proposed

Mt Arthur
UNDERGROUND PROJECT

Appendix 5

Subsidence Assessment

Mt. Arthur Coal Pty Limited

Mt. Arthur Underground Project

REPORT

on

THE PREDICTION OF SUBSIDENCE PARAMETERS AND THE ASSESSMENT OF MINE SUBSIDENCE IMPACTS ON NATURAL FEATURES AND ITEMS OF SURFACE INFRASTRUCTURE DUE TO THE EXTRACTION OF LONGWALLS IN THE WOODLANDS HILL, GLEN MUNRO, ARROWFIELD, BOWFIELD AND PIERCEFIELD SEAMS AT THE MT. ARTHUR UNDERGROUND PROJECT IN SUPPORT OF AN ENVIRONMENTAL ASSESSMENT

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Previous reports:- MSEC234 (Revision C, April 2006) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Items of Surface Infrastructure due to the Extraction of Longwalls in the Woodlands Hill, Glen Munro, Arrowfield, Bowfield and Piercefield Seams at the Mt. Arthur Underground Project.

EXECUTIVE SUMMARY

Mt. Arthur Coal Pty Limited (Mt. Arthur Coal) proposes to commence underground coal mining operations at the Mt. Arthur Underground Project (the project), which is located in the Hunter Coalfield of New South Wales, by extracting coal using multi-seam longwall mining techniques. Mt. Arthur Coal proposes to extract longwalls from the Woodlands Hill, Glen Munro, Arrowfield, Bowfield, and Piercefield Seams. The locations of the proposed longwalls within each seam are overlaid in Drawing No. MSEC263-100, which together with all other drawings is included in Appendix H.

There are a number of natural features and items of surface infrastructure which may be affected by the extraction of the proposed longwalls. The "Study Area" has been defined as the surface area that is likely to be affected by mining the proposed longwalls for the 21 year plan. The Study Area has been drawn by combining the areas bounded by the 26½ degree angle of draw lines from the goaf edges of the proposed longwalls within each seam, and by the predicted total 20 mm subsidence contour resulting from the extraction of all proposed longwalls. Nearby features outside of this area have also been included in the assessment, where these features may be subjected to far-field movements and may be sensitive to these movements.

The majority of the land and surface infrastructure within the Study Area is owned by Mt. Arthur Coal. The land has generally been cleared for grazing and for mining activities. The major natural features and items of surface infrastructure which have been assessed are described in Chapter 2 of this report, and include the Hunter River, Quarry and Saddlers Creeks, steep slopes, flora and fauna, Edderton and MacDonalds Roads, road bridges, the planned road diversion and bridge, drainage culverts, the 330/500 kV transmission line, low voltage powerlines, copper telecommunication lines, farm buildings, tanks, fences, farm dams, water bores, open cut pits, the planned spoil heap, archaeological sites, survey control marks and houses.

The Incremental Profile Method, which is described in Chapter 3 and Appendix D of this report, was used to predict the systematic subsidence parameters resulting from the extraction of the proposed longwalls. The maximum predicted systematic subsidence parameters resulting from the extraction of the proposed longwalls are summarised in Chapter 4 of this report. Subsidence predictions and impact assessments were made for the natural features and items of surface infrastructure within the Study Area, which are provided in Chapter 5 of this report. The findings are provided below and are summarised in Table A at the end of the executive summary.

The Hunter River is located at a distance of 2 kilometres north of the proposed longwalls, at its closest point. The river will not be subjected to any significant systematic subsidence or valley related movements resulting from the extraction of the proposed longwalls. The river may be subjected to low levels of far-field horizontal movements, however, these movements tend to be bodily movements, which are not associated with any significant strains, and are likely to be in the order of natural ground movements and survey tolerance. Based on previous experience of mining at these distances from rivers, the Hunter River will not be impacted by the predicted systematic, valley related or far-field horizontal movements resulting from the extraction of the proposed longwalls.

The upper reaches of Quarry Creek are located within the Study Area, and a length of approximately 650 metres of the creek is located directly above the proposed longwalls within the Bowfield and Piercefield Seams. It is likely that additional ponding will occur along the ephemeral creek where the proposed longwalls mine directly beneath it, however, as the creek has an alluvial bed it is likely that the extent of any additional ponding would decrease during subsequent flow events. Systematic tensile cracking in the alluvial creek bed, and fracturing and dilation of the underlying strata is likely to occur where the proposed longwalls mine beneath the creek. The depth of cover to the Bowfield Seam is shallow at the location of the creek and it is likely, therefore, that the collapsed zone will extend near to the surface, increasing the hydraulic connectivity between the surface and the mine workings. Remedial works might be required, therefore, including the grouting of any significant fractures and dilation which occur within the strata near the surface.

Saddlers Creek is located at a distance of greater than 500 metres south of the proposed longwalls, at its closest point. The creek will not be subjected to any significant systematic subsidence or valley related movements resulting from the extraction of the proposed longwalls. The creek may be subjected to low levels of far-field horizontal movements, however, it is extremely unlikely that the creek would be impacted by these movements.

There are natural steep slopes within the Study Area having gradients between 1 in 3 and 1 in 2, with some isolated slopes having gradients up to 1 in 1.5. It is possible that soil slumping may occur down the steep slopes which are located above the proposed longwalls within the Glen Munro Seam. Soil slumping may result in tensile cracking at the tops of the slopes, and compressive ridges at the bases of the slopes. Any soil slumping which occurs can be remedied by regrading, recompacting, and revegetating the slopes.

Tensile surface cracking is expected to occur above the proposed longwalls, especially where the depths of cover are the shallowest. The tensile cracks are predicted to be typically in the order of 200 mm wide, where the depths of cover are shallow, and could be as large as 500 mm wide where the depths of cover are the shallowest. The largest surface cracks are expected to occur as a result of soil slumping down the steep slopes, as has been observed in the past at other collieries having similar surface topography and depths of cover. Cracks are predicted to be typically in the order of 250 mm wide along the steep slopes, and could be in the order of 500 mm wide where the slopes are the steepest. Surface tensile cracking can be remedied by regrading, recompacting, and revegetating the surface.

MacDonalds Pit, Belmont Pit, and the planned Belmont West Pit will be mined beneath by the proposed longwalls. It is likely that the highwalls will be adversely impacted by the proposed longwalls. It is proposed that these pits will be closed in accordance with the Mt. Arthur Coal Mine Closure Plan, that bunds will be provided at the tops and bottoms of the highwalls, and that access will be restricted to the pits, prior to mining beneath each pit.

Edderton and MacDonalds Roads will be directly mined beneath by the proposed longwalls within each seam. Edderton Road is a sealed public road, which is likely to require remedial measures using standard road maintenance techniques, where the proposed longwalls mine beneath it. MacDonalds Road is an unsealed closed road located on Mt. Arthur owned land, which is also likely to require remedial measures, including regrading and recompacting, where the proposed longwalls mine beneath it. The drainage culverts along Edderton Road are also likely to be impacted as they are mined beneath. The impacts on the roads and culverts are expected to be limited to the area above the active longwall, and can be managed by locally regrading and resurfacing the roads, and by repairing the drainage culverts where the proposed longwalls are mined beneath them.

The road bridges along Edderton Road are reinforced concrete structures with an integrally connected deck, supporting walls, and ground slab. The predicted systematic subsidence movements at the bridges could result in the road pavements pulling away from or rippling at the bridge structures. It is also possible that the predicted valley related movements at the bridge above proposed Longwall WH107 within the Woodlands Hill Seam could result in stepping in the road pavement where it joins the bridge deck. Any differential movement between the road pavement and the bridge abutments can be rectified using normal road maintenance techniques.

The 330/500 kV transmission line will be directly mined beneath by the proposed longwalls within the Woodlands Hill, Arrowfield, Bowfield, and Piercefield Seams. Initially, the transmission line will be mined beneath by workings within the Woodlands Hill Seam, which is a single seam extraction. The first multi-seam mining at the project will be when the longwalls within the Arrowfield Seam (seven panels) mine beneath the previous goafs formed by the longwalls within the Glen Munro Seam. The longwalls within these seams do not mine beneath the transmission line.

Following mining within the Arrowfield Seam, the fourth panel in the Bowfield Seam will be the first instance of multi-seam mining beneath the transmission line. Hence, the predictions made using the Incremental Profile Method for multi-seam mining will have been calibrated using actual monitoring data from elsewhere in the Hunter Valley (eg: the Bulga mining complex) and from two separate instances at the project prior to multi-seam mining beneath the transmission line.

The greatest predicted movements at the transmission line occur as a result of the extraction of the longwalls within the Woodlands Hill Seam, which are single seam extractions. The predictions made using the Incremental Profile Method for single seam extractions in the Hunter Valley have been shown to be appropriate. A greater degree of conservatism has been provided in the travelling wave predictions and, hence, we expect that the actual observed travelling wave movements will be less than the predicted values, especially at the shallow depths of cover.

It is likely that preventive measures will be required for the towers which are directly mined beneath addressing the stability of the tower bases, the management of the aerial cables and the differential cable tensions that may be induced across Tower 29. These issues might be typically managed using cruciform bases and cable sheaves. The angled tower (Tower 36) along the 330/500 kV transmission line is located outside the predicted total 20 mm subsidence contour, however, the tower may experience higher lateral loads due to changes in the cable catenaries in the adjacent bays. The predicted subsidence parameters at the transmission towers have been provided to TransGrid so that an analysis of the towers could be undertaken and management strategies developed.

The low voltage powerline along Edderton Road is likely to be impacted where the proposed longwalls mine beneath it. It is likely that some preventive measures will be required for the powerline, including the installation of cable sheaves, additional poles, and guy wires.

The underground telecommunication copper cables are likely to be impacted where the proposed longwalls mine beneath them. It is likely that some preventive measures will be required for the cables including the relocation of the cables to conduits, and the installation of additional lengths of cable at pits and other anchor points.

There are 90 farm dams within the Study Area, of which 85 are owned by Mt. Arthur Coal. The farm dams are located across the project area and they will be, therefore, subjected to the full range of predicted systematic subsidence movements. It is expected that some cracking and leakage of water will occur at the dams subjected to the greatest tensile strains, but any cracking or leakages can be easily identified and repaired as required.

There are 50 building structures located across the Study Area and they will be, therefore, subjected to the full range of predicted systematic subsidence movements. All of the building structures are of light-weight constructions which are flexible, and more able to tolerate subsidence movements than masonry structures.

There are 39 rural building structures within the Study Area, not including the houses, all of which are owned by Mt. Arthur Coal. There are 21 rural building structures which are predicted to experience tilts greater than 10 mm/m, of which 11 structures are predicted to experience tilts greater than 30 mm/m. There are 12 rural building structures which are assessed to experience Category 4 or 5 strain impacts. It is recommended that all rural building structures should be inspected by a structural engineer before and after each longwall mines beneath them, to assess and make recommendations regarding the stability of these structures.

There are ten houses within the Study Area, all of which are owned by Mt. Arthur Coal. Seven houses are predicted to experience tilts greater than 7 mm/m at some stage during the mining period, however, two of these houses are predicted to have tilts of less than 7 mm/m at the completion of mining. Six houses are assessed to experience Category 3 or greater strain impacts. It is recommended that all houses should be inspected by a structural engineer before and after each longwall is mined beneath them, to assess and make recommendations regarding the stability of these structures. The Edderton Homestead and the associated heritage wall are both located outside the predicted total 20 mm subsidence contour.

It is recommended that the natural features and items of surface infrastructure within the Study Area are visually inspected on a regular basis throughout the mining period. The natural features such as Quarry Creek, the steep slopes, and the general land surface within the Study Area should be visually inspected for tensile surface cracking and irregular subsidence movements. Each item of surface infrastructure should be visually inspected prior, during, and after the proposed longwalls mine beneath them, to ensure that they are maintained in a safe and serviceable condition throughout the mining period.

The monitoring of ground movements is also recommended as subsidence occurs, to allow the comparison between predicted and observed movements, and to periodically review the impact assessments in the light of measured data. The predictions made using the Incremental Profile Method will be further calibrated to local data, and to the findings from the geotechnical consultants during the SMP Assessment stage. Further calibration and refinement of the predictions will also be made based on the monitoring data obtained during the extraction of the proposed longwalls.

An independent peer review of the methods of subsidence prediction and impact assessment for the project has been undertaken and details are provided in the report by Frith Consulting Services (Frith, 2006).

It is recommended that management strategies are developed in consultation with each stakeholder, so that the subsidence impacts are managed throughout the mining period. The infrastructure stakeholders include:-

- Muswellbrook Shire Council – Roads, bridges, and drainage culverts.
- TransGrid – 330/500 kV transmission line.
- Energy Australia – Low voltage powerlines.
- Telstra – Underground copper telephone lines.
- Rural Lands Protection Board – Travelling stock reserve.
- Private owners – Farm infrastructure.
- Department of Lands – Survey control marks.
- The Mine Subsidence Board – Compensation for damaged infrastructure.

Table A – Summary of Subsidence Impacts, Typical Monitoring, Management and Remediation Measures

Feature	Predicted Impact	Typical Subsidence Monitoring Activity	Typical Management and Remediation Options
Hunter River	• No predicted impact.	• Not applicable.	• Not applicable.
Quarry Creek	• Increased flooding, ponding and scouring during rainfall events. • Cracking in alluvial bed and potential surface water flow diversions.	• Visual monitoring of creek during and after the extraction of longwalls beneath the creek.	• Earthworks for grade and ponding management. • Seal significant fracturing and dilation in the underlying strata using a method such as low strength cement / bentonite grouting.
Saddlers Creek	• No predicted impact.	• Not applicable.	• Not applicable.
Steep slopes	• Surface tensile cracking and potential downhill movement.	• Visual monitoring.	• Earthworks, soil remediation and revegetation as required.
Roads, culverts and bridges	• Changes in grades and cracking in road surfaces and culverts. • Gap or step forming between road pavement and bridge structures.	• Survey monitoring line along the Edderton and MacDonalds Roads. • Survey monitoring points on road bridge abutments and decks. • Visual monitoring along the roads for irregular subsidence movements.	• Impacts on roads, culverts and bridges managed using standard maintenance techniques. • Replace impacted or unserviceable culverts. • Traffic management using temporary lights, stop-go signs, other signage and speed restrictions. • Suitable management strategies to be developed in consultation with Muswellbrook Shire Council.
330kV/500kV transmission line	• Tilting of towers and relative lateral and vertical movements between towers resulting in variations in aerial cable tensions. • Potential increased imbalance in differential aerial cable tensions at Tower 29. • Tower bases impacted by ground strains.	• Survey monitoring points around each tower within the Study Area. • Visual monitoring along the transmission line easement for irregular subsidence movements.	• Engineering measures to allow inter-tower cable movements, eg: cable sheaves. • Reinforcement or re-engineering of tower bases to prevent impact, eg: cruciform bases. • Engineering measures to facilitate increased aerial cable tensions at Tower 29.
Low voltage powerlines	• Tilting of poles and relative movements between poles resulting in variations in aerial cable tensions.	• Survey monitoring line along Edderton Road could be used to monitor main low voltage line. • Visual monitoring of cable catenaries and pole tilts.	• Low voltage powerlines inspected by suitably qualified person prior to mining beneath to determine existing condition. • Suitable management strategies developed in consultation with Energy Australia.

Feature	Predicted Impact	Typical Subsidence Monitoring Activity	Typical Management and Remediation Options
Underground copper telecommunications cables	• Locally increased cable tensions which could result in cable breaks.	• Survey monitoring line along Edderton Road could be used to monitor movements along main copper cables.	• Cables in pits inspected by suitably qualified person prior to mining beneath to determine existing condition and requirements for conduits and additional lengths of cables in pits. • Suitable management strategies developed in consultation with Telstra / infrastructure owner.
Rural building structures and houses	• Full range of predicted systematic movements. Note that all building structures are owned by Mt. Arthur Coal and will be unoccupied / unused prior to subsidence impacts.	• Visual monitoring of structures.	• Inspection by structural engineer to assesses best option for each structure. Range of options include: demolition or relocation prior to mining, prevention of access, demolish after mining, or repair* after mining.
Farm dams	• Full range of predicted systematic subsidence movements that could result in cracking and leakage of dam walls or base.	• Visual monitoring of dams.	• Repair* leaking dams as required.
Wells and bores	• Differential strata movements within the bores which could potentially result in blockage or reduced capacities.	• Visual monitoring of water levels and water quality.	• Repair* impacted bores as required.
Survey control marks	• Systematic and far-field movements.	• Not applicable.	• Resurvey locations of survey control marks after cessation of ground movement. • Suitable management strategies developed in consultation with the Department of Lands.
Archaeological sites	• Refer to "Environmental Assessment Proposed Mt. Arthur Underground Project", Umwelt 2007.		

Note: * denotes that repairs will be carried out by Mt. Arthur Coal or the Mine Subsidence Board as per the previsions of the Mine Subsidence Compensation Act 1961 and the Mining Act 1992 and so as to allow the facilities to remain in a safe and serviceable condition.

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CHAPTER 1. INTRODUCTION

1.1. Background

Mt. Arthur Coal Pty Limited (Mt. Arthur Coal) proposes to commence underground coal mining operations at the Mt. Arthur Underground Project (the project), which is located in the Hunter Coalfield of New South Wales, by extracting coal from the Woodlands Hill, Glen Munro, Arrowfield, Bowfield, and Piercefield Seams. The overall layout of the proposed longwalls at the project is shown in Drawing No. MSEC263-100, which together with all other drawings is included in Appendix H.

MSEC was initially commissioned by Mt. Arthur Coal to undertake subsidence predictions and impact assessments for the natural features and surface infrastructure at the project in support of the Prefeasibility Study. Report No. MSEC234 (Revision C) was issued in April 2006 on the completion of that work.

MSEC has now been commissioned by Mt. Arthur Coal to undertake subsidence predictions and impact assessments for the natural features and surface infrastructure at the project for the 21 year plan. This report has been prepared to support an Environmental Assessment for the extraction of the proposed longwalls.

1.2. Mining Geometry

Mt. Arthur Coal is proposing to extract coal from the Woodlands Hill, Glen Munro, Arrowfield, Bowfield, and Piercefield Seams at the project using multi-seam longwall mining techniques. Although the Glen Munro Seam is the top most seam proposed to be extracted, the Woodlands Hill Seam will be extracted first using longwall mining techniques in the southern part of the project area. The Glen Munro Seam will then be extracted using longwall mining techniques in the northern part of the project area. Longwalls are then proposed to be extracted from the Arrowfield, Bowfield, and Piercefield Seams.

A summary of the proposed longwalls for the current concept mine plan, in the order in which they are proposed to be extracted, and the drawing references showing the proposed longwall layouts, are provided in Table 1.1.

Table 1.1 Proposed Longwalls at the Mt. Arthur Underground Project

Seam (In Order of Extraction)	Longwalls (In Order of Extraction)	Drawing Number
Woodlands Hill Seam	WH101 to WH110	MSEC263-101
Glen Munro Seam	GM101 and GM102	MSEC263-102
	GM201 to GM205	
	GM301 and GM302	
Arrowfield Seam	AF101 to AF105	MSEC263-103
	AF201 and AF202	
Bowfield Seam	BF101 and BF102	MSEC263-104
	BF201 to BF203	
Piercefield Seam	PF101 to PF106	MSEC263-105
	PF201 to PF204	

The proposed longwall layouts were provided by Mt. Arthur Coal as detailed in Table 1.2.

Table 1.2 Longwall Layout Information Provided by Mt. Arthur Coal

Longwalls	Date	File Name	Layout Reference
Woodlands Hill Seam	15th August 2007	xn_WH04_BC0M28_EA.dxf	WH04
Glen Munro Seam	14th July 2006	EA_UG_GM10.dwg	GM10
Arrowfield Seam	14th July 2006	EA_UG_AF08.dwg	AF08
Bowfield Seam	14th July 2006	EA_UG_BF08.dwg	BF08
Piercefield Seam	14th July 2006	EA_UG_PF01.dwg	PF01

A summary of the proposed longwall dimensions are provided in Table 1.3 to Table 1.7.

Table 1.3 Proposed Dimensions of Longwalls within the Woodlands Hill Seam (Based on WH04 Longwall Layout)

Longwall	Length (m)	Overall Void Width Including Headings (m)	Solid Chain Pillar Width (m)
WH101	4425	286	-
WH102	4190	286	26
WH103	4270	286	26
WH104	4225	286	26
WH105	4295	286	26
WH106	4070	286	26
WH107	4135	286	26
WH108	4060	286	26
WH109	3200	286	26
WH110	1455	250	26

Table 1.4 Proposed Dimensions of Longwalls within the Glen Munro Seam (Based on GM10 Longwall Layout)

Longwall	Length (m)	Overall Void Width Including Headings (m)	Solid Chain Pillar Width (m)
GM101	2315	285	-
GM102	2110	285	25
GM201	2590	285	-
GM202	2525	285	25
GM203	2415	285	25
GM204	2520	285	25
GM205	2450	285	25
GM301	1775	285	-
GM302	1725	210	25

Table 1.5 Proposed Dimensions of Longwalls within the Arrowfield Seam (Based on AF08 Longwall Layout)

Longwall	Length (m)	Overall Void Width Including Headings (m)	Solid Chain Pillar Width (m)
AF101	2430	286	-
AF102	3445	286	30
AF103	2960	286	30
AF104	2690	286	30
AF105	2450	286	30
AF201	2745	286	-
AF202	2585	286	30

Table 1.6 Proposed Dimensions of Longwalls within the Bowfield Seam (Based on BF08 Longwall Layout)

Longwall	Length (m)	Overall Void Width Including Headings (m)	Solid Chain Pillar Width (m)
BF101	3270	286	-
BF102	2860	286	30
BF201	4570	286	-
BF202	2025	286	30
BF203	1765	286	30

Table 1.7 Proposed Dimensions of Longwalls within the Piercefield Seam (Based on PF01 Longwall Layout)

Longwall	Length (m)	Overall Void Width Including Headings (m)	Solid Chain Pillar Width (m)
PF101	3420	286	-
PF102	3080	286	32
PF103	2945	286	32
PF104	3000	286	32
PF105	3245	286	32
PF106	1750	286	32
PF201	3995	286	-
PF202	4380	286	70
PF203	4625	286	70
PF204	4890	286	70

1.3. Surface Level and Seam Information

The surface level information was provided by Mt. Arthur Coal on the 2nd September 2005 in a file titled *DUMP-WS-FLOOR-ROOF-THICK.XYZ*. The file provided the surface levels on a 25 metre by 25 metre grid across the project area. The proposed longwalls and the Study Area, which is defined in Section 2.1, have been overlaid on an orthophoto of the area, which is shown in Fig. 1.1. The major topographical features in the area can be seen in this figure.

