Strata Control Technology

REPORT TO:

ASHTON UNDERGROUND MINE

Longwall 5 - End of Panel Subsidence Report

ASH3728

Mining Research and Consulting Group
SCT Operations Pty Ltd PO Box 824 Wollongong NSW 2520 Australia
sctnsw@sct.gs

Report To Phil Fletcher
Technical Services Manager
Ashton Underground Mine
PO Box 699
SINGLETON NSW 2330

Subject Longwall 5 - End of Panel Subsidence Report

Report No ASH3728

Prepared By Ken Mills

Date 7 February 2011

Ken Mills
Senior Geotechnical Engineer

SUMMARY

Ashton Coal Operations Ltd (ACOL) has monitored surface subsidence movements during the retreat of Longwall 5 on two longitudinal subsidence lines over the start and finish of the panel and a cross-line that extends across all the panels. ACOL commissioned SCT Operations Pty Ltd (SCT) to analyse the subsidence results for Longwall 5. This report presents a desktop analysis of the results of Longwall 5 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 5 is consistent with supercritical subsidence behaviour similar to the behaviour in the four previous panels although the central section where full subsidence has occurred is slightly narrower than in previous panels because the overburden depth has increased.

The predicted and measured subsidence values are summarised in Table 1. The subsidence monitoring results for Longwalls 1 to 4 are presented in SCT (2008), SCT (2009), SCT (2009a). These results are presented again in this report in summary form as context for the Longwall 5 measurements.

The 1.38m maximum vertical subsidence measured over Longwall 5 is within the 1.2-1.4m range predicted in the EIS for Longwall 5. 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 5 are generally less than those measured.

The vertical subsidence measured is less than the 1.6m predicted in SCT (2006) for the SMP. Measured tilt and strain values above Longwall 5 are within the range predicted in the SMP.

Horizontal movements of 400mm have been measured in the direction of mining over the start of Longwall 5. Approximately 200mm of eastward or upslope horizontal movement has occurred above the middle part of Longwall 5 similar to the up slope horizontal movement that has been observed over previous longwall panels. This behaviour is consistent with lateral dilation on strata that is dipping in a downslope direction. 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 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.

Subsidence measurements over Longwall 5 indicate an increasing angle of draw with depth. The nominal angle of draw and goaf edge subsidence measured over the maingate goaf of Longwall 5 are 29° and 105mm respectively at an overburden depth of 145m.

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
Longwall 5			**CL1**	**CL2**	**XL5**	
Subsidence (mm)	1430	1600	1266	1326	1376	
Tilt (mm/m)	29	78	23	29	35	
Horizontal Movement (mm)	-	300-500	399	339[2]	360	
Tensile Strain (mm/m)	4	23	21	6	5	
Compressive Strain (mm/m)	5	31	9	8	17	

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

[2] Maximum measured at end of line so actual maximum expected to be greater.

Dynamic overburden bridging at the start of Longwall 5 is consistent with the dynamic bridging observed at the start of Longwalls 2 to 4. 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.

TABLE OF CONTENTS

PAGE NO

1. INTRODUCTION

Ashton Coal Operations Ltd (ACOL) has monitored surface subsidence movements during the retreat of Longwall 5 on two longitudinal subsidence lines over the start and finish of the panel and a cross-line that extends across all the panels. ACOL commissioned SCT Operations Pty Ltd (SCT) to analyse the subsidence results for Longwall 5. This report presents a desktop analysis of the results of Longwall 5 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 1-5 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 5 is nominally 2.5m. The seam dips to the south west at a nominal grade of 1 in 10. The overburden ranges in thickness along Longwall 5 from 155m at start of the panel to 145m at XL5 subsidence line and then decreases to 110m at the northern end. The final extraction void is nominally 216m with chain pillars 25m rib-to-rib at 100m cut-through centres.

Longwall 5 commenced mining in January 2010 and finished in June 2010.

3. RESULTS OF SUBSIDENCE MONITORING

In this section, the results of each of the subsidence lines monitored during the retreat of Longwall 5 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 80-145m across Longwalls 1-5.

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 a nominal standard spacing of $1/20^{th}$ of overburden depth.

