Strata Control Technology

REPORT TO:

ASHTON UNDERGROUND MINE

Longwall 4 - End of Panel Subsidence Report

ASH3602

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Report To	Phil Fletcher Technical Services Manager Ashton Underground Mine PO Box 699 SINGLETON NSW 2330
Subject	Longwall 4 - End of Panel Subsidence Report
Report No	ASH3602
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SUMMARY

Ashton Coal Operations Ltd (ACOL) has monitored surface subsidence movements during the retreat of Longwall 4 on two longitudinal subsidence lines over the start and finish of the panel and two cross-lines that extend across the panel. ACOL commissioned SCT Operations Pty Ltd (SCT) to analyse the subsidence results for Longwall 4 suitable for inclusion in an end of panel report as required by Section 21 of the Subsidence Management Plan (SMP) Approval for Longwalls 1-4 at Ashton (DPI 2007). This report presents a desktop analysis of the results of Longwall 4 subsidence monitoring and a comparison of these results with predictions in the SMP and Environmental Impact Assessment (EIS) (HLA Envirosciences 2001).

The subsidence behaviour above Longwall 4 is consistent with supercritical subsidence behaviour similar to the behaviour above the three previous panels although the central section where full subsidence has occurred is narrower than previously as a result of increasing overburden depth.

The predicted and measured subsidence values are summarised in Table 1. The subsidence monitoring results for Longwalls 1, 2 and 3 are presented in SCT (2008) and SCT (2009). These results are presented again in this report in summary form as context for the Longwall 4 measurements.

The maximum vertical subsidence of 1.56m measured over Longwall 4 is greater than the 1.2-1.4m range predicted in the EIS for Longwall 4 (GHA 2001). However, the mining geometry for which the EIS predictions were made is different to that mined and the overburden depths are also different. As a consequence, the strains and tilts predicted in the EIS for Longwall 4 are generally less than or equal to those measured.

The vertical subsidence measured is less than the 1.6-1.8m predicted in SCT (2006) for the SMP. Measured tilt and strain values above Longwall 4 are within the range predicted in the SMP except for what appears to be a compression override 160m from the northern end of Longwall 4 where a high compressive strain of 67mm/m and 560mm of horizontal movement are greater than the 31mm/m and 300-500mm predicted in the SMP.

Horizontal movements of 560mm have been measured over the northern end of Longwall 4. Approximately 200-250mm of eastward or upslope horizontal movement has occurred above the middle part of Longwall 4 similar to the up slope horizontal movement that has been observed over previous longwall panels.

The mechanics causing horizontal movement at Ashton are thought to be the same as at other sites with the only difference being that the strata dips to the west so that the whole process is effectively rotated and horizontal movement usually seen as downslope movement is actually occurring in an upslope direction because of the rotation. Dilation of the subsiding strata toward the free surface of the outcrop is recognised as the mechanism that causes horizontal movement in horizontally bedded strata (Mills 2001). In flatly bedded strata, this movement is usually in a downslope

direction. In dipping strata, the mechanics are similar, but the process is rotated by the dip of the strata, so that the dilation still causes movement toward the free surface created by the outcrop. The difference is that the net movement is now actually in an upslope direction.

Table 1: Subsidence Comparison with Predictions

	Maximum Predicted EIS	Maximum Predicted SMP	Maximum Measured			
North End of LW1			**CL2**	**XL8**		
Subsidence (mm)	1430	1800	1528	1500		
Tilt (mm/m)	122	244	100	103		
Horizontal Movement (mm)	-	>500	476	500		
Tensile Strain (mm/m)	16	73	40	15		
Compressive Strain (mm/m)	25	98	28	27		
Remainder of LW1			**CL1**	**XL5**		
Subsidence (mm)	1690	1700	1318	1436		
Tilt (mm/m)	60	141	60	75		
Horizontal Movement (mm)	-	300-500	480	503		
Tensile Strain (mm/m)	8	42	49	17		
Compressive Strain (mm/m)	12	56	23	24		
Longwall 2			**CL1**	**CL2**	**XL5**	
Subsidence (mm)	1690	1600	1296	1513	1266	
Tilt (mm/m)	91	102	40	82	78	
Horizontal Movement (mm)	-	300-500	440	298	390	
Tensile Strain (mm/m)	12	30	17	16	11	
Compressive Strain (mm/m)	18	41	16	32	28	
Longwall 3			**CL1**	**CL2**	**XL5**	
Subsidence (mm)	1500	1600	1420	1354	1429	
Tilt (mm/m)	65	78	41	48	97	
Horizontal Movement (mm)	-	300-500	463	345	394	
Tensile Strain (mm/m)	9	23	10	17	22	
Compressive Strain (mm/m)	13	31	7	18	24	
Longwall 4			**CL1**	**CL2**	**XL5**	**XL10**
Subsidence (mm)	1430	1600	1397	1194	1546	1263
Tilt (mm/m)	46	78	36	40	53	33
Horizontal Movement (mm)	-	300-500	230	560	360	258[1]
Tensile Strain (mm/m)	6	23	10	18	9	6
Compressive Strain (mm/m)	9	31	9	67	9	10

[1] XL10 was installed after some horizontal movement associated with the previous longwall may already have occurred so not all horizontal movements were measured.

Horizontal movements outside the longwall panels have been generally less than 100mm and decreasing with distance from the goaf edge. Over the sides of each panel, horizontal movements are perceptible to a distance of up to 200m from the goaf edge. At the start of each of the panels, horizontal movements are observed to a distance of approximately 100m beyond the start line. At the finish of each panel, most of the horizontal movements occur within 50m of the goaf edge.

Dynamic overburden bridging at the start of Longwall 4 is consistent with the dynamic bridging observed at the start of Longwalls 2 and 3. Dynamic subsidence starts to increase when the goaf width to overburden depth ratio increases above 0.8. Long term, static subsidence is expected to be greater than dynamic subsidence.

Subsidence measurements at Ashton show that the angle of draw increases with overburden depth. A 0° angle of draw is observed at about 60m overburden depth. The maximum angle of draw measured to date has been 23° at the start of Longwall 3 where the overburden depth is approximately 112m.

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1. INTRODUCTION

Ashton Coal Operations Ltd (ACOL) has monitored surface subsidence movements during the retreat of Longwall 4 on two longitudinal subsidence lines over the start and finish of the panel and two cross-lines that extend across the panel. ACOL commissioned SCT Operations Pty Ltd (SCT) to analyse the subsidence results for Longwall 4 suitable for inclusion in an end of panel report as required by Section 21 of the Subsidence Management Plan (SMP) Approval for Longwalls 1-4 at Ashton (DPI 2007). This report presents the results of Longwall 4 subsidence monitoring and a comparison of these results with predictions in the SMP and Environmental Impact Assessment (EIS) (HLA Envirosciences 2001).

The report is structured to provide a brief description of the site, the monitoring undertaken, the key results and comparison with predicted behaviour.

2. SITE DESCRIPTION

Figure 1 shows a plan of Longwalls 1-4 and the location of the subsidence lines superimposed onto a 1:25,000 topographic series map of the area (updated with a diversion to the New England Highway and changes to minor roads made after the map was originally produced in 1982).