The latest seam floor and seam extraction height information was supplied by Mt. Arthur Coal on the 17th July 2006 in a file titled *20060717_MAC-UG.XYZ*. The file provided the seam floors and seam extraction heights on a 25 metre by 25 metre grid across the project area. A summary of the seam information supplied by Mt. Arthur Coal is provided in Table 1.8.

Table 1.8 Seam Information Provided By Mt. Arthur Coal

Seam	Seam Floor	Seam Extraction Height
Woodlands Hill Seam	WWH10SF	WWH10ST
Glen Munro Seam	WGM01SF	WGM01ST
Arrowfield Seam	WAF01SF	WAF01ST
Bowfield Seam	WBF02SF	WBF02ST
Piercefield Seam	WPF04SF	WPF04ST

The depths of cover to each seam, being the heights between the existing surface and the tops of each seam, were determined from the information provided by Mt. Arthur Coal. The depths of cover contours for each seam are shown in Drawings Nos. MSEC263-111 to MSEC263-115. The proposed extraction height contours for each seam are shown in Drawings Nos. MSEC263-121 to MSEC263-125.

A summary of the ranges of the depths of cover and proposed extraction heights for the proposed longwalls, and the ranges of interburden between the proposed longwalls within neighbouring seams, is provided in Table 1.9.

Table 1.9 Depths of Cover, Proposed Extraction Heights and Interburden for the Proposed Longwalls within Each Seam

Seam	Depth of Cover (m)	Proposed Extraction Height (m)	Interburden (m)
Woodlands Hill Seam	70 ~ 175	2.0 ~ 3.6	-
Glen Munro Seam	< 35 ~ 225	1.8 ~ 3.8	-
Arrowfield Seam	95 ~ 310	2.2 ~ 3.0	80 ~ 95
Bowfield Seam	50 ~ 220	2.2 ~ 3.6	60 ~ 70
Piercefield Seam	210 ~ 435	2.0 ~ 3.0	115 ~ 190

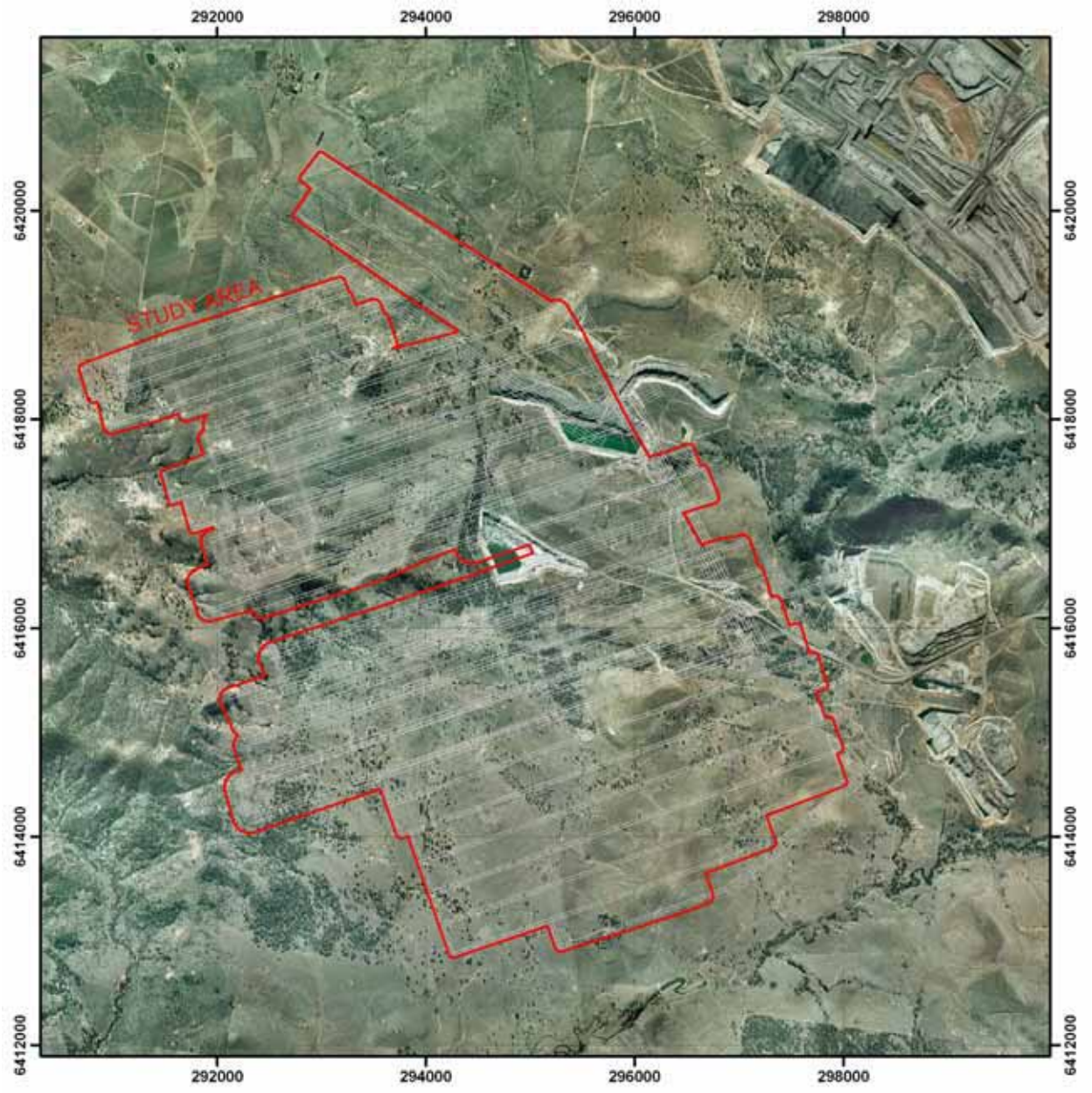

Fig. 1.1 Aerial Photograph Showing the Proposed Longwalls and the Study Area

1.4. Geology

The project area lies in the Hunter Coalfield within the Northern Sydney Basin. The strata associated with the coal seams were laid down during the Permian Period and comprise of the Wollombi and Wittingham Coal Measures of the Singleton Supergroup. The stratigraphy of the Hunter Coalfield (Stevenson et al, 1998) is shown in Table 1.10, and a stratigraphic section at the project area is shown in Fig. 1.2.

The Glen Munro Seam lies within the Wollombi Coal Measures, which also comprise the Watts Sandstone and the Apple Tree Flat, Horseshoe Creek, Doyles Creek and Glen Gallic Subgroups. The Woodlands Hill, Arrowfield, Bowfield, and Piercefield Seams lie within the Jerrys Plains Subgroup of the Wittingham Coal Measures, which is overlain by the Denman Formation, and is underlain by the Archerfield Sandstone, Vane, and Saltwater Creek Formation Subgroups.

The strata of both the Wollombi and Wittingham Coal Measures mainly comprise frequently bedded sandstones and siltstones, but also include isolated thinner beds of conglomerate and tuff. The strata beds within the coal measures are generally less than 10 metres in thickness.

Tuffaceous units are present throughout the Wittingham Coal Measures, and forms the roofs of the Glen Munro and Woodlands Hill Seams. The floor of the Woodlands Hill Seam comprises of the Milbrodale Claystone. The roofs of the Arrowfield, Bowfield, and Piercefield Seams comprise mainly of claystone units.

There are numerous intrusive sills within the project area, however, most are generally limited in extent and have thicknesses of only a few metres. There is, however, a large sill which has been identified within the Narrabeen Group, which is up to 35 metres thick. There are also several large dykes identified within the project area which are variable in nature.

A major geological feature within the project area is the monocline which is located along the eastern extent of the proposed longwalls. There are also a number of faults within the project area including the Cottage Fault and Trig Fault. The major geological features identified at seam level are shown in Drawing No. MSEC263-131.

SCT Operations has reported that the horizontal stress ($\sigma_{H\,max}$) varies from 6 MPa at 100 metre depth of cover, to 13 MPa at 500 metres depth of cover. The maximum principal stress direction, based on borehole breakout data, is ENE-WSW to E-W (060° – 100° TN), with 75 % of the dataset within this range (SCT 2006a). Variations in the principal stress direction occur about the major geological structures including the Cottage and Trig Faults. Localised high stress zones were also observed above the Cottage Fault, Trig Fault, and the Calool Syncline.

Detailed characterisations and descriptions of the geology at the project are provided in the reports by SCT (2006a, 2006b, 2006c, and 2006d).

Table 1.10 Middle Permian to Quaternary Stratigraphy of the Hunter Coalfield (Stevenson, et at, 1998)

Period	Stratigraphy			Lithology
Quaternary				silt, sand, gravel
Tertiary				basalt
Jurassic				basalt
Triassic	Hawkesbury Sandstone			massive quartz sandstone with minor siltstone
	Narrabeen Group	Terrigal Formation		sandstone, interbedded sandstone and siltstone, mudstone, claystone
		Clifton Subgroup	Patonga Claystone Tuggerah Formation Widden Brook Conglomerate	sandstone, interbedded sandstone and siltstone, claystone
Permian	Singleton Supergroup	Wollombi Coal Measures	Glen Gallic Subgroup Doyles Creek Subgroup Horseshoe Creek Subgroup	coal, claystone, siltstone, shale, sandstone, conglomerate, tuffaceous sediments
			Watts Sandstone	medium to coarse sandstone
		Wittingham Coal Measures	Denman Formation Jerrys Plains Subgroup Archerfield Sandstone Vane Subgroup Saltwater Creek Formation	sandstone, siltstone, laminite coal, claystone, tuff, siltstone, sandstone, conglomerate well-sorted quartz-lithic sandstone coal, siltstone, lithic sandstone, shale, conglomerate sandstone, siltstone, minor coal

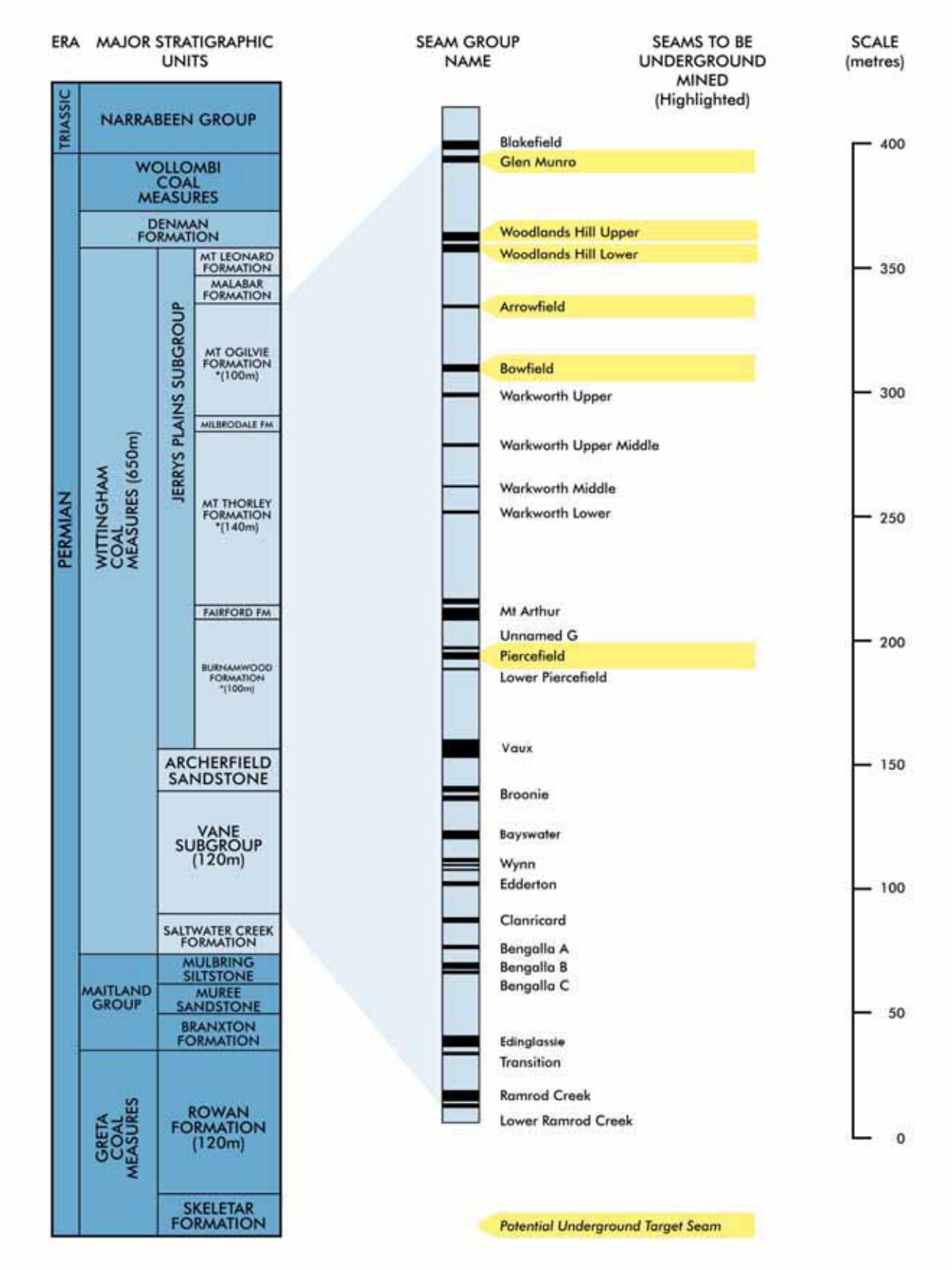

Fig. 1.2 Stratigraphic Section at the Mt. Arthur Underground Project

CHAPTER 2. IDENTIFICATION OF NATURAL FEATURES AND ITEMS OF SURFACE INFRASTRUCTURE

2.1. Definition of the Study Area

The "Study Area" has been defined as the surface area that is likely to be affected by the mining of the proposed longwalls within the Woodlands Hill, Glen Munro, Arrowfield, Bowfield, and Piercefield Seams at the project for the 21 year plan. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- The 26½ degree angle of draw lines from the goaf edges of the proposed longwalls within each seam,
- The predicted vertical limit of subsidence, taken as the predicted total 20 mm subsidence contour, and
- Features sensitive to far-field movements.

The 26½ degree angle of draw lines from the goaf edges of the proposed longwalls within the Woodlands Hill, Glen Munro, Arrowfield, Bowfield, and Piercefield Seams, are shown in Drawings Nos. MSEC263-101 to MSEC263-105. The predicted total 20 mm subsidence contour has been determined using the Incremental Profile Method, which is described in Chapter 3 and Appendix D of this report, and is shown in Drawing No. MSEC263-305.

The predicted total 20 mm subsidence contour is generally bounded by the 26½ degree angle of draw lines. In some isolated locations, however, the predicted total 20 mm subsidence contour extends beyond the 26½ degree angle of draw lines as the result of local topography, or due to the re-activation of previously extracted longwalls within overlying seams.

The Study Area has, therefore, been defined as the area bounded by the 26½ degree angle of draw lines for each seam, and by the predicted total 20 mm subsidence contour, and is shown in Drawing No. MSEC263-100. Nearby features outside of this area have also been included in this assessment, where the features may be subjected to far-field movements and may be sensitive to these movements. These features include the Hunter River, Saddlers Creek, water bores, and survey control marks.

2.2. General Description of Natural Features and Surface Infrastructure within the Study Area

The major natural features and surface infrastructure within the Study Area are shown on the 1:25,000 Topographical Maps of the area, published by the Central Mapping Authority (CMA), numbered MUSSWELLBROOK 9033-2-N and JERRYS PLAINS 9033-2-S.

A summary of the natural features and surface infrastructure within the Study Area is provided in Table 2.1. Descriptions of these features are provided in Sections 2.3 to 2.12 and are shown in Drawings Nos. MSEC263-140 to MSEC263-156. The majority of the land and surface infrastructure within the Study Area are owned by Mt. Arthur Coal. There is, however, some privately owned land, public utilities, and farm infrastructure within the Study Area.

The locations and details of the above ground infrastructure within the Study Area were determined from an aerial photograph of the area, and from site inspections undertaken by MSEC and Mt. Arthur Coal. The locations and details of the underground infrastructure within the Study Area were provided by the infrastructure owners through a *Dial before You Dig* request (Job No: 1822699).

Table 2.1 Natural Features and Surface Improvements

Item	Within Study Area	Section Number Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas		
Rivers or Creeks	✓	2.3.2
Aquifers or Known Groundwater Resources	✓	2.3.3
Springs		
Sea or Lakes		
Shorelines		
Natural Dams		
Cliffs or Pagodas		
Steep Slopes	✓	2.3.9
Escarpments		
Land Prone to Flooding or Inundation		
Swamps, Wetlands or Water Related Ecosystems		
Threatened, Protected Species or Critical Habitats	✓	2.3.13
National Parks or Wilderness Areas		
State Recreational or Conservation Areas		
State Forests		
Natural Vegetation	✓	2.3.17
Areas of Significant Geological Interest		
Any Other Natural Feature Considered Significant	✓	2.3.18
PUBLIC UTILITIES		
Railways		
Roads (All Types)	✓	2.4.2
Bridges	✓	2.4.3
Tunnels		
Culverts	✓	2.4.5
Water, Gas or Sewerage Pipelines		
Liquid Fuel Pipelines		
Electricity Transmission Lines or Associated Plants	✓	2.4.10
Telecommunication Lines or Associated Plants	✓	2.4.11
Water Tanks, Water or Sewage Treatment Works		
Dams, Reservoirs or Associated Works		
Air Strips		
Any Other Public Utilities		
PUBLIC AMENITIES		
Hospitals		
Places of Worship		
Schools		
Shopping Centres		
Community Centres		
Office Buildings		
Swimming Pools		
Bowling Greens		
Ovals or Cricket Grounds		
Race Courses		
Golf Courses		
Tennis Courts		
Any Other Public Amenities		

Item	Within Study Area	Section Number Reference
FARM LAND AND FACILITIES		
Agricultural Utilisation, Agricultural Improvements or Agricultural Suitability of Farm Land	✓	2.6.1
Farm Buildings or Sheds	✓	2.6.2 2.6.3
Gas or Fuel Storages	✓	2.6.4
Poultry Sheds	✓	2.6.5
Glass Houses or Green Houses		
Hydroponic Systems		
Irrigation Systems	✓	2.6.6
Fences	✓	2.6.7
Farm Dams	✓	2.6.8
Wells or Bores	✓	2.6.9
Any Other Farm Features		
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories		
Workshops		
Business or Commercial Establishments or Improvements		
Gas or Fuel Storages or Associated Plants		
Waste Storages and Associated Plants		
Buildings, Equipment or Operations that are Sensitive to Surface Movements		
Surface Mining (Open Cut) Voids and Rehabilitated Areas	✓	2.7.7
Mine Infrastructure Including Tailings Dams or Emplacement Areas		
Any Other Industrial, Commercial or Business Features		
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	2.8.1 2.8.2
ITEMS OF ARCHITECTURAL SIGNIFICANCE		
PERMANENT SURVEY CONTROL MARKS	✓	2.10
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	2.11.1
Flats or Units		
Caravan Parks		
Retirement or Aged Care Villages		
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts		
Any Other Residential Features		
ANY OTHER ITEM OF SIGNIFICANCE		

2.3. Natural Features

2.3.1. Drinking Water Catchment Areas and Declared Special Areas

There are no drinking water catchment areas or declared special areas within the Study Area.

2.3.2. Rivers and Creeks

The watercourses located within the Study Area are shown in Drawing No. MSEC263-140, and are briefly described below.

There are no rivers within the Study Area. The closest river is the **Hunter River** which is located more than 2 kilometres north of the proposed longwalls, at its closest point. The river may be subjected to small far-field movements and may be sensitive to these movements and has, therefore, been included as part of this assessment.

Quarry Creek crosses the northern edge of the Study Area, and a length of approximately 650 metres of the creek is located directly above the proposed Longwalls BF101 and BF102 within the Bowfield Seam, and above proposed Longwall PF101 within the Piercefield Seam. The creek is ephemeral and generally flows in a north-westerly direction into the Hunter River.

Saddlers Creek is located outside the Study Area, and is located at a distance of greater than 500 metres south of the proposed longwalls, at its closest point. The creek may be subjected to far-field movements and may be sensitive to these movements and has, therefore, been included as part of this assessment.

There are also numerous drainage lines around and between the hills within the Study Area, which are described in the report by Umwelt (2007a).

2.3.3. Aquifers and Known Groundwater Resources

A detailed survey of the aquifers and groundwater resources within the Study Area has been undertaken, and are described in the report by Mackie (2007).

