APPENDIX 10:

SUBSIDENCE AND VIBRATION

Reports and Policy

APPENDIX 10

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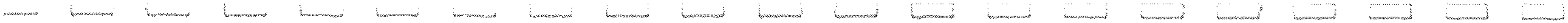
1.0 ASSESSMENT OF THE IMPACT OF SUBSIDENCE FROM PROPOSED LONGWALL OPERATIONS IN THE BELLBIRD SOUTH EXTENSION OF ELLALONG COLLIERY, G. E. HOLT & ASSOCIATES, MAY 1995



G E Holt & Associates Pty Ltd
Geotechnical Engineers

ASSESSMENT OF THE IMPACT OF SUBSIDENCE FROM PROPOSED LONGWALL OPERATIONS IN THE BELLBIRD SOUTH EXTENSION OF ELLALONG COLLIERY

May 1995

ACN 003551184

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ASSESSMENT OF THE IMPACT OF SUBSIDENCE FROM PROPOSED LONGWALL OPERATIONS IN THE BELLBIRD SOUTH EXTENSION OF ELLALONG COLLIERY

1.0 INTRODUCTION

This report has been prepared to determine likely subsidence levels and impacts arising from proposed mining of the Greta Seam by the longwall method of operation in the Bellbird South extension to Ellalong Colliery, N.S.W. It covers prediction of likely subsidence levels in the proposed mining area, assessment of the likely impacts of coal extraction, and suggests measures that might be employed to mitigate the effects of subsidence.

Particular issues of concern with regard to subsidence are the impact on houses, farm structures and improvements, public roads, water courses and vibration. Vibration is subject to separate reporting, and is not considered in this assessment report.

The report outlines the mine plan proposed by Ellalong Colliery, and before discussing detailed subsidence calculations for the mine layout, provides some background information on subsidence prediction for readers less familiar with subsidence prediction methods. An explanation of terminology is also given in Appendix I at the end of the report.

1.1 PROPOSED MINE PLAN

The location of the proposed longwall mining area is shown in Figure 1. The proposed mining area includes 14 longwall panels located to the north of the original 9 panels mined in Ellalong Colliery. The Greta Seam is at approximately 400 m depth near the old Bellbird South shafts, and dips south easterly to a depth of around 600 m at the end of the proposed 14 panels. This compares with mining depths between 300 m and 550 m in the current workings.

The mine will be developed from headings driven north east then east from the current longwalls. These headings are designed to be permanently stable by incorporation of solid pillars between the access headings, and large solid barriers between the roads and adjoining longwall panels. The first eight longwall panels, numbered 15 to 22, will be developed east from panels 13 and 14 for which approval has already been granted. The next 6 panels, numbered 23 to 28 will be located north of the first set. Future mining beyond these panels will be subject to a separate application some time in the future.

The longwall extraction panels will be formed by driving two roadways (gate roads) away from the main headings, forming pillars of coal (chain pillars) 100 m long and 38 m wide (rib-rib) between them on each side of the block to be mined. Panel lengths will vary according to location. At the end of a planned panel the two sets of double roadways will be connected (by a start road) to allow installation of the longwall equipment. The first eight panels will be 211.7 m wide, and the later 6 panels will probably be widened to 255 m.

The Greta Seam has variable thickness and will not be mined in its entirety due to mining and coal quality constraints. The height of workings will vary between 3.4 m and 4.5 m.

The pillars remaining between the access roadways for each panel will yield in time, but will not entirely crush out. The coal remaining in the yielded pillars will provide some support for overlying strata, and this will reduce the amount of settlement of the roof rocks above the workings compared settlement resulting from with total extraction of coal.

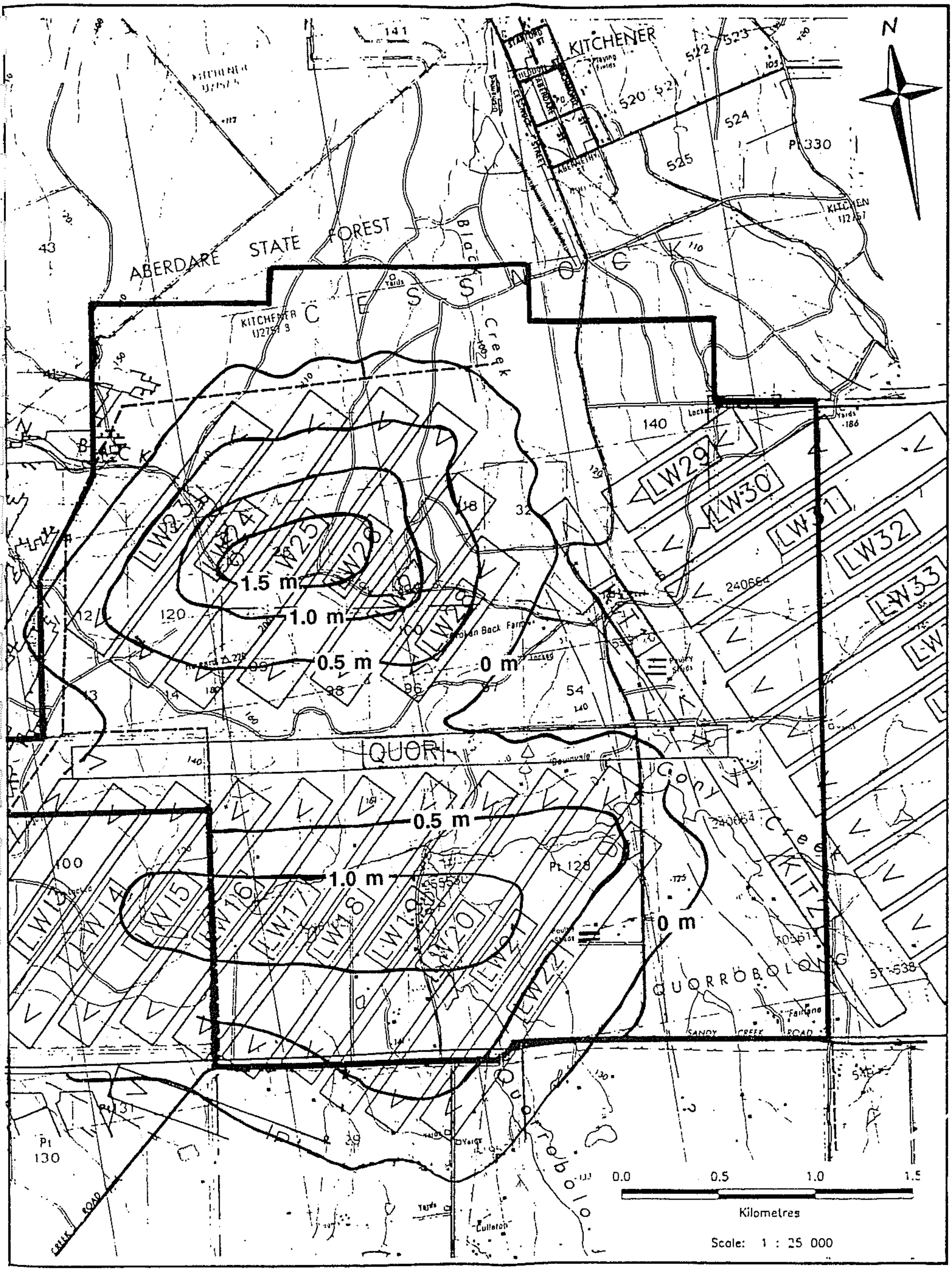


FIGURE 1: MINE LAYOUT & SUBSIDENCE CONTOURS FOR PROPOSED ELLALONG EXPANSION

2.0 SUBSIDENCE REGULATION AND PREDICTION METHODS

2.1 SUBSIDENCE TERMINOLOGY

A standard set of symbols, terms and definitions has developed for empirical subsidence prediction and are set out in Appendix I. A diagram showing the relationship of the terms is also provided in the Appendix.

In general the amount of ground strain and curvature arising from subsidence determines how much surface damage might occur, not the actual amount of vertical subsidence. However the best understood measure is the vertical ground movement, or vertical subsidence because all the other parameters; strain, tilt, position of maximum subsidence, position of inflection point etc, are calculated from this.

This is why commonly only the maximum subsidence is discussed in reports. The other values can be calculated empirically from the subsidence value if the vertical subsidence and depth of mining are known, and also in the case of Ellalong Colliery be extrapolated from measured data.

2.2 REGULATORY FRAMEWORK

To further assist landowners the Mine Subsidence Board was set up in 1929 to assist in managing problems before, during and after subsidence, and legislation in this field has been periodically updated since then. The Board concentrates on payment of compensation for damage to land and/or improvements caused by subsidence, and regulating surface development within proclaimed mine subsidence districts. The Ellalong area is not within a proclaimed Mine Subsidence District, but this does not affect payment of compensation for damage, or repair of damage as a result of subsidence.

The Board has pointed out that not all damage to structures in coal mining areas is due to subsidence. Soil movement is common, particularly with our climate of prolonged dry followed by short, intense, wet spells. These climatic conditions play havoc with soils subject to shrinkage and expansion, and these soils occur particularly in the Newcastle and Hunter Valley coalfields.

Consequential loss arising from subsidence events is not covered by the Mine Subsidence Compensation Act (1961), but by The Coal Mining Act (1973), since replaced by the Mining Act (1992), through the Mining Warden for an order of compensation against the mining company. There are available damage criteria tables based on strain, developed from British mining experience (Appendix II). While there are no local damage assessment tables, strain is the same the world over, and if 5 mm/m strain damages a masonry wall in Britain, 5 mm/m will damage a similar masonry wall in Australia. Consequently it is possible to make reasonable engineering judgements concerning likely subsidence damage by reference to British experience.

Provided a land owner and mining company can reach an agreement prior to mining current practice is for individual mining companies to come to agreement with land owners for repair of land, while monitoring operations to build a site specific data base of knowledge on subsidence. Otherwise claims for consequential loss must be made through the Mining Warden.

Subsidence guidelines are used to predict the maximum likely subsidence levels in order to design for worst case conditions. Predictions are based on conceptual mine plans which often change, as mining is a dynamic process. Often only average cover depths and seam thickness dimensions are available, and while there is variation about average values, the predictions are sufficiently accurate to determine the likely impacts.

Actual subsidence can vary significantly from predictions if unknown geological anomalies cause changes to expected ground movement. Cross cutting dykes of hard rock, such as occur in the worked out longwall area of Ellalong Colliery can cause marked change from expected subsidence. If the structures are identified in new mining areas, some allowance can be made. Much effort is expended searching for such structures because they can also have a severe impact on the mining of coal. This reduces the risk of mining, and the consequent risk of large variations in expected subsidence.

2.3 PREDICTION METHODS FOR ELLALONG EXPANSION PROPOSAL

2.3.1 Introduction

When coal is mined from a coal seam by underground methods, the support provided by the coal to overlying rocks is removed. Some rocks such as siltstone and shale can span over small distances, and not collapse into an opening below. Others such as sandstone and conglomerate can span 80 m or more before collapsing, or caving.

When the distance to span over mined out areas becomes too much for the particular strata (or layers), they break and fall in to the space underneath. If enough roof strata are affected by the collapse then effects can be carried through to the surface. The movement of the surface is known as subsidence. Movement continues until caving rock blocks up the available space.

Unlike a steel beam, which is made of the same material throughout, and whose strength and behaviour properties can be predicted accurately, strata are extremely variable in composition, strength and behaviour. There are no physical laws that can accurately describe the way in which rocks behave, and all assessments of the behaviour of rocks and rock strata must be through approximations based on experience (empirical methods) or computer based mathematical modelling.

2.3.2 Empirical Guidelines Method

In New South Wales the Department of Minerals and Energy has produced three booklets detailing empirical methods for predicting subsidence from single seam workings. These are for the Southern, Western and Newcastle Coalfields (Holla, 1985 & 1987). The method contained in each booklet is based on the results of a number of subsidence surveys carried out in each of the coalfields. The methods are completely empirical, based on real subsidence monitoring of single seam workings. The early workings at Ellalong Colliery were utilised in preparation of the Newcastle Coalfield Guideline.

