Strata Control Technology

REPORT TO:

ASHTON UNDERGROUND MINE

Review of Subsidence Monitoring and Comparison with Predictions of Longwall 2 and Longwall 3 at Completion of Longwall 3

ASH3485

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REPORT TO	Phil Fletcher Technical Services Manager Ashton Underground Mine PO Box 699 SINGLETON NSW 2330
SUBJECT	Review of Subsidence Monitoring and Comparison with Predictions of Longwall 2 and Longwall 3 at Completion of Longwall 3
REPORT NO	ASH3485
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SUMMARY

Ashton Coal Operations Ltd (ACOL) has monitored surface subsidence movements during the retreat of Longwalls 2 and 3 on two longitudinal subsidence lines over the start and finish of each panel and a cross-line that extends across all the panels. ACOL commissioned SCT Operations Pty Ltd (SCT) to analyse the subsidence results for Longwalls 2 and 3 and compare them to predictions made during the EIS (GHA 2001) and SMP (SCT 2006) processes. This report presents the results of Longwall 2 and 3 subsidence monitoring and a comparison with predictions.

The subsidence monitoring results for Longwall 1 were presented in SCT (2008). The Longwall 1 results are included here for completeness.

Our review indicates that subsidence behaviour above the longwall panels so far mined at Ashton Underground Mine is consistent with supercritical subsidence behaviour.

Maximum subsidence has been less than the maximum predicted in the EIS. The maximum strains and tilts measured over Longwalls 1-3 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.

Subsidence movements have been less than the maximum predicted in the SMP with two minor 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.

The predicted and measured subsidence values are summarised in Table 1.

This comparison indicates that the vertical subsidence measured is within the range predicted but variable from panel to panel. The measured tilt and strain values are generally within the range predicted in SCT Report ASH3084.

Horizontal movements of 300-500mm have been measured over the panel on all three longwalls mined to date. Approximately 200mm of horizontal movement has occurred in an eastward direction directly above each of the panels even though this movement has occurred in an up slope direction. These horizontal movements are somewhat unusual in that horizontal movements in sloping terrain typically occur in a downslope direction.

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

The horizontal movements observed at Ashton have predominantly occurred over the longwall panel. There has been no evidence of far-field horizontal movement or even movements outside the immediate vicinity of the longwall panels.

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 0.6. 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 an overburden depth of 112m.

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1. INTRODUCTION

Ashton Coal Mine has monitored the subsidence movements on the surface during the retreat of Longwalls 2 and 3 on two longitudinal subsidence lines over the start and finish of each panel and a cross-line, XL5, that extends across all the panels mined so far. This report presents the results of the subsidence monitoring and a comparison with predictions provided in Table 1 of GHA (2001) and SCT Report ASH3084 suitable to meet the end of panel reporting requirements of the Department of Primary Industries (DPI 2007 Clause 21) in relation to subsidence.

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 1-3 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 produced in 1982).

Figure 2 shows a plan of the overburden depth to the Pikes Gully Seam. The seam section mined ranges along the length of Longwalls 2-3. The seam section mined along the length of Longwalls 2 and 3 ranges 2.4m to 2.65m. The seam dips to the south west at a nominal grade of 1 in 10. The overburden ranges in thickness from 35m at end of Longwall 1 to 130m at the start of Longwall 3. The final extraction void is nominally 216m with chain pillars 25m rib-to-rib at 100m cut-through centres.

Longwall operation commenced in February 2007 in Longwall 1 and Longwall 3 was completed in March 2009.

3. RESULTS OF SUBSIDENCE MONITORING

In this section, the results of each of the subsidence lines monitored during the retreat of Longwalls 2 and 3 are presented and discussed. The goaf edge subsidence and angle of draw for all the lines are presented and discussed together at the end of the section.

3.1 XL5

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 1-3.

Figure 3 shows a summary of the subsidence movements that have been measured. Seven resurveys were made during mining of each of Longwalls 2 and 3.