2.3.4. Natural Springs

There are no identified natural springs within the Study Area.

2.3.5. Sea or Lake

There is no sea or lake within the Study Area.

2.3.6. Shorelines

There are no shorelines within the Study Area.

2.3.7. Natural Dams

There are no natural dams within the Study Area. There are, however, a number of farm dams within the Study Area which are described in Section 2.6.8.

2.3.8. Cliffs or Pagodas

For the purposes of this report, a cliff has been defined as a continuous rockface having a minimum height of ten metres and a minimum slope of 2 in 1, i.e. having a minimum angle to the horizontal of 63°. There are no cliffs or pagodas identified within the Study Area.

2.3.9. Steep Slopes

The reason for identifying the steep slopes is to highlight areas in which existing ground slopes are considered to be marginally stable. For the purposes of this report, a steep slope has been defined as an area of land having a gradient between 1 in 3 (ie: a grade of 33 %, or an angle to the horizontal of 18°) and 2 in 1 (ie: a grade of 200 %, or an angle to the horizontal of 63°).

The minimum gradient of 1 in 3 represents a slope that would generally be considered stable for slopes consisting of rocky soils or loose rock fragments. Clearly the stability of natural slopes varies depending on their soil or rock types, and in many cases, natural slopes are stable at much higher gradients than 1 in 3.

The steep slopes within the Study Area were identified by MSEC from the 2 metre surface contours which were generated from an aerial survey of the area, and the locations have been shown in Drawing No. MSEC263-141. The steepest slopes in the vicinity of the proposed longwalls are located adjacent to Mount Ogilvie and Mount Arthur, although Mount Ogilvie and Mount Arthur will not be directly mined beneath.

There are two main areas within the Study Area having natural steep slopes which have been called the "Northern Hills" and the "Western Hills" in this report. There are also artificial steep slopes within the MacDonalds and Belmont Pits along the highwalls and low-walls. It is planned that the Belmont Pit will be extended to form the Belmont West Pit, and a new highwall and low-walls will be constructed. The locations of the pits are shown in Drawing No. MSEC263-141.

2.3.10. Escarpments

There are no escarpments within the Study Area

2.3.11. Land Prone to Flooding or Inundation

The land within the Study Area is undulating to hilly, having numerous drainage lines which divert surface water into Quarry Creek and the Hunter River to the north of the Study Area, and into Saddlers Creek to the south of the Study Area. There are no areas of land within the Study Area which would be considered to be flood prone.

2.3.12. Swamps, Wetlands and Water-Related Ecosystems

There are no swamps, wetlands, or water-related ecosystems within the Study Area.

2.3.13. Threatened and Protected Species

A detailed survey of threatened and protected species within the Study Area has been undertaken, which is described in the report by Umwelt (2007b).

2.3.14. National Parks or Wilderness Areas

There are no National Parks or Wilderness Areas within the Study Area.

2.3.15. State Recreation Areas or State Conservation Areas

There are no State Recreation, or State Conservation Areas within the Study Area.

2.3.16. State Forests

There are no State Forests within the Study Area.

2.3.17. Flora and Fauna

A detailed survey of the flora and fauna within the Study Area has been undertaken, which is described in the report by Umwelt (2007b).

2.3.18. Any Other Natural Feature Considered Significant

There is a small area of crown land present within the Study Area, referred to as the Travelling Stock Reserve (TSR). The location of the TSR is shown in Drawing No. MSEC263-150. The relocation of the TSR was approved under the Bayswater No. 3 Development Consent. The TSR is discussed in further detail in the report by Umwelt (2007a).

2.4. Public Utilities

2.4.1. Railways

There are no railways within the Study Area.

2.4.2. Roads

The roads and the crown road reserves within the Study Area are shown in Drawing No. MSEC263-142. In addition to the existing roads, it is planned that a road diversion will be constructed across the Belmont Pit, which is also shown in this drawing.

The major public road within the Study Area is **Edderton Road** which crosses the proposed longwalls in a north-south direction. The road is the main connection between Denman Road, which is located over 1 kilometre north of the Study Area, and the Golden Highway, which is located over 4 kilometres south of the Study Area. The road has a bitumen seal, but does not have any kerb or guttering within the Study Area. A typical section of the road can be seen in the photograph in Fig. 2.4. There are a number of drainage culverts along the road which are described in Section 2.4.5.

MacDonalds Road is an unsealed road which is located on Mt. Arthur Coal owned land. Public access has been restricted to the section of road within the Bayswater No. 3 Mine Lease. The road connects Edderton Road with properties located east of Edderton Road.

2.4.3. Bridges

There are two bridges along Edderton Road within the Study Area. One bridge crosses Quarry Creek and is located just north of proposed Longwall BF102 within the Bowfield Seam. The other bridge crosses a channel between two farm dams and is located directly above proposed Longwall WH107 within the Woodlands Hill Seam.

The locations of the bridges are shown in Drawing No. MSEC263-142 and details are provided in Table 2.2. The details and GPS locations of the bridges were determined on site by MSEC.

Table 2.2 Bridges within the Study Area

Bridge ID	Crossing	MGA Easting (Approximate)	MGA Northing (Approximate)
ER-BR1	Quarry Creek	294575	6419490
ER-BR2	Channel between dams B21d04 and A12d02	295250	6413980

Both bridges consist of a reinforced concrete deck supported by reinforced concrete abutment wingwalls and a centre span reinforced concrete wall. A reinforced concrete ground slab has been constructed in the bed of the creek and channel to prevent erosion. The bridge deck, walls, and base slab are tied together and, therefore, form an integral structure. Photographs of bridges ER-BR1 and ER-BR2 are provided in Fig. 2.1 and Fig. 2.2, respectively.

A new bridge is also planned to be constructed along the Edderton Road diversion across the Belmont Pit, the location of which is shown in Drawing No. MSEC263-142. It is planned that the bridge will be a two span structure, with a total length of approximately 38 metres, with the deck fixed at the southern abutment, and a movement joint provided at the northern abutment. The bridge structure will be founded on spoil.

Fig. 2.1 ER-B1 – Bridge Over Quarry Creek

Fig. 2.2 ER-B2 – Bridge over Channel between Farm Dams B21d04 and A12d02

2.4.4. Tunnels

There are no tunnels within the Study Area.

2.4.5. Drainage Culverts

A number of drainage culverts have been identified along Edderton Road within the Study Area. The sizes, types, and GPS locations of the culverts were determined on site by MSEC. The locations of the culverts are shown in Drawing No. MSEC263-142 and details are provided in Table 2.3.

Table 2.3 Drainage Culverts within the Study Area

Culvert ID	MGA Easting (Approximate)	MGA Northing (Approximate)	Culvert Diameter(s)
ER-C08	294615	6419465	3 x ϕ600
ER-C09	294400	6419115	1 x ϕ450
ER-C10	294450	6418595	1 x ϕ450
ER-C11	294435	6418470	1 x ϕ450
ER-C12	294405	6418300	1 x ϕ1500
ER-C13	294455	6418070	1 x ϕ450
ER-C14	294485	6417715	2 x ϕ1500
ER-C15	294450	6417400	1 x ϕ600
ER-C16	294415	6417120	1 x ϕ600
ER-C17	294395	6416880	1 x ϕ600
ER-C18	294405	6416795	1 x ϕ450
ER-C19	294550	6416490	1 x ϕ450
ER-C20	294570	6416365	1 x ϕ450
ER-C21	294575	6416295	1 x ϕ450
ER-C22	294585	6416145	2 x ϕ600
ER-C23	294635	6416005	3 x ϕ600
ER-C24	294655	6415950	1 x ϕ450
ER-C25	294775	6415685	1 x ϕ450
ER-C26	294905	6415510	2 x ϕ600
ER-C27	294975	6415420	2 x ϕ600
ER-C28	295215	6415165	1 x ϕ450
ER-C29	295275	6415080	1 x ϕ450
ER-C30	295385	6414830	1 x ϕ450
ER-C31	295410	6414675	1200W x 300D
ER-C32	295375	6414450	1200W x 300D
ER-C33	295295	6413700	1 x ϕ600
ER-C34	295300	6413565	1 x ϕ600
ER-C35	295370	6413100	1 x ϕ600

All drainage culverts have a concrete headwall at each end.

2.4.6. Water Infrastructure

There is no public water infrastructure within the Study Area. There are, however, local water distribution pipelines connecting the houses with local water storage tanks on each property.

2.4.7. Sewerage Pipelines and Sewerage Treatment Works

There are no public sewerage pipelines or sewage treatment works within the Study Area. The houses within the Study Area have local sewer connections to septic tanks.

2.4.8. Gas Pipelines

There are no gas pipelines within the Study Area.

2.4.9. Liquid Fuel Pipelines

There are no liquid fuel pipelines within the Study Area.

2.4.10. Electricity Transmission Lines and Associated Plants

There are above ground electrical services within the Study Area, the locations of which are shown in Drawing No. MSEC263-143. A 330 kV transmission line, which is owned by TransGrid, crosses the Study Area generally in an east-west direction. The line is likely to be upgraded to a 500 kV transmission line within the early stages of the 21 year plan.

A photograph of a typical transmission tower is provided in Fig. 2.3. The locations of the transmission towers, which were determined by MSEC from the aerial photograph, are shown in Drawing No. MSEC263-143.

Fig. 2.3 Typical Transmission Tower along the 330/500 kV Transmission Line

A number of above ground 11 kV, 66 kV, and consumer lines, which are owned by Energy Australia, cross the Study Area. The main low voltage powerline within the Study Area runs adjacent to Edderton Road, a photograph of which is provided in Fig. 2.4.

Fig. 2.4 Low Voltage Powerline along Edderton Road

2.4.11. Telecommunication Lines and Associated Plants

There are underground telecommunication copper cables within the Study Area, which are owned by Telstra, the locations of which are shown in Drawing No. MSEC263-144. The main underground copper cables within the Study Area are located along Edderton Road, with underground consumer lines connecting the properties along this road.

2.4.12. Water Tanks, Water and Sewerage Treatment Works

There are no Water or Sewage Treatment Works within the Study Area. There are, however, a number of water storage tanks on the rural properties, which are owned by Mt. Arthur Coal, and are described in Section 2.6.3.

2.4.13. Dams, Reservoirs or Associated Works

There are no public dams, reservoirs, or associated works within the Study Area. There are, however, a number of farm dams on the rural properties which are described in Section 2.6.8.

2.4.14. Air Strips

There are no air strips within the Study Area.

2.4.15. Any Other Public Utilities

There are no other public utilities within the Study Area.

2.5. Public Amenities

2.5.1. Hospitals

There are no hospitals within the Study Area.

2.5.2. Places of Worship

There are no places of worship within the Study Area.

2.5.3. Schools

There are no schools within the Study Area.

2.5.4. Shopping Centres

There are no shopping centres within the Study Area.

2.5.5. Community Centres

There are no community centres within the Study Area.

2.5.6. Office Buildings

There are no office buildings within the Study Area.

2.5.7. Swimming Pools

There are no public swimming pools within the Study Area.

2.5.8. Bowling Greens

There are no bowling greens within the Study Area.

2.5.9. Ovals or Cricket Grounds

There are no ovals or cricket grounds within the Study Area.

2.5.10. Racecourses

There are no racecourses within the Study Area.

2.5.11. Golf Courses

There are no golf courses within the Study Area.

2.5.12. Tennis Courts

There are no public tennis courts within the Study Area.

2.5.13. Any Other Public Amenities

There are no other public amenities within the Study Area.

2.6. Farm Land and Facilities

2.6.1. Agriculture Utilisation and Agriculture Improvements

There is a small vineyard within the Study Area, which is owned by Mt. Arthur Coal, which was associated with a former dwelling at 680 Edderton Road. The location of the vineyard is shown in Drawing No. MSEC263-156 and a photograph is shown in Fig. 2.5

Fig. 2.5 Vineyard at 680 Edderton Road

2.6.2. Farm Buildings and Sheds

There are 39 farm buildings and sheds (Structure Type R) located within the Study Area, all of which are owned by Mt. Arthur Coal. The locations and plan dimensions of the rural building structures were determined by MSEC from an aerial photograph of the area. The details and heights of the rural building structures were determined from site inspections undertaken by MSEC and Mt. Arthur Coal.

The locations of the rural building structures are shown in Drawings Nos. MSEC263-150 to MSEC263-156 and details are provided in Table 2.4.

Table 2.4 Farm Buildings and Sheds within the Study Area

Property Name	Number of Rural Building Structures	Structure Reference	Drawing Number
Cooks House	1	A05b	MSEC263-151
Hospital	3	A06b ~ A06d	MSEC263-151
Roxburgh South	3	A07b ~ A07d	MSEC263-152
550 Edderton Rd	3	A08b ~ A08d	MSEC263-153
680 Edderton Rd	3	A09a ~ A09c	MSEC263-156
Belmont Homestead	6	A10a, A10c ~ A10g	MSEC263-154
Edderton Homestead	20	A12e ~ A12j, A12l ~ A12n, A12q ~ A12aa	MSEC263-155

The rural building structures at the Edderton Homestead property which are located just outside the Study Area have been included in this assessment. The above table does not include details of on-site storage containers.

Some rural building structures located at the Belmont Homestead property have heritage significance, which is discussed in the report by Umwelt (2007a). The significant structures include Structure Refs. A10a, A10d, and A10e, photographs of which are shown in Fig. 2.6, Fig. 2.7, Fig. 2.8, respectively.

Fig. 2.6 Structure Ref. A10a on the Belmont Homestead Property

Fig. 2.7 Structure Ref. A10d on the Belmont Homestead Property

Fig. 2.8 Structure Ref. A10e on the Belmont Homestead Property

2.6.3. Tanks

There are 36 water tanks (Structure Type T) located within the Study Area. All tanks, apart from Tank A13t01, are owned by Mt. Arthur Coal. The locations and diameters of the tanks were determined by MSEC from an aerial photograph of the area. The details of the tanks were determined from site inspections undertaken by MSEC and Mt. Arthur Coal.

The locations of the tanks are shown in Drawings Nos. MSEC263-150 to MSEC263-156 and details are provided in Table 2.5.

Table 2.5 Water Tanks within the Study Area

Property Name	Number of Tanks	Tank References	Drawing Number
Cooks House	2	A05t01 ~ A05t02	MSEC263-151
Hospital	3	A06t01 ~ A06t03	MSEC263-151
Roxburgh South	3	A07t01 ~ A07t03	MSEC263-152
550 Edderton Rd	3	A08t01 ~ A08t03	MSEC263-153
680 Edderton Rd	5	A09t01 ~ A09t05	MSEC263-156
Belmont Homestead	4	A10t01 ~ A10t04	MSEC263-154
Edderton Homestead	15	A12t01~ A12t015	MSEC263-155
Wolfgang	1	A13t01	MSEC263-150

The tanks at the Edderton Homestead property which are located just outside the Study Area have been included in this assessment.

2.6.4. Gas and/or Fuel Storages

There are two fuel storage tanks (Structure Type T) located within the Study Area, both of which are owned by Mt. Arthur Coal. The locations of the tanks, which were determined by MSEC from an aerial photograph of the area, are shown in Drawing No. MSEC263-152. Details of the tanks are provided in Table 2.6.

Table 2.6 Gas and Fuel Storages within the Study Area

Property Name	Farm Building Structure References	Description
Roxburgh South	A07t04	2 Diesel Storage Tanks

2.6.5. Poultry Sheds

There are a number of small poultry sheds on the rural properties within the Study Area which have been included in the rural building structures described in Section 2.6.2.

2.6.6. Hydroponic or Irrigation Systems

There are no known hydroponic systems within the Study Area. There is a drip water supply system associated with the small vineyard at 680 Edderton Road, which is owned by Mt. Arthur Coal, the location of which is shown in Drawing No. MSEC263-156.

2.6.7. Fences

There are a number of fences identified within the Study Area. The majority of fences mark property boundaries and are constructed from timber or steel posts, and have fencing wire or timber railings. The majority of the fences are owned by Mt. Arthur Coal, and are all less than 2.4 metres in height.

2.6.8. Farm Dams

There are 90 farm dams located within the Study Area, of which 85 are owned by Mt. Arthur Coal. The sizes and locations of the farm dams were determined by MSEC from an aerial photograph of the area. The locations of the farm dams are shown in Drawing No. MSEC263-145 and details are provided in Table F.05 in Appendix F. The farm dams have been typically constructed within the natural drainage lines.

2.6.9. Wells and Bores

There are 11 registered water bores located within the Study Area, of which eight are owned by Mt. Arthur Coal, and three are privately owned, being Refs. GW029646 and GW29661 (2 off bores). In addition to this, there are also a number of water bores located adjacent to the Study Area. The locations of the water bores within the vicinity of the Study Area are shown in Drawing No. MSEC263-146 and details of these water bores are provided in Table 2.7.

Table 2.7 Registered Water Bores within the Vicinity of the Study Area

Bore ID	Approximate MGA Easting (m)	Approximate MGA Northing (m)	Diameter (mm)	Depth (m)	Purpose
GW018298	294395	6423510	N/A	9.1	Irrigation / Stock
GW024700	295585	6423270	N/A	N/A	Stock
GW027311	292055	6422785	N/A	11.6	Irrigation
GW029646	292830	6414890	N/A	9.1	Stock
GW029647	291015	6413910	N/A	36.6	Domestic / Stock
GW029648	290880	6413870	N/A	31.1	Domestic / Stock
GW029649	291315	6413800	N/A	25.9	Domestic / Stock
GW029661 (A)	293060	6414700	N/A	42.7	Stock
GW029661 (B)	293060	6414700	N/A	N/A	Stock
GW030745	296045	6422840	N/A	220.0	Coal Exploration
GW031622	294450	6415945	152	91.4	Stock
GW031623	294120	6417460	152	38.1	Stock
GW031859	294645	6415465	152	61.0	Stock
GW032077	294255	6416785	152	53.3	Stock
GW032512	294380	6418640	152	33.5	Stock
GW033193	293695	6417035	152	46.9	Stock
GW033547	296175	6415470	152	12.0	Stock
GW033915	294185	6419510	152	39.6	Stock
GW038607	290215	6420910	152	13.4	Stock
GW045469	295545	6420540	127	49.1	Stock
GW049223	298120	6413670	127 ~ 165	67.1	Stock
GW053572	291650	6423265	N/A	10.5	Domestic / Irrigation / Stock
GW060282	292590	6422610	N/A	N/A	Domestic / Irrigation / Stock
GW078026	294350	6419980	N/A	N/A	Stock

The locations and details of the registered water bores were provided by the Department of Natural Resources.

There are also a number of monitoring bores within the Study Area which are associated with the project, which are shown and described in the report by Mackie (2007).

2.6.10. Any Other Farm Features

There are no other known major farm features within the Study Area.

2.7. Industrial, Commercial and Business Establishments

2.7.1. Factories

There are no factories within the Study Area.

2.7.2. Workshops

There are no workshops within the Study Area.

2.7.3. Business or Commercial Establishments or Improvements

There are no business, or commercial establishments within the Study Area.

2.7.4. Gas or Fuel Storages and Associated Plants

There are no public gas or fuel storages within the Study Area.

2.7.5. Waste Storages and Associated Plants

There are no waste storages or associated plants within the Study Area.

2.7.6. Buildings, Equipment or Operations that are Sensitive to Surface Movements

There are no known buildings, equipment, or operations that are sensitive to surface movements within the Study Area.

2.7.7. Surface Mining (Open Cut) Voids and Rehabilitated Areas

There are surface mining (open cut) voids and rehabilitated areas within the Study Area. The locations of the Belmont and MacDonalds Pits, and the location of the planned Belmont West Pit are shown in Drawing No. MSEC263-141.

2.7.8. Any Other Industrial, Commercial or Business Features

There are no other major industrial, commercial, or business features within the Study Area.

2.8. Areas of Archaeological or Heritage Significance

2.8.1. Items of Archaeological Significance

There is one scared tree, numerous isolated finds, numerous artefact scatters, and potential subsurface deposits within the Study Area. Detailed surveys of the archaeological sites within the Study Area have been undertaken, which are described in the report by Umwelt (2007c).

2.8.2. Items of Heritage Significance

Detailed surveys of the heritage sites within the Study Area have been undertaken, which are described in the report by Umwelt (2007a).

2.8.3. Items on the Register of the National Estate

There are no items on the register of the National Estate within the Study Area.

2.9. Items of Architectural Significance

There are no items of architectural significance within the Study Area.

2.10. Permanent Survey Control Marks

There are a number of permanent survey control marks within and adjacent to the Study Area, the locations of which are shown in Drawing No. MSEC263-147. The locations of the survey control marks within the Study Area are summarised in Table 2.8. The survey control marks adjacent to the Study Area may experience far-field horizontal movements and have, therefore, been included as part of this assessment.

Table 2.8 Permanent Survey Control Marks within the Study Area

Survey Control Mark	MGA Easting	MGA Northing
PM 46560	294550	6414155
PM 46565	295290	6416725
PM 46566	296450	6413450
PM 74661	294635	6415940
SS 20785	292220	6414545
SS 24710	293475	6418480
SS 94013	292910	6416975
SS 94014	293920	6416880
TS 10524	293475	6418475

The locations of the survey marks were provided by the Department of Lands.

2.11. Residential Establishments

2.11.1. Houses

There are ten houses located within the Study Area, all of which are owned by Mt. Arthur Coal, and the majority of which are unoccupied. The locations and plan dimensions of the houses were determined by MSEC from an aerial photograph of the area. The details and heights of the houses were determined from site inspections by MSEC and Mt. Arthur Coal. The locations of the houses are shown in Drawings Nos. MSEC263-150 to MSEC263-156, and details are provided in Table F.03 in Appendix F. The houses are briefly described below.