Recent experience on prediction of subsidence for multiple longwall panels (Holla, 1988) has seen the development of curves which relate individual panel dimensions to pillar widths in order to determine likely maximum subsidence levels. This replaces the method of working with the effective mined height and percentage of coal extracted, to determine maximum subsidence. This yields more realistic estimates of maximum subsidence.

The curves were developed for the Southern Coalfield but are considered by Holla to be applicable to other areas, they have been used in recent Development

Guidelines are clearly an indicator of maximum values over a coalfield and it is accepted that predictions for a specific mine site can be improved if local knowledge is available. Ellalong Colliery has conducted subsidence surveys over its longwall panels for many years. The results of the surveys enables future subsidence prediction to be estimated more accurately than reliance on the Guideline and Multiple Panel Method, and summary relevant details are given in the next section.

Consequently the best practical means for prediction at Ellalong Colliery is to use the empirical methods from the Surface Subsidence Prediction Guidelines (Holla,1987), updated by recent experiences with multiple longwall panel subsidence (Holla, 1988), and employing local subsidence experience at Ellalong Colliery.

2.3.3 Subsidence Measurement at Ellalong Colliery

Several subsidence lines and grids have been monitored above the workings since 1983. Detailed surveys were conducted over a grid established in Ellalong village, and lines were established over the main group of panels covering longwall panels 5 to 9. A further line was set up over the more recent panels 10 to 12A. Locations of the subsidence lines are shown in Figure 2. The most useful surveys for future prediction of subsidence are those along Sandy Creek Road. This survey line detects the maximum subsidence and strains experienced at the surface and yields sufficient information to provide site specific modifications to the general guideline prediction method. A summary of the survey information is given in Figure 3.

Maximum subsidence recorded is 1.145 m over a supercritical area of extraction, Panels 5 to 9, with chain pillar width of 38 m. Cover depth varied between 350 m and 500 m, and mined thickness averaging 3.7 m.

PANEL NUMBER	RANGE OF WORKING DEPTH (m)	AVERAGE DEPTH H (m)	MINING HEIGHT T (m)	PANEL WIDTH W (m)	PILLAR WIDTH (m)	PILLAR WIDTH / H	W / H	Sm / T	MAXIMUM SUBSIDENCE Sm (m)	ANGLE OF DRAW (Degrees)	GOAF EDGE SUBSID. (m)	ZERO SUBSID. Distance From Panel	Tensile Strain (mm/m) 400Sm/H	Compress. Strain (mm/m) 600Sm/H	Tilt (mm/m) 1800Sm/H	Radius of Curvature (km)	Inflection Point Posn. - inside D/H	D (m)	0.5Sm (m)
ELLALONG MEASURED DATA #	aver. values	412.50	3.55	201.00	34.00	0.08	0.49	0.32	1.14	35.00 perp. to panel		300.00							0.57
	400.00 to		3.50 to	190.00	30.00	0.08	0.48	0.26	0.91		0.20	to	1.00	0.60	3.00	not available			0.46
PANELS 5 TO 9	425.00		3.60	212.00	38.00	0.09	0.50	0.32	1.15	22.00 parallel to panel		230.00					-0.29	-123.00	0.58
ELLALONG PREDICTED DATA	aver. values	412.50	3.55	201.00	34.00	0.08	0.49	0.38 *	1.35		0.86	206.25 **					-0.22	-90.75	0.67
	400.00 to		3.50 to	190.00	30.00	0.08	0.48	0.37	1.30	26.50	0.82	200.00 to	1.31	1.96	5.89	5.00	-0.24	-96.00	0.65
PANELS 5 TO 9	425.00		3.60	212.00	38.00	0.09	0.50	0.39	1.40	26.50	0.91	212.50					-0.17	-72.25	0.70

TABLE 1: MEASURED AND PREDICTED MAXIMUM SUBSIDENCE DATA ATELLALONG COLLIERY

* Maximum subsidence based on multi-panel curves (Holla, 1988)