Figure 2 shows a plan of the overburden depth to the Pikes Gully Seam. The seam section mined along Longwall 4 is typically 2.5-2.6m (ranging 2.4 to 2.65m). The seam dips to the south west at a nominal grade of 1 in 10. The overburden ranges in thickness along Longwall 4 from 125m at start of the panel to 130m at XL5 subsidence line and then decreases to 75m at the northern end. The final extraction void is nominally 216m with chain pillars 25m rib-to-rib at 100m cut-through centres.

Longwall 4 commenced mining in April 2009 and finished in October 2009.

3. RESULTS OF SUBSIDENCE MONITORING

In this section, the results of each of the subsidence lines monitored during the retreat of Longwall 4 are presented and discussed.

3.1 XL5 – Main Cross Line

XL5 is the main cross-line over all the longwall panels. The line is located midway along the panels. The overburden depth ranges 80-130m across Longwalls 1-4.

The peg spacing on XL5 has increased from 5m over Longwalls 1 and 2 and half of Longwall 3 to 10m over the remainder of the line. This increase in spacing is likely to cause a reduction in the magnitude of peak tilts and strains compared to the tilts and strains measured when the pegs are spaced at the nominal 1/20th of overburden depth.

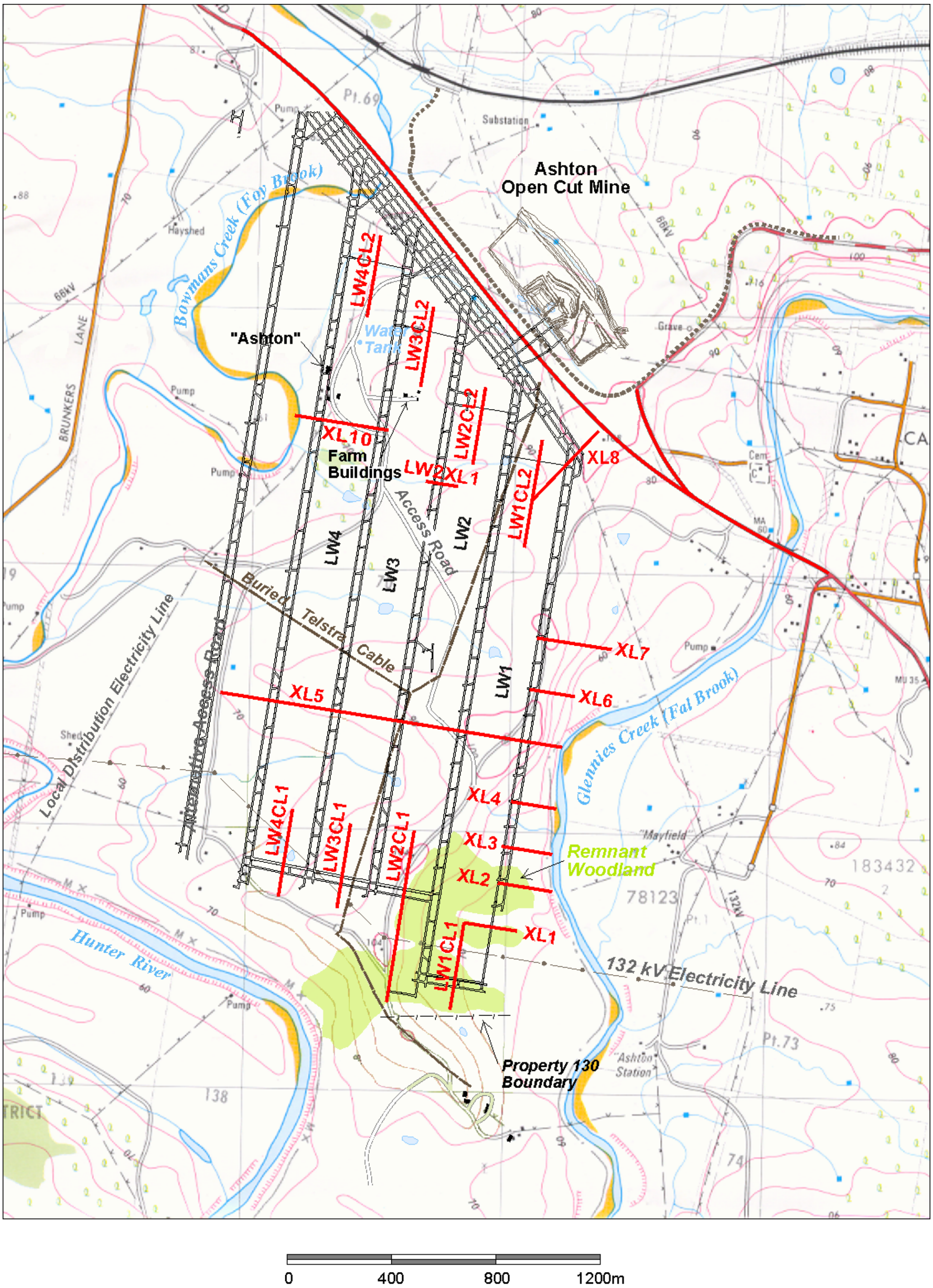

Figure 1: Site plan showing mine plan and location of the subsidence lines superimposed onto 1:25,000 topographic series map updated to reflect current infrastructure.