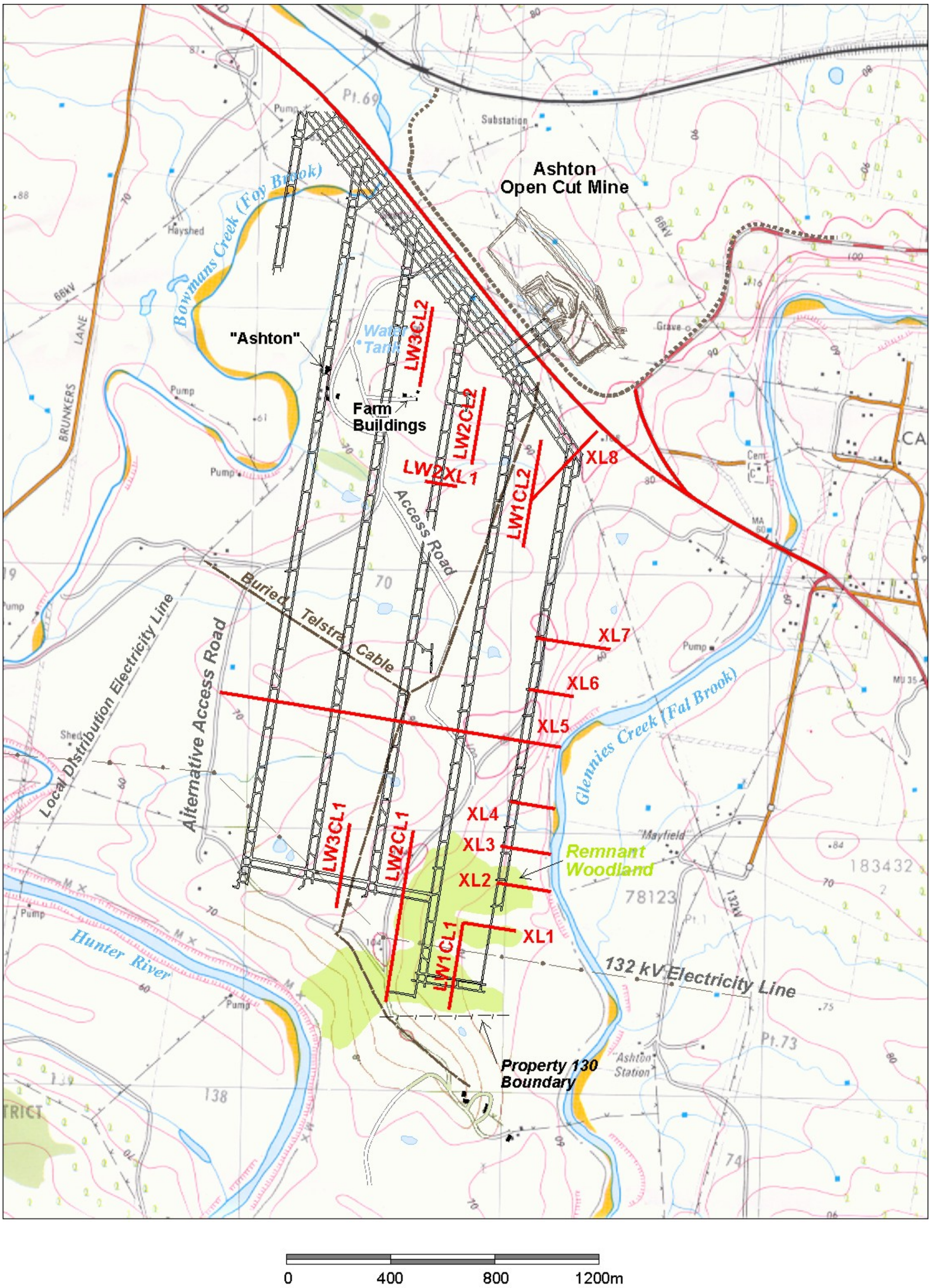

Figure 1 Site plan showing mine plan and location of the subsidence lines superimposed onto 1:25,000 topographic series map updated to reflect current infrastructure.

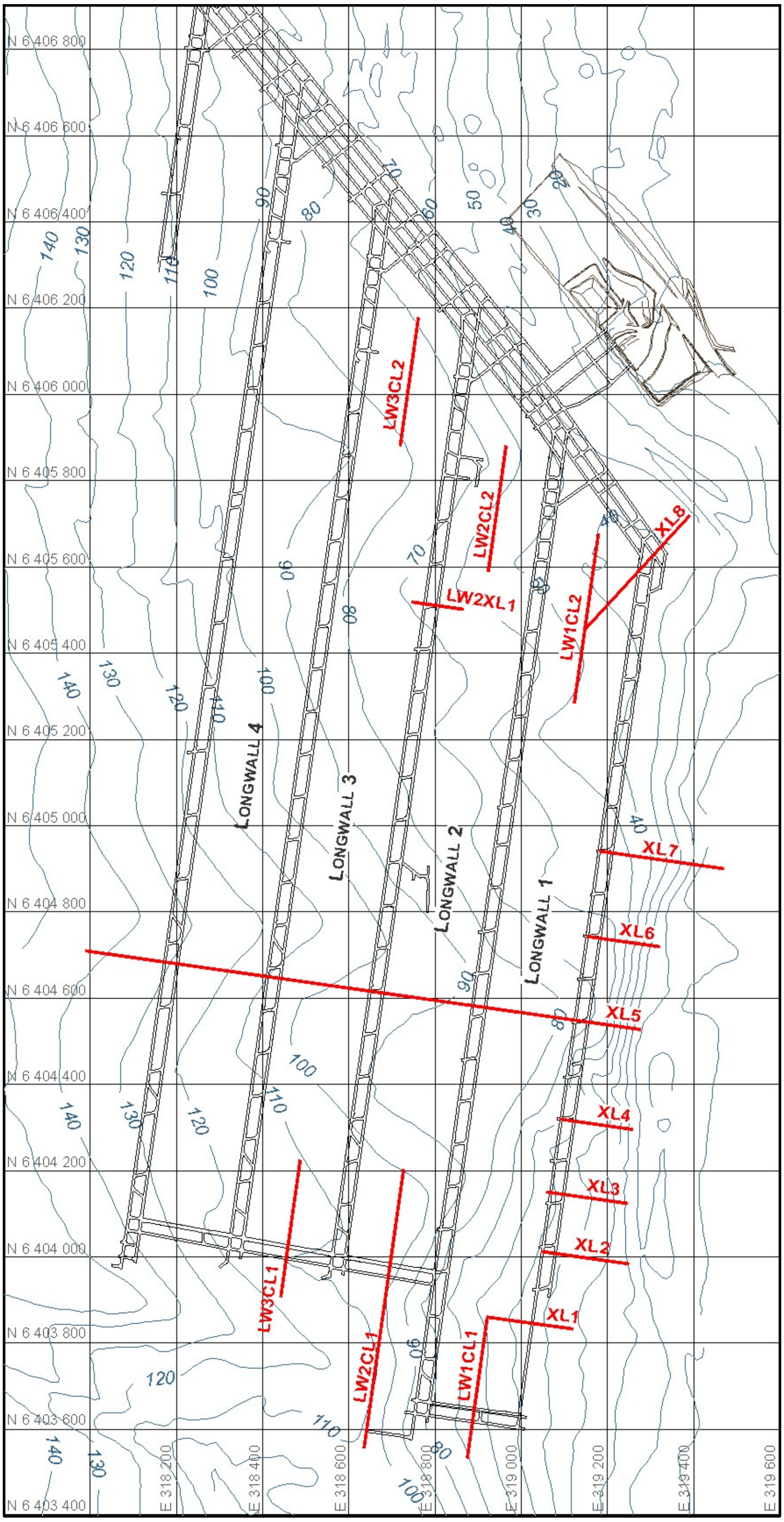

Figure 2 Overburden depth to the Pikes Gully Seam.