Mine measured data based on Longwall Panels 5 to 9

** Maximum strains, tilt etc based on Newcastle Guideline (Holla, 1987)

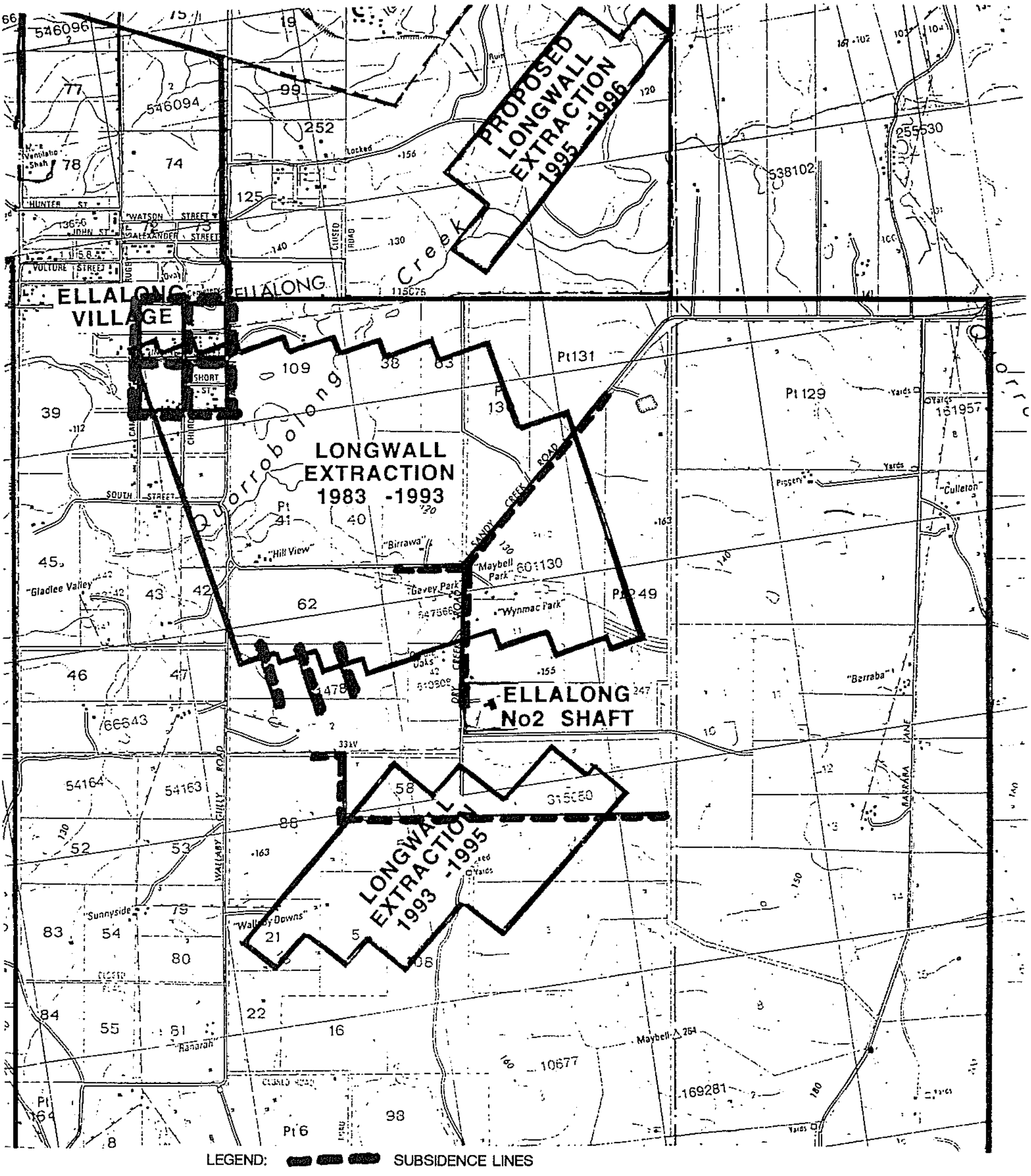


FIGURE 2: SUBSIDENCE LINE LOCATION PLAN - ELLALONG COLLIERY

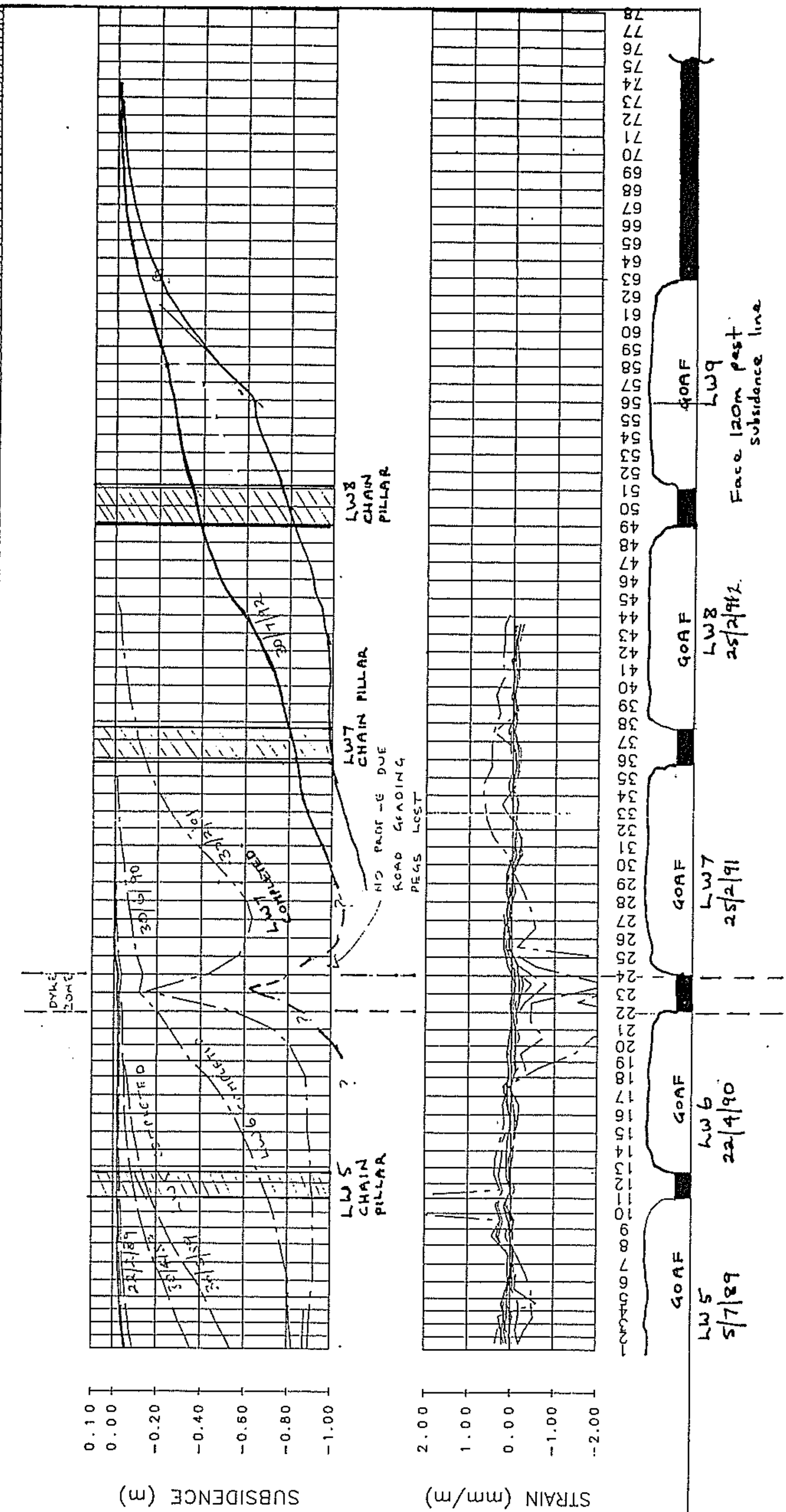


FIGURE 3: SUMMARY OF MAXIMUM MEASURED SUBSIDENCE AT ELLALONG COLLIERY

DATE FIRST MEASURED	PEG	DIST	R L	STRAIN
30-10-87	1	0.000	120.546	
30-10-87	2	14.831	120.749	0.20
30-10-87	3	14.915	120.987	0.20
30-10-87	4	15.050	120.956	0.13
30-10-87	5	14.308	121.330	0.21
30-10-87	6	18.518	121.772	0.11
30-10-87	7	20.270	122.361	0.00
30-10-87	8	21.763	123.215	0.00
30-10-87	9	18.424	123.978	0.00
30-10-87	10	18.007	124.684	0.06
30-10-87	11	17.224	125.294	0.17
30-10-87	12	16.871	125.770	0.00
30-10-87	13	18.152	126.037	0.11
30-10-87	14	19.580	126.126	0.10
30-10-87	15	20.441	125.020	0.10
30-10-87	16	20.529	125.758	0.00
30-10-87	17	21.148	125.472	0.09
30-10-87	18	21.212	125.151	0.09
30-10-87	19	17.470	124.789	0.06
30-10-87	20	18.588	124.430	0.11
30-10-87	21	18.744	124.127	0.05
30-10-87	22	20.320	123.980	0.00
30-10-87	23	21.903	124.032	0.05
30-10-87	24	20.913	124.321	-0.10
30-10-87	25	21.184	124.806	0.09
30-10-87	26	21.336	125.534	0.19
30-10-87	27	21.147	126.448	0.19
30-10-87	28	21.642	127.430	0.00
30-10-87	29	21.467	128.447	0.14
30-10-87	30	22.132	129.471	0.14
01-06-88	31	20.484	130.393	0.00
01-06-88	32	20.479	131.345	0.00
01-06-88	33	20.471	132.378	0.00
01-06-88	34	20.462	133.443	0.00
01-06-88	35	20.474	134.412	0.00
01-06-88	36	20.462	135.436	0.00
01-06-88	37	20.485	136.423	0.00
01-06-88	38	20.466	137.366	0.00
01-06-88	39	20.481	138.270	0.00
01-06-88	40	20.503	139.071	0.00
01-06-88	41	20.490	139.737	0.00
01-06-88	42	20.501	140.203	0.00
01-06-88	43	20.494	140.501	0.00
01-06-88	44	20.507	140.563	0.00
30-02-91	45	20.550	140.396	
30-02-91	46	20.446	140.035	
30-02-91	47	20.497	139.504	
30-02-91	48	20.468	138.856	
30-02-91	49	20.472	138.156	
30-02-91	50	20.498	137.379	
30-02-91	51	20.539	136.628	
30-02-91	52	20.456	135.788	
30-02-91	53	20.531	134.851	
30-02-91	54	20.531	133.923	
30-02-91	55	20.487	132.972	
30-02-91	56	20.559	132.126	
30-02-91	57	20.492	131.405	
30-02-91	58	20.534	130.969	
30-02-91	59	20.476	130.782	
30-02-91	60	20.501	130.841	
30-02-91	61	20.508	131.074	
30-02-91	62	20.546	131.422	
30-02-91	63	20.492	131.864	
30-02-91	64	20.505	132.467	
30-02-91	65	20.480	133.257	
30-02-91	66	20.481	134.128	
30-02-91	67	20.484	134.972	
30-02-91	68	20.494	135.893	
30-02-91	69	20.477	136.814	
30-02-91	70	20.483	137.728	
30-02-91	71	20.481	138.682	
30-02-91	72	20.482	139.620	
30-02-91	73	20.488	140.425	
30-02-91	74	20.484	141.239	
30-02-91	75	20.493	141.765	
30-02-91	76	20.490	142.128	
30-02-91	77	20.502	142.328	
30-02-91	78	20.505	142.287	

The maximum subsidence is around 31% of mined thickness. This range is low compared with predictions based on the multiple panel method of prediction for maximum subsidence, which would give a maximum subsidence value of 1.4 m. Comparison of the actual subsidence data and predicted information, based on the same mining dimensions is given in Table 1. The data suggest that the massive nature of the marine sandstone sequence above the Greta Seam is responsible for the reduction.

In addition the chain pillars will yield some amount with time but the coal still remains to reduce the amount by which all the roof strata can collapse. As a consequence the actual subsidence will be less than that indicated by the curves of Holla (1988). Strain and tilt values calculated by Ellalong Colliery from observed data are also lower than those calculated using the Newcastle Guideline method.

The maximum observed subsidence (32% of the mined height) is 1.145 m. It is likely that the actual maximum was missed because of the interference by a large dyke, and location of the surface subsidence grid as mentioned above, and that the maximum subsidence is closer to 1.2 m.

3.0 PREDICTION OF SUBSIDENCE LEVELS

3.1 MAXIMUM SUBSIDENCE PREDICTIONS

The proposed longwall workings will be single seam, extracting coal from part of the Greta Seam. The strata sequence above the Greta Seam consists of silty sandstone, sandstone and conglomerate of the marine Branxton Formation, with siltstone, sandstone and shales of the Paxton Formation forming the roof rocks to the Greta Seam. The Branxton Formation varies in thickness across the proposed longwall area, ranging between 350 m and 570 m thick, and it has massive bedding characteristics.

The maximum possible subsidence occurs in the Newcastle Coalfields when the width of the extracted area exceeds 1.6 x Depth of Cover(H). At Ellalong with chain pillars remaining between panels, extraction width never exceeds 1.6 x Cover Depth. It varies between 0.37 and 0.66 x Cover Depth.

PANEL NUMBER	RANGE OF WORKING DEPTH (m)	AVERAGE DEPTH H (m)	MINING HEIGHT T (m)	PANEL WIDTH W (m)	PILLAR WIDTH (m)	PILLAR WIDTH / H	W / H	Sm / T	MAXIMUM SUBSIDENCE Sm (m)	ANGLE OF DRAW (Degrees)	GOAF EDGE SUBSID. (m)	ZERO SUBSID. Distance From Panel	Tensile Strain (mm/m) 400Sm/H	Compress. Strain (mm/m) 600Sm/H	Tilt (mm/m) 1800Sm/H	Radius of Curvature (km)	Inflection Point Posn. - inside D/H	D (m)	0.5Sm (m)
NEW MINE	aver. values	495.00	3.95	211.70	38.00	0.08	0.43	0.29	1.15	26.50	0.20	247.50	0.93	1.39	4.17		0.26	128.70	0.57
	400.00		3.40	211.70	38.00	0.10	0.53	0.32	1.09	26.50	0.20	200.00	1.09	1.63	4.90		0.33	132.00	0.54
PREDICTED	to		to													5.00			
PANELS												to							
15 TO 22	590.00		4.50	211.70	38.00	0.06	0.36	0.31	1.40	26.50	0.30	295.00	0.95	1.42	4.26		0.25	147.50	0.70
NEW MINE	aver. values	485.00	3.95	255.00	38.00	0.08	0.53	0.36	1.42	26.50	0.30	242.50	1.17	1.76	5.28		0.31	150.35	0.71
	420.00		3.40	255.00	38.00	0.09	0.61	0.37	1.26	26.50	0.30	210.00	1.20	1.80	5.39		0.36	151.20	0.63
PREDICTED	to		to													5.00			
PANELS												to							
23 TO 28	550.00		4.50	255.00	38.00	0.07	0.46	0.35	1.58	26.50	0.30	275.00	1.15	1.72	5.15		0.27	148.50	0.79
NEW MINE	aver. values	495.00	3.95	211.70	38.00	0.08	0.43	0.29	1.15	26.50	0.30	247.50	0.93	1.39	4.17		0.30	148.50	0.57
PREDICTED	400.00		4.50	211.70	38.00	0.10	0.53	0.32	1.44	26.50	0.30	200.00	1.44	2.16	6.48		0.38	152.00	0.72
MAX DIMEN	to		to													5.00			
LIMITS												to							
15 TO 28	590.00		3.40	211.70	38.00	0.06	0.36	0.31	1.05	26.50	0.20	295.00	0.71	1.07	3.22		0.22	129.80	0.53

TABLE 2: PREDICTED MAXIMUM SUBSIDENCE CALCULATIONS FOR ELLALONG COLLIERY EXTENSION

* Maximum subsidence modified by mine site survey

** Maximum strains, tilt etc based on Newcastle Guideline (Holla, 1987)

The chain pillars at Ellalong will have limited width (38 m) compared with the depth of mining, and will yield a little over time but will probably not fail. This phenomenon is observed in the records of subsidence over Longwall Panels 5 to 9 at Ellalong. Although the relatively smooth surface profiles could be attributed solely to the great thickness of cover strata, the coal remaining in pillars between each longwall panel also reduces the amount of subsidence, strain and tilt.

The mining height will influence subsidence levels. The mining height in the proposed longwall panels will vary between 3.4 m and 4.5 m depending on coal quality. This compares with 3.5 m to 3.6 m in the existing mine, and it complicates prediction because it is not known where the variation will be. Despite this the uncertainty can be quantified by considering the end points of subsidence based on maximum working height at shallowest depth of cover, and minimum working height at greatest depth, along with variation in longwall panel width.

The predicted maximum subsidence values are shown in Table 2 prefaced "NEW MINE PREDICTED PANELS 15 to 22, and 23 to 28". The values are reduced to take into account the particular local geology of the Ellalong area. Maximum subsidence is between 1.0 m and 1.6 m depending on cover depth and mined height. The maximum subsidence range for the first eight panels (15 to 22) will be between 1.1 and 1.4 m, while the range for the other 6 panels (23 to 28) is 1.3 m to 1.6 m. The maximum subsidence will occur with 4.5 m high workings at 550 m depth in the second group of eight widened panels.

The variation in maxima with other combinations of mining height, seam depth and panel width is also shown for all panels. It demonstrates that the extremes of subsidence influencing factors are catered for in the generalised calculations for each block of panels.

3.2 MAXIMUM STRAINS AND TILT

Surface strains have been calculated using the empirical formulae provided in the Newcastle Subsidence Guideline. The formulae in this guideline have been selected because the measured strains at Ellalong Colliery do approach the values predicted by the Newcastle Guideline, although actual ground strains are lower. The values given are consequently slightly higher than expected maxima.

Maximum compressive and tensile strain plus surface tilt predictions are given for in Table 2. Overall tensile strain values are in the range 1 mm/m to 1.7 mm/m while compressive strain values are in the range 1.0 mm/m to 2.2 mm/m. Tilt, which is the change in vertical movement over the measured interval, ranges between 3 mm/m and 7 mm/m. Maximum ground curvature is around 2 km, but commonly around 5 km.

Measured strains over Ellalong Panels 5 to 9 are the maximum recorded by the colliery, and peaked at 3.82 mm/m Tensile in the region of a cross cutting dyke. Otherwise surface strains remained close to zero. One compressive strain value of 5.5 mm/m is recorded but it is isolated, and the survey peg showed no previous history of movement, so is discounted.

Tilt measurements were not recorded, but a cross cutting dyke impacted on surface subsidence to the extent that Sandy Creek Road was disrupted, so localised tilts would have been very high at that time. The low strain records indicate that without discontinuities like the dyke tilt levels would be low.

3.3 SHAPE OF SUBSIDENCE PROFILES

A complete subsidence profile can be constructed with additional points, Goaf Edge Subsidence, Inflection Point, and the Zero Subsidence Limit. The zero limit is taken as 20 mm of ground movement to account for seasonal soil movements. Subsidence at the Inflection Point, which is the location of the change in surface stresses from tensile to compressive, is half the maximum measured, while the amount of goaf edge subsidence is the that measured over the outer most edge of the mined zone.

The guideline does predict high, and this is shown with determination of the Point of Inflection, and Goaf Edge Subsidence in Table 1, row 2.

Table 1 shows the real location of the Inflection Point over Panel 9, and the actual amount of subsidence, at the end of the first row. The predicted value is shown in the row beneath. The actual subsidence is 0.6 m at 123 m inside the goaf edge, whereas the guide would give its location 102 m inside, and with subsidence of 0.7 m. The differences are small, and thus give justification for using the guide for those determinations that cannot be made any other way. But it is clear that the maxima listed in Table 2 for the new mining area are indeed maxima.