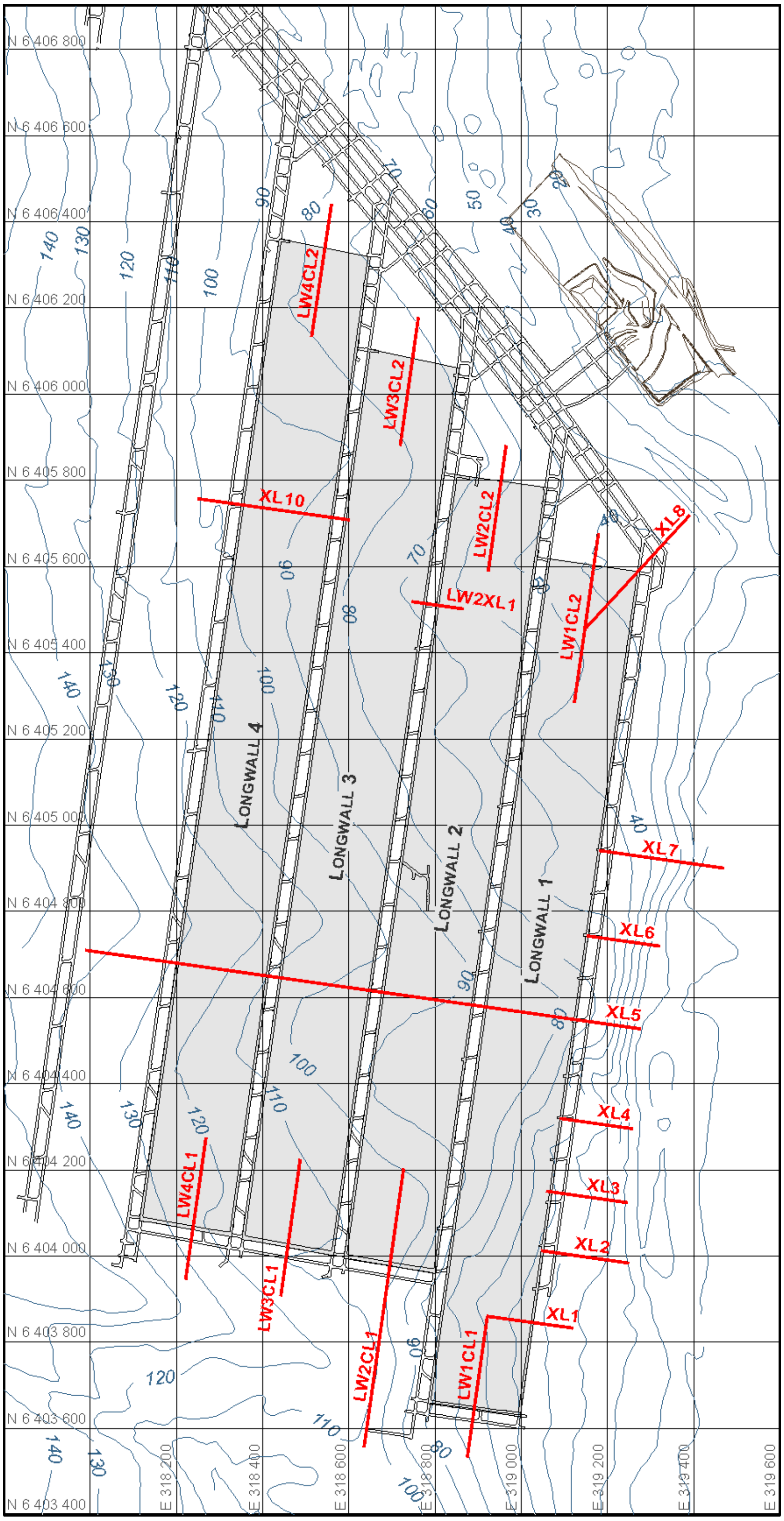

Figure 2: Overburden depth to the Pikes Gully Seam.

Figure 3 shows a summary of the subsidence movements that have been measured on XL5. Eight resurveys were made during mining of Longwall 4 as the longwall face approached and mined past the subsidence line.

The vertical subsidence profile measured is typical of the subsidence expected in a supercritical width panel. The central section where full subsidence has occurred is decreasing in width as the overburden depth increases. Maximum subsidence measured in the centre of Longwall 4 is 1.56m or 59% of a nominal 2.65m seam section mined. The ratios of maximum subsidence over seam thickness mined were 54%, 53% and 57% respectively for Longwalls 1 to 3. The ratio appears to be generally increasing with overburden depth.

Maximum tilt measured on XL5 over Longwall 4 was 53mm/m on the eastern edge or upslope side of the panel. Tilts measured on the upslope side of each panel are consistently higher than on the downslope side of the panel.

Horizontal movements above Longwall 4 are similar to those measured over previous panels. Horizontal movements occurred initially toward the approaching longwall face with a magnitude reaching 200mm at the peak and then, soon after the face passed, the horizontal movements reversed direction causing a final offset in the direction of mining of approximately 100mm. There has been a consistent cross-panel horizontal movement of 200-250mm in an eastward or upslope direction across all four panels. The mechanics of this process are discussed in Section 5.

Maximum strains measured on XL5 above Longwall 4 were 9mm/m in tension and 9mm/m in compression. These values are lower than the maxima over previous panels, partly because of the increased peg spacing.

The goaf edge subsidence measured over the western goaf edge of Longwall 4 on XL5 was 108mm and the angle of draw to 20mm of subsidence was approximately 21° at an overburden depth of 130m.

3.2 XL10 – Secondary Cross-Line Adjacent to Bowmans Creek

XL10 is a secondary cross-line located in the area where Bowmans Creek approaches closest to Longwall 4. The overburden depth ranges from 87m over the tailgate side of Longwall 4 to 95m over the maingate side. The pegs are spaced at 10m centres. The line was installed after the Longwall 3 subsidence movements had occurred.

Figure 4 shows a summary of the incremental XL10 subsidence movements associated with Longwall 4.

The vertical subsidence profile is typical of supercritical width subsidence behaviour. Full subsidence is measured in the central part of the longwall. Maximum subsidence measured on XL10 was 1263mm or 51% of the nominal 2.5m mining section. Maximum tilt was 33mm/m on the upslope side of the panel and 28mm/m on the downslope or western side.