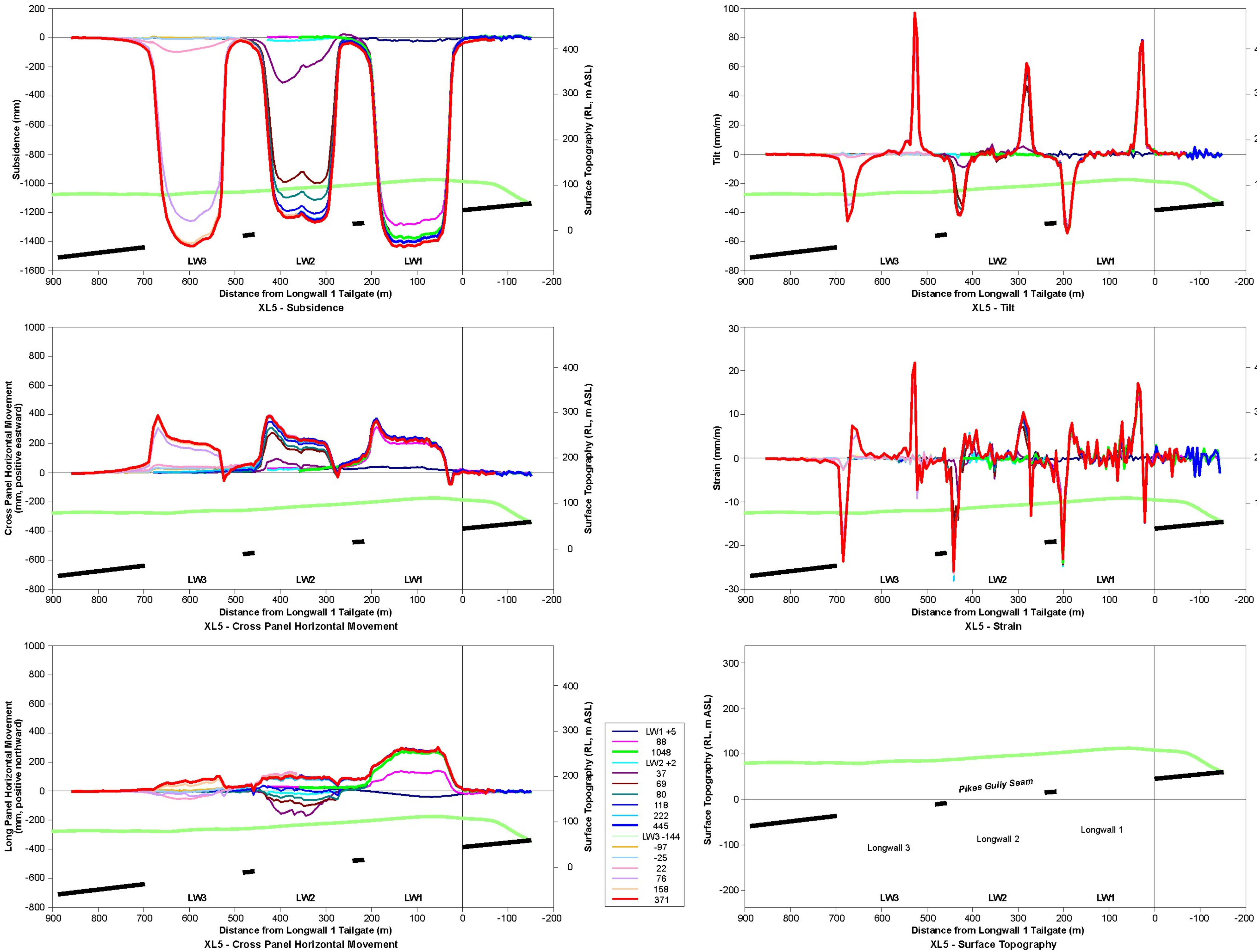

Figure 3 XL5 subsidence - Longwall 2, Ashton Mine.

The vertical subsidence profile measured is typical of the subsidence expected in a supercritical width panel. Maximum subsidence measured in the centre of Longwall 1 is panel is 1436mm or 54% of a nominal 2.65m seam section mined, a 2% increase in the maximum subsidence measured at the completion of Longwall 1. Maximum subsidence measured in the centre of Longwall 2 was 1253mm at the completion of Longwall 2 and 1266mm at the completion of Longwall 3, or 53% of a nominal 2.4m mining section. Maximum subsidence over Longwall 3 was 1429mm or 57% of a nominal 2.5m mining section.

Maximum tilts measured on XL5 across each of the three panels were 75mm/m, 78mm/m and 97mm/m respectively. The tilts on the upslope side of the panel are consistently higher than on the downslope side of the panel.

Horizontal movements occurred initially toward the approaching longwall face and then, soon after the face passed, the horizontal movements reversed direction causing a final offset in the direction of mining of approximately 250mm on Longwall 1 and 100mm on Longwalls 2 and 3. There was a consistent cross-panel horizontal movement of 200-250mm in an eastward or upslope direction across all three panels. The mechanics of this process are discussed in Section 5.

Maximum strains ranged 15-28mm/m. The maximum tensile strains were less than the maximum compressive strains.

3.2 CL1 – Longwall 2

Figure 4 shows a summary of the subsidence movements measured on the centreline subsidence line CL1 located over the start of Longwall 2. The overburden depth along CL1 is approximately 100m.

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 1296mm or 50% of the nominal 2.6m seam section mined.

Maximum tilt occurred over the start line and reached a peak of 40mm/m. Over the moving longwall face, the tilt peaked in the range 20-30mm/m.