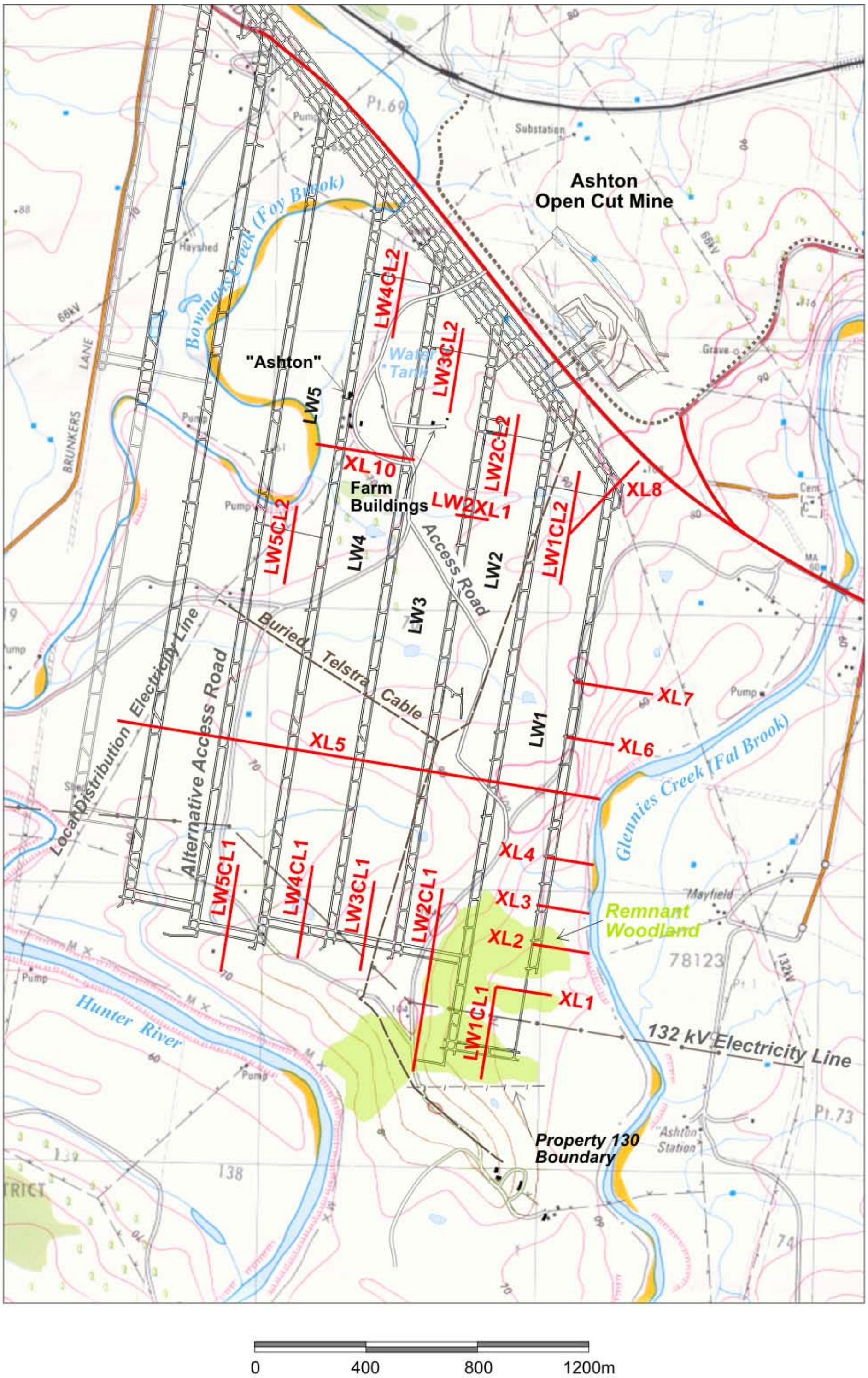

Figure 1: Site plan showing mine plan and location of the subsidence lines superimposed onto 1:25,000 topographic series map updated to reflect current infrastructure.

