively modest except for a short section immediately upstream of WRS1. Further upstream again, vertical subsidence has been reduced by bridging across the corner of Longwall 10. Further downstream, the river channel is mainly located over Longwalls 11 and 12 and these panels have yet to be completed. Valley closure and associated upsidence is apparent in the river channel outside the mining area, particularly in areas adjacent to topographic spurs.

Monitoring at WRS1 indicates that there has been approximately 140-150mm of upsidence and this is caused by strata dilation within the top 9m of the rockbar. Stress change monitoring indicates a compressive stress regime with the stress change magnitude consistent with significant fracturing, shear movement and strata failure.

There has been no further change in the groundwater levels at WRS1 due to mining Longwall 10. The main changes occurred during mining of Longwall 9. The groundwater table appears to be laterally connected across the site. The eastern piezometer responds slightly to rainfall events, but remains lower than it was prior to mining Longwall 9. The groundwater table appears to be responding more to rainfall events now than it did immediately after Longwall 9 mined through the area suggesting some natural remediation may be occurring.

Monitoring at WRS3 has so far showed very little change in dilation, stress change or water level as a result of mining Longwall 10. There was some visible shear movement in an area on the eastern edge of the rockbar where the upper layer of rock has overridden the lower layers by about 3cm in a westerly direction.

6. References

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