Horizontal subsidence movements across the panel were relatively uniform with a magnitude of 200mm in an easterly or upslope direction. During the early stages of caving, the cross panel subsidence movements developed in proportion to the magnitude of vertical subsidence suggesting a correlation between the two. The long panel subsidence movements were initially symmetrical about the goaf. When the goaf was fully developed, initial movement was toward the void and then a reversal occurred leaving a final offset in the direction of mining of up to 370mm near the start of the panel and a peak horizontal movement in the direction of mining of approximately

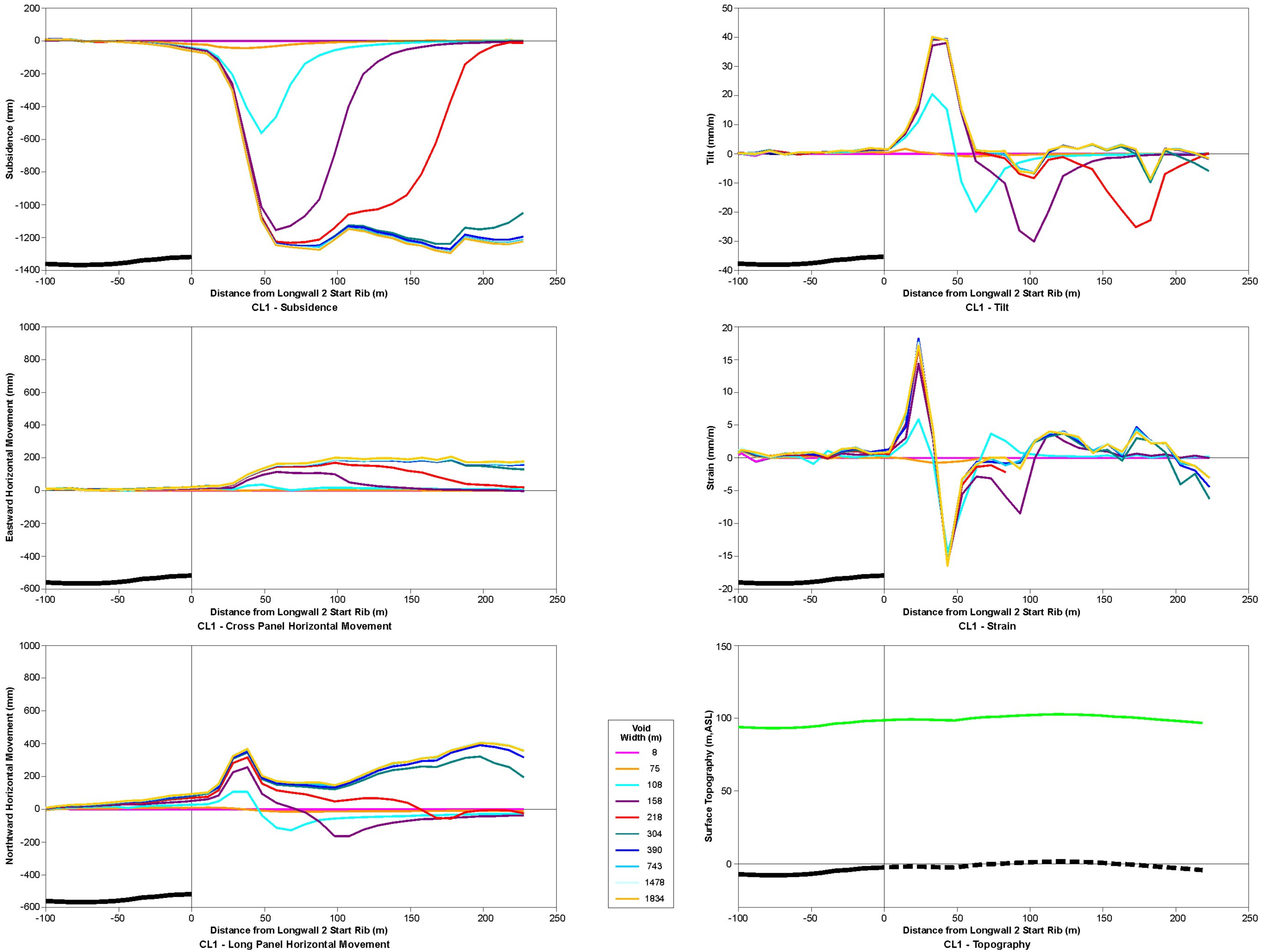

Figure 4 CL1 subsidence - Longwall 2, Ashton Mine.

450mm. The horizontal movements extend back over the solid starting rib approximately 100m, or a distance equal to the overburden depth.

Maximum horizontal strain along the panel reached 18mm/m adjacent to the starting rib, but was generally less than 5mm/m further over the panel.

3.3 CL2 – Longwall 2

Figure 5 shows a summary of the subsidence movements measured on CL2, a longitudinal subsidence line located on the centreline of Longwall 2 at the northern end of the panel. The overburden depth in this area is approximately 60m.

Maximum vertical subsidence measured on CL2 was 1513mm or 59% of a nominal 2.55m mining section. The vertical subsidence profiles developed regularly and consistently behind the longwall face when the longwall was moving and sharpened up when the longwall supports were removed and the face had been standing for a while.
Maximum tilt measured along CL2 was 40-50mm/m, but increased to 80mm/m at the end of the panel when the longwall supports have been removed.

Horizontal movements were initially toward the approaching longwall face and then offset in the direction of mining by approximately 100mm. The cross-panel component occurred in an eastward, upslope direction with a magnitude of 150-200mm.

Maximum horizontal strains ranged 10-15mm/m in tension and 15-36mm/m in compression with the maximum of 36mm/m measured adjacent to the finish line once the longwall supports had been removed.

3.4 CL1 – Longwall 3

Figure 6 shows a summary of the subsidence movements measured on the centreline subsidence line CL1 located over the start of Longwall 3. The overburden depth in this area is approximately 110m.

Vertical subsidence develops as the longwall goaf developed. The monitoring data 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 1420mm or 55% of the nominal 2.6m seam section mined. Maximum tilt occurs over the start line and reached a peak of 41mm/m. Over the moving longwall face, the tilt peaked in the range 30-40mm/m.