The subsidence profiles developed at Ellalong are much flatter than the Guide would predict because of the massive nature of the cover rocks. While the profile is flatter, particularly in the tensile stress zone away from a mined panel, the actual limit of subsidence is similar for both measured and predicted distances. The zero limit ranges between 200 and 300 m from the edge of a mined area.

In summary the measurements at Ellalong Colliery to date indicate that less subsidence, strain and tilt occur over the surface than the best available guideline, the Newcastle Guideline, would predict. Actual subsidence is 300 mm to 400 mm less, strains are up to half predictions, and tilts also up to half predicted values. Goaf edge subsidence, and Inflection Point subsidence are substantially less, yet the limit for subsidence remains similar.

At the same time unusual surface events occurred in the vicinity of a large dyke, which extends from below seam to surface.

4.0 MINING SUBSIDENCE IMPACTS

4.1 SURFACE FEATURES

The land surface above the proposed workings comprises part of the valley of Ellalong Creek and the slopes of part of the Broken Back Range. Creek level drops from RL 130 on the eastern side to RL 120 on the western side of the longwall area. The creek RL remains at RL 120 west of the proposed longwall panels, and has undergone subsidence from previous colliery workings. The land on either side of the creek has been cleared and developed for farming.

The Broken Back Range is north of the creek and is covered by State Forest, Crown Land, and land owned by the colliery/partners. Maximum RL is 227 m at Howard Trig, while the spine of the range varies between 194 m and 170 m. Howard Trig is a prominent hill within the proposed mining area. The northern side of the range slopes down to approximately RL 110 m within the longwall area.

The ridge line of the Broken Back Range accounts for the large variation in depth of the Greta Seam over Longwall Panels 23 to 28.

The land around Ellalong Creek is subdivided, and 21 properties will be within the Zero Subsidence Line as outlined in Figure 1. The properties are numbered in accordance with the EIS document, and are listed in Table 3 for ready reference. The area is not in a declared Mine Subsidence District. However this makes no difference as recent changes to the Mine Subsidence Act means that property owners are protected as if the area was already declared.

Most houses and sheds, including poultry sheds are visible from public roads, and the visible buildings are listed in Table 3 below. However restrictions on entry to private land mean that the list is incomplete. In general houses are either older homes built on piers, or newer homes of brick veneer on slab construction. Some house have concrete water tanks nearby, and most have garages or sheds.

Property 15 has two long poultry sheds with feed silos in addition to farm sheds, and the Duff property has horse stables at the northern end.

All properties are fenced, and have power to dwellings from the main feeder lines along Sandy Creek and Quorrobolong Roads. The spans of the lines to dwellings is very large in a number of cases. Underground telephone lines are laid throughout the area. A number of properties have stockyards.

There is one licensed water bore within the longwall mining area (Property 12), and one licensed bore at the zero subsidence limit (Property 14). The aquifer in the Property 12 water bore is 10.7 metres deep, and is 0.6 m thick, while the borehole depth is nearly 40 m. Recorded yield is 1 L/sec, and water is "salty", but there is no record of its use on public file.

There are two timber bridges, and several concrete culverts that will be affected by subsidence. Three concrete culverts occur along Sandy Creek Road opposite the property 48, which also has some erosion control structures.
In the mining area a short section of Sandy Creek Road, and all of Quorrobolong Road are sealed.

In addition to improvements there are more than 30 dams situated on the alluvial plain or on the slopes adjacent to the plain, which will be undermined, or within the zone of subsidence.

4.2 IMPACT OF SUBSIDENCE ON IMPROVEMENTS

Subsidence will be confined to the area immediately above the planned longwall panels, and from approximately 200 m to 300 m beyond the longwall extraction area. Coal extraction will lower the land surface by up to 1.6 m as shown in Figure 1.

The amount of subsidence beyond the actual mining panels is low at 300 mm or less. This amount, along with the low strain values predicted will cause minimal to no disturbance to structures and improvements, where there are normal strata beneath.

Surface disturbance above the actual mining panels will generally be low because of the depth and dimensions of workings. The strain values measured over workings at Ellalong have been less than 1 mm/m tensile or compressive, except around a major dyke. These levels applied to house and farm sheds would result in negligible damage. Long poultry sheds would suffer some distortion because of their length. The prediction figures equate with low damage levels according to established criteria. There are however invariably occasional exceptions to the expected maximum because of unknown localised variability in rock strata, topography or geology.

Properties 9, 10, 11, 12, and 15 will experience maximum subsidence. Structures close to Sandy Creek Road on properties 10 and 11 will experience subsidence between 0.3 and 1.0 m. Strains and tilt levels should be considered as the maximum predicted. Cottages on properties 9, and 12 will experience maximum subsidence by virtue of locations towards the centre of the longwall area.
The chicken sheds on property 15 are positioned over the goaf edge of panel 22 and will be subsided around 0.5 m at the western end and 0.2 m at the eastern end. Strains and tilt will be near the maxima predicted. The cottage on property 15 will experience far less subsidence than 0.2 m because it is well beyond the longwall panels. This also applies to properties 13, 14, 20, 21, 30, and 52.

PROPERTY NUMBER	UNDERMINED BY LONGWALL Nos	VISIBLE IMPROVEMENTS
9	15 - 17	Nil visible
10	15 - 18	Metal clad workshop/shed plus 2 small metal clad sheds
11	16 - 19	Metal roof cottage, 1 small & 2 large sheds
12	17 - 22	Large metal roof cottage, 2 large metal sheds
13	18 - 19	Metal roof cottage & stable plus metal shed
14	19 - 22	W'board/metal roof cottage, 2 metal sheds, 1 Galv. shed
15	20 - 22	W'board/metal roof cottage, large metal shed, 1 C'bond shed, 2 Chicken Houses, food silos
16	15 - 16	Nil
17	22	Brick/tile cottage, 2 brick/metal garages
18	Edge of Zero Subsidence	Nil
20	22	3 Brick/tile cottages, 1 C'bond garage
21	Within subsidence	B/V house, other details not known
22	Within Subsidence	Nil
28	27 - 28	Nil visible
29	28	Nil visible
30	Edge of Zero Subsidence	House, concrete tanks, shed
32	27 - 28	Brick/Tile cottage, 3 Chicken sheds
42	Within Subsidence	Nil visible
48	Within Subsidence	Nil visible
51	22	Powerline
52	Within Subsidence	New W'board cottage, older cottage

TABLE 3: PRIVATE PROPERTIES AFFECTED BY SUBSIDENCE

* "Edge of Zero Subsidence", or "Within Subsidence" means that there is no longwall panel under the property but the property is within the Zero Subsidence Limit.

Other improvements within the mining area which include fences, power lines, concrete culverts, two timber bridges and buried telephone lines will be minimally affected. Location of water mains is unknown.

With regard to dams there has been no reported damage to any since commencement of longwall operations. With at least 30 dams in the area the experience to date is important. It follows that maintenance of water supplies and a mechanism for repairs assistance will be necessary should there nevertheless be any of water loss from a dam as a result of subsidence.

4.3 IMPACT ON LAND SURFACE

The land surface varies from the rolling flats adjacent to Ellalong Creek to the steep ridges of the Broken Back Range. The creek drops 10 m in elevation across the mining area, and the lowering of sections of the creek by up to 1.6 m will increase ponding along its course. The impact of previous subsidence of the creek has been minimal, and it is expected that lowering of the creek, and the surrounding land will have a similar minimum impact. The nature of strata, coupled with the low strains and tilt mean that there will be negligible impact on water bearing capability of unconsolidated soils. The one water bore in the area is shallow, and no impact is expected.

The impact of subsidence along the Broken Back Range will also be negligible. Although there are small extremes in topographic relief in the forest covering the range, it is unlikely that there will be any visible effects. On the steeper slopes some ground creep may occur down the slopes, particularly where panels retreat in the same direction as the slope. Surface cracking is unlikely due to the low strains expected at the surface.

Subsidence will be progressive as mining proceeds actual ground movement at any one time will be local in area, and will vary in effect. Measured strain and tilt levels are low, while predicted maxima, based on guidelines that are over predicting values, do approach levels where significant structural damage to buildings is likely on anything but a small scale.

Subsidence movements of any point at the surface are delayed until well after the passage of the longwall beneath. This delay is due to the massive nature of the Branxton Formation. Holla (1986) measured sub-surface movements over Longwall Panel 2 and found that surface movements were negligible when the face passed beneath. Mining face retreated 400 m before 90% of surface subsidence was recorded. There after movement will continue, as adjoining panels are mined. At some stage the massive strata fails because the amount of roof hanging up is too great. In the past such roof caving, or settlement appears to have produced pronounced vibration events that are subject to separate environmental assessment elsewhere within the Environmental Impact Statement.

4.4 IMPACT ON ARCHAEOLOGICAL SITES

Mining by underground methods at Ellalong will lower the surface by between 1.0m to 1.4 m. In the process the surface can move transversely by small amounts (ie, millimetres) as well as vertically downward. After mining the ground surface stabilises again.

Virtually all the ground surface remains intact. There are no cave structures known to contain archaeological remains that would be affected by mining, nor are there any cliff faces that might fall, nor soil faces that could subside and bury currently visible archaeological sites.

Concern has been previously expressed that erosion caused by subsidence, or loss of relics down cracks opened by subsidence will damage the archaeological record. The incidence of these two events will be so low that consideration of such an event should be discounted. The incidence would be infinitesimally small compared with the ongoing damage caused by farming and grazing. It ought to be remembered that the area has been subjected to intensive surface modification for the last 100 years.

Underground coal extraction, while lowering the surface, is still going to leave an essentially intact surface. The levels of subsidence are low, as are strain values, above the planned longwall panels which will undermine the sites. These factors will limit any movement of archaeological material from their present positions.

5.0 SURFACE MANAGEMENT

Management measures to mitigate the impact of subsidence caused by full seam extraction can be generally incorporated into normal land management programs for Company owned land. The principal management measures required will be any necessary to cover any ground cracking to avoid the chance of stock injury in the short term.

The most productive land is the alluvial land surrounding Ellalong Creek. The land is used primarily for grazing, and sometimes for cropping. Both land uses may require minor regrading of any ponded areas resulting from subsidence. Experience to date has not shown this to be necessary, but the issue is noted to ensure full awareness of the possible likelihood. The need for, and extent of regrading will depend on the land use.

Ellalong Colliery has in place a subsidence policy to assist private land owners where the provisions of the Mine Subsidence Compensation Act do not apply. With the mechanistic framework for covering the cost of any rehabilitation in place, land surface repair can be carried out by agreement with the land owner, and Ellalong Colliery. The policy also covers replacement of water supplies in the event of a loss. No such replacement has proved necessary to date.

The actual amount and timing of likely subsidence at any point on the surface can be determined accurately from the location of workings, and the delay before surface effects appear. Consequently any areas containing structures that might be adversely affected by subsidence can be visually monitored, and remedial action quickly undertaken if required. The emphasis is on possible impacts because the experience to date is one of little disturbance to surface improvements. However even the rare possibilities are required to be addressed by the impact assessment process, and are discussed below.

For dams this may mean partial reconstruction. In the unlikely event that any surface cracks appear they will be dozed over to prevent injury to stock, and restore the surface land. Fences can be inspected and repaired if posts are move out of alignment or wire broken. Pumps may need to be re-seated. Power lines, especially private ones, should be monitored as poles can tilt, causing power lines to break. Houses will need to be given the most attention, and slight damage is likely to occur at levels considered repairable.

The banks of the creeks will need to be monitored for signs of slippage and erosion. Any such damage should be speedily stabilised before installation of permanent bank stabilisation measures. This work would be under the control of the relevant authorities. Experience to date with settlement of creeks and swampy areas is that there has been no discernible change.

The forgoing indicates that there may be impacts on the surface, but those impacts will not stop present land uses. Damage that might occur, as listed in this report, is capable of speedy repair. Any temporary loss of land use is recoverable through the Mining Act provisions, or by legal agreement with Ellalong colliery. The National Coal Board (NCB) damage code suggests that damage will be slight. This assessment considers the damage levels will be little different that already experienced (leaving aside vibration events).