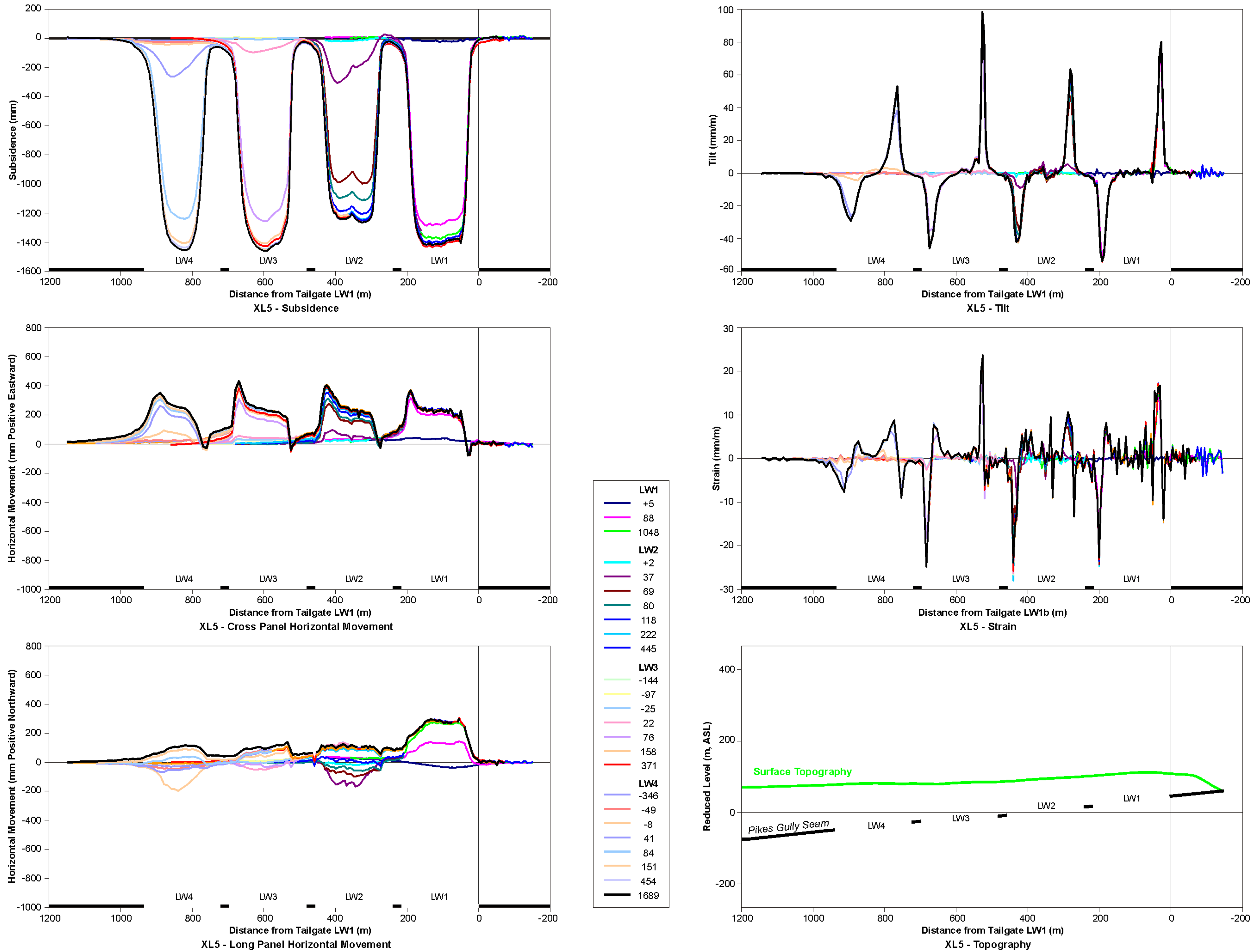

Figure 3: XL5 subsidence - Longwall 4, Ashton Mine.

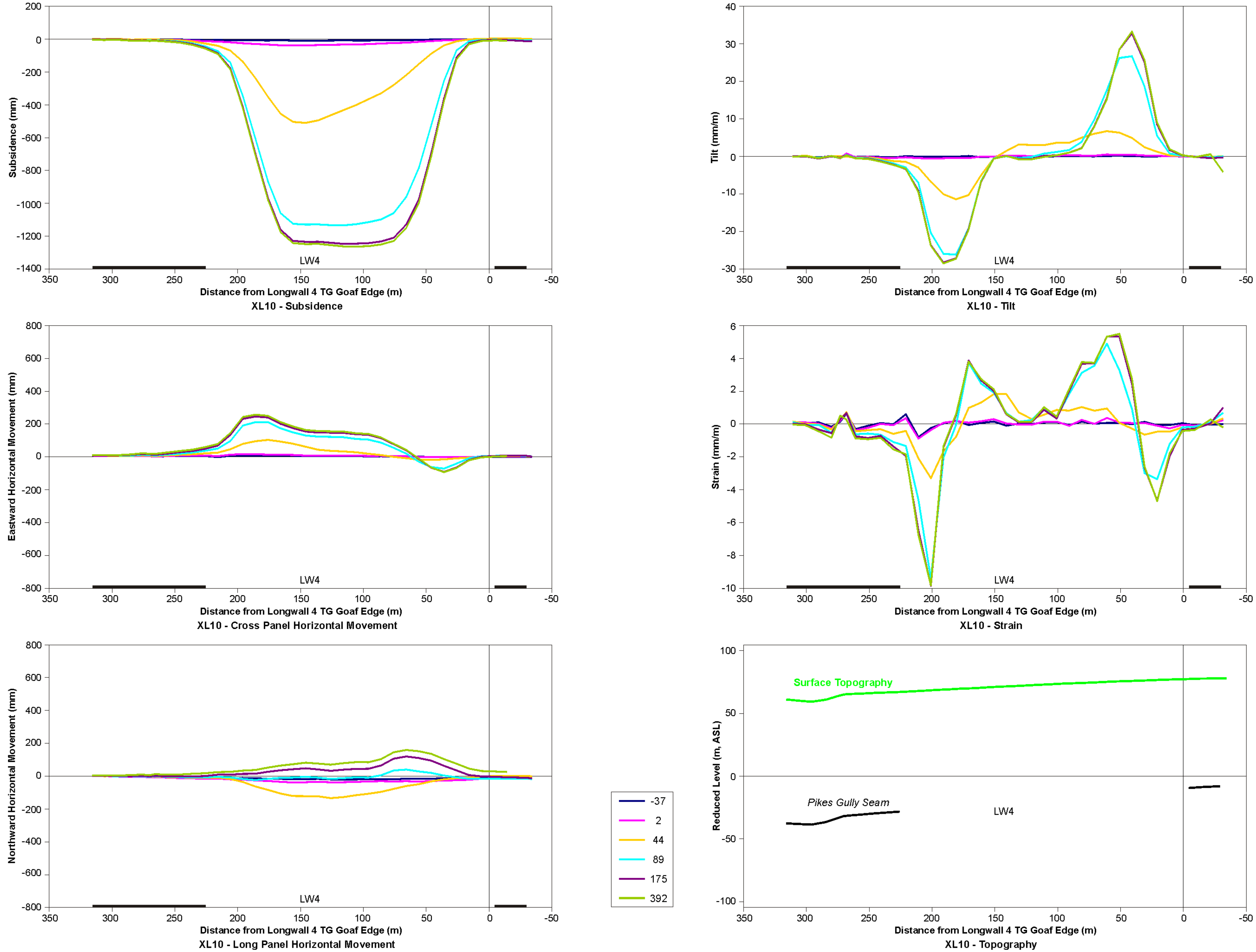

Figure 4: XL10 subsidence - Longwall 4, Ashton Mine.

Horizontal movements associated with Longwall 3 were not measured for XL10. The cross-panel movements for Longwall 4 range up to 250mm in an upslope direction consistent with other measurements at Ashton. The long panel horizontal movements are initially in a direction toward the approaching longwall face with a maximum measured magnitude of 120mm (although this may not be the maximum) in a southerly direction followed by a reversal with final movements occurring in a northerly direction with a magnitude of approximately 150mm. The horizontal movements along the panel are biased to the eastern side of the panel. The reason for this bias is not clear.

Maximum horizontal strains of 5.5mm/m in tension and 9.8mm/m in compression were measured on XL10.

Goaf edge subsidence of 90mm was measured over the western goaf edge of Longwall 4. The angle of draw to 20mm of subsidence over this goaf edge was 22° at an overburden depth of 95m.

3.3 CL1 – Longwall 4 Start Line

Figure 5 shows a summary of the subsidence movements measured on the centreline subsidence line CL1 located over the start of Longwall 4. The overburden depth along CL1 is approximately 125m. The pegs are spaced at 10m centres.

Vertical subsidence developed as the longwall panel moved forward and the effective width of the void widened. The development of subsidence with void width provides an indication of the caving characteristics of the overburden strata. This relationship is discussed in more detail in Section 5 of this report. The maximum subsidence measured on CL1 was 1397mm or 54% of the nominal 2.6m seam section mined.

Maximum tilt occurred over the start line and reached a peak of 36mm/m. Over the moving longwall face, the tilt peaked at about 20mm/m.

Horizontal movements occur in the direction of mining and in an upslope direction across the panel. The cross-panel movements occur approximately in proportion to the vertical subsidence with a magnitude of 5-10% of the vertical subsidence. Further along the panel, the final cross-panel horizontal movements of 180mm are approximately 13% of the final vertical subsidence.

Horizontal strains are greatest within the first 100m of the panel reaching a peak of approximately 10mm/m. During the initial stages of mining when the void width is about 116m and subsidence just starts to develop, the horizontal strains are compressive from 20m to 80m. At 160m of panel retreat, there is a compressive peak in the centre of the void from 50-100m with two tensile peaks on either side. The tensile peak over the retreating longwall face disappears, but the tensile peak and the compressive peak at the start of the panel remain permanently locked in.