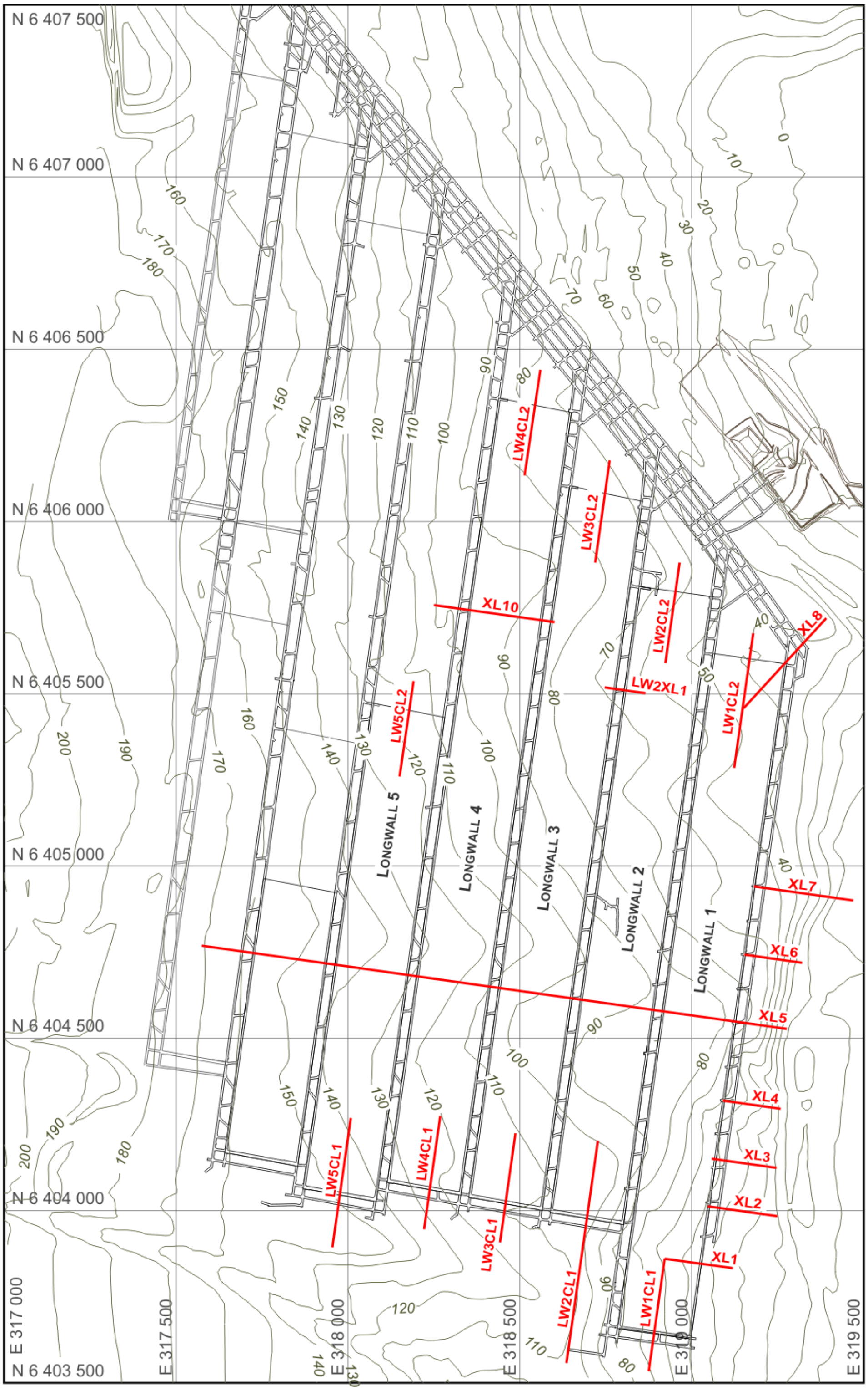

Figure 2: Overburden depth to the Pikes Gully Seam and location of subsidence lines.

Figure 3 shows a summary of the subsidence movements that have been measured on XL5. Seven resurveys were made during mining of Longwall 5 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 5 is 1.38m or 55% of a nominal 2.5m seam section mined (seam thickness ranged from 2.45m to 2.72m). By comparison, the ratios of maximum subsidence over seam thickness mined were 54%, 53%, 57% and 59% respectively for Longwalls 1 to 4.

Maximum tilt measured on XL5 over Longwall 5 was 35mm/m on the western edge of the panel.

Horizontal movements above Longwall 5 are similar to those measured over previous panels. Horizontal movements occur initially toward the approaching longwall face with a magnitude reaching 200mm at the peak and then, soon after the face passes, the horizontal movements reverse direction causing a final offset in the direction of mining of approximately 100mm (80mm in Longwall 5). There has been a consistent cross-panel horizontal movement of 200-250mm in an eastward or upslope direction across all five panels in addition to the systematic horizontal movements toward the centre of the panel. The mechanics of this process are discussed Section 5.

Maximum strains measured on XL5 above Longwall 5 were 16mm/m in tension and 5mm/m in compression. These values are lower than most of the maxima over previous panels, partly because of the increased peg spacing and partly because of increased overburden depth.

The goaf edge subsidence measured over the western goaf edge of Longwall 5 on XL5 was 105mm and the angle of draw to 20mm of subsidence was approximately 29° at an overburden depth of 145m.

3.2 CL1 – Longwall 5 Start Line

Figure 4 shows a summary of the subsidence movements measured on the centreline subsidence line CL1 located over the start of Longwall 5. The overburden depth along CL1 is approximately 145m. 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 1266mm or 51% of the nominal 2.5m seam section mined.