Houses for example, have on detailed investigation proven to be little affected by subsidence events such as settlement, tilt, and strain. The Mines Subsidence Board has paid claims for 4 house subject to subsidence damage in these categories, and purchased one property. This past experience provides a good indication of expected future structural damage to dwellings and other structures. The ability to protect and repair the houses will be improved by monitoring over panels preceding those underlying houses at risk. Once some monitoring data are available detailed impact studies on the houses will be possible.

The second phase of the application process required by Ellalong Colliery to undertake mining according to the requirements of the Department of Mineral Resources also affords protection to property owners. At this stage detailed predictions are carried out on all relevant structures and plans to avoid, minimise or repair are put in place in consultation with property owners.

6.0 CONCLUSIONS

Longwall extraction operations in the Greta Seam will cause surface subsidence estimated at between 1.0 m and 1.6 metres, depending on working thickness within the seam, and depth and width of workings. At the same time depth of cover increases to the southeast and under the Broken Back Range. This means that the amount of subsidence will vary slightly across the mine area.

In general the impact on the surface is expected to be low. While the damage code indicates slight damage, the location, age and construction of the houses might result in greater damage. Improved assessment of possible structural damage will become available with results of ongoing subsidence monitoring.

The Company's subsidence management policy will have provision for assistance where any damage is not covered by legislation.

Existing water courses will not be unduly affected, and are expected to re-establish.

There is a low probability that some dams might suffer minor damage, requiring replacement water supplies until repaired and refilled.

The impact on surface run off and ground water is predicted to be minimal.

There is expected to be minimal to no impact on archaeological sites within the mined area. The nature and concentration of sites coupled with the small amount of actual surface damage that might occur renders the chance of damage to a particular site extremely small, and this must be considered a tolerable risk level.

Overall the subsidence impacts from longwall operations in the Greta Seam will be small, and capable of mitigation and control. They will require ongoing subsidence monitoring, coupled with land management practices, and arrangements to protect, assist or compensate property owners. Experience in managing the surface, particularly the more productive cleared land will increase with time, and management plans should be capable of adjustment to use experience gained.

G E HOLT & ASSOCIATES PTY LTD

Graham Holt

Graham Holt MIEAust CPEng
Principal Geotechnical Engineer

REFERENCES

HOLLA, L (1988) Effects of Underground Mining on Domestic Structures - Prediction Versus Performance. 5th Aust.-New Zealand Conference on GEomechanics, Sydney, N.S.W. August.

HOLLA, L (1987) Mining Subsidence in New South Wales. 2. Surface Subsidence Prediction in the Newcastle Coalfield. Dept. of Mineral resources, N.S.W.

APPENDIX I

SUBSIDENCE TERMINOLOGY

SUBSIDENCE TERMINOLOGY

The following symbols, terms and definitions are taken from " Mining Subsidence in New South Wales 1. Surface Subsidence Prediction in the Southern Coalfield" by L. Holla, published by the Dept of Mineral Resources, December, 1985. Units of measurement are given in brackets.

H = cover depth (m)
L = panel length (m)
T = effective extracted seam thickness (m)
W = panel width (m)
e = distance between panel centre line and point of maximum subsidence

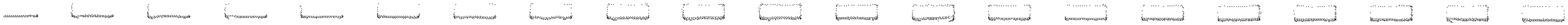
D = distance of inflection point from goaf edge (m)
S = subsidence at any point (m)
Sc = subsidence at panel centre line
S_z (or S_{max}) = maximum subsidence along a profile (m)
Gmax = maximum change in tilt along a subsidence profile (mm/m)
Rmin = minimum radius of curvature along a profile (km)
+Emax = maximum tensile strain along a profile (mm/m)
-Emax = maximum compressive strain along a profile (mm/m)
K1 = tensile strain factor (non-dimensional)
K2 = compressive strain factor (non-dimensional)
K3 = tilt factor (non-dimensional)

TERMS AND DEFINITIONS

Cover depth(H): The depth of a seam below the surface averaged over the extraction panel.

Critical area: The area of panel which causes the maximum possible subsidence of one point on the surface. The area which causes S_{max} to reach its maximum value.

Extracted seam thickness: The thickness of seam extracted, averaged over the panel.



Effective extracted seam thickness (T): The extracted seam thickness, modified if required, to account for unmined pillars (modification based on the percentage of extraction within the panel).

Goaf: Mined out area into which the immediate roof layers break off in large fragments.

Inflection Point: The point on the subsidence profile at which strain changes sign and subsidence is half S_{max}.

Panel: The plan area of coal extraction.

Panel length (L): The longitudinal distance along a panel measured in the direction of mining.

Panel width (W): The transverse distance across a panel, usually equal to the face length plus the widths of roadways on two sides.

Sub-critical area: An area of panel smaller than the critical area.

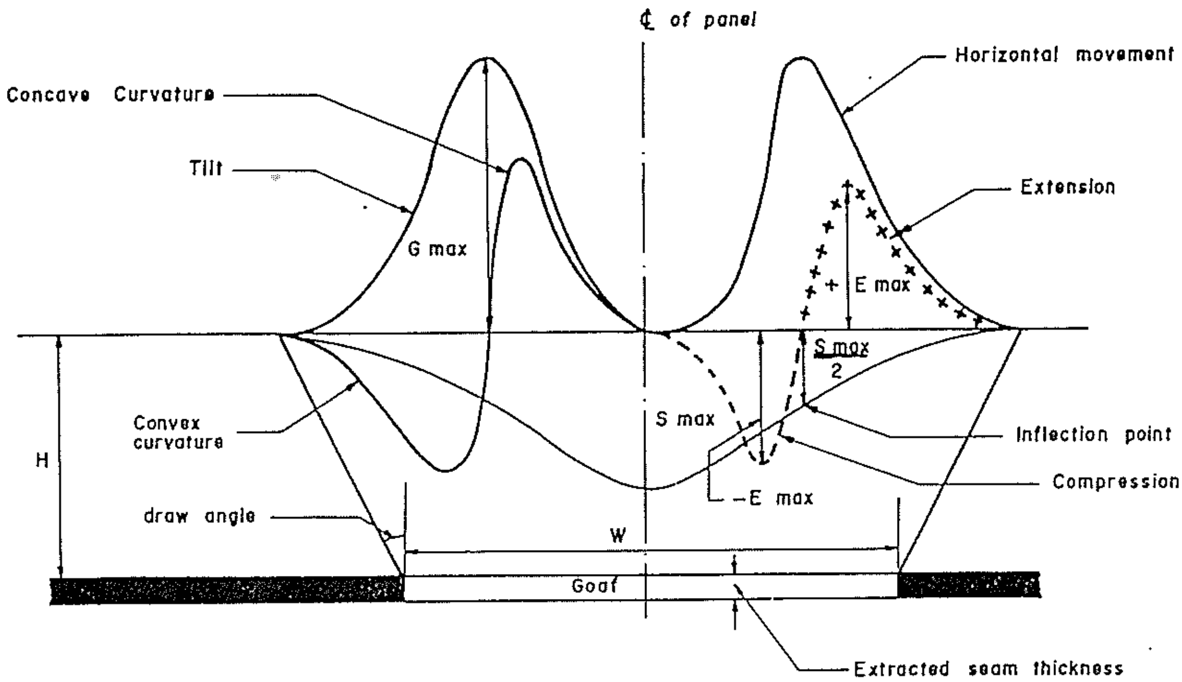
Super-critical area: An area of panel greater than the critical area.

CRITERIA FOR DETERMINATION OF MAXIMUM SUBSIDENCE

Maximum subsidence can be predicted using the empirical guidelines if the following criteria are met:

- Only one seam is extracted, or in the case of multi-seam extraction, the workings in the other seams are too far away to have any influence.
- The extraction panel is nearly rectangular. Otherwise average width used.
- The extracted seam thickness is adjusted, if required to account for unmined pillars or pillar remnants. The adjusted thickness is referred to as the effective extracted seam thickness (T).
- The residual subsidence has occurred.
- The roof contained within the extracted panel is caved.
- The overburden is free from dykes, faults or other geological discontinuities which can alter the normal subsidence behaviour.

For the Newcastle Coalfield, maximum subsidence S_{max} occurs when panel width is equal to or greater than 1.6 x cover depth (H). The probable value of the maximum possible subsidence for critical and super-critical extraction widths can be taken as 0.55T. For the Southern Coalfield, S_{max} is 0.65T when W > or = 1.4 x cover depth (H).

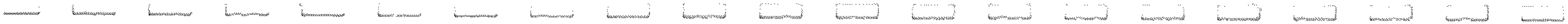


Characteristics of trough subsidence
Left half of profile: Vertical Components
Right half of profile: Horizontal Components

APPENDIX II

NATIONAL COAL BOARD (GREAT BRITAIN)

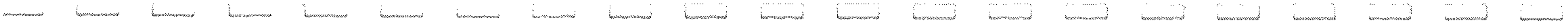
CLASSIFICATION OF SUBSIDENCE DAMAGE



As a result of experience gained over many years (in Great Britain)...... a damage scale classification has been devised which lists five accepted grades of subsidence damage. The classification is shown in the table below. The factors of strain and building length used in compiling the classification give only a general guide in the prediction of damage intensity. Accurate prediction also depends upon an expertise difficult to reduce in quantitative terms and which can only be acquired from a wide experience with buildings of various age and type of construction.

Change of Length of Structure	Class of Damage	Description of Typical Damage
Up to 0.03 m	1. Very slight or negligible	Hair cracks in plaster Perhaps isolated slight fracture in the building, not visible on outside.
0.03 m – 0.06 m	2. Slight	Several slight fractures showing inside the building. Doors and windows may stick slightly. Repairs to decoration probably necessary.
0.06 m – 0.12 m	3. Appreciable	Slight fracture showing on outside of building (or one main fracture). Doors and windows sticking; service pipes may fracture.
0.12 m – 0.18 m	4. Severe	Service pipes disrupted. Open fractures requiring rebonding and allowing weather into the structure. Window and door frames distorted; floors sloping noticeably; walls leaning or bulging noticeably. Some loss of bearing in beams. If compressive damage, overlapping of roof joints and lifting of brickwork with open horizontal fractures.
More than 0.18 m	5. Very severe	As above, but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken with distortion. Severe slopes on floors. If compressive damage, severe buckling and bulging of the roof and walls.

National Coal Board Classification of Subsidence Damage (from Subsidence Engineers Handbook, Mining Department, NCB, 1975)



2.0 ELLALONG COLLIERY EXTENSION REPORT ON GROUND VIBRATION CAUSED BY MINING SUBSIDENCE, RENZO TONIN AND ASSOCIATES, 5 JANUARY 1995

TECHNICAL REPORT

RENZO TONIN & ASSOCIATES PTY LTD
Level 16, 9 Castlereagh St., SYDNEY NSW 2000 Ph: 231 1633 Fax: 232 7260
ACN 002 225 078

ELLALONG COLLIERY EXTENSION

REPORT ON GROUND VIBRATION CAUSED BY MINING SUBSIDENCE

Report No: T379F105

5 January, 1995

TABLE OF CONTENTS

1. INTRODUCTION

Underground mining in the current workings of the Greta Seam located approximately 350m beneath the Ellalong township began approximately in July 1983. The proposal considered in this report is an area located to the north of the current workings. The long wall panels which are the subject of this report are numbered LW16 to LW28.

It is now widely recognized that ground subsidence resulting from underground mining may also have associated with it ground vibration caused by the sudden failure of the rock strata above.

The aim of this report is to assess the likely impact of ground vibration caused by underground mining on houses in the immediate vicinity, in particular the likelihood of damage which may possibly occur.

As with the study of Earthquakes, it is not possible to predict the magnitude of ground vibration resulting from subsidence nor is it possible to predict the epicentre or the likely time of occurrence. Geologists point to the edge of the longwall as being the most likely place for shear fractures but lack of data prevents a more positive prediction.

The fact is, that interest in vibration has only occurred over the past few years in Sydney and therefore data relating to this subject is very scarce.