Horizontal subsidence movements across the panel were relatively uniform with a magnitude of 200mm in an easterly or upslope direction. During the early stages of caving, the cross panel subsidence movements developed in proportion to the magnitude of vertical subsidence suggesting a correlation between the two. The long panel subsidence movements were initially symmetrical about the goaf. When the goaf was fully developed, initial

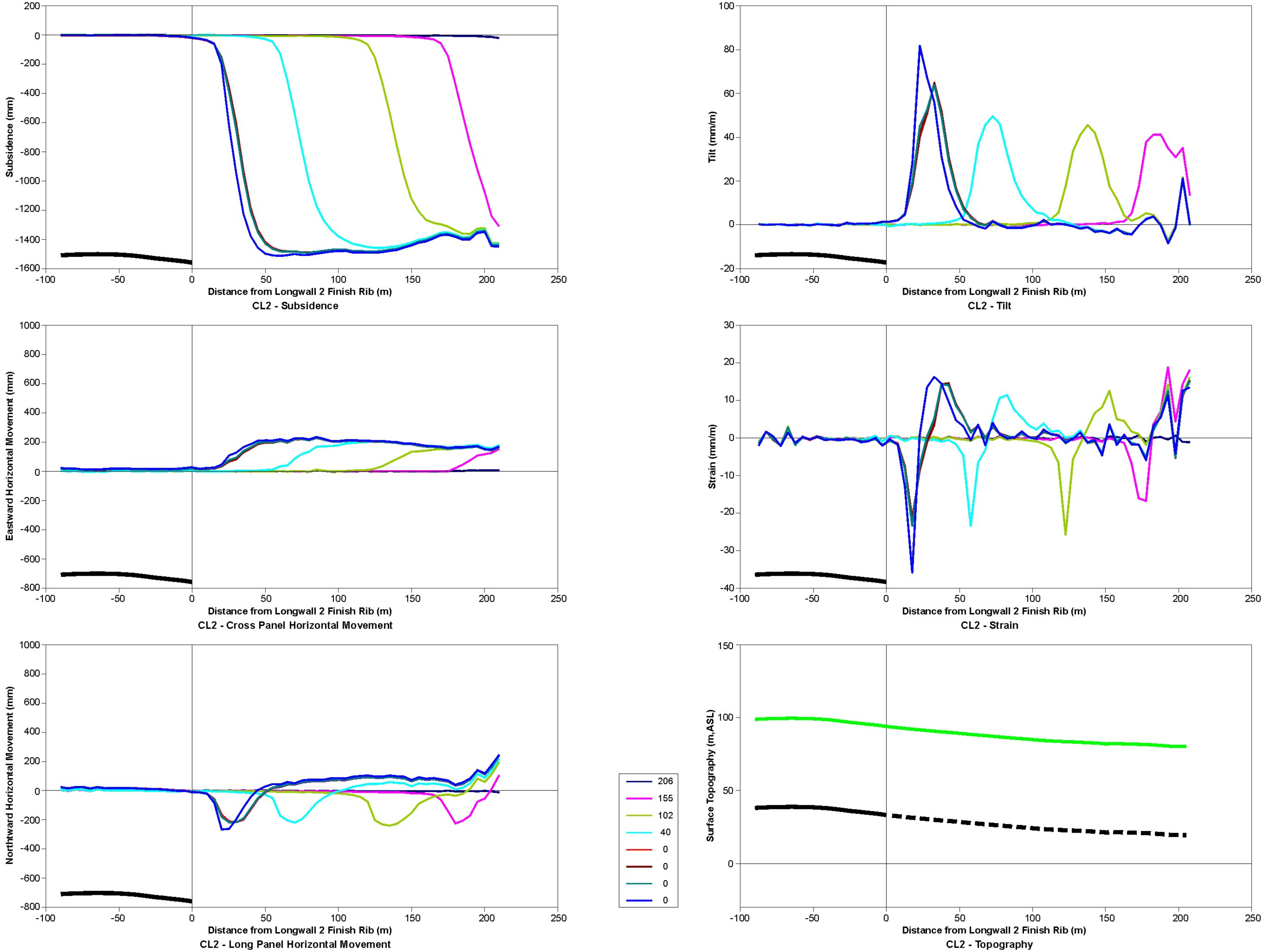

Figure 5 CL2 subsidence - Longwall 2, Ashton Mine.