Cooks House (Ref. A05a) is a single storey timber framed structure founded on brick piers and a low level perimeter brickwall, with weatherboard cladding to the walls and a metal deck roof. The house is located within the planned extension of the Belmont Pit and will be removed prior to being mined beneath. A photograph of the house is provided in Fig. 2.9. The house is owned by Mt. Arthur Coal.

Fig. 2.9 Cooks House (Ref. A05a)

Hospital (Ref. A06a) is a single storey timber framed structure founded on concrete piers with metal sheet and fibro cladding to the walls and a metal deck roof. The house was relocated from Muswellbrook and is proposed to be removed prior to the planned extension of the Belmont Pit. A photograph of the house is provided in Fig. 2.10. The house is owned by Mt. Arthur Coal.

Fig. 2.10 Hospital (Ref. A06a)

Roxburgh South (Ref. A07a) located at 370 Edderton Road is a single storey timber framed house founded on brick piers and a low level perimeter brickwall, with weatherboard cladding to the walls and an asbestos sheeted roof. A photograph of the house is provided in Fig. 2.11. The house is owned by Mt. Arthur Coal.

Fig. 2.11 Roxburgh South (Ref. A07a)

550 Edderton Road (Ref. A08a) is a single storey timber framed house with weatherboard cladding to the external walls and a metal sheeted roof. A photograph of the house is provided in Fig. 2.12. The house is owned by Mt. Arthur Coal.

Fig. 2.12 550 Edderton Road (Ref. A08a)

Belmont Homestead (Ref. A10b) is a single storey timber framed structure founded on brick piers and a low level perimeter brickwall, with fibresheet cladding to the walls and a metal sheeted roof. The homestead was constructed in the mid 1930's. The heritage significance of the homestead is discussed in the report by Umwelt (2007a). A photograph of the homestead is provided in Fig. 2.13. The homestead is owned by Mt. Arthur Coal.

Fig. 2.13 Belmont Homestead (Ref. A10b)

Edderton Homestead (Ref. A12a) is a single storey timber framed structure founded on brick piers and a low level perimeter brickwall, with weatherboard cladding to the walls and metal sheeted roof. The homestead also has a cellar area. The heritage significance of the homestead and associated structures are discussed in the report by Umwelt (2007a). A photograph of the homestead is provided in Fig. 2.14. The homestead is owned by Mt. Arthur Coal.

Fig. 2.14 Edderton Homestead (Ref. A12a)

Other houses on the Edderton Homestead property include Structure Refs. A12b, A12c, A12d and A12p, photographs of which are shown in Fig. 2.15, Fig. 2.16, Fig. 2.17 and Fig. 2.18, respectively. All of the houses are owned by Mt. Arthur Coal.

Fig. 2.15 House on the Edderton Homestead Property (Ref. A12b)

Fig. 2.16 House on the Edderton Homestead Property (Ref. A12c)

Fig. 2.17 House on the Edderton Homestead Property (Ref. A12d)

Fig. 2.18 House on the Edderton Homestead Property (Ref. A12p)

There are no houses at 680 Edderton Road. There is some private land that is partly located within the Study Area, however, there are no privately owned houses within the Study Area.

2.11.2. Flats or Units

There are no flats or units within the Study Area.

2.11.3. Caravan Parks

There are no caravan parks within the Study Area.

2.11.4. Retirement or Aged Care Villages

There are no retirement or aged care villages within the Study Area.

2.11.5. Any Other Associated Structures

Refer to Sections 2.6.2 and 2.6.3 for the descriptions of the rural building structures and tanks.

2.11.6. Any Other Residential Feature

There are no other major residential features within the Study Area.

2.12. Any Other Items

There are no other major items within the Study Area.

CHAPTER 3. OVERVIEW OF LONGWALL MINING, THE DEVELOPMENT OF SUBSIDENCE, AND THE METHOD USED TO PREDICT MINE SUBSIDENCE

3.1. Introduction

This chapter provides a brief overview of longwall mining, the development of mine subsidence, and the method that has been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls at the project. Detailed descriptions of longwall mining and the development of subsidence are provided in Appendix C of this report. Detailed descriptions of methods used to predict mine subsidence movements are provided in Appendix D of this report.

3.2. Overview of Longwall Mining

The coal at the project is proposed to be extracted using multi-seam longwall mining techniques. The proposed longwalls for the current concept mine plan vary in void widths between 210 and 286 metres, vary in overall lengths between 1450 and 4900 metres, and vary in seam extraction heights between 1.8 and 3.8 metres.

A cross-section along the length of a typical longwall at the coal face is shown in Fig. 3.1.

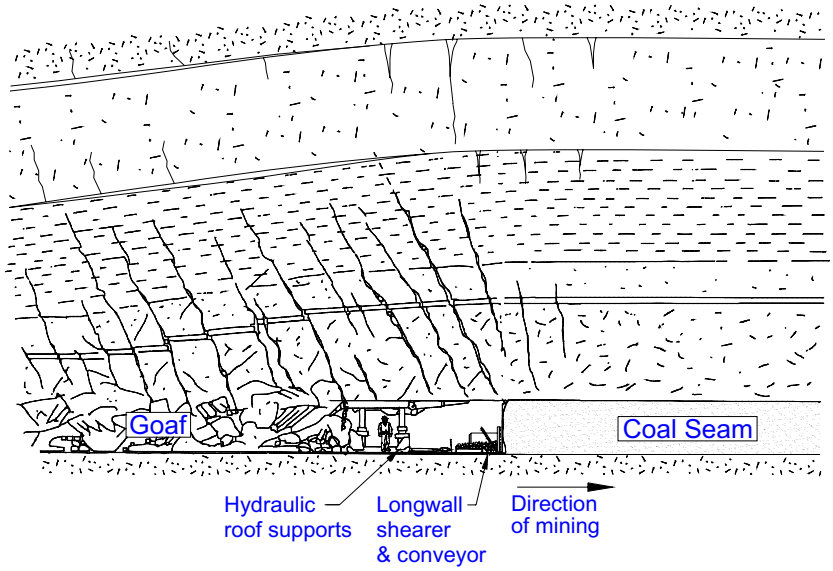

Fig. 3.1 Cross-section along the Length of a Typical Longwall at the Coal Face

The coal is removed by a shearer which cuts the coal from the coal face on each pass as it traverses the width of the longwall. The roof at the coal face is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata, and provides a working space at the coal face. The coal is then transported by a face conveyor belt which is located behind the shearer. As the coal is removed from each section of the coal face, the hydraulic supports are stepped forward, and the coal face progresses (retreats) along the length of the longwall.

The strata directly behind the hydraulic supports, immediately above the coal seam, is allowed to collapse into the void that is left as the coal face retreats. The collapsed zone comprises of loose blocks and can contain large voids. Immediately above the collapsed zone, the strata remains relatively intact and bends into the void, resulting in new vertical factures, opening up of existing vertical fractures, and bed separation. The amount of strata sagging, fracturing, and bed separation reduces towards the surface.

At the surface, the ground subsides vertically as well as moves horizontally towards the centre of the mined goaf area. The maximum subsidence at the surface varies, depends on a number of factors including longwall geometry, depth of cover, extracted seam thickness, and geology. The maximum achievable subsidence in the Hunter Coalfield is typically between 60 to 65 % of the extracted seam thickness.

3.3. Overview of Systematic Subsidence Movements

The normal ground movements resulting from the extraction of longwalls are referred to as systematic subsidence movements. These movements are described by the following parameters:-

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.
- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %.
- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (1/km)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.
- **Strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur where the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

A cross-section through a typical single longwall panel showing typical profiles of subsidence, tilt, curvature, and strain is provided in Fig. 3.2.

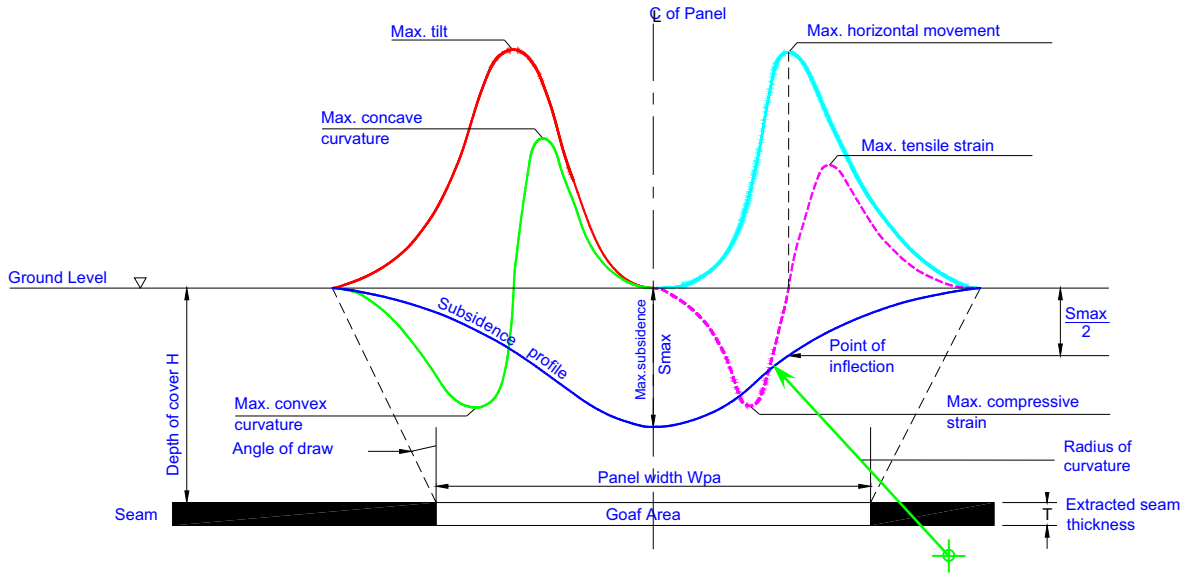

Fig. 3.2 Typical Profiles of Predicted Subsidence Parameter for a Single Longwall Panel

The definitions of incremental, cumulative, total, and travelling subsidence parameters are defined as follows:-

- **Incremental** subsidence parameters provided in this report, are the additional subsidence, tilts, curvatures, and strains which occur due to the extraction of a single longwall. Observed incremental subsidence profiles are determined by subtracting the observed subsidence profiles before from the observed subsidence profiles after the extraction of each longwall.
- **Cumulative** subsidence parameters provided in this report, are the accumulated subsidence, tilts, curvatures, and strains which occur due to the extraction of all proposed series of longwalls within a single seam.
- **Total** subsidence parameters provided in this report, are the accumulated subsidence, tilts, curvatures, and strains which occur after the extraction of all proposed series of longwalls within the current and preceding seams.
- **Travelling** subsidence parameters provided in this report, are the transient tilts, curvatures, and strains which occur as the longwall extraction faces mine directly beneath a point.

3.4. The Incremental Profile Method

The predicted systematic subsidence parameters for the proposed longwalls at the project were made using the Incremental Profile Method, which was developed by MSEC, formally known as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter, and Western Coalfields of New South Wales.

The database consists of detailed subsidence monitoring data from collieries including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Bulli, Chain Valley, Clarence, Coalcliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Gretly, Invincible, John Darling, Kemira, Lambton, Liddell, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, West Cliff, West Wallsend, and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each longwall within a series of longwalls. It can be seen from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the Incremental Profile Method use the database of observed subsidence profiles, the proposed longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the systematic subsidence parameters (ie: is slightly conservative) where the proposed mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the proposed mining area.

A detailed description of the standard Incremental Profile Method is provided in Appendix D.1.3. A detailed description of the method used to predict multi-seam subsidence interactions is provided in Appendix D.4.

The standard Hunter Coalfield profiles from the database were used to predict the systematic subsidence, tilt, curvature, and strain profiles for the proposed longwalls within the Woodlands Hill, Glen Munro, Arrowfield, Bowfield, and Piercefield Seams. Multi-seam subsidence interactions were used for the predictions for longwalls which are proposed to be extracted beneath previously extracted longwalls.

Modifications to the standard Incremental Profile Method have not been made for the presence of thick massive strata units, as the strata within the Study Area is generally thinly bedded and does not have any significant thick conglomerate units which are typically found elsewhere in the Hunter and Newcastle Coalfields. In addition to this, the spanning capacity of any thick massive strata units would be dramatically reduced, as the longwalls are proposed to be extracted as a series of longwalls within multiple seams, the majority of which are supercritical.

Modifications to the standard Incremental Profile Method have not been made for the presence of soft tuffaceous units within the coal seam roofs and floors, though these units are most notably present at the Woodlands Hill and Glen Munro Seams, because these longwalls are supercritical and, therefore, have already achieve the maximum possible subsidence for single seam extractions of 60 to 65 % of extracted seam thickness.

The subsidence model uses the surface level contours, seam floor contours, and seam thickness contours to make the predictions. The surface level information was provided by Mt. Arthur Coal on the 2nd September 2005 in a file titled *DUMP-WS-FLOOR-ROOF-THICK.XYZ*. The surface level contours are shown in Drawing No. MSEC263-110. The latest seam information was provided by Mt. Arthur Coal on the 17th July 2006 in a file titled *20060717_MAC-UG.XYZ*. The depth of cover contours for each seam are shown in Drawings Nos. MSEC263-111 to MSEC263-115. The proposed extraction heights for each seam are shown in Drawings Nos. MSEC263-121 to MSEC263-125.

Subsidence predictions have been made at points on regular grids orientated north-south and east-west across the Study Area. A grid spacing of 10 metres in each direction was adopted, which provides sufficient resolution for the generation of subsidence, tilt, and strain contours.

The maximum predicted systematic subsidence parameters resulting from the extraction of the proposed longwalls at the project are provided in Chapter 4. The predicted systematic subsidence parameters at the natural features and items of surface infrastructure are provided in Chapter 5.

An independent peer review of the methods of subsidence prediction and impact assessment for the project has been undertaken and details are provided in the report by Frith Consulting Services (Frith, 2006).

3.5. Overview of Non-Systematic Subsidence Movements

Non-systematic subsidence movements include far-field horizontal movements, irregular subsidence movements, and valley related movements. These movements are briefly described below, and more detailed descriptions are provided in Appendix D.

3.5.1. Far-Field Horizontal Movements

In addition to the systematic horizontal movements which occur above extracted longwalls, far-field horizontal movements have been observed at considerable distances from extracted longwalls. Such movements are predictable and occur whenever significant excavations occur at the surface or underground.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. These movements generally do not result in impact, except where they occur at large structures which are very sensitive to differential horizontal movements.

Detailed descriptions of far-field horizontal movements, and the method used to predict such movements, are provided in Section 5.24 and Appendix D.7.9.

3.5.2. Irregular Subsidence Movements

Irregular subsidence movements can result from near surface geological structures, including faults, dykes and abrupt changes in geology. The presence of these features near the surface can result in a bump in the subsidence profile, which is accompanied by locally higher tilts and strains.

Irregular subsidence movements can also occur at shallow depths of cover, where the collapsed zone above the extracted longwalls extends near to the surface. In this situation, the resulting subsidence profile become very erratic, which is accompanied by higher tilts and strains.

The non-systematic tilts and strains resulting from irregular subsidence movements can be much greater than those resulting from the normal systematic subsidence movements. Irregular subsidence movements, and the impacts resulting from such movements, are described in Section 5.22 and Appendices D.7.8 and D.8.

3.5.3. Valley Related Movements

The watercourses within the Study Area may be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield, but less commonly observed in the Hunter Coalfield. The reason that valley related movements are less commonly observed in the Hunter Coalfield could be that the systematic subsidence movements are typically much larger than those observed in the Southern Coalfield, which tend to mask any smaller valley related movements which may occur.

Valley related movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.3.

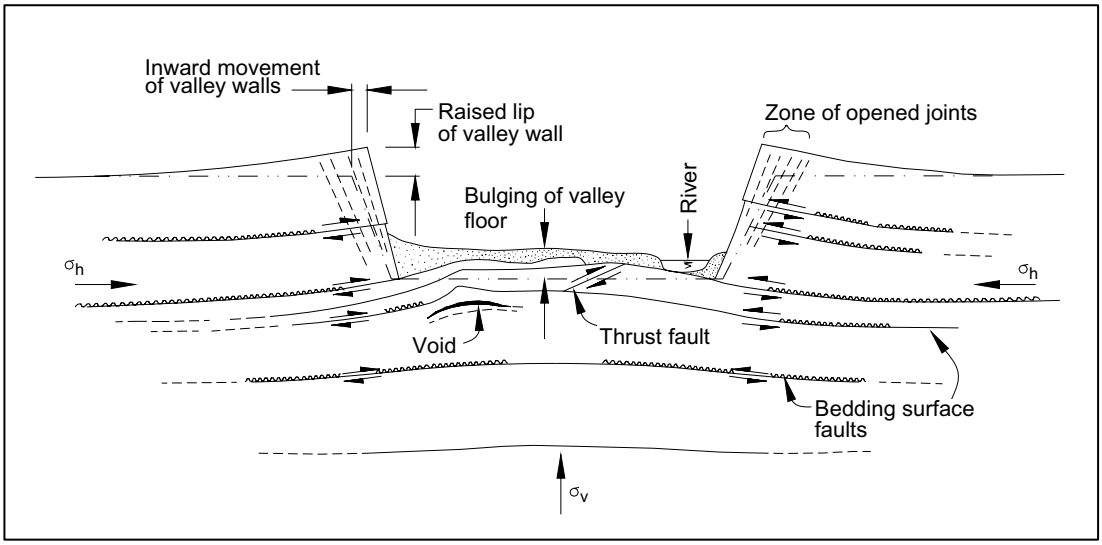

Fig. 3.3 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

Valley related movements can be accelerated by mine subsidence, and are described by the following parameters:-

- **Upsidence** is the reduced subsidence, or the net uplift within the base of a valley, and is typically expressed in units of *millimetres (mm)*. Upsidence results from the buckling of near surface strata in the base of the valley which results from the redistribution of, and increase in the horizontal stresses around the collapsed zones above extracted longwalls.
- **Closure** is the reduction in the horizontal distance between the valley sides, and is expressed in units of *millimetres (mm)*. Closure also results from the redistribution of, and increase in the horizontal stresses around the collapsed zones above extracted longwalls.
- **Compressive Strains** occur within the valley as the result of valley closure and are calculated as the decrease in horizontal distance over a standard bay length, divided by the original bay length. **Tensile Strains** also occur adjacent to the valley as the result of valley closure, and are calculated as the increase in horizontal distance over a standard bay length, divided by the original bay length. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20. Compressive and tensile strains due to valley closure are typically expressed in units of *millimetres per metre (mm/m)*.

The predicted valley related movements resulting from the extraction of the proposed longwalls at the project were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington 2004). A detailed description of valley related movements, and the method used to predict such movements, are provided in Appendix D.7.3 to D.7.7.

CHAPTER 4. MAXIMUM PREDICTED SYSTEMATIC SUBSIDENCE PARAMETERS AT THE PROJECT

4.1. Introduction

The following sections provide the maximum predicted systematic subsidence parameters resulting from the extraction of the proposed longwalls at the project for the current concept mine plan. The predictions for the natural features and items of surface infrastructure are provided in Chapter 5.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report are the systematic movements, and do not include the valley related upsidence and closure movements, or the effects of faults and other geological structures, or the additional subsidence of unconsolidated spoil heaps. Such effects have been addressed separately in the impact assessments provided in Sections 5.2 to 5.20, and in Section 5.22.

4.2. Maximum Predicted Cumulative and Total Systematic Subsidence

The predicted cumulative systematic subsidence contours, due to the extraction of the proposed series of longwalls within each seam, are shown in Drawings Nos. MSEC263-201 to MSEC263-205. The predicted total systematic subsidence contours, after the extraction of the proposed series of longwalls within each seam, are shown in Drawings Nos. MSEC263-302 to MSEC263-305.

A summary of the maximum predicted cumulative and total systematic subsidence, resulting from the extraction of the proposed series of longwalls within each seam, is provided in Table 4.1.

Table 4.1 Maximum Predicted Cumulative and Total Systematic Subsidence Resulting from the Extraction of the Proposed Series of Longwalls within Each Seam

Longwall Series	Maximum Predicted Cumulative Systematic Subsidence due to the Extraction of the Proposed Series of Longwalls within Each Seam (mm)	Maximum Predicted Total Systematic Subsidence after the Extraction of the Proposed Series of Longwalls within Each Seam (mm)
Woodlands Hill Seam	2350	2350
Glen Munro Seam	2875	2875
Arrowfield Seam	2150	4125
Bowfield Seam	2275	4125
Piercefield Seam	2025	5600

4.3. Maximum Predicted Cumulative Systematic Tilt

A summary of the maximum predicted cumulative systematic tilts, due to the extraction of the proposed series of longwalls within each seam, is provided in Table 4.2.

Table 4.2 Maximum Predicted Cumulative Systematic Tilts due to the Extraction of the Proposed Series of Longwalls within Each Seam

Longwall Series	Maximum Predicted Cumulative Systematic Transverse Tilts due to the Extraction of the Proposed Series of Longwalls within Each Seam (mm/m)	Maximum Predicted Cumulative Systematic Longitudinal Tilts due to the Extraction of the Proposed Series of Longwalls within Each Seam (mm/m)
Woodlands Hill Seam	100	100
Glen Munro Seam	140	140
Arrowfield Seam	60	55
Bowfield Seam	95	90
Piercefield Seam	20	15

The maximum predicted cumulative systematic tilt is 140 mm/m (ie: 14 %), or a change in grade of 1 in 70, which occurs due to the extraction of the proposed series of longwalls within the Glen Munro Seam. The maximum predicted cumulative tilts resulting from the extraction of the proposed series of longwalls within each seam generally occur where the depths of cover are the shallowest.