However, over the years, Ellalong Colliery and the Mines Subsidence Board have monitored a number of ground vibration excursions at various locations in Ellalong resulting from the current mining activity. The data was analysed by Renzo Tonin & Associates Pty Ltd in report reference T331FT05 dated 5th October 1994. An important conclusion of the report was that the vibration data was shown to scale in a manner consistent with ground vibrations associated with subsidence.

It is possible to derive from the data a set of scaling laws which are assumed to apply to this region generally. The scaling laws assist in predicting vibration levels at given distances provided that the magnitude of the events (equivalent to the Richter strength of an earthquake) and the epicentre of the vibrations are known.

The difficulty we face is that the magnitude and epicentre of ground tremors are not known with any certainty and cannot be determined *a priori*. Therefore, the approach taken in this report is to assume that the magnitudes previously measured are likely to occur again in the subject region of mining considered here.

The epicentre is assumed to be located anywhere in the subject region. For this site, however, the exact location of the epicentre is not a critical factor because there is no predominance of housing development in any one region on the site.

We point out that these are conservative assumptions given that the cantilever surcharging (cover depth) is 100m less for longwalls 13, 14,15 and 16 compared with the current workings at Ellalong and hence it is less likely that the same magnitude of events would be expected. However, for longwall 17 onwards, the same magnitude of events may occur.

Based on these assumptions, we are able to determine a possible range in vibration levels which can be expected **if a vibration history similar to that experienced in the current workings is repeated here.**

We stress that there is no mechanism by which we are able to predict that the vibration history will repeat itself. In fact it is quite possible that no vibration will occur at all.

2. DESCRIPTION OF HOUSES IN THE AREA AND SUSCEPTIBILITY TO DAMAGE

The location of the closest houses potentially affected by vibration from the mine are shown in Figure 1. Houses in the area were inspected from a vantage point on public roads nearby.

Houses in the region range from new residences to others which are possibly more than 50 years old. Construction materials included timber frame clad with weatherboard or compressed fibre cement sheeting. There were also a significant proportion which were brick veneer or possibly full brick construction. Practically all houses are single storey constructions. Some structures are chicken sheds.

Troublesome soft clays, or sands having a small clay content are not expected to be prevalent in this area. By comparison with other houses in the Ellalong area, foundations are expected to be strip or pad footings in buildings of more recent origin and brick or timber posts in some of the older houses. It is expected that the newer buildings are constructed on reinforced concrete raft slabs.

Visual inspections shows that some houses have corrugated iron or metal deck roofing and others are tiled.

Our experience with inspection of damage to houses in Ellalong from the current workings shows no consistent pattern which would categorise one particular form of construction as being more prone to reports of defects than another.

Neither does it appear on the evidence that a particular type of construction is more or less likely to suffer from a particular type of defect. For example no pattern emerges in the case of ceiling defects which would distinguish metal roof from tiled roof construction.

Vibration generally causes damage to structures by the action of differential movement in the structure. The upper part of a structure usually moves more than the foundation. If the upper part twists about the foundation, this racking motion produces characteristic shear stresses and failures particularly in cornices and ceilings.

When attempting to provide explanations for a defect present in a domestic residence it is important to be aware that there can be many underlying causes. In fact a combination of reasons frequently offers the most probable answer.

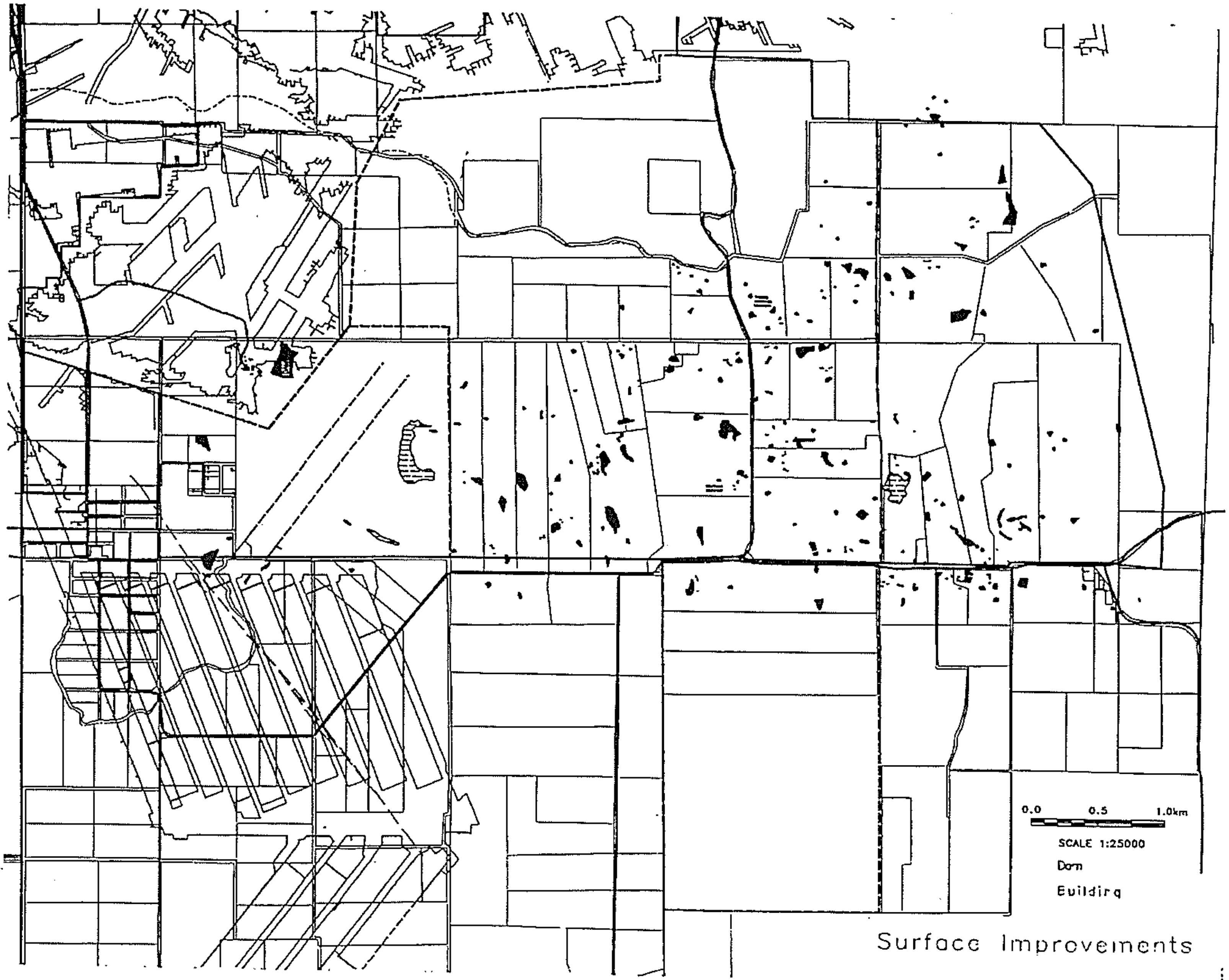


FIGURE 1: SITE PLAN SHOWING LOCATIONS OF HOUSES

In general terms these could include the following.

- There may be defects in the materials supplied for construction.
- Faulty construction techniques may have been used during installation.
- Most materials used in construction are likely to deteriorate with time. This process will be speeded up if circumstances are unfavourable or delayed by regular maintenance.
- A variety of external causes may responsible for the damage.

2.1 VIBRATION DAMAGE TO MASONRY AND CONCRETE

Cracks in the mortar between bricks are the first signs of damage in masonry. Crawford and Ward [1] recommend vibration levels up to 75mm/sec, measured perpendicular to the brick surface, can be tolerated before damage occurs.

Monolithic concrete, however, does not crack until particle velocities exceed 250mm/sec [1].

Reference [2] examines the effects of blasting on houses in Newcastle from channel deepening in the Hunter River. The response of a full brick house was investigated at Nobbys head which had been subjected to ground vibration levels as high as 22 mm/sec. Comparatively large amplitudes of vibration velocity were recorded on the exterior walls of this house. No significant exterior damage was evident in this case.

Brick veneer houses in the Stockton area were also examined in the study. One particular house constructed with lime mortar of poor quality was monitored. This house was one in a group subjected to peak particle velocities greater than 5 mm/sec for a significant number of blasts and all showed similar types of failure although the types of failure and the velocity levels are unreported.

2.2 VIBRATION DAMAGE TO PLASTER AND PLASTERBOARD

Siskind et al [3] in their study of ground vibration from mine blasting concluded that the following (low frequency) vibration levels were safe for residential type structures;

TABLE I - BLASTING VIBRATION LIMITS PROPOSED BY SISKIND et al

Type of Structure	Ground Vibration - Peak Particle Velocity mm/sec
Modern homes, drywall interiors	19
Older homes, plaster on wood lath construction for interior walls	12.5

3.0 THE NATURE AND CAUSE OF VIBRATION RESULTING FROM GROUND SUBSIDENCE

The long wall mining technique utilised to extract the coal resource permits a controlled collapse of the roof or goaf of the area from which coal has been extracted.

The earth subsides gradually over a period of time to fill the void. The pillars and abutments load up and ultimately this results in a tensile failure of the immediate roof cantilevers. Modelling work undertaken by the mine geologists and underground monitoring indicate that this occurs within 100m of the coal seam.

Two possible mechanisms for ground tremors include the following;

1. A sudden fracture of the rock lying above the mined out area due to the tensile and cantilever failure caused by the advancing mine face, and,

2. Slippage along a fault line or rock fracture zone.

This sudden release of energy results in ground vibration not dissimilar to a heavy weight falling on the ground. We refer to these vibration events as "ground tremors".

The ground tremors experienced at Ellalong have and are at present being monitored by a number of highly sensitive vibration instruments. These instruments record the vibration traces and the time of their occurrence.

The central issue of concern is the potential damage caused by the ground tremors to residences.

While very low amplitudes of vibration can be felt, this does not necessarily mean that such vibrations cause damage to buildings. Therefore, central to the discussion in the next section is a review of standards used by the international community to assess damage to structures caused by vibrations.

Ground vibration can be thought of as the rapid backwards and forwards motion of the ground. Most people may think that the best method of measuring the intensity of the vibration is to measure the maximum displacement amplitude of the motion backwards and forwards.

However, this is not the case because the displacement amplitude by itself is not a good indicator of damage potential, rather, one also needs to know how quickly the ground is moving backwards and forwards. For this reason, when assessing the likelihood of damage to structures from vibration, the amplitude or intensity of the vibration is most commonly measured in two ways;

- Acceleration amplitude, and,
- Velocity amplitude.

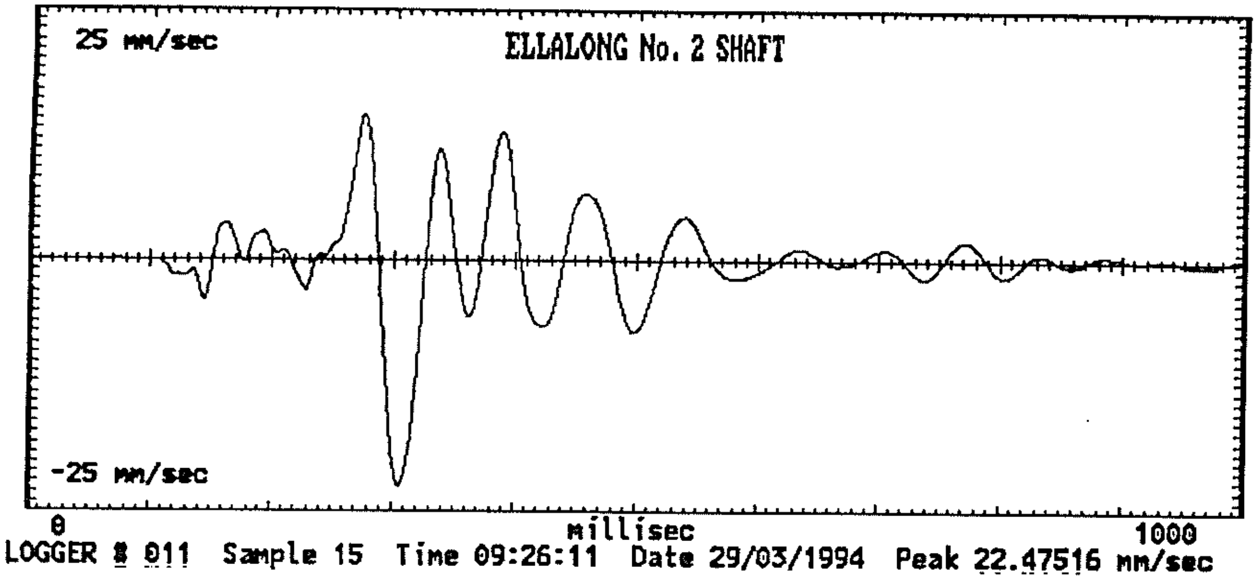
The choice of which of the two to use depends upon whether the ground vibration is of very low frequency (such as an earthquake) or moderately high frequency (such as a ground tremor caused by subsidence or blasting).