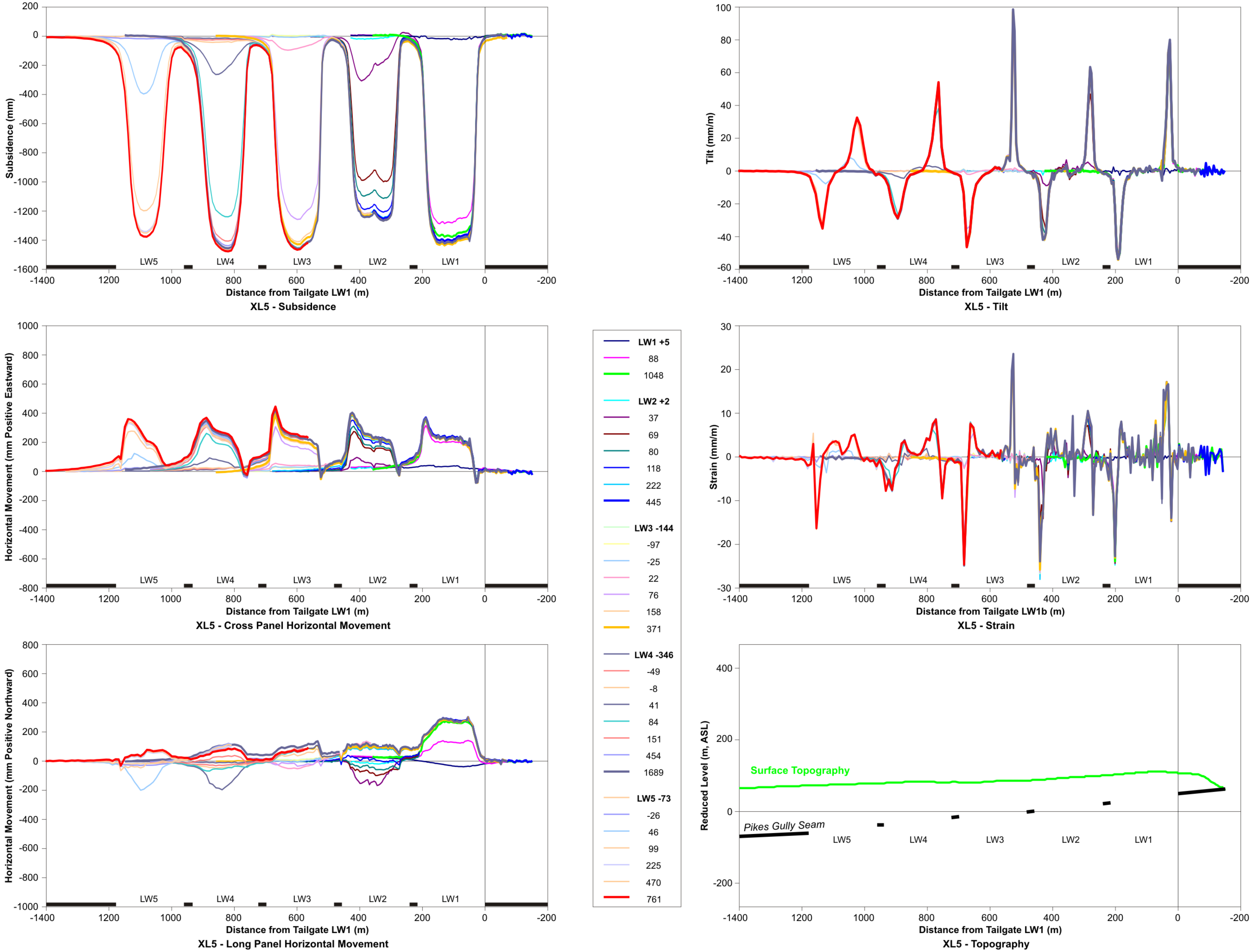

Figure 3: XL5 subsidence - Longwall 5, Ashton Mine.