4.4. Maximum Predicted Cumulative Systematic Strains

A summary of the maximum predicted cumulative systematic strains, due to the extraction of the proposed series of longwalls within each seam, is provided in Table 4.3.

Table 4.3 Maximum Predicted Cumulative Systematic Strains due to the Extraction of the Proposed Series of Longwalls within Each Seam

Longwall Series	Maximum Predicted Cumulative Systematic Transverse Strains due to the Extraction of the Proposed Series of Longwalls within Each Seam (mm/m)		Maximum Predicted Cumulative Systematic Longitudinal Strains due to the Extraction of the Proposed Series of Longwalls within Each Seam (mm/m)	
	Tensile	Compressive	Tensile	Compressive
Woodlands Hill Seam	65	55	65	55
Glen Munro Seam	100	85	100	85
Arrowfield Seam	30	25	30	25
Bowfield Seam	60	50	60	50
Piercefield Seam	5	5	5	5

The maximum predicted cumulative systematic tensile and compressive strains are 100 mm/m and 85 mm/m, respectively, which occur due to the extraction of the proposed series of longwalls within the Glen Munro Seam. The minimum radii of curvatures associated with the maximum predicted cumulative systematic tensile and compressive strains are both 0.1 kilometres.

The maximum predicted cumulative systematic strains and the minimum predicted cumulative radii of curvatures resulting from the extraction of the proposed series of longwalls within each seam generally occur where the depths of cover are the shallowest.

4.5. Maximum Predicted Travelling Tilts, Strains and Curvatures

A summary of the maximum predicted travelling tilts and strains, during the extraction of the proposed longwalls within each seam, is provided in Table 4.4.

Table 4.4 Maximum Predicted Travelling Tilts and Strains during the Extraction of the Proposed Longwalls within Each Seam

Longwall Series	Maximum Predicted Travelling Tilts during the Extraction of the Proposed Longwalls within Each Seam (mm/m)	Maximum Predicted Travelling Tensile Strains during the Extraction of the Proposed Longwalls within Each Seam (mm/m)	Maximum Predicted Travelling Compressive Strains during the Extraction of the Proposed Longwalls within Each Seam (mm/m)
Woodlands Hill Seam	70	45	40
Glen Munro Seam	100	70	60
Arrowfield Seam	40	20	15
Bowfield Seam	65	40	35
Piercefield Seam	15	5	5

The maximum predicted travelling tilt is 100 mm/m (ie: 10 %), or a change in grade of 1 in 100, which occurs during the extraction of the proposed longwalls within the Glen Munro Seam.

The maximum predicted travelling tensile and compressive strains are 70 mm/m and 60 mm/m, respectively, which occur during the extraction of the proposed longwalls within the Glen Munro Seam. The minimum radii of curvatures associated with the maximum predicted travelling tensile and compressive strains are 0.1 kilometres and 0.2 kilometres, respectively.

It should be noted that where the predicted strains are greater than 25 mm/m, the predicted magnitude of strain become meaningless, as these peak strains are often associated with surface cracking or rippling and, hence, they become highly dependant on the baylength over which these strains are measured and local geology. In the remainder of this report, therefore, the magnitudes of the strains greater than 25 mm/m have only been quoted as being greater than this value.

The maximum predicted travelling tilts and strains, and the minimum predicted travelling radii of curvatures resulting from the extraction of the proposed longwalls within each seam generally occur where the depths of cover are the shallowest.

4.6. Maximum Predicted Subsidence as a Percentage of Extracted Seam Height for Single and Multi-seam Conditions

The maximum predicted subsidence as a percentage of extracted seam height (S_{max}/T) for each series of longwalls within each seam depends on a number of factors including single-seam or multi-seam conditions, longwall void widths, solid chain pillar widths, depths of cover, number of longwalls within the series and geology.

For single-seam extractions, the predicted cumulative subsidence, due to the extraction of a series of longwalls within a seam, is made up of a number of components, which include:-

- *Immediate subsidence* which comprises goafing into the void within the collapsed zone, sagging and dilation of strata beds above the collapsed zone, chain pillar squashing and reactivation of previously extracted longwalls within the series. Immediate subsidence is usually defined as the component of subsidence which occurs within the first few months of mining each longwall.
- *Long term or time related subsidence* comprises the ongoing settlement due to the consolidation of the collapsed zone and, to a lesser extent, the fractured zone. The long term subsidence can occur over a number of years and is often not measured in survey ground monitoring. The magnitude of long term subsidence, at the point of maximum subsidence, is typically between 5 to 10 % of the immediate subsidence, and can be greater at locations away from the point of maximum subsidence.

For single-seam longwall extractions having width-to-depth ratios greater than 1.4, the longwalls are supercritical and achieve a maximum immediate subsidence of 60 to 65 % of seam thickness in the Hunter Coalfield. The time component, which is not usually measured in ground surveys, adds an additional 5 to 10 % of subsidence at the point of maximum subsidence. The maximum predicted subsidence for supercritical single-seam conditions has, therefore, been taken as 65 to 68 % of extracted seam height, including long term subsidence.

For multi-seam extractions, the predicted total subsidence, after the extraction of a series of longwalls within a number of seams, not only comprises the components described above for single-seam extractions, but in addition, comprises a complex interaction and reactivation of the overlying goafs and redistribution of loadings on the chain pillars in the upper seams. The interaction between the seams depend on the locations of the voids and pillars within each seam, orientations of the longwall layouts within each seam and interburden thicknesses.

The maximum predicted subsidence, for a single longwall panel under multi-seam conditions, as a percentage of the extracted seam thickness are summarised in Table D. 1 and Table D. 2 in Appendix D. The interburden thicknesses between the proposed longwalls in successive seams at the project vary between 60 metres and 190 metres, with average interburden thicknesses varying between 70 and 90 metres. The multi-seam prediction factors provided in Table D. 2 for single longwall panels are, therefore, more relevant to the proposed longwalls at the project.

Accordingly, the maximum predicted immediate subsidence for a single longwall panel for supercritical multi-seam conditions, having an interburden thickness greater than 80 metres, is 67.5 % of extracted seam height. As successive longwalls within the seam are mined, ongoing subsidence over the chain pillars, reactivation of previously extracted longwalls and reactivation of the goafs above the preceding multi-seam longwalls occur. This is illustrated by the long tails on the multi-seam subsidence profiles shown in Fig. D. 9 in Appendix D. The maximum predicted subsidence for a series of longwalls having supercritical multi-seam conditions and interburden thicknesses greater than 80 metres has, therefore, been determined to be 70 to 75 % of the extraction height, including the reactivation and time components.

A summary of the maximum predicted cumulative subsidence, due to the extraction of the series of longwalls within each seam at the project, as a percentage of extracted seam height is provided in Table 4.5.

Table 4.5 Maximum Predicted Subsidence as a Percentage of Extracted Seam Height

Seam	Maximum Predicted Cumulative Subsidence as a Percentage of Extracted Seam Height		Multi-seam Prediction Factor for Each Series of Longwalls
	Single-seam Conditions	Multi-seam Conditions	
Woodlands Hill	65 ~ 68 %	-	-
Glen Munro	65 ~ 68 %	-	-
Arrowfield	65 ~ 68 %	70 ~ 75 %	1.05 ~ 1.15
Bowfield	65 ~ 68 %	70 ~ 75 %	1.05 ~ 1.15
Piercefield	50 ~ 60 %	65 ~ 70 %	1.10 ~ 1.40

The longwalls are supercritical within the Woodlands Hill and Glen Munro Seams and, where the depths of cover are the shallowest, within the Arrowfield and Bowfield Seams. The maximum predicted subsidence as a percentage of seam height for the longwalls within these seams is, therefore, between 65 and 68 % for single-seam conditions and between 70 and 75 % for multi-seam conditions.

The Piercefield Seam has a greater depth of cover and, therefore, the longwalls within this seam are not supercritical. The maximum predicted subsidence as a percentage of seam height for the longwalls within this seam is, therefore, between 50 and 60 % for single-seam conditions and between 65 and 70 % for multi-seam conditions.

The effective multi-seam prediction factors, which are the predicted proportional increases in subsidence from single-seam to multi-seam conditions, are, therefore, between 1.05 and 1.15 for the series of longwalls within the Arrowfield and Bowfield Seams and between 1.10 and 1.40 for the series of longwalls within the Piercefield Seam. The multi-seam prediction factors for the series of longwalls within the Piercefield Seam are greater than those for the series of longwalls within the Arrowfield and Bowfield Seams, as these longwalls would not normally achieve full subsidence for single-seam conditions and, therefore, have a greater potential for reactivation of the above goafs under multi-seam conditions.

CHAPTER 5. PREDICTED SUBSIDENCE PARAMETERS AND IMPACT ASSESSMENTS FOR NATURAL FEATURES AND SURFACE INFRASTRUCTURE

5.1. Introduction

This chapter describes the detailed subsidence predictions and impact assessments that have been made for the major natural features and items of surface infrastructure within the Study Area resulting from the extraction of the proposed longwalls at the project for the current concept mine plan. Significant natural features and items of surface infrastructure which are located outside the Study Area, which may be subjected to far-field movements and may be sensitive to these movements, have also been included as part of this assessment.

In the case of isolated natural features or items of infrastructure, it is possible that the actual subsidence parameters may be greater or less than those predicted, depending on their position within the subsidence trough. However, as the Incremental Profile Method is generally conservative, the observed parameters are more likely to be less than predicted. For the purposes of this report, however, the predictions provide the best available indication of the overall subsidence parameters that are likely to be experience by each feature.

In determining specific predictions for isolated features, an additional factor of safety has been applied by taking the maximum predicted values of subsidence, tilt, curvature, and strain within 20 metres of the perimeter of each feature.

5.2. The Hunter River

The Hunter River is located north of Denman Road, and is at a distance of 2 kilometres from the proposed longwalls, at its closest point. The location of the Hunter River, the limit of alluvium, and the proposed longwalls are shown in Drawing No. MSEC263-140.

The Hunter River and the limit of alluvium are located well outside the predicted total 20 mm subsidence contour and, therefore, will not be subjected to any systematic subsidence impacts as the result of mining the proposed longwalls, even if the predictions were increased by a factor of 5 times.

The Hunter River is located at a distance of greater than 10 times the depth of cover from the proposed longwalls within each seam. At this distance, it is also unlikely that the river would be subjected to any measurable upsidence and closure movements as the result of mining the proposed longwalls, even if the predictions were increased by a factor of 5 times.

The river may be subjected to low levels of far-field horizontal movements, however, these movements tend to be bodily movements, which are not associated with any significant strains, and are likely to be in the order of natural ground movements and survey tolerance. Impacts on rivers as the result of mining have not been observed in the past at the distance of the Hunter River from the proposed longwalls.

Based on previous experience of mining at these distances from rivers, the Hunter River will not be impacted by the predicted systematic, valley related or far-field horizontal movements resulting from the extraction of the proposed longwalls. The impact assessments for the groundwater system associated with the Hunter River, and the nearby ephemeral watercourses, is provided in the report by Mackie (2007).

5.3. Quarry Creek

The location of Quarry Creek is shown in Drawing No. MSEC263-140. Quarry Creek is partly located within the Study Area, and the upper reaches lie directly above proposed Longwalls BF101 and BF102 within the Bowfield Seam, and proposed Longwall PF101 within the Piercefield Seam.

The predicted profiles of cumulative and total systematic subsidence, tilt, and strain along Quarry Creek, at the completion of the proposed series of longwalls within each seam, are shown in Fig. G.01 in Appendix G. A summary of the maximum predicted values of total systematic subsidence, tilt, and strain, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.1.

Table 5.1 Maximum Predicted Total Systematic Subsidence, Tilt and Strain after the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Woodlands Hill Seam	< 20	< 0.1	< 0.1	< 0.1
Glen Munro Seam	< 20	< 0.1	< 0.1	< 0.1
Arrowfield Seam	< 20	< 0.1	< 0.1	< 0.1
Bowfield Seam	1965	57	> 25	24
Piercefield Seam	3665	57	> 25	24

The creek will also be subjected to travelling tilts and strains where the extraction faces of the proposed longwalls mine beneath it. The travelling tilts and strains are typically aligned along the longitudinal axes of the longwalls with the maximum values typically occurring in the locations of maximum incremental subsidence for each longwall. A summary of the maximum predicted travelling tilts and strains, during the extraction of the proposed longwalls within each seam, is provided in Table 5.2.

Table 5.2 Maximum Predicted Travelling Tilts and Strains at Quarry Creek during the Extraction of the Proposed Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
Bowfield Seam	40	21	17
Piercefield Seam	8.6	4.1	2.4

Quarry Creek may also be subjected to valley related movements resulting from the extraction of the proposed longwalls. A summary of the maximum predicted total upsidence, closure, and compressive strain due to closure at Quarry Creek, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.3.

Table 5.3 Maximum Predicted Total Upsidence, Closure and Compressive Strain due to Closure after the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Equivalent Valley Height (m)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Total Compressive Strain due to Closure (mm/m)
Woodlands Hill Seam	3	< 20	< 20	< 0.1
Glen Munro Seam	3	< 20	< 20	< 0.1
Arrowfield Seam	3	< 20	< 20	< 0.1
Bowfield Seam	3	50	20	2.4
Piercefield Seam	3	105	45	4.4

The equivalent valley height is calculated by multiplying the measured overall valley height by a factor which reflects the shape of the valley and surrounding terrain. The overall valley height is measured after examining the terrain across the valley within a radius of half the depth of cover. The factor varies from 1.0, for steeply sided gorges in flat terrain, to less than 0.5 for valleys of flatter profile in undulating terrain. A factor of 1.0 was conservatively adopted for Quarry Creek.

The predicted strains along the alignment of the creek, due to the systematic movements, as provided in Table 5.1, are perpendicular to the compressive strains across the creek due to closure, as provided in Table 5.3. The strains, therefore, have not been combined as they are independent of each other. Also, the locations of the maximum strains along the creeks and the locations of the maximum strains across the creek valleys do not necessarily coincide.

5.3.1. The Increased Likelihood of Ponding, Flooding and Scouring

Quarry Creek is ephemeral as water only flows during, and for a short period after each rain event. Ponding may naturally develop along Quarry Creek, for a short period of time, after major rain events.

The increased likelihood of ponding can occur at locations where the maximum predicted tilt opposes and is greater than the natural gradient that exists along the creek before mining. The maximum predicted opposing tilt is 57 mm/m (ie: 5.7 %), or a change in grade of 1 in 20, which occurs where Quarry Creek crosses the maingate of proposed Longwall BF102 within the Bowfield Seam. The natural creek gradient in this location is approximately 5 mm/m (ie: 0.5 %), or a natural grade of 1 in 200.

The predicted opposing tilts where the creek crosses the maingate of proposed Longwall BF101 within the Bowfield Seam, and where the creek crosses the tailgate of proposed Longwall PF101 within the Piercefield Seam are 45 mm/m and 37 mm/m, respectively. The average natural creek gradient above these longwalls is approximately 10 mm/m (ie: 1.0 %), or a natural grade of 1 in 100.

It is likely, therefore, that there will be increased ponding above the maingates of proposed Longwalls BF101 and BF102 within the Bowfield Seam, and above the tailgate of proposed Longwall PF101 within the Piercefield Seam. A summary of the maximum predicted depths and extents of the ponds at the completion of the proposed longwalls is provided in Table 5.4.

Table 5.4 Maximum Predicted Depths and Extents of Ponds along Quarry Creek

Location	Predicted Maximum Depth (m)	Predicted Maximum Length (m)
Pond 1	1.7	190
Pond 2	1.2	180
Pond 3	1.2	200

The locations and extents of the predicted ponds are illustrated in Fig. 5.1.

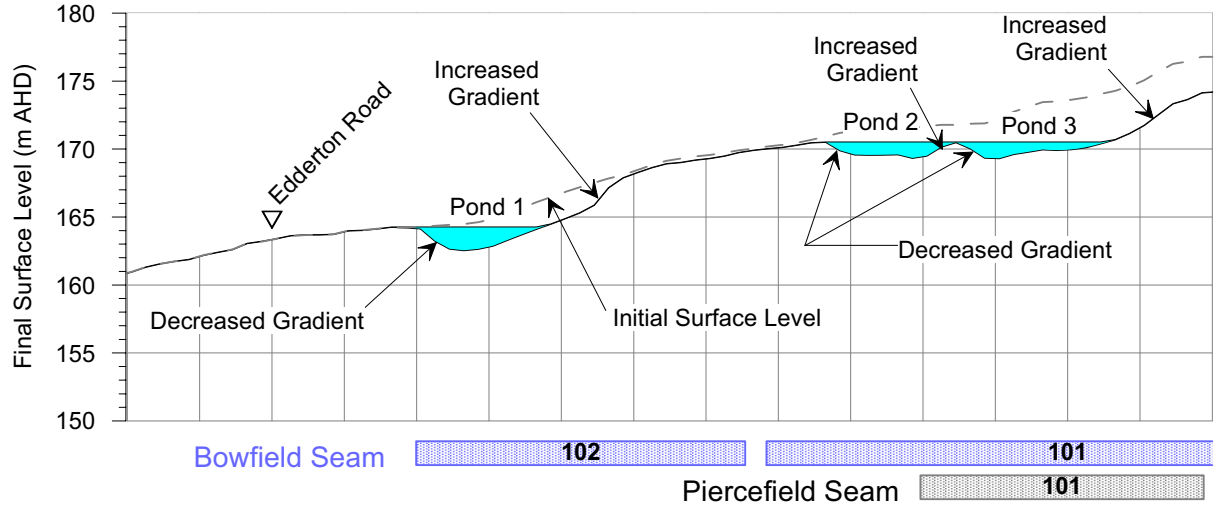

Fig. 5.1 Predicted Locations of Ponds along Quarry Creek

Quarry Creek has an alluvial bed and it is expected, therefore, that the creek bed downstream of the ponds, as shown in Fig. 5.1, would erode during subsequent rain events, especially during times of high flow. It would be expected over time, after a sufficient volume of water has flowed along the creek, that the gradients along the creek bed would approach those which existed before mining. The likelihood and extent of ponding along the creek would, therefore, be expected to decrease with time.

The increased likelihood of scouring can occur at locations where the predicted tilt considerably increases the natural creek gradient that existed before mining, and where the velocity of flow exceeds 1 m/sec. The predicted locations of increased gradient along the creek are shown in Fig. 5.1.

The maximum predicted increasing tilt is 54 mm/m (ie: 5.4 %), or a change in grade of 1 in 20, which occurs where Quarry Creek crosses the tailgate of proposed Longwall BF102 within the Bowfield Seam. The predicted increasing tilts at the tailgate of proposed Longwall BF101 within the Bowfield Seam and at the maingate of proposed Longwall PF101 within the Piercefield Seam are 35 mm/m and 9.8 mm/m, respectively. The average natural creek gradient above these longwalls is approximately 10 mm/m (ie: 1.0 %), or a natural grade of 1 in 100.

Although the maximum predicted increasing tilts are much greater than the natural creek gradients, they occurs along the upper reaches of the creek where the surface water flow rates are small. Also, at these locations, Quarry Creek is a first order stream and is ephemeral, and so water only flows during, and for a short period after rain events. It is unlikely, therefore, that there would be any significant increase in the likelihood of scouring along the creek.

5.3.2. The Likelihood of Cracking in the Alluvial Creek Bed and Fracturing of Bedrock

The maximum predicted strains along Quarry Creek occur adjacent to the goaf edges of proposed Longwall BF102 within the Bowfield Seam. The maximum predicted systematic tensile and compressive strains along the creek are greater than 25 mm/m and 24 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted tensile and compressive strains are less than 0.4 kilometres and 0.4 kilometres, respectively. The maximum predicted compressive strain due to closure, at the completion of the proposed longwalls, is 4.4 mm/m.

The maximum predicted tensile strains are likely to result in cracking in the alluvial bed of Quarry Creek. Tensile cracking is most likely to occur above, and adjacent to the goaf edges of proposed Longwalls BF101, BF102 and PF101. The creek has an alluvial bed and it is likely, therefore, that the surface cracks would be filled by alluvial materials during subsequent flow events.

The maximum predicted compressive strains may be of sufficient magnitude to result in the buckling and dilation of the topmost bedrock, which can induce tensile cracking at the surface. The fracturing and dilation in the bedrock, resulting from the compressive strains, typically occur at depths not greater than 10 to 15 metres. Dilation of the bedrock beneath the creek may occur above, and within 250 metres of the edges of the proposed longwalls, which may result in some local diversion of surface water flows into the dilated bedrock. Surface water which is diverted into dilated bedrock typically remerges further downstream as illustrated in Fig. 5.2.