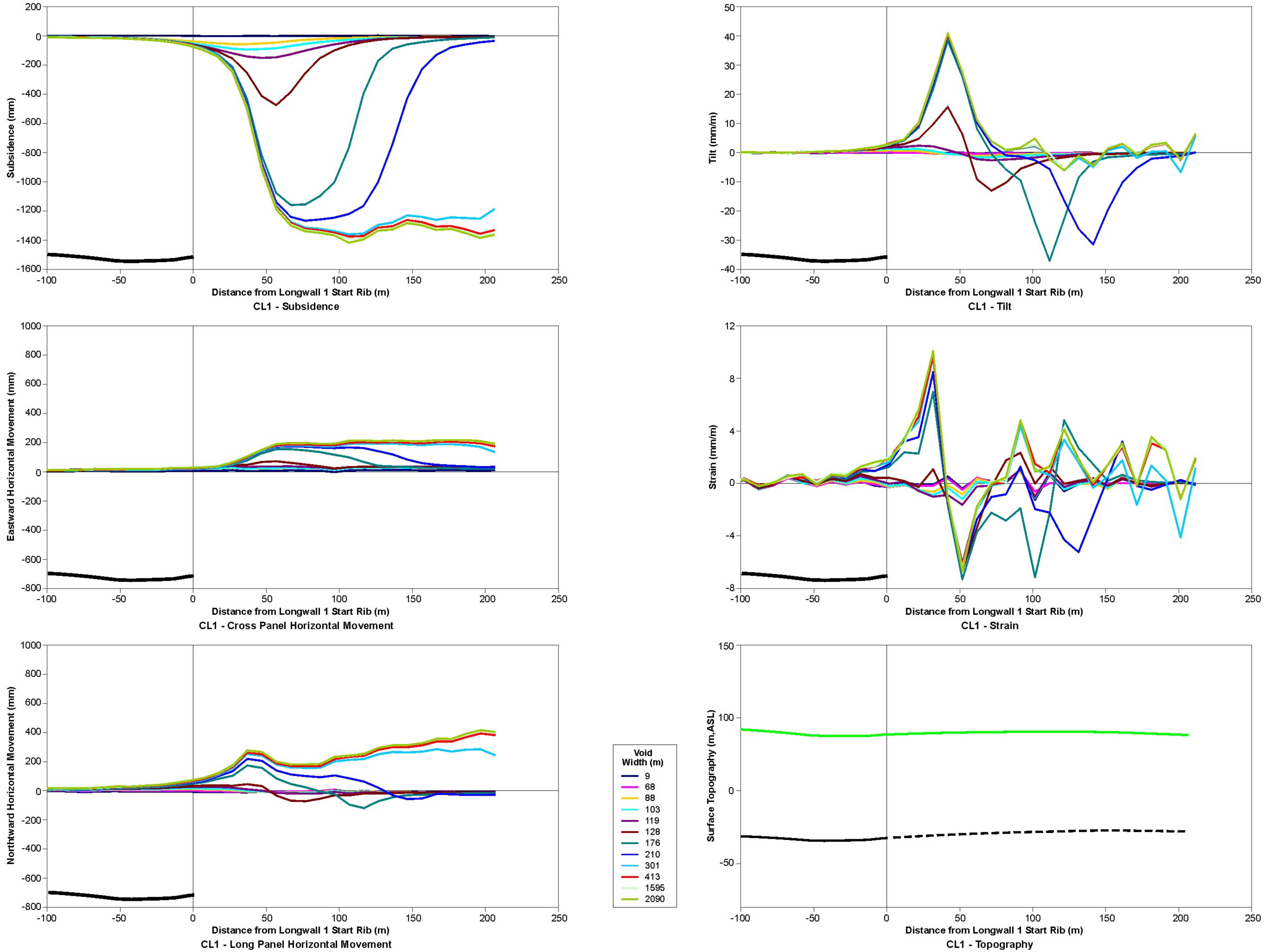

Figure 6 CL1 subsidence - Longwall 3, Ashton Mine.

movement was toward the void and then a reversal occurred leaving a final offset in the direction of mining of up to 276mm near the start of the panel and a peak horizontal movement in the direction of mining of approximately 415mm. The horizontal movements extended back over the solid starting rib to the end of the line where they were still 15mm at 113m from the goaf edge.

Maximum horizontal strain along the panel reached 10mm/m adjacent to the starting rib, but was generally less than 6mm/m further over the panel.

3.5 CL2 – Longwall 3

Figure 7 shows a summary of the subsidence movements measured on CL2, a longitudinal subsidence line located on the centreline of Longwall 3 at the northern end of the panel. The overburden depth in this area is approximately 75m.

Maximum vertical subsidence measured on CL2 was 1354mm or 53% of a nominal 2.5m mining section. The vertical subsidence profiles developed regularly and consistently behind the longwall face when the longwall was moving and sharpened up slightly when the longwall supports were removed and the face had been standing for a while.

Maximum tilt measured along CL2 was 30-45mm/m, but increased to 48mm/m at the end of the panel when the longwall supports had been removed.

Horizontal movements were initially toward the approaching longwall face and then offset in the direction of mining by up to 250mm. The cross-panel component occurs in an eastward, upslope direction with a magnitude of 190-230mm.

Maximum horizontal strains ranged 10-17mm/m in tension and 10-18mm/m in compression with the maximum of 18 mm/m measured adjacent to the finish line once the longwall supports have been removed.

4. COMPARISON WITH PREDICTIONS

In this section, the measured subsidence movements are compared to the subsidence movements predicted in the EIS (GHA 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.