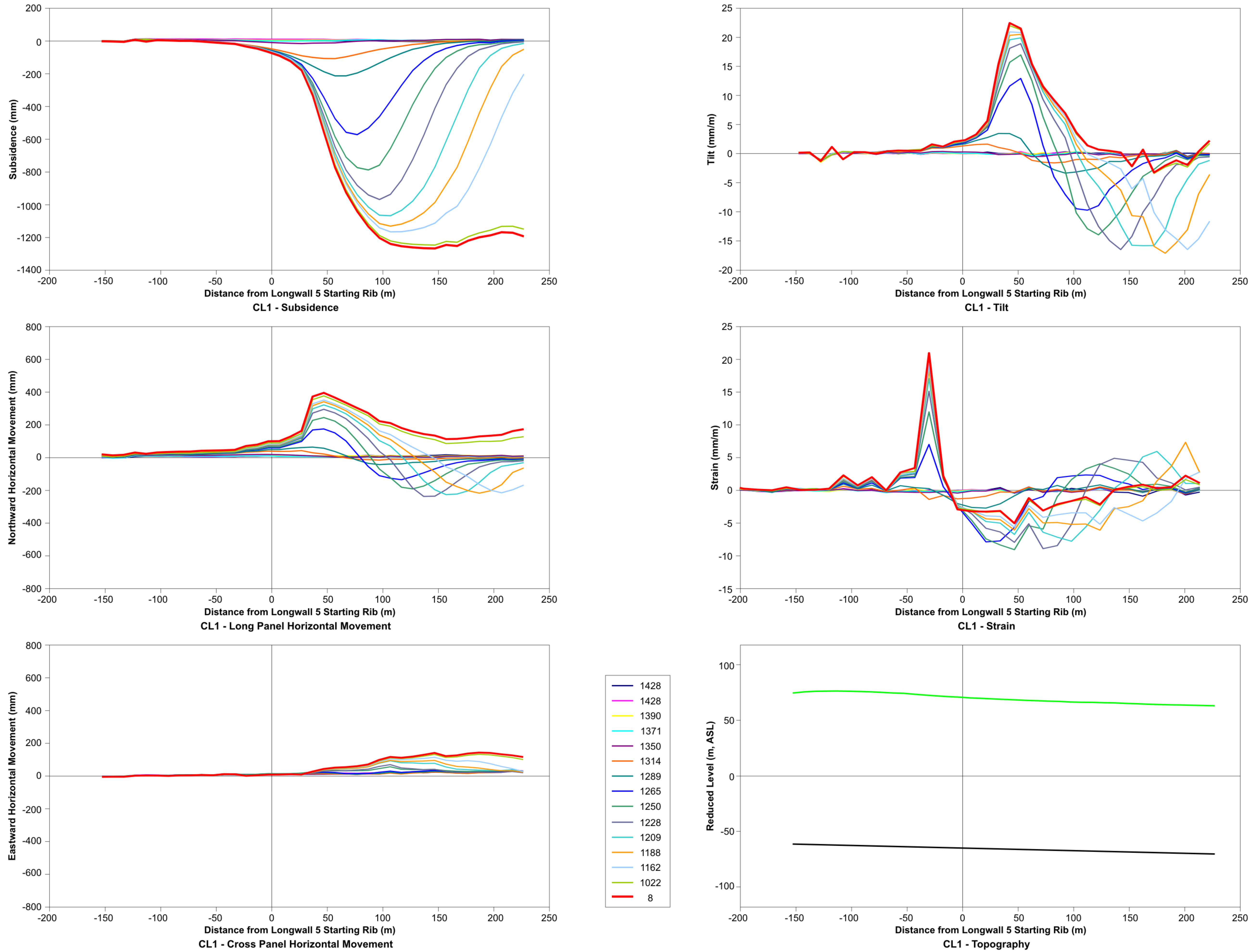

Figure 4: CL1 subsidence - Longwall 5, Ashton Mine.

Maximum tilt occurred over the start line and reached a peak of 22mm/m. Over the moving longwall face, the tilt peaked at about 17mm/m.

Horizontal movements occur in the direction of mining and in an upslope direction across the panel. The final cross-panel horizontal movements of 140mm are approximately 11% of the final vertical subsidence.

Horizontal strains are greatest within the first 100m of the panel reaching a peak of approximately 21mm/m. Horizontal strains remain compressive over the central part of the panel during the initial stages of mining up until the void width reaches about 146m (W/D = 1.0) and vertical subsidence just starts to become significant at 200mm. At 170m of panel retreat and vertical subsidence of 600mm, tensile strain peaks have developed on both edges of the panel. The tensile peak over the retreating longwall face disappears as the panel retreats, but the tensile peak and the compressive peak at the start of the panel remain substantially locked in.

Goaf edge subsidence at the start of the panel is 72mm and the angle of draw to 20mm of subsidence is 11°. The overburden depth at this site is approximately 145m.

3.4 CL2 – Longwall 5 Finish Line

Figure 5 shows a summary of the subsidence movements measured on CL2, a longitudinal subsidence line located on the centreline of Longwall 5 at the northern end of the panel. The overburden depth in this area is approximately 115m. The subsidence monitoring pegs are spaced at 10m centres.

Maximum vertical subsidence measured on CL2 was 1326mm or 53% of a nominal 2.5m mining section. The vertical subsidence profiles developed regularly and consistently behind the longwall face. Maximum tilt measured on CL2 was 29mm/m.