Acceleration amplitudes are typically used by seismologists to quantify damage potential from earthquakes. The low frequencies associated with earthquakes have the potential to produce large particle velocities and enormous displacements.

Earthquakes produce long-duration and very low frequency events. The vibration frequency and consequently the displacement and acceleration amplitudes depend strongly on the local geology. Thick solid overburden create long duration, low frequency wave trains.

Richter [4] observes that the damage potential of a given vibration is dependent on its duration - for example an earthquake lasting only for a few seconds may be insignificant but the same strength earthquake lasting for 25-30 seconds could produce very serious damage.

Ground tremors are short vibration events, usually not lasting more than a second. Figure 2 shows a typical ground tremor produced by subsidence.



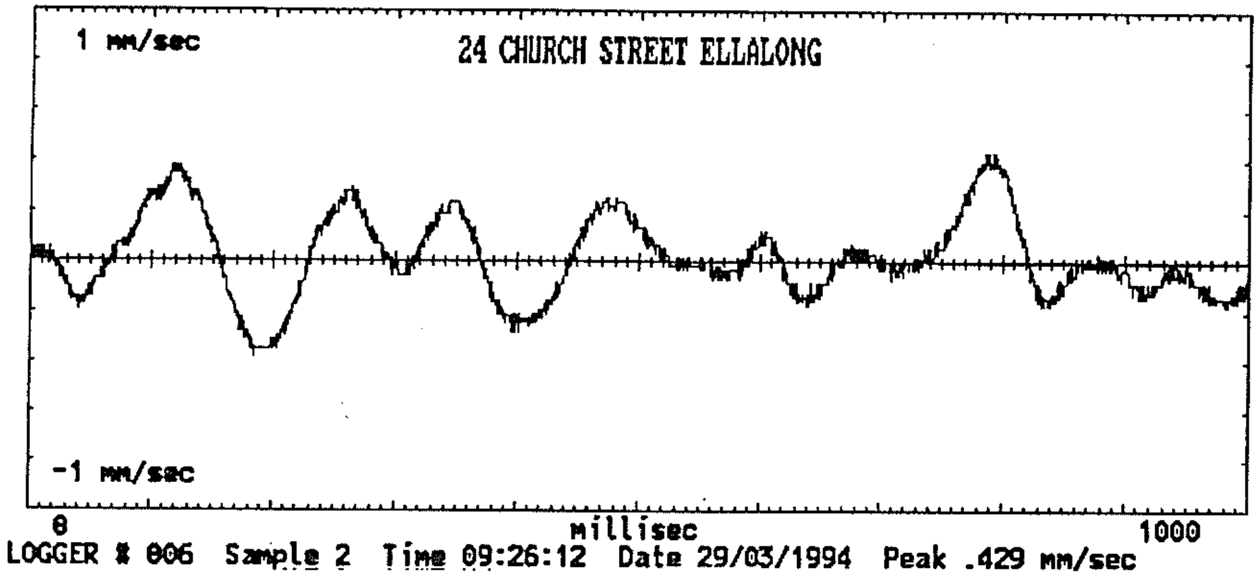


FIGURE 2:TYPICAL GROUND TREMOR CAUSED BY SUBSIDENCE

TOP TRACE- RECORDED AT No. 2 SHAFT

BOTTOM TRACE- RECORDED AT 24 CHURCH St.

4.0 VIBRATION DAMAGE CRITERIA

There are no standards anywhere in the world as far as we are aware that relate specifically to ground vibration caused by tensile failures. However, the nature of the vibration trace shown in Figure 2 is similar to that produced by blasting in open-cut mines. For this reason, and in the absence of any other directly applicable standards, we rely on those standards which specifically relate to damage produced in structures by ground vibration caused by blasting.

Without exception, these standards measure vibration amplitude by reference to the vibration velocity (i.e. the speed of backwards and forwards ground motion) and the units of measurement are millimetres per second, denoted mm/sec.

AS2187

The only standard in Australia which specifically relates to vibration damage resulting from ground vibration is Australian Standard AS2187 - 1993 "Explosives - Storage, transport and use".

This standard specifically relates to vibration effects produced by blasting but is relevant to ground tremors because the vibration resulting from both events is similar in nature.

The proposed limits take into account both human discomfort and structural integrity and would therefore be considered conservative. The standard recommends the following peak particle velocity limits;

TABLE II - VIBRATION LIMITS PROPOSED IN AUSTRALIAN STANDARD AS2187

Type of building or structure	Peak Particle Velocity mm/sec
Houses and low-rise residential buildings; commercial buildings not included below	10
Commercial and industrial buildings or structures of reinforced concrete or steel construction	25

The likelihood of damage in residential areas starts to increase at ground vibration levels above 10mm/sec.

DIN4150

The German standard DIN4150 "Structural Vibration in Buildings" 1986 has guideline values of vibration which may result in damage or a reduction in the utility value of the building. By a reduction in the "utility value" is meant;

1. an impairment of the stability of a structure or a building component,

2. a reduction in the load bearing capacity of floors,

3. the enlargement of cracks already present, or,

4. the separation of partitions or intermediate walls from load bearing walls.

The following table is recommended by the standard for evaluating the effects of short-term vibration in the frequency range of interest here, namely 10 to 50 Hz.

TABLE III - VIBRATION LIMITS PROPOSED BY DIN 4150

Type of structure	Foundation Vibration Velocity Limit mm/sec
Buildings used for commercial purposes, industrial buildings and buildings of similar design.	20 to 40
Residential dwellings and buildings of similar design and/or use.	5 to 15
Structures that, because of their particular sensitivity to vibration, do not correspond to those listed above and are of great intrinsic value (e.g. buildings that are under a preservation order).	3 to 8

Provided the values given in Table III are observed, damage due to vibration, in terms of a reduction in the utility value, is unlikely to occur. If the above velocity values are exceeded, however, it does not follow that damage is inevitable, rather the circumstances of the particular case should be taken into account.

ISO 4866

International Standard ISO 4866 "Mechanical vibration and shock - Vibration of buildings - Guidelines for the measurement of vibrations and evaluation of their effects on buildings" (1990) categorises buildings according to their vibration susceptibility.

For a reason that is not clear, this standard no longer incorporates damage acceptability criteria even though the original draft standard DP 4866 (1975) promulgated the following recommendations;

TABLE IV - VIBRATION LIMITS PROPOSED BY DP 4866

Category of Damage	Velocity Range mm/sec
Threshold damage consisting of visible cracks in non-structural members such as plaster walls, etc	3 to 5
Minor damage consisting of visible cracks in structural members such as masonry walls, beams, columns, slabs, etc	5 to 30
Major damage consisting of large permanent cracks in non-structural members, settlement and displacement	no greater than 100

Based on this information it is our opinion that a level of 5mm/sec peak vibration is a conservatively low level below which damage due to vibration is unlikely to occur. This threshold level is taken to be the criterion for this report.

5.0 MEASURED VIBRATION LEVELS AT ELLALONG

Vibration levels caused by the existing mining activity are continuously measured at Ellalong at No2 Shaft. The Mines Subsidence Board also commenced vibration monitoring at two locations in the community, namely Church St and Wallaby Gully Road in 1993.

Typical vibration traces of a tensile failure on the 29th of March 1994 measured simultaneously at two locations are shown in Figure 2. Reference to the figure shows the typical characteristics of the ground tremor, notably a short vibration signature with maximum energy in the frequency range 10-13Hz.

The duration time of the ground tremors is of importance because in the case of vibrations of short duration the potential for damage is significantly less compared with long duration events.

If only for this reason, one should not apply the same magnitude descriptors to tensile failures as we do to earthquakes. In particular, the Richter scale measurement applied to short duration ground tremors can be entirely misleading as a measure of potential damage to structures.

The results of all the significant vibration events are shown in Figure 3. The squares in this figure depict the vibration measured at No 2 shaft while the diamonds depict the levels measured in Church St and Wallaby Gully Road.

Also shown on this figure is a line representing a vibration level of 5mm/sec below which it is considered, from a review of the standards quoted above, that damage is unlikely to occur.

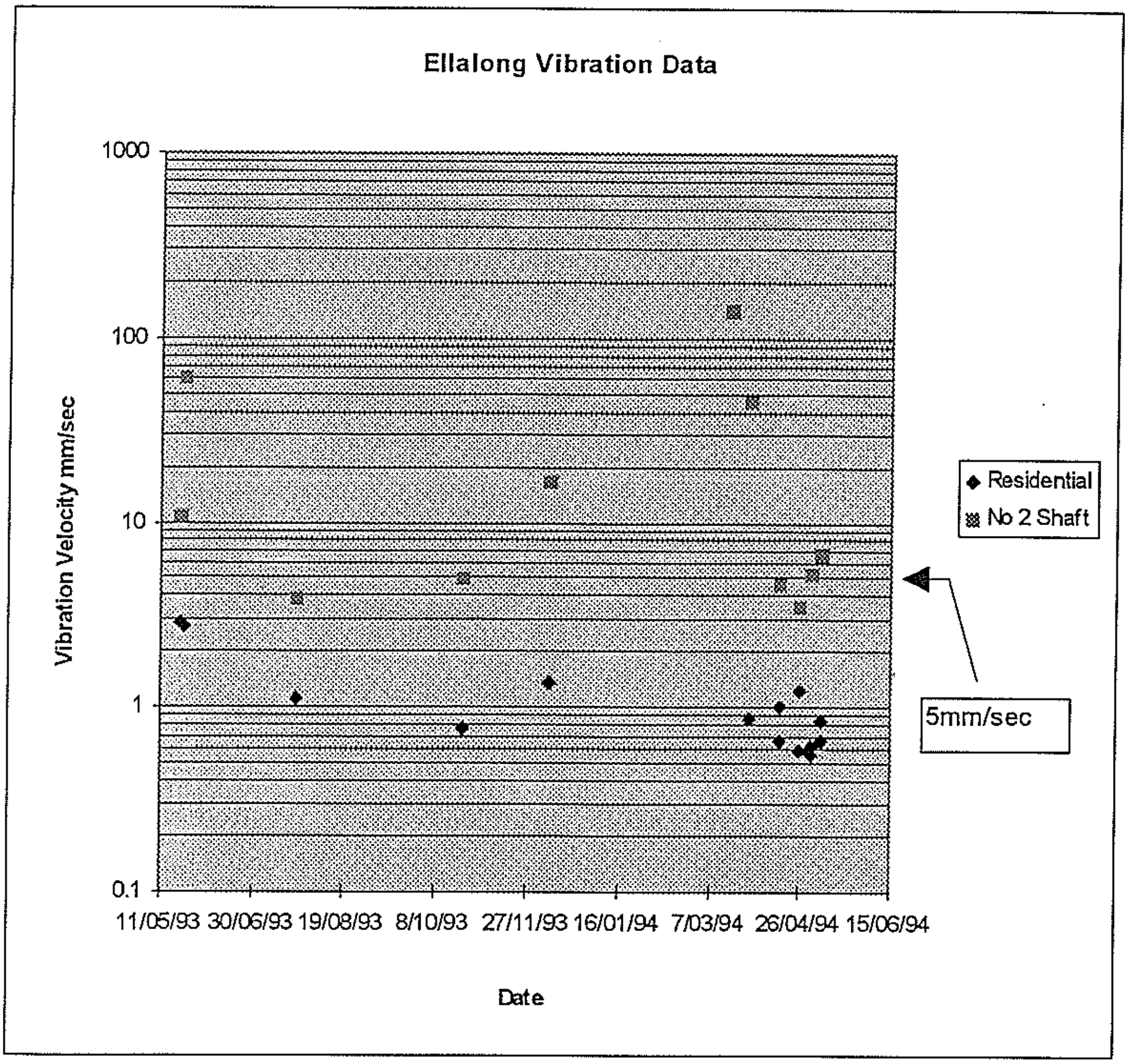


Figure 3 - Measured Vibration Levels at Ellalong from Current Workings

The determination of the epicentre of vibration events normally requires a considerable body of data collected simultaneously at many locations. At Ellalong, most vibration events were recorded simultaneously at only two locations and some at three.