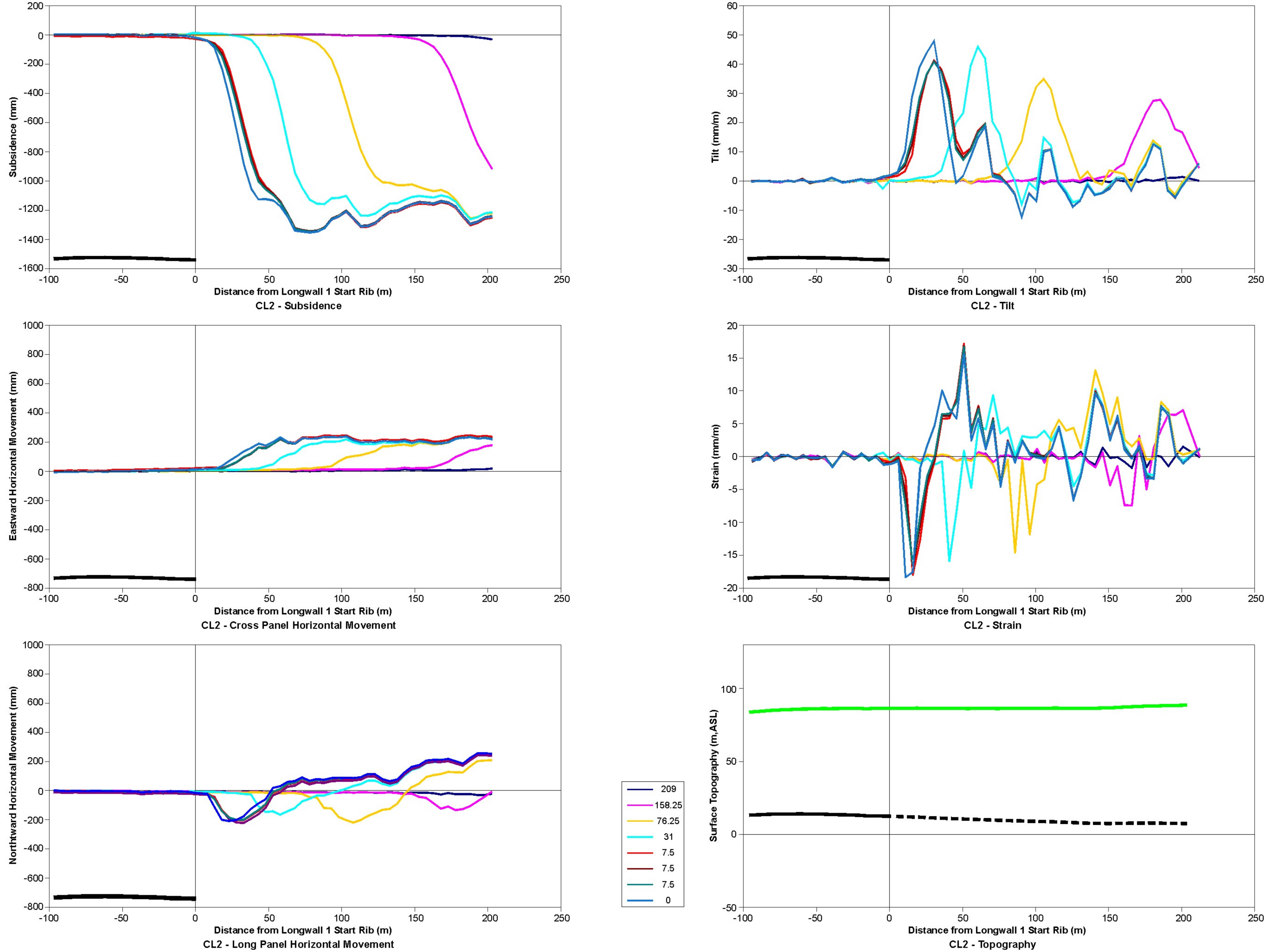

Figure 7 CL2 subsidence - Longwall 3, Ashton Mine.

In general the subsidence movements measured are less than predicted, except for the tensile strains at the start of Longwall 1 measured on CL1, which were 49mm/m compared to the 42mm/m maximum predicted and the maximum tilt on XL5 above Longwall 3, which was 97mm/m compared to the predicted maximum 78mm/m.

The vertical subsidence measured was within the range predicted 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. An unusual characteristic of these movements is that they have occurred in an upslope direction. The mechanics of this process are discussed in the next section.

Horizontal movements outside of the longwall panel are generally less than 10-20mm except at the start of each panel where horizontal movements toward the goaf are approximately 100-150mm at the goaf edge and extend back over the solid for a distance approximately equal to the overburden depth or about 110m.

5. DISCUSSION OF RESULTS

The subsidence monitoring results from Longwalls 1-3 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 magnitude of subsidence movements observed appears to be generally less than predicted magnitudes and 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 from panel to panel and variations in the seam thickness mined.

5.1 Horizontal Movements

There does not appear to have been any significant far-field horizontal movements involving mass movement or stress relief of the overburden strata outside the goaf. At the start of each panel, the horizontal movements extend slightly further outside the panel than elsewhere, but this effect is commonly observed at the start of longwall panels and is not considered unusual.

The horizontal movements directly over each panel have not followed a pattern that is consistent with general experience of horizontal movement in a downslope direction. There has been a consistent trend across all three panels that shows horizontal movement 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 directly 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 the bedding planes. This phenomenon appears able to occur at Ashton directly over the longwall panels 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 8 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.

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 be a best case scenario, 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.

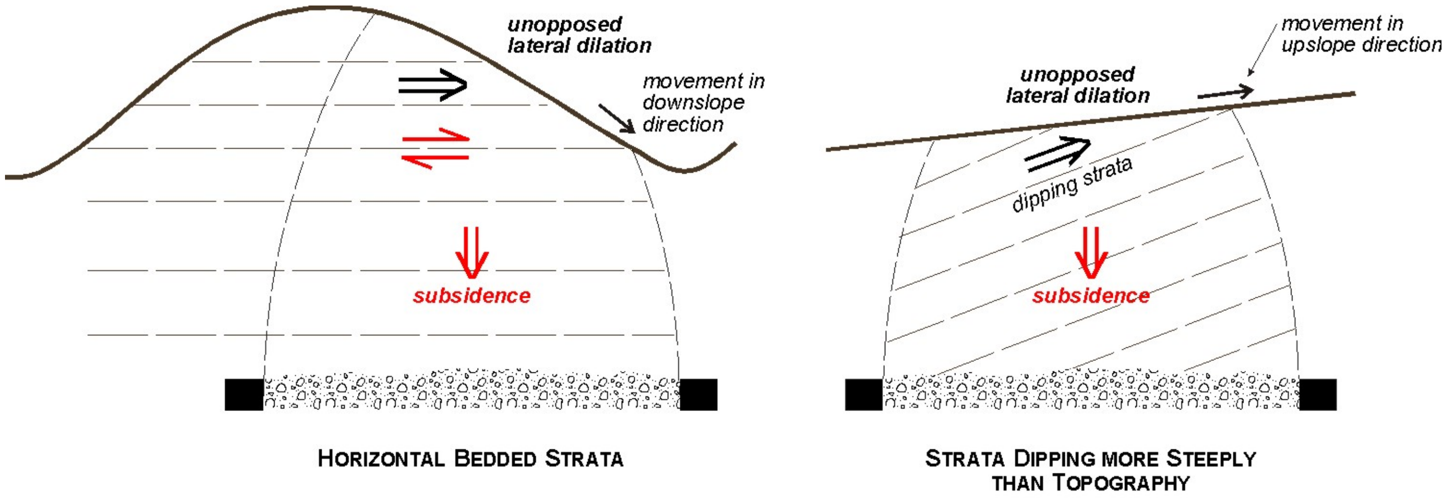

Figure 8 Sketch illustrating the mechanics of horizontal movement.