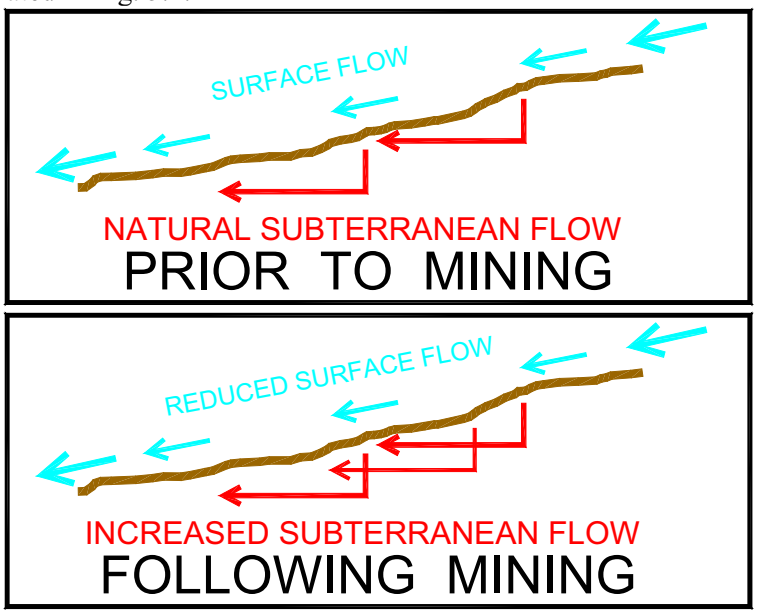

Fig. 5.2 Surface Water Flow Diversion

The depth of cover to the Bowfield Seam, where Quarry Creek crosses proposed Longwall BF102, is less than 100 metres. It is possible that the collapsed zone above this longwall may extend near to the surface, and that the subsidence profile could become irregular, resulting in bumps or small steps along the alignment of the creek. The likelihood and impact of irregular subsidence profiles is discussed in Section 5.22.

It is also possible that the hydraulic connectivity between the surface and the mine workings could increase above proposed Longwalls BF101 and BF102 within the Bowfield Seam. Quarry Creek is ephemeral and it is possible, therefore, that surface water could drain from the creek into the mine workings during rain events. It is possible, therefore, that some remedial measures would be required on the creek, above proposed Longwalls BF101 and BF102, to seal any fracturing and dilation of the underlying strata using various methods, including grouting.

The loss of water from creeks in shallow mining situations have been successfully remediated in the past. At Wambo Colliery, cracking occurred in Wambo Creek, as the result of the systematic strains, where the depth of cover was less than 80 metres. Near vertical cracks developed which interconnected with the bedding planes in the creek bed, increasing the hydraulic connectivity between the surface and the seam, and the inflow of water into the mine. The connectivity was significantly reduced by injecting a low strength cement / bentonite grout beneath the creek bed, to form a grout blanket.

5.4. Saddlers Creek

Saddlers Creek is located south of the Study Area, and is at a distance of greater than 500 metres from the proposed longwalls, at its closest point. The creek is located well outside the predicted total 20 mm subsidence contour and, therefore, will not be subjected to any systematic subsidence impacts.

Saddlers Creek may be subjected to small upsidence, closure, and compressive strains due to valley closure, resulting from the extraction of the proposed longwalls. The creek is located a minimum distance of 2.7 kilometres from the proposed longwalls within the Glen Munro, Arrowfield, Bowfield and Piercefield Seams, and is unlikely, therefore, to be subjected to any significant systematic or valley related movements resulting from the extraction of the proposed longwalls within these seams.

A summary of the maximum predicted total upsidence, closure and compressive strain due to closure at Saddlers Creek, resulting from the extraction of the proposed longwalls within the Woodlands Hill Seam, is provided in Table 5.5.

Table 5.5 Maximum Predicted Total Upsidence, Closure, and Compressive Strain due to Closure due the Extraction of the Proposed Longwalls within the Woodlands Hill Seam

Proposed Series of Longwalls	Equivalent Valley Height (m)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Total Compressive Strain due to Closure (mm/m)
Woodlands Hill Seam	5	< 5	< 5	0.1

An equivalent valley height factor of 1.0 was conservatively adopted for the Saddlers Creek. The predicted valley related movements at Saddlers Creek are very small and, therefore, will not have any significant impact on the creek.

The creek may be subjected to low levels of far-field horizontal movements, however, these movements tend to form bodily movements which are not associated with any significant strains. Impacts on creeks as the result of mining have not been observed in the past at the distance of Saddlers Creek from the proposed longwalls.

It is extremely unlikely, therefore, that Saddlers Creek would be impacted as a result of the extraction of the proposed longwalls.

5.5. Other Watercourses

There are numerous drainage lines around and between the hills within the Study Area which will be subjected to the full range of predicted systematic subsidence movements. The locations, descriptions and impact assessments for the drainage lines are provided in the report by Umwelt (2007a). The impact assessments for the drainage lines have been based on the subsidence predictions provided by MSEC.

5.6. Aquifers and Groundwater Resources

The locations, descriptions, and impact assessments for the aquifers and groundwater resources within the Study Area are provided in the report by Mackie (2007). The impact assessments for the aquifers and groundwater resources have been based on the subsidence predictions provided by MSEC.

5.7. Steep Slopes

The land within the vicinity of the proposed longwalls is undulating to hilly, with the steepest slopes occurring adjacent to Mount Ogilvie, to the west of the Study Area, and adjacent to Mount Arthur, to the east of the Study Area. The proposed longwalls, however, will not be mined beneath Mount Ogilvie and Mount Arthur.

For the purposes of this report, steep slopes have been defined as areas of land having gradients greater than 1 in 3 (ie: a grade of 33 %, or an angle to the horizontal of 18°). Slopes of less than 1 in 3 are generally considered stable and it would be unlikely, therefore, that soil slumping would occur down these slopes as a result of mining the proposed longwalls.

The steep slopes located outside the Study Area will not be subjected to any significant systematic subsidence movements, and it is likely, therefore, that these slopes would remain stable during the mining period. It should also be noted that it was observed during the initial investigations that natural soil slumping has already occurred along some of the steep slopes as the result of natural instability and devegetation.

The locations of the steep slopes within the Study Area are shown in Drawing No. MSEC263-141. There are two main areas within the Study Area having natural steep slopes, which have been called the "Northern Hills" and the "Western Hills" in this report.

There are also artificial steep slopes within the MacDonalds and Belmont Pits along the highwalls and low-walls. The Belmont Pit is also planned to be extended prior to the extraction of the proposed longwalls within the Glen Munro Seam. New highwalls and low-walls are planned to be constructed for the new Belmont West Pit.

5.7.1. Natural Steep Slopes

The natural steep slopes at the "Northern Hills" and the "Western Hills" have grades typically between 1 in 3 and 1 in 2, with some isolated areas having grades up to 1 in 1.5. Longwalls within the Glen Munro, Arrowfield, and Piercefield Seams are proposed to mine beneath the "Northern Hills". Longwalls within the Glen Munro, Arrowfield, Bowfield, and Piercefield Seams are proposed to mine beneath the "Western Hills".

The greatest impacts on the natural steep slopes are likely to occur during the extraction of the Glen Munro Seam, which has the shallowest depth of cover. The maximum predicted total systematic tilt at the natural steep slopes, resulting from the extraction of the proposed longwalls, is 60 mm/m (ie: 6.0 %), or a change in grade of 1 in 15. The maximum predicted total tilt is very small when compared to the existing surface gradients of the natural steep slopes, which typically vary between 1 in 3 and 1 in 2.

The maximum predicted total systematic strains at the natural steep slopes, at any time during or after the extraction of the proposed longwalls, are greater than 25 mm/m tensile and 25 mm/m compressive. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are less than 0.4 kilometres and 0.4 kilometres, respectively.

It is possible that the maximum predicted systematic strains would result in soil slumping down the steep slopes at the "Northern Hills", where the depth of cover is the shallowest, and to a lesser extent down the steep slopes at the "Western Hills". These movements are similar to observed upsidence and closure movements in creek valleys, where compression is developed at the bottoms of the valleys and tension is developed at the tops of the valleys. It is unlikely that mine subsidence will result in any large-scale slope failure, since such failures are generally not observed as the result of longwall mining.

Soil slumping down steep slopes was monitored closely during the extraction of Longwall 6 at Baal Bone Colliery. The width of Longwall 6 was 210 metres, the depth of cover varied between 55 metres and 105 metres, and the gradients of the steep slopes varied between 1 in 3 and 1 in 2. A number of surface cracks were observed at the tops of the steep slopes, with widths varying between 100 mm and 250 mm, and with lengths varying between 25 metres and 100 metres. A number of compression ridges were also observed at the bases of the steep slopes, with lengths varying between 20 metres and 50 metres. Larger surface cracks have also been observed at a number of other Collieries, however, many of these have been associated with movements adjacent to cliffs.

The surface cracking resulting from soil slumping at the "Northern Hills" and "Western Hills" is predicted to be typically in the order of 250 mm wide, which is likely to develop at the tops of the steep slopes, but could be in the order of 500 mm wide where the slopes are the steepest. It is also likely that surface cracking would develop further down the steep slopes resulting from the systematic tensile strains. As the steep slopes typically have gradients of less than 1 in 2, the relationship between surface crack width and depth of cover shown in Fig. D.12 in Appendix D can be adopted. The graph is based upon measured data in the NSW Coalfields and observations over mines in the United Kingdom.

The upper blue line on the graph represents the upper-bound limit of the data in Australia, and the lower red line represents the upper-bound limit of the data measured at South Bulga Colliery. It can be seen from this figure that crack width increases as the depth of cover decreases, and that significant crack widths can develop at low depths of cover.

The depth of cover is the shallowest where Longwall GM102 within the Glen Munro Seam is proposed to be mined beneath the "Northern Hills", and tensile cracks are predicted to be typically in the order of 200 mm wide within the final tensile zones, and could be as large as 500 mm wide where the depths of cover are the shallowest. Where the remaining longwalls within the Arrowfield, Bowfield and Piercefield Seams are proposed to mine beneath the "Northern Hills" and "Western Hills", the depths of cover are generally greater than 150 to 200 metres, and tensile cracks are predicted to be typically in the order of 100 mm wide within the final tensile zones. The ranges of depths of cover and the predicted typical crack widths are illustrated in Drawing No. MSEC263-315.

It is likely that the steep slopes at the "Northern Hills", and to a lesser extent at the "Western Hills", will require some remediation during, and at the completion of mining, including regrading, recompacting, and revegetating the slopes.

It is recommended that management strategies should be developed to ensure that the steep slopes are safely maintained during the mining period. It is also recommended that the steep slopes should be visually monitored for tension cracks during the mining period, and that they should be treated if any significant cracking occurs.

5.7.2. Steep Slopes within the MacDonalds, Belmont and Planned Belmont West Pits

The assessments for the highwalls and low-walls within MacDonalds and Belmont Pits are provided in Sections 5.16.1 and 5.16.2, respectively. The assessments for the planned highwalls and low-walls within the planned Belmont West Pit are provided in Section 5.16.3.

5.8. Flora and Fauna

The locations, descriptions, and impact assessments for the flora and fauna within the Study Area are provided in the report by Umwelt (2007b). The impact assessments for the flora and fauna have been based on the subsidence predictions provided by MSEC.

5.9. Travelling Stock Reserve

The location of the TSR is shown in Drawing No. MSEC263-150. The TSR will be mined beneath by the proposed longwalls within the Glen Munro, Arrowfield and Piercefield Seams, and is likely to be impacted by surface cracking which is discussed in Section 5.25. The surface cracks within the TSR are predicted to be typically in the order of 200 mm wide, which are expected to occur within the final tensile zones resulting from the extraction of proposed Longwalls GM204 and GM205 within the Glen Munro Seam.

The surface cracks will tend to heal naturally, especially during rain events. If significant cracking is left untreated, however, it could form trip hazards for people and farm animals, or result in soil erosion. It is likely that surface cracking between 50 mm and 100 mm would require infilling with soil or other suitable materials, and that surface cracking greater than 100 mm would require regrading and recompacting.

5.10. Roads

5.10.1. Predictions and Impact Assessments for Edderton Road

Edderton Road crosses the Study Area in a north-south direction, and its location is shown in Drawing No. MSEC263-142. It is planned that part of Edderton Road will be diverted across the Belmont Pit, which is also shown in this drawing, and is discussed in Section 5.10.3. The predictions and impact assessments provided in this section are for the existing alignment of Edderton Road.

The predicted cumulative and total systematic subsidence, tilt, and strain profiles along the alignment of Edderton Road, at the completion of the proposed series of longwalls within each seam, are shown in Fig. G.02 in Appendix G. A summary of the maximum predicted values of cumulative systematic subsidence, tilt, and strain along the alignment of Edderton Road, due to the extraction of the proposed series of longwalls within each seam, is provided in Table 5.6. A summary of the maximum predicted values of total systematic subsidence, tilt, and strain along the alignment of Edderton Road, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.7.

Table 5.6 Maximum Predicted Cumulative Systematic Subsidence Parameters along Edderton Road due to the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
Woodlands Hill Seam	1610	39	18	15
Glen Munro Seam	2025	63	> 25	> 25
Arrowfield Seam	1710	34	15	12
Bowfield Seam	1955	60	> 25	> 25
Piercefield Seam	1515	15	1.9	3.1

Table 5.7 Maximum Predicted Total Systematic Subsidence Parameters along Edderton Road after the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Woodlands Hill Seam	1610	39	18	15
Glen Munro Seam	2025	63	> 25	> 25
Arrowfield Seam	3425	63	> 25	> 25
Bowfield Seam	3425	63	> 25	> 25
Piercefield Seam	4290	67	> 25	> 25

The road will also be subjected to travelling tilts and strains where the extraction faces of the proposed longwalls mine beneath it. The travelling tilts and strains are typically aligned along the longitudinal axes of the longwalls with the maximum values typically occurring in the locations of maximum incremental subsidence for each longwall. A summary of the maximum predicted travelling tilts and strains, during the extraction of the proposed longwalls within each seam, is provided in Table 5.8.

Table 5.8 Maximum Predicted Travelling Tilts and Strains at Edderton Road during the Extraction of the Proposed Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
Woodlands Hill Seam	27	13	11
Glen Munro Seam	44	25	21
Arrowfield Seam	24	11	8.4
Bowfield Seam	42	22	19
Piercefield Seam	11	1.3	2.2

Edderton Road is generally orientated perpendicular to the proposed longwalls and, therefore, the predicted travelling tilts and strains are aligned across the road.

The maximum predicted systematic tilt along the road is 67 mm/m (ie: 6.7 %), or a change in grade of 1 in 15, which occurs above the maingate of proposed Longwall GM204 within the Glen Munro Seam. High tilts along the road also occur as a result of the extraction of proposed Longwalls WH101 to WH110 within the Woodlands Hill Seam, proposed Longwall GM205 within the Glen Munro Seam, proposed Longwalls AF102 to AF104 within the Arrowfield Seam, and proposed Longwalls BF101 and BF102 within the Bowfield Seam.

It is possible that there will be a small change in the surface water drainage along the road above these proposed longwalls, where the existing grade of the road is relatively flat. The grade of the road within the Study Area, however, typically varies between 20 mm/m and 100 mm/m and it is expected, therefore, that the road will remain relatively free draining, and that any additional ponding along the road will be very small and localised.

The maximum predicted systematic tilt across the alignment of the road is 44 mm/m (ie: 4.4 %), or a change in grade of 1 in 25, which occurs during the extraction of proposed Longwall GM204 within the Glen Munro Seam. High tilts across the road also occur during the extraction of proposed Longwalls WH101 to WH110 within the Woodlands Hill Seam, proposed Longwall GM205 within the Glen Munro Seam, proposed Longwalls AF102 to AF104 within the Arrowfield Seam, and proposed Longwalls BF101 and BF102 within the Bowfield Seam.

The maximum predicted systematic tilts across the road are predicted to occur where the extraction faces of the proposed longwalls mine directly beneath the road and, therefore, will only temporarily and locally affect the drainage of surface water across the road.

The maximum predicted systematic tensile strain at Edderton Road, at any time during or after the extraction of the proposed longwalls, is greater than 25 mm/m, which occurs above the tailgate of proposed Longwall GM204 within the Glen Munro Seam. The maximum predicted systematic compressive strain at Edderton Road, at any time during or after the extraction of the proposed longwalls, is also greater than 25 mm/m, which occurs above the maingate of proposed Longwall GM204 within the Glen Munro Seam. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are both less than 0.4 kilometres.

High systematic tensile and compressive strains also occur above proposed Longwalls WH101 to WH110 within the Woodlands Hill Seam, proposed Longwall GM205 within the Glen Munro Seam, proposed Longwalls AF102 to AF104 within the Arrowfield Seam, and proposed Longwalls BF101 and BF102 within the Bowfield Seam.

Ground strains of these magnitudes are likely to result in cracking of the road surface in the tensile zones, and some rippling of the road surface in the compressive zones. A series of cracks in the road surface parallel to the proposed longwalls (ie: across the road) of up to 50 mm widths are likely to occur after each longwall is mined beneath the road. Cracks perpendicular to the proposed longwalls (ie: along the road) are also likely to occur as the extraction face of each longwall is mined beneath the road. It is expected, however, that these cracks will be partially closed after the extraction face of each longwall passes beyond the road, as the tensile phase from the travelling wave is followed by a compressive phase.

The road is of flexible construction and can be regraded, repaired, and reconstructed using standard road maintenance techniques as mining proceeds. Each longwall will affect a length of road of approximately 300 to 500 metres, and repairs at any time will be limited to the affected section of road. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

The depths of cover along Edderton Road are less than 100 metres above the proposed Longwalls WH101 to WH106 within the Woodlands Hill Seam, proposed Longwalls GM204 and GM205 within the Glen Munro Seam, and proposed Longwalls BF101 and BF102 within the Bowfield Seam. It is likely that the collapsed zones above these longwalls will extend near to the surface, where the depths of cover are the shallowest. In these locations, it is possible that the subsidence profiles will become irregular resulting in bumps or small steps in the road surface. The likelihood and impacts of irregular subsidence profiles are discussed in Sections 5.21 and 5.22.

It is recommended, therefore, that Edderton Road should be visually monitored on a regular basis, as the extraction face of each longwall mines beneath the road, so that any impacts can be identified and rectified immediately. It may be necessary to introduce a reduced speed limit along the affected section of road, prior to the remedial works being completed. It is also recommended that signage be installed along Edderton Road warning of impacts on the road as the result of mine subsidence. It is unlikely that the traffic signs and other road infrastructure would suffer any impacts due to mine subsidence.

5.10.2. Predictions and Impact Assessments for MacDonalds Road

MacDonalds Road crosses the Study Area in an east-west direction, and its location is shown in Drawing No. MSEC263-142. The predicted cumulative and total systematic subsidence, tilt, and strain profiles along the road, at the completion of the proposed series of longwalls within each seam, are shown in Fig. G.03 in Appendix G.

A summary of the maximum predicted values of cumulative systematic subsidence, tilt, and strain along the alignment of MacDonalds Road, due to the extraction of the proposed series of longwalls within each seam, is provided in Table 5.9. A summary of the maximum predicted values of total systematic subsidence, tilt, and strain along the alignment of MacDonalds Road, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.10.

Table 5.9 Maximum Predicted Cumulative Systematic Subsidence Parameters along MacDonalds Road due to the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
Woodlands Hill Seam	2160	72	> 25	> 25
Glen Munro Seam	< 20	< 0.1	< 0.1	< 0.1
Arrowfield Seam	< 20	< 0.1	< 0.1	< 0.1
Bowfield Seam	1860	35	11	12
Piercefield Seam	1300	4.7	1.5	2.5

Table 5.10 Maximum Predicted Total Systematic Subsidence Parameters along MacDonalds Road after the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Woodlands Hill Seam	2160	72	> 25	> 25
Glen Munro Seam	2160	72	> 25	> 25
Arrowfield Seam	2160	72	> 25	> 25
Bowfield Seam	3660	72	> 25	> 25
Piercefield Seam	4710	72	> 25	> 25

The road will also be subjected to travelling tilts and strains where the extraction faces of the proposed longwalls mine beneath it. The travelling tilts and strains are typically aligned along the longitudinal axes of the longwalls with the maximum values typically occurring in the locations of maximum incremental subsidence for each longwall. A summary of the maximum predicted travelling tilts and strains, during the extraction of the proposed longwalls within each seam, is provided in Table 5.11.

Table 5.11 Maximum Predicted Travelling Tilts and Strains at MacDonalds Road during the Extraction of the Proposed Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
Woodlands Hill Seam	54	> 25	> 25
Bowfield Seam	20	6.5	5.1
Piercefield Seam	4.3	0.4	0.3

MacDonalds Road is orientated at an acute angle to the proposed longwalls and, therefore, the predicted travelling tilts and strains are essentially aligned along the road.

The maximum predicted systematic tilt along the road is 72 mm/m (ie: 7.2 %), or a change in grade of 1 in 15, which occurs above the finishing (eastern) end of proposed Longwall WH106 within the Woodlands Hill Seam. Elsewhere, the maximum predicted tilts above the remaining proposed longwalls varies between 20 mm/m to 50 mm/m, which occur adjacent to the longwall chain pillars.

MacDonalds Road is unsealed and, therefore, surface water is more likely to infiltrate into the ground rather than pond on the surface. In times of heavy rainfall, however, it is possible that there could be a small increase in the ponding of surface water along the road above proposed Longwalls WH101, WH102 and WH106 within the Woodlands Hill Seam. Any increase in ponding is expected to be small and localised.

The maximum predicted systematic tensile and compressive strains along MacDonalds Road, at any time during or after the extraction of the proposed longwalls, are both greater than 25 mm/m which occur near the finishing (eastern) end of proposed Longwall WH106 within the Woodlands Hill Seam. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are both less than 0.4 kilometres.

Ground strains of these magnitudes are likely to result in cracking of the surface in the tensile zones, and some rippling of the surface in the compressive zones. A series of cracks in the road surface parallel to the proposed longwalls of up to 50 mm widths are likely to occur during and after each longwall mines beneath the road. The tensile cracks in the road near the middle of the proposed longwalls, however, are likely to be partially closed after the extraction face of each longwall passes beyond the road, as the tensile phase from the travelling wave is followed by a compressive phase.