Horizontal movements within the last 150m of Longwall 5 are initially toward the approaching longwall face with a peak magnitude of approximately 178mm. There is then a reversal in direction with a permanent offset in the direction of mining that increases to greater than 310mm in the direction of mining. There is also movement upslope toward the east of approximately 180mm consistent with movements above other panels at Ashton.

Maximum horizontal strains measured on CL2 are 5.6mm/m in tension over the finish line and 8.4mm in compression further along the line.

Goaf edge subsidence at the end of the longwall panel is 28mm and the angle of draw to 20mm is 3°.

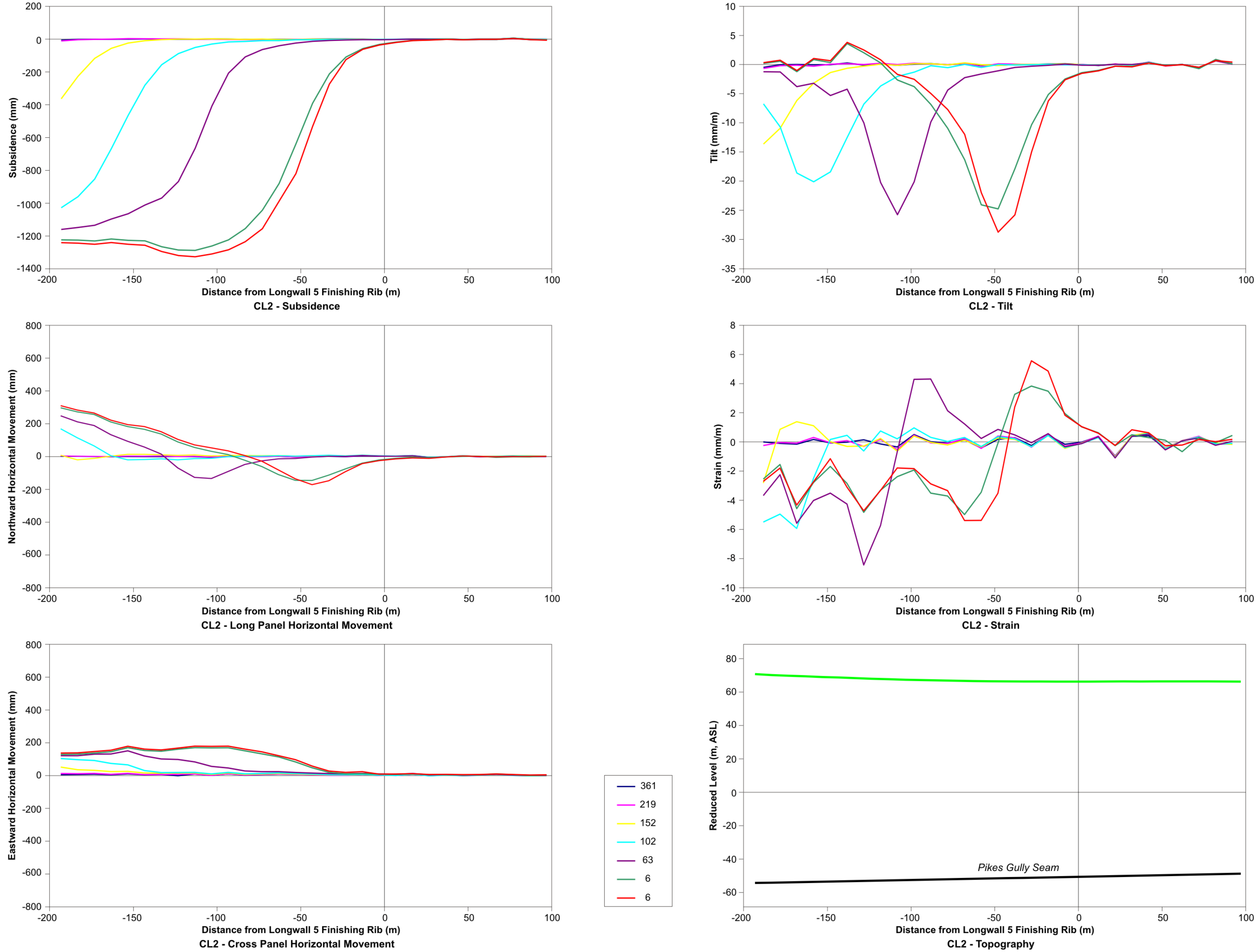

Figure 5: CL2 subsidence - Longwall 5, Ashton Mine.

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 1-5 at Ashton Coal Mine was predicted in Table 1 of 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.