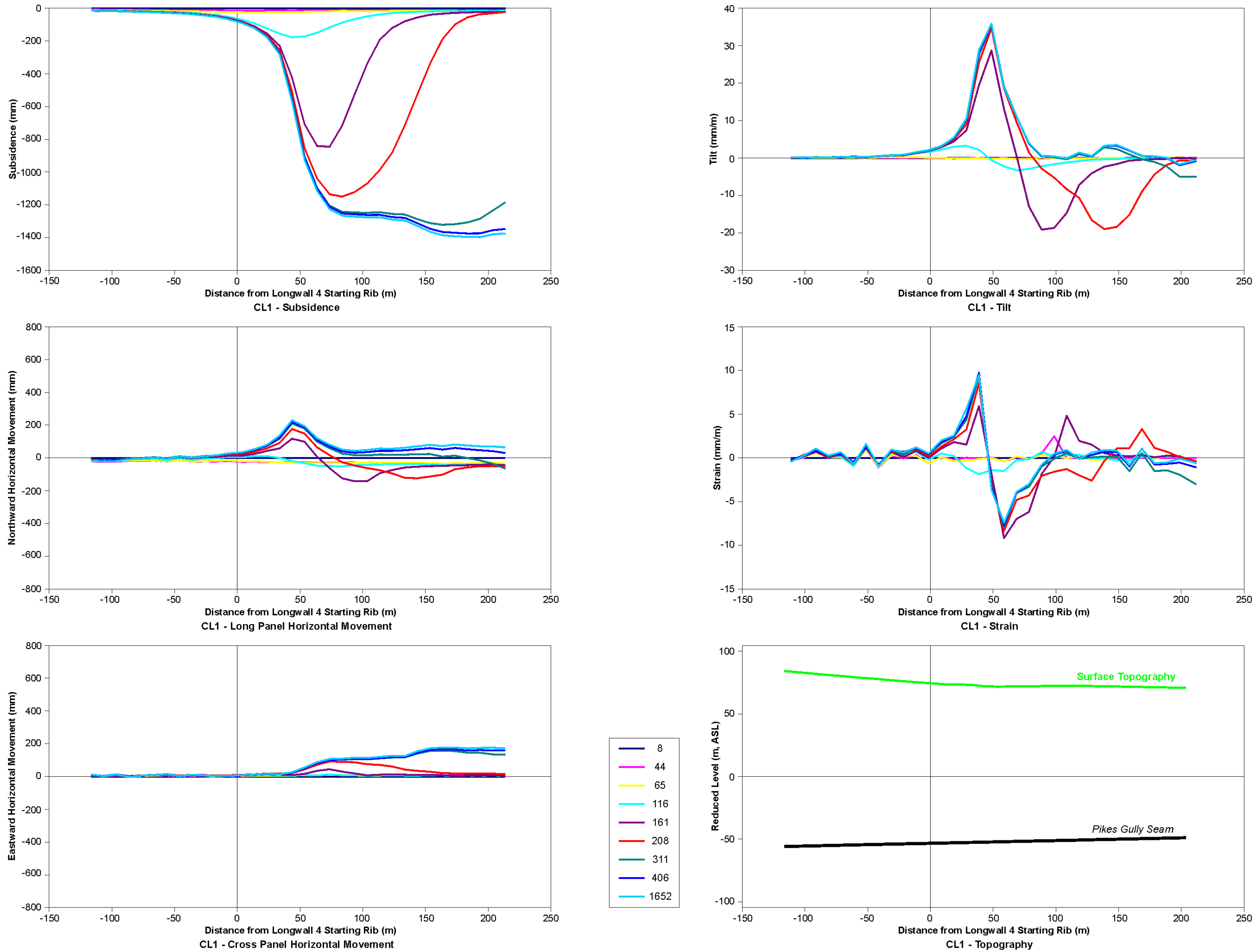

Figure 5: CL1 subsidence - Longwall 4, Ashton Mine.

Goaf edge subsidence at the start of the panel is 83mm and the angle of draw to 20mm of subsidence is 20° allowing for a 14mm offset in the raw survey data. The overburden depth at this site is approximately 125m.

3.4 CL2 – Longwall 4 Finish Line

Figure 6 shows a summary of the subsidence movements measured on CL2, a longitudinal subsidence line located on the centreline of Longwall 4 at the northern end of the panel. The overburden depth in this area is approximately 75m. The subsidence monitoring pegs are spaced at 5m centres.

Maximum vertical subsidence measured on CL2 was 1194mm or 48% of a nominal 2.5m mining section. The vertical subsidence profiles developed regularly and consistently behind the longwall face. There is an anomaly in the vertical subsidence profile 160m from the end of the panel consistent with upward movement associated with what appears to be a horizontal compression override or ripple.

Maximum tilt measured along CL2 is 30-40mm/m adjacent to the ripple. Maximum tilts of 20-30mm/m are more typical of the other profiles on CL2.

Horizontal movements within the last 150m of Longwall 4 are consistent with general experience at other sites in N.S.W. The direction of movement is initially toward the approaching longwall face with a peak magnitude of approximately 200mm. There is then a reversal in direction with a permanent offset in the direction of mining of approximately 100mm.

At 160m from the end of Longwall 4, there is a step change apparent in the plots of horizontal movement with approximately 500mm of relative closure occurring within 25m and 350mm within 5m. This type of behaviour commonly occurs where a low strength bedding plane daylights and differential horizontal movements become concentrated on a single plane. SCT have not had the opportunity to inspect the surface to confirm the nature of the differential movement and whether it follows the contour of the surface as expected.

Maximum horizontal strains are less than 20mm/m along the rest of CL2, but reach a maximum of 67mm/m at the location of the surface ripple approximately 160m from the end of the panel.

Goaf edge subsidence at the end of the longwall panel is 18mm and the angle of draw to 20mm is 1°.