The unsealed road can be regraded, repaired, and reconstructed using standard road maintenance techniques as mining proceeds. Each longwall will affect a length of road of approximately 300 to 500 metres, and repairs at any time will be limited to the affected section of road. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

The depths of cover along MacDonalds Road are less than 100 metres above the proposed Longwalls WH101, WH102, WH103, WH105 and WH106 within the Woodlands Hill Seam. It is likely that the collapsed zones above these longwalls will extend near to the surface, where the depths of cover are the shallowest. In these locations, it is possible that the subsidence profiles will become irregular resulting in bumps or small steps in the road surface. The likelihood and impact of irregular subsidence profiles is discussed in Sections 5.21 and 5.22.

It is recommended, therefore, that MacDonalds Road should be visually monitored on a regular basis, as the extraction face of each longwall mines beneath the road, so that any impacts can be identified and rectified immediately. It is also recommended that signage be installed along MacDonalds Road warning of impacts on the road as the result of mine subsidence. It is unlikely that the traffic signs and other road infrastructure would suffer any impacts due to mine subsidence.

5.10.3. Predictions and Impact Assessments for the Planned Diversion of Edderton Road

The location of the planned diversion of Edderton Road is shown in Drawing No. MSEC263-142. A new bridge is planned to be constructed where the road diversion crosses the Belmont Pit, and the predictions and impact assessments for the bridge are provided in Section 5.11.3. The predictions provided in this section are for the road diversion only.

The predicted cumulative and total systematic subsidence, tilt, and strain profiles along the alignment of the road diversion, at the completion of the proposed series of longwalls within each seam, are shown in Fig. G.04 in Appendix G. A summary of the maximum predicted values of cumulative systematic subsidence, tilt, and strain along the alignment of the road diversion, due to the extraction of the proposed series of longwalls within each seam, is provided in Table 5.12. A summary of the maximum predicted values of total systematic subsidence, tilt, and strain along the alignment of the road diversion, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.13.

Table 5.12 Maximum Predicted Cumulative Systematic Subsidence Parameters along the Road Diversion due to the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
Woodlands Hill Seam	< 20	< 0.1	< 0.1	< 0.1
Glen Munro Seam	2025	72	> 25	> 25
Arrowfield Seam	1560	11	9.9	9.7
Bowfield Seam	1890	19	3.9	3.3
Piercefield Seam	1475	17	3.7	6.9

Table 5.13 Maximum Predicted Total Systematic Subsidence Parameters along the Road Diversion after the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Woodlands Hill Seam	< 20	< 0.1	< 0.1	< 0.1
Glen Munro Seam	2025	72	> 25	> 25
Arrowfield Seam	2940	65	> 25	> 25
Bowfield Seam	2940	65	> 25	> 25
Piercefield Seam	3850	66	> 25	> 25

The road diversion will also be subjected to travelling tilts and strains where the extraction faces of the proposed longwalls mine beneath it. The travelling tilts and strains are typically aligned along the longitudinal axes of the longwalls with the maximum values typically occurring in the locations of maximum incremental subsidence for each longwall. A summary of the maximum predicted travelling tilts and strains, during the extraction of the proposed longwalls within each seam, is provided in Table 5.14.

Table 5.14 Maximum Predicted Travelling Tilts and Strains at the Road Diversion during the Extraction of the Proposed Longwall within Each Seam

Proposed Series of Longwalls	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
Glen Munro Seam	50	> 25	> 25
Arrowfield Seam	7.5	6.9	6.8
Bowfield Seam	14	2.7	2.3
Piercefield Seam	12	2.6	4.8

The maximum predicted systematic tilt along the road diversion is 72 mm/m (ie: 7.2 %), or a change in grade of 1 in 15, which occurs above the finishing (eastern) end of proposed Longwall GM204 within the Glen Munro Seam. The predicted systematic tilts along the road elsewhere are less than 20 mm/m (ie: 2.0 %), or a change in grade of 1 in 50.

It is possible that there will be a small increase in the ponding of surface water along the road diversion above proposed Longwall GM204, if the constructed grade of the road is small in this location. It is likely, however, that the road diversion will remain relatively free draining and that any additional ponding along the road will be very small and localised.

The maximum predicted systematic tilt across the road diversion is 50 mm/m (ie: 5.0 %), or a change in grade of 1 in 20, which occurs during the extraction of proposed Longwall GM204 within the Glen Munro Seam. The maximum predicted tilts across the road only occur as the extraction face of each longwall mines directly beneath the road and, therefore, will only temporarily and locally affect the drainage of surface water across the road diversion.

The maximum predicted systematic tensile and compressive strains at the road diversion, at any time during or after the extraction of the proposed longwalls, are both greater than 25 mm/m which occur after the extraction of proposed Longwall GM204 within the Glen Munro Seam. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are both less than 0.4 kilometres.

The maximum predicted cumulative systematic tensile and compressive strains at the road diversion, due to the extraction of the remaining proposed longwalls, are 9.9 mm/m and 9.7 mm/m, respectively, and the associated minimum radii of curvatures are both 1.0 kilometre.

Ground strains of these magnitudes are likely to result in cracking of the road surface in the tensile zones, and some rippling of the road surface in the compressive zones. A series of cracks in the road surface parallel to the proposed longwalls of up to 50 mm widths are likely to occur after each longwall mines beneath the road. Cracks perpendicular to the proposed longwalls are also likely to occur as the extraction face of each longwall mines beneath the road. It is likely, however, that these cracks will be partially closed after the extraction face of each longwall passes beyond the road diversion, as the tensile phase from the travelling wave is followed by a compressive phase.

It is planned that the road will be of flexible construction which can be regraded, repaired, and reconstructed using standard road maintenance techniques as mining proceeds. Each longwall will affect a length of road of approximately 300 to 500 metres, and repairs at any time will be limited to the affected section of road. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

The depths of cover along the road diversion are less than 100 metres above proposed Longwall GM204 within the Glen Munro Seam, and proposed Longwall BF101 within the Bowfield Seam. It is likely that the collapsed zones above these longwalls will extend near to the surface, where the depths of cover are the shallowest. In these locations, it is possible that the subsidence profiles will become irregular resulting in bumps or small steps in the road surface. The likelihood and impact of irregular subsidence profiles is discussed in Sections 5.21 and 5.22.

It is recommended, therefore, that the planned road diversion be visually monitored on a regular basis, as the extraction face of each longwall mines beneath it, so that any impacts can be identified and rectified immediately. It may be necessary to introduce a reduced speed limit along the affected section of road diversion, prior to the remedial works being completed. It is also recommended that signage be installed along the road diversion warning of impacts on the road as the result of mine subsidence. It is unlikely that the traffic signs and other road infrastructure would suffer any impacts due to mine subsidence.

5.10.4. Predictions and Impact Assessments for the Unsealed Local Roads

There are a number of unsealed local roads within the Study Area, the locations of which are shown in Drawing No. MSEC263-142. These roads are likely to experience the full range of predicted systematic subsidence impacts. The unsealed roads can be regraded and repaired using standard road maintenance techniques as mining proceeds. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

5.11. Bridges

The locations of the two road bridges along Edderton Road are shown in Drawing No. MSEC263-142. It is also planned that a bridge be constructed along the planned diversion of Edderton Road across the Belmont Pit, which is also shown in this drawing. The predictions and impact assessments for each bridge are provided in the following sections.

5.11.1. Predictions and Impact Assessments for Bridge ER-BR1

Bridge ER-BR1 is located just north the maingate of proposed Longwall BF102 within the Bowfield Seam. The bridge is located a minimum distance of 650 metres from the proposed longwalls within the Woodlands Hill, Glen Munro, Arrowfield, and Piercefield Seams and, therefore, is unlikely to be subjected to any significant systematic subsidence impacts resulting from the extraction of the longwalls within these seams. A summary of the maximum predicted total systematic subsidence, tilt, and strain at Bridge ER-BR1, after the extraction of the proposed series of longwalls within the Bowfield Seam, is provided in Table 5.15.

Table 5.15 Maximum Predicted Total Systematic Subsidence, Tilt and Strain at Bridge ER-BR1 after the Extraction of the Proposed Series of Longwalls within the Bowfield Seam

Proposed Series of Longwalls	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Bowfield Seam	215	8.9	8.1	< 0.1

The parameters provided in the above table are the maximum values predicted to occur within 20 metres of the centre of the bridge. Bridge ER-B1 is located outside the proposed longwall goaf areas and, therefore, is unlikely to be subjected to any significant travelling tilts or strains.

Bridge ER-BR1 crosses Quarry Creek and, therefore, may be subjected to valley related movements. A summary of the maximum predicted total upsidence, closure, and compressive strain due to closure, after the extraction of the proposed series of longwalls within all seams, is provided in Table 5.16.

Table 5.16 Maximum Predicted Total Upsidence, Closure and Compressive Strain due to Closure at Bridge ER-BR1 after the Extraction of the Proposed Series of Longwalls within All Seams

Bridge	Equiv. Valley Depth (m)	Maximum Total Upsidence (mm)	Maximum Total Closure (mm)	Maximum Total Compressive Strain due to Closure (mm/m)
ER-B1	3	15	20	2.1

The maximum predicted systematic tilt at the bridge is 8.9 mm/m (ie: 0.9 %), of a change in grade of 1 in 112, which is orientated along the alignment of the bridge. The maximum predicted tilt is less than 1 % and is unlikely, therefore, to result in any significant changes in the surface water drainage along the bridge.

The maximum predicted systematic strain at the bridge is 8.1 mm/m tensile, and the associated minimum radius of curvature is 1.2 kilometres. It is unlikely, however, that the maximum predicted systematic strain would be fully transferred into the bridge structure, due to the low shear capacity of the alluvial soils. The bridge is a reinforced concrete structure with an integrally connected deck, supporting walls, and ground slab. It is expected, therefore, that the ground strains would tend to arch around the bridge, which could result in the road pavement pulling away from the bridge structure at the abutments.

The differential horizontal movements at the abutments can be conservatively determined by taking the maximum predicted strain over the full length of the bridge. It is predicted, therefore, that the maximum differential horizontal movement between the road pavement and bridge, resulting from systematic subsidence movements, is approximately 30 mm at each abutment, based on a maximum predicted strain of 8.1 mm/m and a span of 7 metres.

Any differential horizontal movement between the road pavement and bridge can be rectified using normal road maintenance techniques. It should also be noted that Bridge ER-B1 is planned to be closed, and traffic diverted onto the planned road diversion over the Belmont Pit, prior to proposed Longwall BF102 mining adjacent to the bridge. Any repairs required to the road surface or bridge, therefore, can be undertaken prior to traffic being reverted back along Bridge ER-B1.

The maximum predicted total upsidence at the bridge is 15 mm, which occurs along the centreline of Quarry Creek. The maximum predicted total closure at the bridge is 20 mm, which occurs across the valley of the creek. It is likely that the observed upsidence and closure at the bridge will be less than those predicted, as the bridge structure has been constructed integrally and is likely to restrain the valley related movements at this location. The maximum predicted upsidence and closure movements are small and are unlikely, therefore, to have any significant impact on the bridge.

The maximum predicted total compressive strain due to valley closure is 2.1 mm/m, which occurs in the middle of Quarry Creek. It is unlikely, however, that this compressive strain would be fully transferred into the bridge structure, due to the low shear capacity of the alluvial soils, and would tend to arch around the integral bridge structure. It is unlikely, therefore, that the maximum predicted compressive strain due to closure would have a significant impact on the bridge.

5.11.2. Predictions and Impact Assessments for Bridge ER-BR2

Bridge ER-BR2 is located above proposed Longwall WH107 within the Woodlands Hill Seam. The bridge is located a minimum distance of 1.1 kilometres from the proposed longwalls within the Glen Munro, Arrowfield, Bowfield, and Piercefield Seams and, therefore, is unlikely to be subjected to any significant systematic subsidence impacts resulting from the extraction of the longwalls within these seams. A summary of the maximum predicted total systematic subsidence, tilt, and strain at Bridge ER-BR2, after the extraction of the proposed series of longwalls within the Woodlands Hill Seam, is provided in Table 5.17.

Table 5.17 Maximum Predicted Total Systematic Subsidence, Tilt and Strain at Bridge ER-BR2 after the Extraction of the Proposed Series of Longwalls within the Woodlands Hill Seam

Proposed Series of Longwalls	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Woodlands Hill Seam	1600	13	< 0.1	6.4

The parameters provided in the above table are the maximum values predicted to occur within 20 metres of the centre of the bridge. Bridge ER-B2 is located above proposed Longwall WH107 and, therefore, will be subjected to travelling tilts and strains during the extraction of this longwall. A summary of the maximum predicted travelling tilt and strains at Bridge ER-B2, during the extraction of proposed Longwall WH107, is provided in Table 5.18.

Table 5.18 Maximum Predicted Travelling Tilt and Strains at Bridge ER-BR2 during the Extraction of Proposed Longwall WH107 within the Woodlands Hill Seam

Proposed Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
WH107	31	18	15

Bridge ER-B2 is orientated perpendicular to proposed Longwall WH107 and, therefore, the predicted travelling tilts and strains are aligned perpendicular to the bridge.

Bridge ER-B2 crosses a channel connecting two farm dams and, therefore, may be subjected to valley related movements. A summary of the maximum predicted total upsidence, closure, and compressive strain due to closure, after the extraction of the proposed series of longwalls within all seams, is provided in Table 5.19.

Table 5.19 Maximum Predicted Total Upsidence, Closure and Compressive Strain due to Closure at Bridge ER-BR2 after the Extraction of the Proposed Series of Longwalls within All Seams

Location	Equiv. Valley Depth (m)	Maximum Total Upsidence (mm)	Maximum Total Closure (mm)	Maximum Total Compressive Strain due to Closure (mm/m)
ER-BR2	2	45	20	2.3

The maximum predicted systematic tilt along the alignment of the bridge is 13 mm/m (ie: 1.3 %), or a change in grade of 1 in 75, which occurs after the extraction of proposed Longwall WH107. The maximum predicted tilt along the alignment of the bridge is likely to increase the surface water drainage towards the northern end of the bridge. It is unlikely, however, that the maximum predicted systematic tilt along the alignment of the bridge would have any significant impact on the structural integrity or serviceability of the bridge.

The maximum predicted systematic tilt across the alignment of the bridge is 31 mm/m (ie: 3.1 %), or a change in superelevation of 1 in 30. The maximum predicted change in superelevation is small and only occurs temporarily as the extraction face of proposed Longwall WH107 passes beneath the bridge. It is unlikely, therefore, that the maximum predicted systematic tilt across the alignment of the bridge will have any significant impact on the structural integrity or serviceability of the bridge.

The maximum predicted total systematic tensile and compressive strains along the alignment of the bridge are less than 0.1 mm/m and 6.4 mm/m, respectively, which occur after the extraction of proposed Longwall WH107. The minimum radii of curvatures associated with the maximum predicted tensile and compressive strains along the alignment of the bridge are greater than 100 kilometres and 1.6 kilometres, respectively.

It is unlikely that the maximum predicted systematic strains would be fully transferred into the bridge structure, due to the low shear capacity of the alluvial soils within the channel. The bridge is a reinforced concrete structure with an integrally connected deck, supporting walls, and ground slab. It is expected, therefore, that the ground strains would tend to arch around the bridge, which could result in the road pavement rippling between the bridge structure and the abutments.

The differential horizontal movements at the abutments can be conservatively determined by taking the maximum predicted strain along the alignment of the bridge, over the full length of the bridge. It is predicted, therefore, that the maximum differential horizontal movement between the road pavement and bridge, resulting from systematic subsidence movements, is approximately 25 mm at each abutment, based on a maximum predicted strain along the alignment of the bridge of 6.4 mm/m and a span of 7 metres.

Any differential horizontal movement between the road pavement and bridge can be rectified using normal road maintenance techniques. It is recommended that signage be placed on the approaches to the bridge, prior to the extraction of proposed Longwall WH107, warning of possible differential movements at the bridge as the result of mine subsidence.

The maximum predicted systematic tensile and compressive strains across the alignment of the bridge are 18 mm/m and 15 mm/m, respectively, which occur as the extraction face of proposed Longwall WH107 passes beneath the bridge. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains across the alignment of the bridge are 0.6 kilometres and 0.7 kilometres, respectively.

The maximum predicted systematic strains across the alignment of the bridge are orientated along the strong axes of the supporting abutment wingwalls and the central supporting wall. It is unlikely that the predicted strains would be fully transferred into the bridge structure, due to the low shear capacity of the alluvial soils within the channel. It is expected, therefore, that the ground strains would tend to arch around the bridge structure and would not result in any significant impacts on the bridge structure.

The maximum predicted total upsidence is 45 mm which occurs in the middle of the channel. The maximum predicted total closure is 20 mm which occurs across the channel. It is likely that the observed upsidence and closure movements at the bridge will be much less than those predicted, as the bridge structure has been constructed integrally and is likely to restrain the valley related movements at this location.

The maximum predicted total compressive strain due to valley closure is 2.3 mm/m, which is orientated along the alignment of the bridge and occurs in the middle of the channel. It is unlikely, however, that the maximum predicted compressive strain would be fully transferred into the bridge structure, due to the low shear capacity of the alluvial soils within the channel, and would tend to arch around the integral bridge structure.

It is possible that the maximum predicted upsidence could induce an upwards load on the base slab and the central supporting concrete wall, and in turn, on the bridge deck. The bridge deck, walls, and base slab are tied together and, therefore, the bridge will act an integral structure. It is likely that the weight of the bridge structure would be sufficient to restrain the upwards load resulting from the predicted upsidence.

If this upwards load was of sufficient magnitude, however, it is possible that tensile cracking could occur in the road surface directly above the central supporting concrete wall. If the bridge structure moves uniformly, it is also possible that tensile cracking, or a small step in the road surface could occur above the concrete wingwalls at the abutments. It is unlikely, however, that the maximum predicted upwards load would be of sufficient magnitude to overstress the bridge structure.

The depth of cover to the Woodlands Hill Seam at the location of Bridge ER-B2 is approximately 100 metres. It is likely that the collapsed zone above the proposed longwalls could extent near to the surface where the depth of cover is less than 100 metres. It is possible, therefore, that the subsidence profile could be irregular, with a stepped profile at the location of the bridge. If the subsidence profile is irregular at the bridge, the movement along the bridge will not be uniform which may result in cracking in the road surface above the concrete wingwalls at the abutments, or above the central supporting concrete wall. The likelihood and impact of irregular profiles are discussed in Sections 5.21 and 5.22.

It is recommended, therefore, that the bridge should be visually monitored during the extraction of proposed Longwalls WH107 and WH108 within the Woodlands Hill Seam, so that any cracking or bumps in the road surface can be identified and repaired. It may also be necessary to introduce a reduced speed limit across the bridge during the extraction of these longwalls.

5.11.3. Predictions for the Planned Bridge along the Planned Road Diversion

It is planned that a bridge will be constructed along the planned diversion of Edderton Road across the Belmont Pit, which is located above proposed Longwall PF103 within the Piercefield Seam. It is planned that the bridge will be a two span structure, with a total length of approximately 38 metres, with the deck fixed at the southern abutment, and a movement joint provided at the northern abutment. The bridge structure will be founded on spoil.

The predicted total systematic subsidence parameters at the bridge have been taken as the maximum parameters along the road diversion within the Belmont Pit, and are summarised in Table 5.20.

Table 5.20 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Planned Bridge across the Belmont Pit after the Extraction of Proposed Longwall PF103

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Planned Bridge	1395	14	2.6	3.0

The bridge is founded on spoil and, therefore, the total predicted subsidence at the bridge will be greater than that shown in the above table, due to the consolidation of the spoil as subsidence occurs. The consolidation of spoil as a result of subsidence is discussed further in Section 5.16.4.

The differential subsidence between the abutments can be conservatively determined by taking the maximum predicted tilt along the alignment of the bridge over the full length of the bridge. It is predicted, therefore, that the southern abutment will subside approximately 530 mm more than the northern abutment, based on a maximum predicted tilt of 14 mm/m and a span of 38 metres.

The differential horizontal movement between the abutments can be conservatively determined by taking the maximum predicted strain along the alignment of the bridge over the full length of the bridge. It is predicted, therefore, that the maximum horizontal movement at the expansion joint, resulting from systematic subsidence, will be 115 mm, based on a maximum predicted strain of 3.0 mm/m and a span of 38 metres.

The bridge will also be subjected to travelling tilts and strains as the extraction face of proposed Longwall PF103 passes beneath it. The travelling tilts and strains will be aligned across the bridge, with the maximum values occurring in the location of maximum incremental subsidence of the longwall. A summary of the maximum predicted travelling tilts and strains, during the extraction of proposed Longwall PF103, is provided in Table 5.21.

Table 5.21 Maximum Predicted Travelling Tilts and Strains at the Planned Bridge during the Extraction of Proposed Longwall PF103

Proposed Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
PF103	12	2.6	4.8

The bridge structure should be designed, as a minimum, to tolerate the maximum predicted systematic subsidence movements along and across the alignment of the bridge as provided in Table 5.20 and Table 5.21. An allowance should also be made for the additional subsidence resulting from the consolidation of the spoil as discussed in Section 5.16.4. The maximum predicted subsidence movements at the planned bridge will be further defined, with specific predictions of subsidence and horizontal movement at the abutments and the central support, as the design of the bridge is further developed.

5.12. Drainage Culverts

There are a number of road drainage culverts identified within the Study Area, the locations of which are shown in Drawing No. MSEC263-142. A summary of the maximum predicted values of total subsidence, tilt, and strain at the drainage culverts, after the extraction of the proposed series of longwalls within all seams, is provided in Table 5.22.