The subsidence movements measured over Longwall 5 are less than predicted in the SMP.

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 5 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 variations in 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 five 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 five 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 6 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.

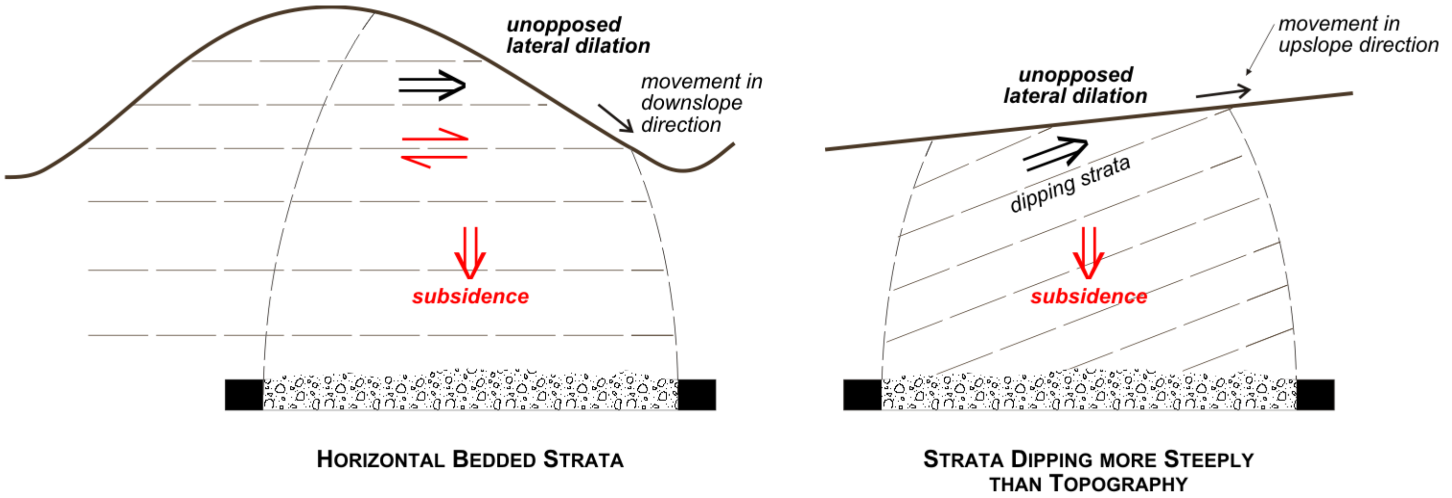

Figure 6: Sketch illustrating the mechanics of horizontal movement.

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 shows the relationship between sag subsidence and effective panel width over the first five longwall panels at Ashton. The subsidence monitoring shows Longwall 1 exhibited a different behaviour but that all the subsequent panels are behaving in a similar manner. No significant subsidence is 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.

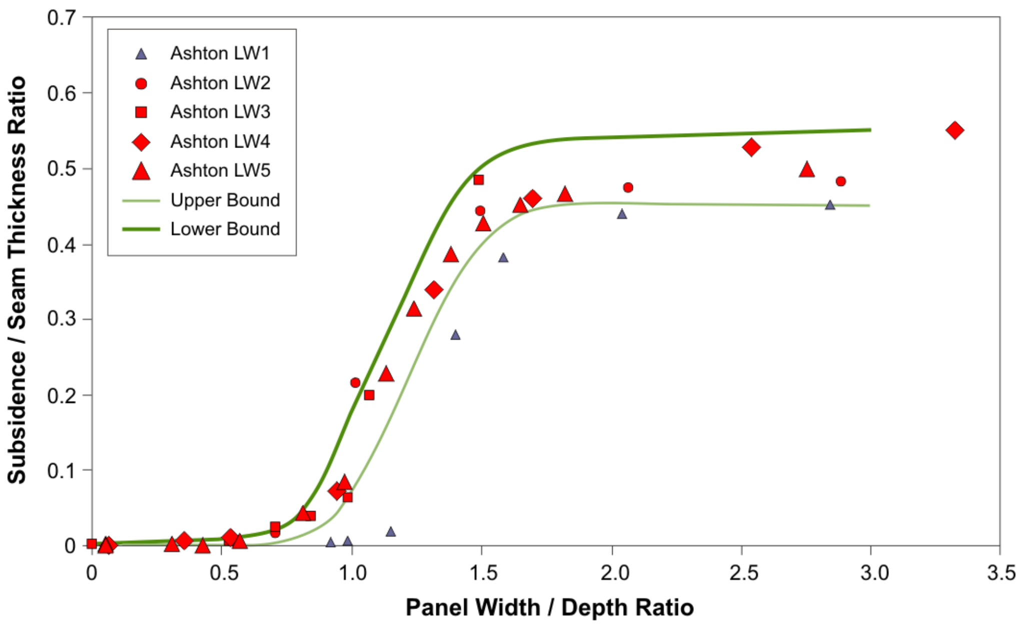

Figure 7: Relationship between dynamic subsidence and panel width measured at Ashton.