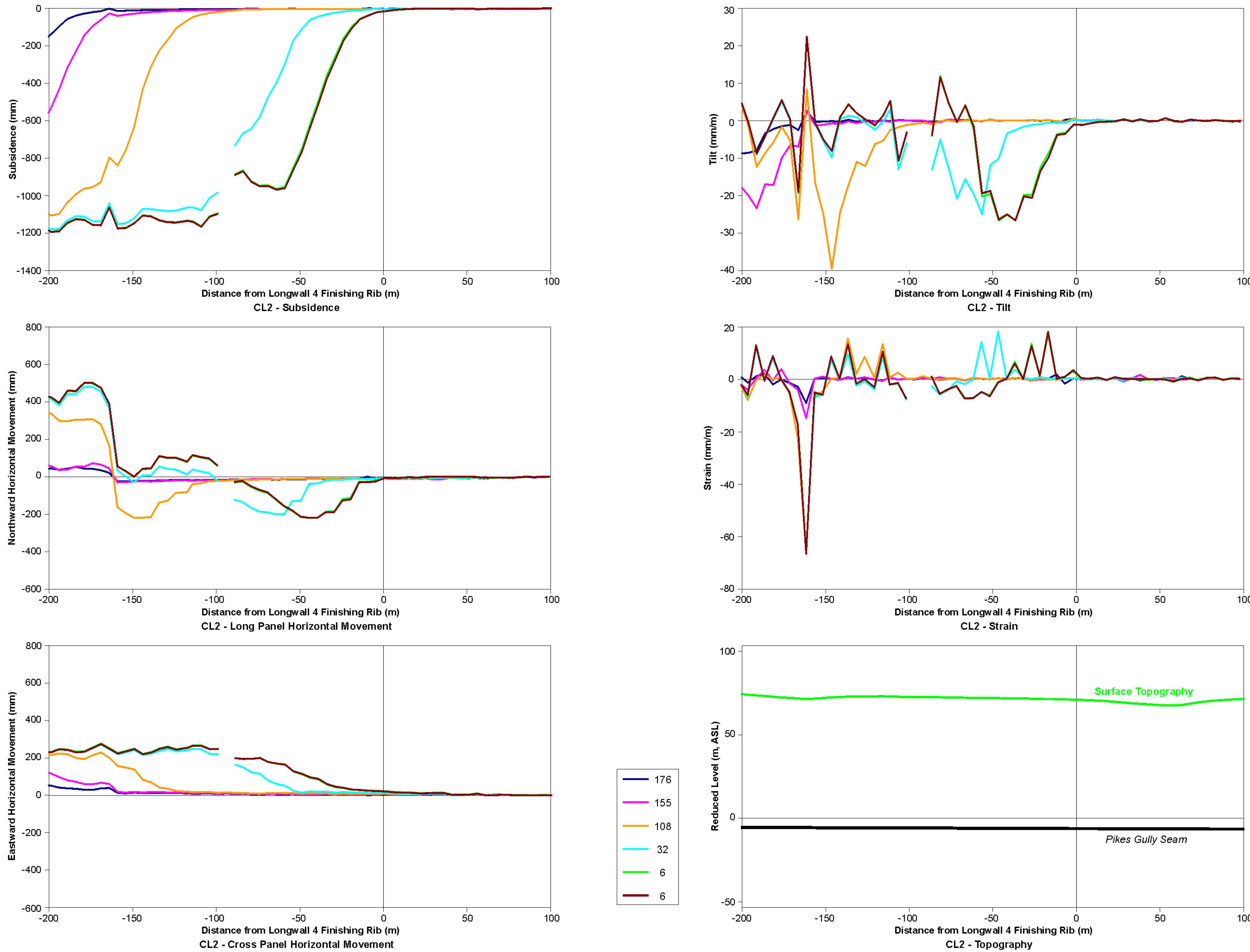

Figure 6: CL2 subsidence - Longwall 4, Ashton Mine.

4. COMPARISON WITH PREDICTIONS

In this section, the measured subsidence movements are compared to the subsidence movements predicted in the EIS (HLA Envirosciences 2001) and the SMP (SCT 2006).

The magnitude of subsidence movements above Longwalls 1-4 at Ashton Coal Mine was predicted in Table 1 of GHA (2001) for the EIS and Table 1 of SCT (2006) for the SMP approval process. The predicted and measured subsidence values are summarised in Table 1 at the beginning of this report.

In general, the subsidence movements measured are less than predicted in the SMP. Exceptions include:

- Tensile strains at the start of Longwall 1 measured on CL1, where 49mm/m was measured compared to 42mm/m predicted.
- Maximum tilt on XL5 above Longwall 3, where 97mm/m was measured compared to 78mm/m predicted.
- Horizontal compressive strains on CL2 at 160m from the finish line of Longwall 4 where strain of 67mm/m was measured compared to 31mm/m predicted and horizontal movements were 560mm compared to 300-500mm predicted.

The vertical subsidence measured was within the range predicted in the SMP at all locations. High levels of tilt and strain predicted at the north end of the panel of Longwall 1 did not eventuate because the rippling effect that has been observed in shallow cover at other sites did not develop. The measured strains and tilts are therefore well within the predicted range.

Horizontal movements of up to 500mm were measured within the bounds of each panel and were only exceeded, by approximately 60mm, in the vicinity of the ripple 160m from the finish line of Longwall 4. An unusual characteristic of these movements is that they have occurred in an upslope direction. The mechanics of this process are discussed in Section 5.

Horizontal movements of greater than 20mm are observed outside the longwall goafs to a distance of 150-200m from the goaf edge. These movements are most apparent on XL5. The distance appears to be increasing with overburden depth.

The predictions made in the EIS (HLA Envirosciences 2001) relate to a different mining geometry so that the actual overburden depths are less than the depths for which the predictions are made. The predictions are therefore less than they would be for the actual mined geometry. The measured subsidence is greater, in most cases by only a small margin, than the predictions made in the EIS for approximately 50% of the observations.

5. DISCUSSION OF RESULTS

The subsidence monitoring results from Longwalls 1 to 4 provide a good indication of the subsidence behaviour that can be expected over future longwall panels at the mine. The subsidence behaviour observed is consistent with the supercritical width subsidence behaviour. The width of the central part of the subsidence profile where full subsidence is observed is decreasing as the overburden depth increases.

The magnitude of subsidence movements observed appears to be generally in the range 50-60% of seam thickness. There is some variability from panel to panel that may be a consequence of overburden caving and bulking characteristics as well as variations in the seam thickness mined.

5.1 Horizontal Movements

Horizontal subsidence movements occur predominantly within the goaf area of each longwall panel and generally have a magnitude in the range 300-500mm. Outside the goaf, horizontal movements diminish with distance from the goaf edge.

On the lateral edge of each of the four longwall panels mined to date, horizontal subsidence movements are observed at distances of up to about 200m from the goaf edge. At the start of each of the panels, horizontal movements are observed to a distance of approximately 100m beyond the start line. At the finish of each panel, most of the horizontal movements occur within 50m of the goaf edge.

The difference in horizontal behaviour between the start and the end of each panel is commonly observed at other sites and appears to be a characteristic of the caving process. The greater extent of horizontal movement over the lateral goaf edge has been observed at other sites, but the magnitude of horizontal movements, typically much less than 100mm and tapering to zero, requires a higher degree of survey control than is typically available for routine subsidence monitoring.

At Ashton, the horizontal movements directly over each panel do not follow a pattern that is consistent with general experience of horizontal movements occurring in a downslope direction. The horizontal movements observed within the longwall panels and for some distance outside occur consistently in an easterly or upslope direction with a magnitude over the longwall panels of 200-250mm.

There has been a consistent trend across all four panels for horizontal movement to occur in an easterly direction that is both upslope and up dip. Measurements at the start of each panel indicate that the magnitude of this horizontal movement is approximately proportional to the magnitude of the vertical subsidence.

The reason for the observed movement at Ashton is considered to be consistent with the well recognised phenomenon of horizontal movement in a downslope direction. One of the key drivers of horizontal movement in a downslope direction is lateral dilation of subsiding strata (Mills 2001). This dilation is a direct result of vertical subsidence and is essentially proportional to the amount of vertical subsidence. In horizontally bedded strata, subsidence under a topographic high point causes dilation of the strata and outward movement of the sides of the slope. These movements are not laterally constrained because the ground is free to move toward the free surface of the valley, and so movements can occur in a downslope direction.