The measured vibration data scales reasonably well with known theory as shown in Figure 4. This implies that the data is consistent with vibration events relating to tensile failures.

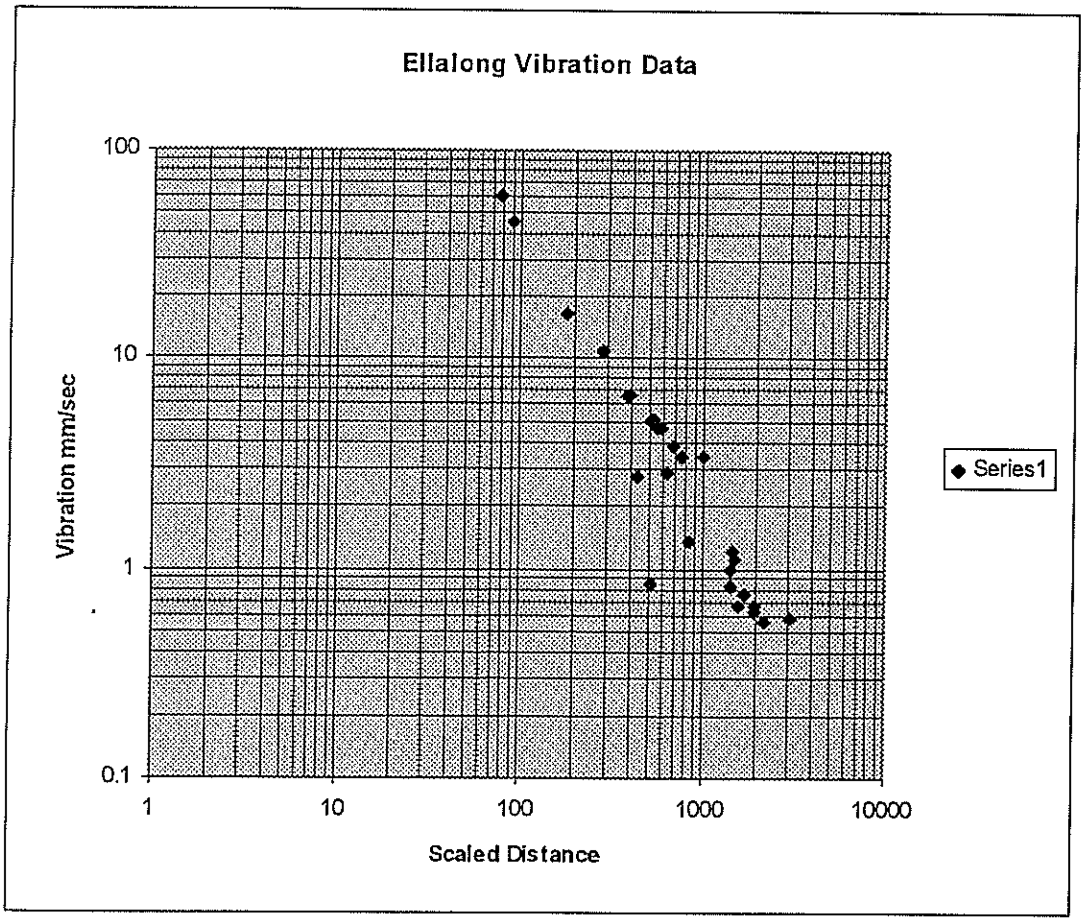


Figure 4 - Measured Vibration levels Scaled for Distance Measured from Epicentre

6.0 PREDICTED VIBRATION LEVELS FROM CURRENT PROPOSAL

We make the conservative assumption that magnitudes previously measured in Ellalong from the current workings are probable in the subject region of mining considered here. However, as previously stated, the cover depth is 100m less for longwalls 13, 14,15 and 16 compared with the current workings at Ellalong and hence it is less likely that the same magnitude of events would be expected. However, for longwall 17 onwards, the same magnitude of events may occur.

The epicentre is assumed to be located anywhere in the subject region although it is more likely that it is located close to the advancing longwall face. The exact location of the epicentre, however, is not critical to this study because there is no predominance of housing development in any one region on the site.

Based on these assumptions, we are able to determine a possible range in vibration levels which can be expected **if a vibration history similar to that experienced in the current workings is repeated here.**

The magnitude of ground tremors is measured by a non-dimensional number which can be likened to the Richter scale for earthquakes. The maximum vibration magnitude recorded at Ellalong is 3.05. The typical highest levels are in the range 1.0 to 2.0. Must vibrations measured have a magnitude less than 0.5

The following table shows, for magnitudes in the range considered, the horizontal distance beyond which the vibration level will be less than 5mm/sec peak.

TABLE V - SUMMARY OF THE EXTENT OF VIBRATION IMPACT ON HOUSES

Vibration Magnitude	Probable Relative Occurrence	Distance at Which Vibration Level Will be < 5mm/sec pk	Number of Houses Potentially Affected
3.0	0.7%	5,200m	50
2.0	1.4%	2,700m	9-18
1.0	1.4%	1,000m	6-12
0.5	7.5%	660m	3-4
<0.5	89%	Always	Nil

The column "Probable Relative Occurrence" means the likelihood, if a vibration were to occur, that its magnitude would be of the order indicated. A magnitude of order 3.0 may occur once in 1 or 2 years. This data is based on the Ellalong vibrations monitored by the mine and the MSB.

The approximate number of houses potentially affected by vibration of given magnitude are also shown. These numbers were determined by counting the houses within a given radius assuming the vibration epicentre is located anywhere on site.

If vibration occurs and the level of damage is similar to that experienced at Ellalong at present, then the type of damage one can expect will generally be cracks in cornices and wall junctions and the like which are more cosmetic than structural problems. The probability of vibration causing structural damage is extremely remote and even if it were to occur, would at most only amount to superficial damage consisting of visible cracks in structural members such as masonry walls, beams, columns, slabs, etc. In such a case, this would effect at most 2 or 3 houses.

We note that the Mines Subsidence Board has mechanisms for compensating damage caused by ground tremors resulting from tensile failures.

7.0 CONCLUSION

We conclude that a level of 5mm/sec peak vibration is a conservatively low level below which damage due to vibration is unlikely to occur.

If we assume that, for the new workings, the vibration history will be similar to that currently experienced then the potential damage to homes is likely to amount to cracks in cornices and wall junctions and the like which are more cosmetic than structural problems.

We stress that there is no mechanism by which we are able to predict that the vibration history will repeat itself. If ground tremors do occur, it is likely that the magnitude of vibration, for long walls 13-16, will be less than previously experienced. However, it is quite possible that no vibration will occur at all.

At worst, the probability of vibration causing structural damage is extremely remote and even if it were to occur, would at most only amount to superficial damage consisting of visible cracks in structural members such as masonry walls, beams, columns, slabs, etc. This would effect at most a small number of houses.

We conclude that the proposed extensions to the underground working may produce vibration which causes damage to houses but that such damage is likely to be of a minor nature.

REFERENCES

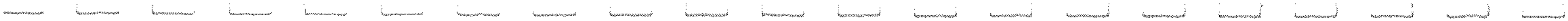
[1] Crawford, R and H.S. Ward. Dynamic Strains in Concrete and Masonry Walls. Dir. Bldg. Res. National Res. Council, Ottawa, Canada, Bldg. Res. Note 54, December 1965, 13pp.

[2] Goldberg, Meldrum and Drew. The Response of High-Rise and Domestic Buildings to Ground Vibration from Blasting, and its Relevance to the SAA Explosives Code AS2187. Trans I.E.Aust (Civil Transactions) CE27 No 3 August 1985.

[3] Siskind D. E. et al. Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting. Report RI 8507. US Department of Interior (1980).

[4] Richter, C.F. Elementary Seismology. W. H. Freeman and Co. San Francisco, 1958.

3.0 SUBSIDENCE MANAGEMENT POLICY FOR PRIVATE LANDS, ELLALONG / PELTON COLLIERY



THE NEWCASTLE WALLSEND COAL COMPANY PTY LIMITED

Subsidence Management Policy for Private Lands
ELLALONG/PELTON COLLIERY

THE NEWCASTLE WALLSEND COAL COMPANY PTY LIMITED (NWCC) WILL MAKE A COPY OF THIS POLICY AVAILABLE TO ALL OWNERS OF PRIVATE LAND WHOSE LAND WILL BE UNDERMINED.

Mine subsidence is the lowering of the surface due to the removal of the underlying coal seams.

In some instances, mine subsidence may cause damage to "improvements" and water resources.

"Improvements" are defined in the Mine Subsidence Compensation Act (1962) and include:

- any building or work erected or constructed on land
- any formed road, street, path, walk or driveway
- any pipeline, water, sewer, telephone, gas or other service main, whether above or below the surface of the land

This document addresses actions NWCC intends to take to minimise the impact of subsidence on landowners that may be affected by mining at Ellalong.

1. Landowners have the right to know when portions of their properties may be affected.

2. Schedules of extraction will be prepared showing the expected subsidence areas at quarterly intervals, two years ahead of mining. These schedules will be block outlines superimposed on aerial photos and copies will be supplied to affected landowners.

3. Immediately prior to mining, a structural report, including a comprehensive set of photos will be prepared in conjunction with Mine Subsidence Board (MSB) officials. Particular attention will be paid to plaster work in homes, door frames, window frames, operation of doors and windows, and the condition of fences and dams.

   The report, including a fully documented set of photos will be supplied to the potentially affected landowner, and the MSB.

4. Whilst the MSB is ultimately responsible for the cost of repairs to improvements damaged by subsidence, NWCC will assist the landowners if requested in making application to the MSB and to assist in arranging for any such repair work to be carried out at a time convenient to the landowner.

5. Repair work for surface damage caused by subsidence which is not covered by the Mine Subsidence Act, including ripping, ploughing or grading to repair surface damage or restore drainage patterns will be undertaken by NWCC to the reasonable satisfaction of the landowner.

   5.1 The landowner is to detail this work in writing, and where appropriate by the use of plans and submit a request to NWCC that this work be undertaken.

   5.2 NWCC shall within three months of the date of receiving this request carry out this work if it is satisfied on reasonable grounds that the damage has been caused by subsidence.

   5.3 In the event that NWCC does not agree within the time limit to carry out the work, then the matter shall be referred to the MSB who shall appoint an independent agricultural expert to carry out an assessment of the work required on the land.

   5.4 Upon receipt of the report by the independent agricultural expert, NWCC will carry out all of the work identified in that report.

   5.5 NWCC shall bear the cost of reference to the independent agricultural expert.

   Note that the MSB does cover earthwork repairs where these are required to eliminate Public or Private Danger.

6. **NWCC undertakes to:**

   6.1 Deliver in the event of an interruption to water supplies caused by subsidence, (either through a change in quality or surface quantity) an equivalent amount of water of at least equivalent quality to a location convenient to the private landowner. If required NWCC is to provide at its cost a storage receptacle appropriate for the volume of water to be delivered.

   6.2 Take such steps as are necessary to overcome the sterilisation of lands through ponding.

7. Surveys will be undertaken as a means of measuring subsidence for the purpose of improving prediction methods and to establish changes in drainage patterns caused by subsidence.

8. A copy of this policy will be provided to both landowners and the Mine Subsidence Board.