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.

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 8.

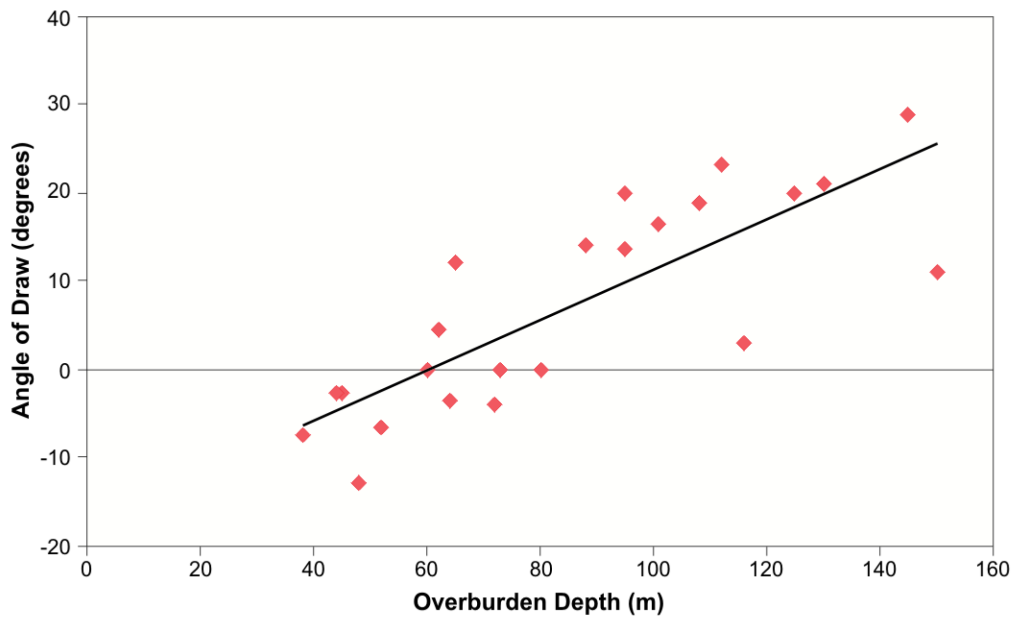

Figure 8: Relationship between angle of draw measured at Ashton and overburden depth.

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
Longwall 5	CL1	30	150	11
	CL2	7	116	3
	XL5	82	145	29

Figure 8 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.

The angle of draw is approximately 0° at about 60m overburden depth. The maximum angle of draw measured to date has been 29° at an overburden depth of 145m. The angle of draw at the finish line of each panel (measured on CL2) is consistently smaller than the angle of draw over other goaf edges.

6. CONCLUSIONS

Our review indicates that subsidence behaviour above the first five 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 5 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.

Approximately 200-250mm of horizontal movement has occurred in an eastward or upslope direction above each of the longwall panels. 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 5 is consistent with the dynamic bridging observed at the start of Longwalls 2, 3 and 4. 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 29° over the maingate goaf edge of Longwall 5 where the overburden depth is approximately 145m.

7. REFERENCES

HLA Envirosciences 2001 Environmental Impact Statement (EIS) prepared for White Mining Limited Ashton Coal Project, dated 1November 2001.

GHA 2001 "Ashton Coal Project – Assessment of the Impact of Subsidence from Longwall Mining" G.E. Holt and Associates Report prepared for White Mining Ltd dated 23 October 2001.

Mills, K.W. 2001, "Observations of horizontal subsidence movement at Baal Bone Colliery" Proceedings of 5th Triennial Conference on Coal Mine Subsidence - Current Practice and Issues, 26-28 August 2001, Maitland NSW, pp. 99-111.

SCT 2006, SCT Report ASH3084 "Subsidence Assessment for Ashton Coal Mine Longwalls 1 to 4" 30 August 2006.

SCT 2008, SCT Letter Report ASH3342a "Review of Longwall 1 Subsidence Monitoring and Comparison with Predictions" dated 13 February 2008.

SCT 2009, SCT Report ASH3485 "Review Subsidence Monitoring and Comparison with Predictions of Longwall 2 and Longwall 3 at Completion of Longwall 3" dated 20 August 2009.

SCT 2009a, SCT Report ASH3602 "Longwall 4 – End of Panel Subsidence Report" dated 31 December 2009.