At Ashton, this same phenomenon is occurring, but the geometry is rotated slightly by the dipping strata. In strata that is dipping, bedding planes outcrop on the surface in much the same way that horizontal bedding planes outcrop in sloping topography. As the strata subsides, dilation allows movement to occur toward the free surface by moving along bedding planes. This phenomenon appears able to occur at Ashton even though the movement occurs in an up dip direction along the bedding planes. The surface is sloping in the same direction as the strata is dipping, so the net movement is in an upslope direction, which is opposite to the normal downslope direction observed in horizontally bedded strata.

Figure 7 shows the mechanism that is recognised to cause movement in a downslope direction in horizontally bedded strata and the variation on this mechanism that is thought to be causing the upslope movement directly over each panel. There has been no mass movement of the overburden strata toward Glennies Creek detected outside the longwall panels indicating that at Ashton this mechanism does not have sufficient energy to push the overburden strata uphill except within the confines of each longwall panel.

The upslope horizontal movements observed outside the goaf cannot be related to vertical subsidence because there is no significant vertical subsidence outside the goaf. The horizontal movement toward the goaf that occurs outside the goaf is considered likely to be associated with horizontal stress relief and the overall geometry of the longwall panels.

5.2 Overburden Bridging

During the early stages of mining before a panel becomes square, the minimum width of the panel is the distance between the longwall face and the back rib of the goaf. By measuring the subsidence repeatedly as this distance increases, the relationship between panel width and surface subsidence can be determined for a range of panel widths. The subsidence in this area is recognised to be dynamic and relationship observed is likely to indicate minimum subsidence with potential for less bridging capacity and more subsidence for the same geometry in the longer term under static loading conditions.

Monitoring at the start of each longwall panel provides an indication of the sag subsidence behaviour and caving characteristics of the overburden strata.

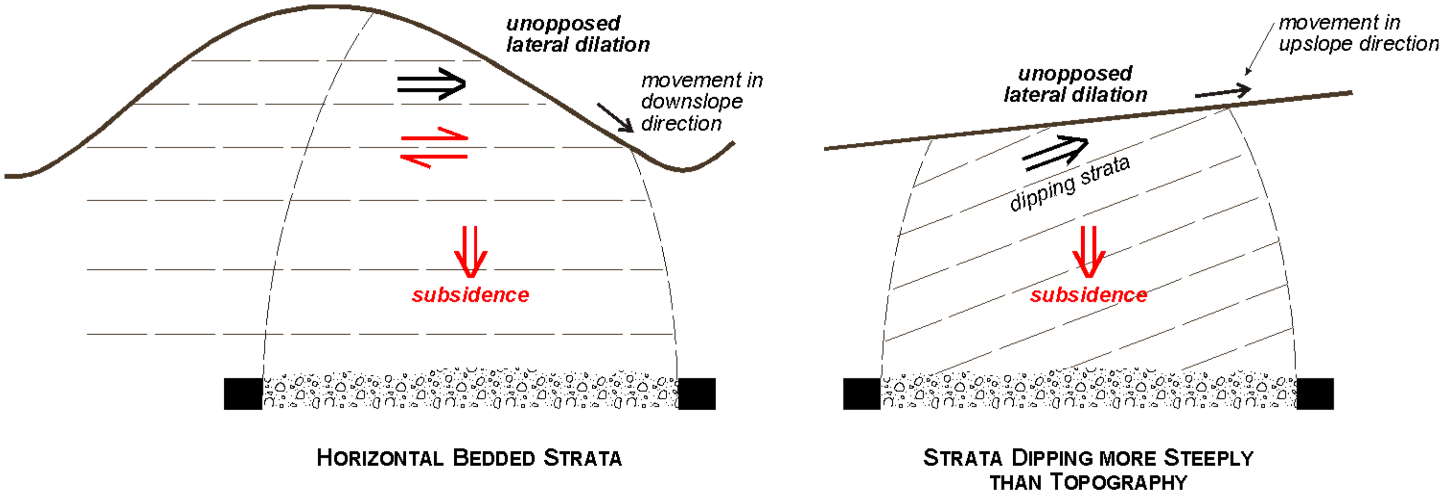

Figure 7: Sketch illustrating the mechanics of horizontal movement.

Figure 8 shows the relationship between sag subsidence and effective panel width over the first four longwall panels at Ashton. The subsidence monitoring shows significant variability in bridging behaviour when the results from Longwall 1 are included, but a more consistent pattern emerges when Longwall 1 monitoring is ignored. This is no significant subsidence measured when the goaf width is less than 0.6 and even when the goaf width is 0.8, the dynamic subsidence has been less than 0.04 times seam thickness or less than 100mm for a 2.5m mining section.

Dynamic overburden bridging at the start of each longwall panel indicates less than 100mm of subsidence has occurred for a goaf width to overburden depth ratio of 0.8 and less than 40mm of subsidence has been observed at a goaf width to overburden ratio of less than 0.6. Long term, static subsidence is expected to be greater than the subsidence indicated by this dynamic subsidence.

Experience elsewhere in NSW indicates that maximum subsidence is typically less than 100mm when the goaf width to depth ratio is less than 0.6, excluding any elastic compression of the chain pillars.

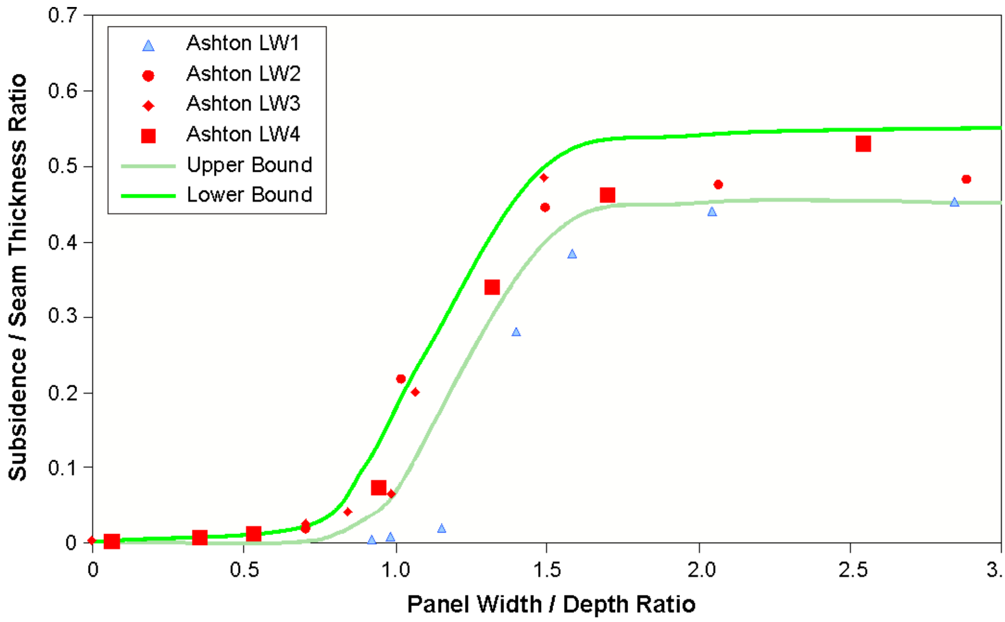

Figure 8: Relationship between dynamic subsidence and panel width measured at Ashton.