Figure 9 shows the relationship between sag subsidence and effective panel width over the first three longwall panels at Ashton. The subsidence monitoring shows significant variability in bridging behaviour, which is thought to relate to relatively low horizontal stresses in the overburden strata. There has been 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 dynamic subsidence.

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

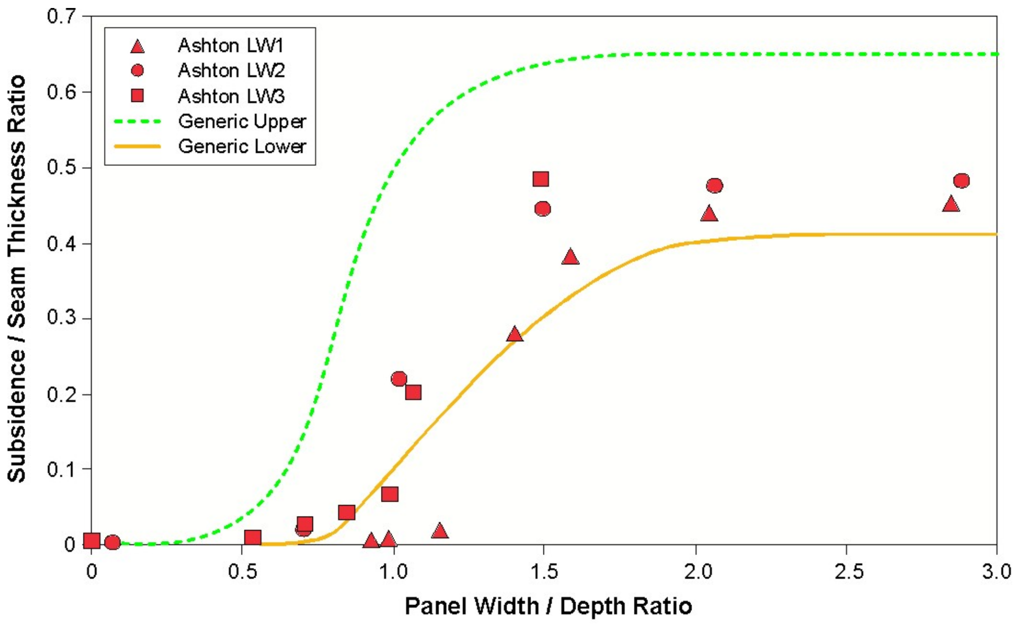

Figure 9 Relationship between dynamic subsidence and panel width measured at Ashton.

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 of 20mm subsidence that equals 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 10.

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

Figure 10 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.

Subsidence measurements at Ashton show that the angle of draw increases 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 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.

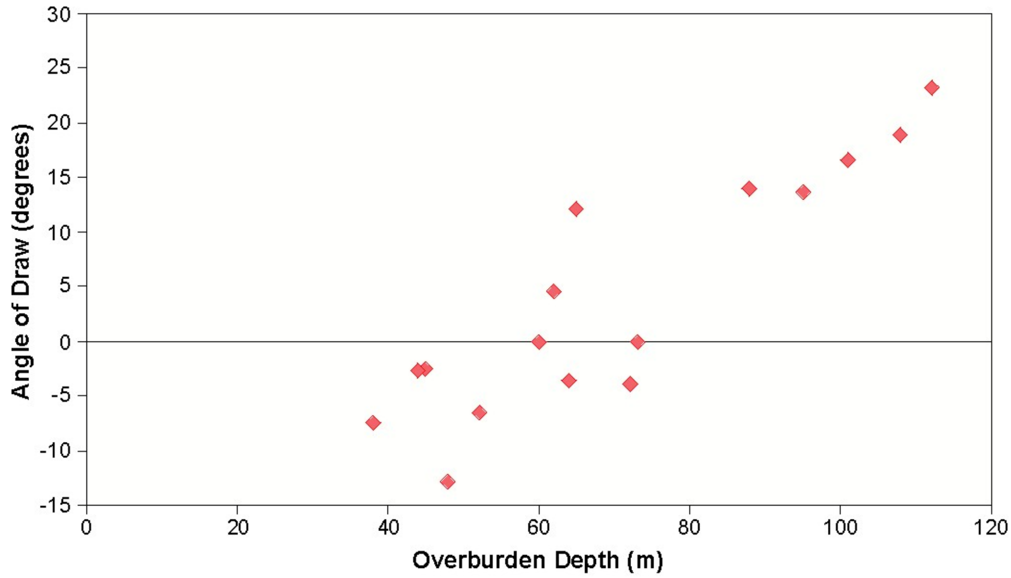

Figure 10 Relationship between angle of draw measured at Ashton and overburden depth.

6. CONCLUSIONS

Our review indicates that subsidence behaviour above the longwall panels so far mined at Ashton Underground Mine is consistent with supercritical subsidence behaviour.

Maximum subsidence has been less than the maximum predicted in the EIS. The maximum strains and tilts measured over Longwalls 1-3 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.

Subsidence movements have been less than the maximum predicted in the SMP with two minor 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.

The vertical subsidence measured is within the range predicted in the EIS and SMP documents but it is quite variable from panel to panel. The measured tilt and strain values are generally within the range predicted in SCT Report ASH3084 for the SMP but are not consistently within the EIS predictions which were made for a different mining geometry.

Horizontal movements of 300-500mm have been measured over the panel on all three longwalls mined to date. Approximately 200mm of horizontal movement has occurred in an eastward direction directly above each of the panels even though this movement has occurred in an up slope direction. 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 horizontal movement are thought to be the same 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.

The horizontal movements observed at Ashton have predominantly occurred over the longwall panel. There has been no evidence of far-field horizontal movement or even movements outside the immediate vicinity of the longwall panels.

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 0.6. Long term, static subsidence is expected to be greater than dynamic subsidence.

Subsidence measurements at Ashton show that the angle of draw with overburden depth with a 0° angle of draw at about 60m overburden depth. The maximum angle of draw measured to date has been 23° at an overburden depth of 112m.

7. REFERENCES

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

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