5.3 Angle of Draw

Angle of draw is the angle between a vertical line draw up from the goaf edge and a line drawn from the goaf edge at seam level to a point on the surface where the vertical subsidence becomes less than 20mm. An angle of draw of 26.5° is equivalent to a distance from the goaf edge to the point equal to half the overburden depth.

The point at which subsidence reaches 20mm tends to be sensitive to small changes in vertical subsidence that may occur simply because of survey tolerance. The approach used to estimating the angle of draw for the subsidence measurements at Ashton has been to determine the point of 20mm subsidence relative to any far-field subsidence that may have been determined. This approach is intended to eliminate errors associated with small differences between repeat surveys that occur within normal survey tolerance.

Table 2 shows a summary of the angle of draw measurements for each of the subsidence lines crossing solid goaf edges at Ashton. This same information is plotted in Figure 9.

Table 2: Summary of Angle of Draw Measurements at Ashton

		Dist to 20mm	Depth (m)	Angle of Draw
Longwall 1	CL1	14	65	12
	CL2	-5	38	-7
	XL1	-2	45	-3
	XL2	-11	48	-13
	XL3	-6	52	-7
	XL4	5	62	5
	XL5E	-5	72	-4
	XL5W	22	88	14
	XL6	-4	64	-4
	XL7	-2	44	-3
Longwall 2	CL1	30	101	17
	CL2	0	60	0
	XL5	23	95	14
Longwall 3	CL1	48	112	23
	CL2	0	73	0
	XL5	37	108	19
Longwall 4	CL1	46	125	20
	CL2	1	80	0
	XL5	51	130	21
	XL10	34	95	20

Figure 9 indicates that there is a trend toward increasing angle of draw with increasing overburden depth. This relationship is also observed at other mine sites. As the overburden depth increases, there is a capacity within the overburden strata to distribute abutment weight further from the longwall panel. The total weight of overburden strata redistributed also increases as the overburden depth increases. The combination of these two effects causes the distance from the goaf edge at which 20mm of subsidence occurs to increase with overburden depth.

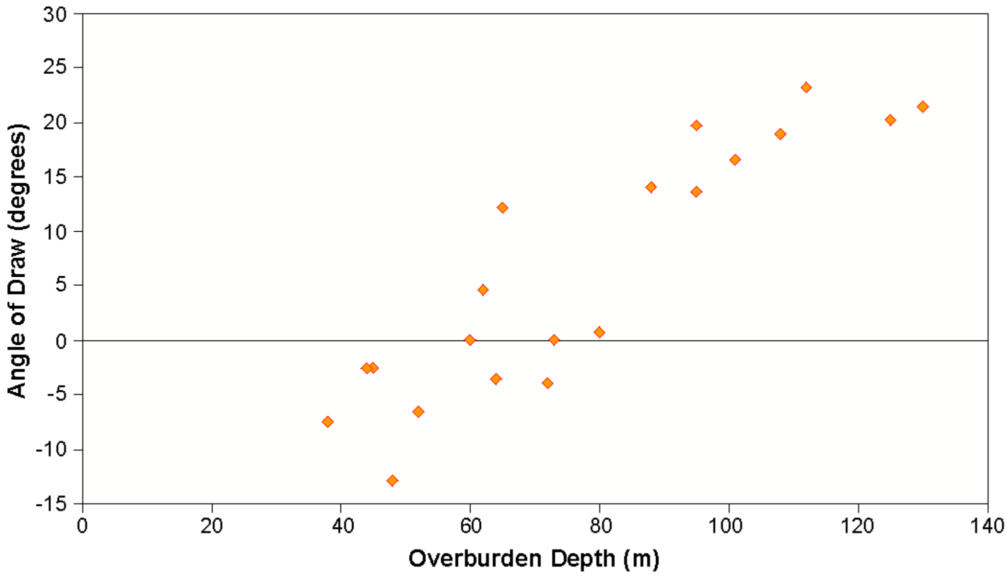

Figure 9: Relationship between angle of draw measured at Ashton and overburden depth.

The angle of draw is approximately 0° at about 60m overburden depth. The maximum angle of draw measured to date has been 23° at an overburden depth of 112m. The angle of draw is likely to increase above 23° as the overburden depth increases to a maximum of about 190m.

6. CONCLUSIONS

Our review indicates that subsidence behaviour above the first four longwall panels at Ashton Underground Mine is consistent with supercritical subsidence behaviour.

Maximum subsidence has been generally less than the maximum predicted in the EIS (HLA Envirosciences 2001) and is generally in the range 50-60% of seam thickness mined. The maximum strains and tilts measured over Longwalls 1 to 4 have exceeded the maximum values predicted in the EIS, although we note that the mining geometry for which the EIS predictions were made is different to that actually mined and the overburden depths are different as a consequence.

Subsidence movements have been less than the maximum predicted in the SMP with three exceptions. The maximum tensile strain measured at the start of Longwall 1 was 49mm/m compared to the 42mm/m predicted in the SMP. The maximum tilt on XL5 above Longwall 3 was 97mm/m compared to the maximum of 78mm/m predicted in the SMP. A feature that appears to be a compression override or ripple 160m from the end of Longwall 4 is associated with horizontal movement of 560mm and horizontal compressive strain of 67mm/m compared to the predicted horizontal movements of 300-500mm and predicted strain of 31mm/m.

Maximum horizontal movements ranging 230-560mm have been measured over the first four longwall panels. Approximately 200-250mm of horizontal movement has occurred in an eastward or upslope direction above each of the. These horizontal movements are somewhat unusual in that horizontal movements in sloping terrain typically occur in a downslope direction.

At Ashton, the mechanics of the process causing horizontal movement are thought to be the same as in flat terrain with the only difference being that the strata dips to the west so that the whole process is effectively rotated and horizontal movement usually seen as downslope movement is actually occurring in an upslope direction because of the rotation associated with the dipping strata.

The horizontal movements observed at Ashton have predominantly occurred over the longwall panel. Horizontal movements outside the longwall panels have been generally less than 100mm and decreasing with distance from the goaf edge. Over the sides of each panel, horizontal movements are perceptible to a distance of up to 200m from the goaf edge. At the start of each of the panels, horizontal movements are observed to a distance of approximately 100m beyond the start line. At the finish of each panel, most of the horizontal movements occur within 50m of the goaf edge.

Dynamic overburden bridging at the start of Longwall 4 is consistent with the dynamic bridging observed at the start of Longwalls 2 and 3. Dynamic subsidence starts to increase when the goaf width to overburden depth ratio increases above 0.8. Long term, static subsidence is expected to be greater than dynamic subsidence.

Subsidence measurements at Ashton show that the angle of draw increases with overburden depth as is commonly observed at other sites. A 0° angle of draw is observed at about 60m overburden depth. The maximum angle of draw measured to date has been 23° at the start of Longwall 3 where the overburden depth is approximately 112m.

7. REFERENCES

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