Table 5.22 Maximum Predicted Total Systematic Subsidence, Tilt and Strain at the Drainage Culverts after the Extraction of the Proposed Series of Longwalls within All Seams

Drainage Culvert	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total or Travelling Tensile Strain (mm/m)	Maximum Predicted Total or Travelling Compressive Strain (mm/m)
ER-C08	< 20	1.9	4.0	0.1
ER-C09	1920	5.5	21	18
ER-C10	1390	4.2	13	11
ER-C11	220	3.9	2.0	1.8
ER-C12	1355	19	11	10
ER-C13	1825	36	7.5	6.7
ER-C14	1120	15	8.4	8.3
ER-C15	3985	19	24	20
ER-C16	2245	50	20	> 25
ER-C17	1065	44	> 25	8.8
ER-C18	25	0.4	0.2	0.2
ER-C19	< 20	0.1	0.1	< 0.1
ER-C20	275	5.1	2.5	2.2
ER-C21	900	12	8.2	7.3
ER-C22	1030	22	> 25	7.0
ER-C23	2495	3.4	18	15
ER-C24	2760	12	> 25	13
ER-C25	1290	11	8.0	7.2
ER-C26	2675	11	11	9.6
ER-C27	835	18	7.2	5.4
ER-C28	440	2.6	2.2	2.0
ER-C29	1600	1.1	12	9.7
ER-C30	1410	8.4	11	8.8
ER-C31	1395	12	11	8.7
ER-C32	1565	0.8	12	9.8
ER-C33	1610	0.8	13	10
ER-C34	125	0.4	1.2	0.8
ER-C35	1475	1.4	12	9.2

The maximum predicted tilts in the above table are the maximum total tilts at the completion of each proposed series of longwalls within each seam, and do not include the travelling tilts which only occur for a short period of time as the proposed longwalls mine beneath the culverts. The maximum predicted strains in the above table are the maximum total strains at the completion of each proposed series of longwalls within each seam, or the maximum travelling strains where the extraction faces of the proposed longwalls mine beneath the culverts, whichever is greatest.

The culverts are located within drainage lines and, therefore, may be subjected to upsidence and closure movements. The predicted upsidence, closure and compressive strains due to closure movements are expected to be an order of magnitude smaller than the maximum predicted systematic movements, as the culverts are directly mined beneath and the equivalent valley heights for the culverts are very small. The valley related movements at the culverts have not been determined, as they are expected to be insignificant when compared to the systematic movements.

The maximum predicted total systematic tilt at the culverts is 50 mm/m (ie: 5.0 %), or a change in grade of 1 in 20, which occurs at Culvert ER-C16 after the extraction of proposed Longwall GM205 within the Glen Munro Seam. The maximum predicted tilt is essentially orientated across the alignment of Culvert ER-16 and slightly increases the grade of the culvert and, therefore, is unlikely to have any significant impact on the drainage of water through this culvert.

Predicted systematic tilts greater than 20 mm/m (ie: 2.0 %), or a changes in grade of 1 in 50, also occur at Culverts ER-C13, ER-C17 and ER-C22. The predicted tilts, however, are essentially orientated across the alignments of these culverts and are unlikely, therefore, to have any significant impact on the drainage of water through these culverts.

The maximum predicted total systematic tensile and compressive strains at the culverts are both greater than 25 mm, which occur at Culverts ER-C16, ER-17, ER-22 and ER-C24. All culverts within the Study Area, with the exception of Culverts ER-C18 and ER-C19, are predicted to experience a tensile strain greater than 0.5 mm/m, which is sufficient to result in cracking in concrete. In practice, however, the ground strains are unlikely to be fully transferred into the culverts.

It is likely that a number of culverts will be impacted as the longwalls mine beneath Edderton Road. Each longwall will affect a length of road of approximately 300 to 500 metres, and repairs at any time will be limited to the affected culverts within that section. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

It has been observed in the past, that the headwalls at the ends of culverts are more susceptible to impact than the culverts themselves. The headwalls of the culverts can be more easily repaired than the culverts themselves. It should also be noted that during the initial site inspections, it was observed that a number of concrete headwalls were already damaged and had existing cracks.

Any potential impacts on the culverts are manageable by monitoring followed by the implementation of remedial or mitigatory measures, as required. The ground movements will occur gradually as mining progresses, which will provide adequate time to repair the culverts at an appropriate time, should remedial works be required.

5.13. Electrical Services

The major electrical services within the Study Area include the 330/500 kV transmission line, and the low voltage powerline along Edderton Road, both of which are shown in Drawing No. MSEC263-143. The following sections provide the predictions and impact assessments for these electrical services.

5.13.1. Predictions and Impact Assessment for the 330/500 kV Transmission Line

The 330/500 kV transmission line crosses the Study Area generally in an east-west direction, and is located directly above the proposed longwalls within the Woodlands Hill, Arrowfield, Bowfield and Piercefield Seams. Each transmission tower which supports the 330/500 kV overhead powerlines has an identification number, ranging between 21 and 38, which is shown in Drawing No. MSEC263-143. The locations of the transmission towers were determined by MSEC from an aerial photograph of the area.

Initially, the transmission line will be mined beneath by workings within the Woodlands Hill Seam, which is a single seam extraction. The first multi-seam mining at the project will be when the longwalls within the Arrowfield Seam (seven panels) mine beneath the previous goafs formed by the longwalls within the Glen Munro Seam. The longwalls within these seams do not mine beneath the transmission line.

Following mining within the Arrowfield Seam, the fourth panel in the Bowfield Seam will be the first instance of multi-seam mining beneath the transmission line. Hence, the predictions made using the Incremental Profile Method for multi-seam mining will have been calibrated using actual monitoring data from elsewhere in the Hunter Valley (eg: the Bulga mining complex) and from two separate instances at the project prior to multi-seam mining beneath the transmission line.

The cables are not affected by ground strains, as they are supported by the towers above ground level. The cables are, however, affected by the changes in bay length, ie: the distances between the towers at the level of the cables, resulting from mining induced differential subsidence, horizontal ground movements, and lateral movements at the tops of the towers due to tilting of the towers. The stabilities of the towers are affected by the mining induced tilts and ground strains at the location of each tower and by changes in the catenary profiles of the cables.

The predicted values of travelling and total systematic subsidence, tilt, and strain at the locations of the towers, during and at the completion of the proposed series of longwalls within each seam, are provided in Table F.01 in Appendix F. The original bay lengths, and the predicted changes in bay lengths during, and at the completion of the proposed series of longwalls within each seam, are provided in Table F.02.

The greatest predicted movements at the transmission line occur as a result of the extraction of the longwalls within the Woodlands Hill Seam, which are single seam extractions. The predictions made using the Incremental Profile Method for single seam extractions in the Hunter Valley have been shown to be appropriate (Refer to Section 5.29.3). A greater degree of conservatism has been provided in the travelling wave predictions and, hence, we expect that the actual observed travelling wave movements will be less than the predicted values, especially at the shallow depths of cover.

The predicted changes in bay lengths at the highest level of the cables, which were provided by TransGrid, and are based on the predicted differential subsidence, horizontal ground movements, and tilting of the towers. The original bay lengths and the maximum predicted changes in the bay lengths, at any time during or at the completion of the proposed longwalls, whichever is greatest, are summarised in Table 5.23.

Table 5.23 Maximum Predicted Changes in Bay Lengths at the Level of the Highest Cables along the 330/500 kV Transmission Line at Any Time during the Extraction of the Proposed Longwalls

Bay between Towers	Original Bay Length (m)	Maximum Increase in Bay Length (mm)	Maximum Decrease in Bay Length (mm)	Maximum Percentage Increase in Bay Length (%)	Maximum Percentage Decrease in Bay Length (%)
38 to 37	591.6	115	< -20	< 0.1	< -0.1
37 to 36	456.1	< 20	-115	< 0.1	< -0.1
36 to 35	451.1	< 20	< -20	< 0.1	< -0.1
35 to 34	449.1	< 20	< -20	< 0.1	< -0.1
34 to 33	407.1	115	< -20	< 0.1	< -0.1
33 to 32	459.7	50	-385	< 0.1	< -0.1
32 to 31	361.8	375	-555	0.1	-0.2
31 to 30	238.5	480	-1330	0.2	-0.6
30 to 29	637.7	1225	-1015	0.2	-0.2
29 to 28	513.6	115	-2855	< 0.1	-0.6
28 to 27	450.7	3240	-625	0.7	-0.1
27 to 26	380.6	1660	-140	0.4	< -0.1
26 to 25	449.6	125	-1825	< 0.1	-0.4
25 to 24	365.0	2065	-2190	0.6	-0.6
24 to 23	498.1	2510	-1010	0.5	-0.2
23 to 22	423.2	< 20	< -20	< 0.1	< -0.1
22 to 21	449.0	< 20	< -20	< 0.1	< -0.1

Note: - Positive (+ve) changes in bay lengths are expansions, and negative (-ve) changes in bay lengths are contractions, at the level of the highest overhead cables.

The maximum predicted systematic tilt at the locations of the transmission towers, at any time during or at the completion of the proposed longwalls, is 50 mm/m, or a change in verticality of 1 in 20, which occurs at Tower 24 during the extraction of proposed Longwall WH105 within the Woodlands Hill Seam. The maximum predicted total systematic tilt at the location of the transmission towers, at the completion of each proposed series of longwall, or at the completion of all proposed series of longwalls, whichever is the greater, is 36 mm/m, or a change in verticality of 1 in 30, which occurs at Tower 28 after the extraction of proposed Longwall PF203 within the Piercefield Seam.

High tilts in the locations of the transmission towers can adversely impact on the stability of the towers, by inducing eccentricities between the towers and footings, resulting in higher loads in the tower legs, or by inducing additional horizontal loads in the towers resulting from changes in the cable catenaries. The changes in the cable catenaries are the result of the changes in bay lengths between adjacent towers.

The maximum predicted increase in bay length is 3240 mm, which occurs between Towers 27 and 28 during the extraction of proposed Longwall WH102, and represents a change of 0.7 % of the original bay length. The maximum predicted decrease in bay length is 2855 mm, which occurs between Towers 28 and 29 during the extraction of proposed Longwall WH102, and represents a change of 0.6 % of the original bay length.

The stability of the towers is also affected by the ground strains. The maximum predicted total systematic tensile strain at the locations of the towers is greater than 25 mm/m, which occur at Towers 24, 25 and 28 during the extraction of proposed Longwalls WH105, WH104 and WH102, respectively. The maximum predicted systematic compressive strain at the locations of the towers is also greater than 25 mm/m, which occur at Towers 24, 25, 27, 28 and 30 during the extraction of proposed Longwalls WH105, WH104, WH103, WH102 and WH101, respectively.

Two important towers along the transmission line are Tower 36, which is an angled tower, and Tower 29 which is a tension tower. Tower 36 is located outside the predicted total 20 mm subsidence contour resulting from the extraction of the proposed longwalls. The maximum predicted total systematic tilt and strain at Tower 36 are, therefore, both less than 0.1 mm/m. The maximum predicted total systematic tilt at Tower 29 is 11 mm/m, which occurs during the extraction of proposed Longwall BF202. The maximum predicted total systematic strains at Tower 29 are 3.7 mm/m tensile and 4.3 mm/m compressive, which also both occur during the extraction of proposed Longwall WH102.

The depths of cover at the tower locations are similar to, or less than 100 metres above the proposed Longwalls WH101, WH102 and WH105 within the Woodlands Hill Seam. It is likely that the collapsed zones above these longwalls will extend near to the surface, where the depths of cover are the shallowest. In these locations, it is possible that the subsidence profiles will become irregular resulting in bumps or small steps in the surface. The likelihood and impact of irregular subsidence profiles is discussed in Sections 5.21 and 5.22.

It is likely that preventive measures will be required for some of the transmission towers, including the installation of cable sheaves, to allow for the predicted differential movements at the levels of the cables, and the strengthening of some towers, including the installation of cruciform bases. Alternatively, the cables could be temporarily supported by timber or steel structures where the existing towers are predicted to be adversely affected by the proposed longwalls.

The predicted subsidence parameters at the transmission towers were initially provided to TransGrid at the Prefeasibility Stage in February 2006, so that an analysis of the towers could be undertaken and management strategies developed. Updated predicted subsidence parameters at the transmission towers were provided to TransGrid in December 2006 based on a revised concept mine plan. It is recommended that Mt. Arthur Coal develop management strategies, in consultation with TransGrid, for the protection of the transmission line throughout the mining period.

The 330/500 kV transmission line should be monitored during mining, to confirm that the actual movements are in line with the predicted movements. This will also identify any non-systematic movements and allow for any preventive measures that might be required to be implemented, to ensure that the towers and cables are maintained in a safe and serviceable condition at all times.

5.13.2. Predictions and Impact Assessment for the Low Voltage Powerline along Edderton Road

The main low voltage powerline within the Study Area generally follows the alignment of Edderton Road, the location of which is shown in Drawing No. MSEC263-143. The predicted systematic subsidence parameters along this powerline are, therefore, the same as those along Edderton Road.

The cables are not affected by ground strains, as they are supported by the poles above ground level. The cables are, however, affected by the changes in the bay lengths, ie: the distances between the poles at the height of the cables, as the result of mining induced differential subsidence, horizontal ground movements, and lateral movements at the tops of the poles caused by tilting of the poles. The stabilities of the poles are also affected by the tilting of the poles, and the changes in the catenary profiles of the cables.

The predicted profiles of cumulative and total systematic subsidence and tilt along Edderton Road and hence the powerline, at the completion of the proposed series of longwalls within each seam, are shown in Fig. G.02 in Appendix G. A summary of the maximum predicted values of cumulative systematic subsidence and tilt along Edderton Road and hence the powerline, due to the extraction of the proposed series of longwalls within each seam, is provided in Table 5.6. A summary of the maximum predicted values of total systematic subsidence and tilt at Edderton Road and hence the powerline, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.7.

The powerline will also be subjected to travelling tilts where the extraction faces of the proposed longwalls mine beneath it. A summary of the maximum predicted travelling tilts at Edderton Road and hence the powerline, during the extraction of the proposed longwalls, is provided in Table 5.8.

The maximum predicted tilt along the powerline is 67 mm/m (ie: 6.7 %), or a change in verticality of 1 in 15, which occurs above the maingate of proposed Longwall GM204 within the Glen Munro Seam. High tilts at the powerline are also predicted to occur as the result of the extraction of proposed Longwalls WH101 to WH110 within the Woodlands Hill Seam, proposed Longwall GM205 within the Glen Munro Seam, proposed Longwalls AF102 to AF104 within the Arrowfield Seam, and proposed Longwalls BF101 and BF102 within the Bowfield Seam.

High tilts at the locations of power poles can adversely affect the stability of the poles, especially the tension poles that are supported by guy ropes. The maximum predicted tilts are likely to result in adverse impacts on the powerline as the proposed longwalls mine beneath it. It is likely that cable sheaves and guy ropes will be required where the predicted tilts are greater than 20 mm/m at the power poles.

Each longwall will affect a length of powerline of approximately 300 to 500 metres, and preventive measures at any time will be limited to the affected section of powerline. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

It is recommended that the low voltage powerlines should be inspected by a suitably qualified person, to assess the existing conditions of the powerlines, and to determine where cable sheaves and additional guy ropes are required.

Monitoring of the powerlines will be necessary, during the extraction of the proposed longwalls beneath the powerlines, in order to identify any potential problems and any preventive measures that might be required, to ensure that the poles and cables are maintained in a safe and serviceable condition at all times. Mt. Arthur Coal should develop management strategies, in consultation with Energy Australia, for the protection of the powerlines throughout the mining period.

5.14. Telecommunication Services

The main underground copper telecommunication cables within the Study Area generally follow the alignment of Edderton Road, the location of which is shown in Drawing No. MSEC263-144. The predicted systematic subsidence parameters along the copper cables are, therefore, the same as those along Edderton Road. The cables are direct buried and, therefore, will not be adversely affected by tilt.

The predicted profiles of cumulative and total systematic subsidence and strain along Edderton Road and hence the copper cables, at the completion of the proposed series of longwalls within each seam, are shown in Fig. G.02 in Appendix G. A summary of the maximum predicted values of cumulative systematic subsidence and strain at Edderton Road and hence the copper cables, due to the extraction of the proposed series of longwalls within each seam, is provided in Table 5.6. A summary of the maximum predicted values of total systematic subsidence and strain at Edderton Road and hence the copper cables, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.7.

The underground copper telephone cables will also be subjected to travelling strains where the extraction faces of the proposed longwalls mine beneath it. A summary of the maximum predicted travelling strains at Edderton Road and hence the copper cables, during the extraction of the proposed longwalls within each seam, is provided in Table 5.8.

The maximum predicted systematic tensile and compressive strains at the underground copper cables, at any time during or after the extraction of the proposed longwalls, are both greater than 25 mm/m. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are both less than 0.4 kilometres.

The existing conditions of the underground copper cables are not known, however, modern copper cables can in some cases tolerate tensile strains of up to 20 mm/m, without impact. It is possible, therefore, that the underground copper cables will be adversely impacted during the extraction of proposed Longwalls WH101 to WH110 within the Woodlands Hill Seam, proposed Longwalls GM204 and GM205 within the Glen Munro Seam, and proposed Longwalls BF101 and BF102 within the Bowfield Seam.

It is recommended that the underground copper cables should be inspected by a suitably qualified person prior to mining, to determine the existing condition of the cables, any protective conduits, and to record the locations and lengths of any additional loops of cable that are provided in draw pits. It may be necessary to undertake preventive measures, including the relocation of the cables to conduits, and the installation of additional lengths of cable at pits and other anchor points.

Monitoring of the copper cables will be necessary, during the extraction of the proposed longwalls beneath the cables, in order to identify any potential problems, and any preventive measures that might be required, to ensure that the cables are maintained in a safe and serviceable condition at all times. It is recommended that Mt. Arthur Coal establish management strategies, in consultation with Telstra, for the protection of the underground copper cables throughout the mining period.

5.15. Farm Land and Facilities

The following sections provide the subsidence predictions and impact assessments for the farm land and facilities within the Study Area, resulting from the extraction of the proposed longwalls.

5.15.1. Vineyards

There is a small vineyard at 680 Edderton Road, which is owned by Mt. Arthur Coal, the location of which is shown in Drawing No. MSEC263-156. The vineyard contains trellises and a drip water supply system. The vineyard is located on Mt. Arthur Coal owned land.

The vineyard will be directly mined beneath by proposed Longwall BF201 within the Bowfield Seam and proposed Longwall PF201 within the Piercefield Seam. The depths of cover at the location of the vineyard are 145 metres to the Bowfield Seam and 270 metres to the Piercefield Seam.

Vineyards within the Hunter Coalfield have been mined beneath in the past at depths of cover as low as 110 metres. It was observed in these cases that tilting of the trellis posts resulted in changes in the tensions in the trellis wires and irrigation pipes. The maximum displacement at the top of the trellises was approximately 210 mm and the trellis wires lost their tension in many cases. Notwithstanding the significant tilts and strains that had occurred, none of the trellises collapsed and none of the irrigation pipes failed.

It will be necessary, as subsidence occurs beneath the vineyard, to monitor the conditions of the trellises and the tensions in the trellis wires and irrigation pipes, so that they can be adjusted as necessary to maintain the trellises in a satisfactory working condition throughout the mining period.

The nearest private vineyard to the proposed longwalls is Roxburgh Estate, which is located outside the predicted total 20 mm subsidence contour and, therefore, will not be subjected to any significant systematic subsidence movements. It is unlikely that the vineyards outside the Study Area would be impacted by systematic subsidence movements, resulting from the extraction of the proposed longwalls.

5.15.2. Farm Buildings and Sheds

A total of 39 rural building structures (Structure Type R) have been identified within the Study Area. The rural building structures at Edderton Homestead just outside the Study Area have been included as part of this assessment. All rural building structures within the Study Area are owned by Mt. Arthur Coal.

The rural building structures include farm sheds, garages and other non-residential structures. The locations of the rural building structures within the Study Area are shown in Drawings Nos. MSEC263-150 to MSEC263-156 and details are provided in Table F.03 in Appendix F.

The rural building structures on the Edinglassie and Rous Lench properties, which are located more than 1.3 kilometres outside the Study Area, could experience some small far-field horizontal movements as a result of the extraction of the proposed longwalls. These movements, however, tend to be bodily movements which are not associated with any significant strains. The building structures on the Edinglassie and Rous Lench properties will not be impacted as a result of the extraction of the proposed longwalls.

Predictions of systematic subsidence, tilt, and strain have been made at the centroid and at the vertices of each structure within the Study Area. The maximum predicted values of systematic subsidence, tilt, and strain have been determined during, and at the completion of the proposed series of longwalls within each seam.

The maximum predicted systematic subsidence, and the impact assessments for tilt and strain for each rural building structure are provided in Table F.04 in Appendix F. A summary of the tilt and strain impact assessments for the rural building structures within the Study Area, at the completion of the proposed series of longwalls within each seam, is provided in Table 5.24.

Table 5.24 Summary of Tilt and Strain Impacts for the Rural Building Structures within the Study Area after the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Tilt Impact Categories				Strain Impact Categories					
	Cat A	Cat B	Cat C	Cat D	Cat 0	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
Woodlands Hill Seam	32	0	0	7	26	1	1	5	1	5
Glen Munro Seam	31	0	0	8	21	1	1	5	1	10
Arrowfield Seam	25	0	1	13	17	3	2	5	2	10
Bowfield Seam	24	0	1	14	15	4	2	6	2	10
Piercefield Seam	21	1	4	13	14	2	3	7	2	11

Tilt Impact Categories A, B and C represent predicted tilts of up to 5 mm/m, 7 mm/m and 10 mm/m, respectively. Tilt Impact Category D represents predicted tilts of greater than 10 mm/m. Strain Impact Categories 0, 1, 2, 3 and 4 represent predicted approximate crack width limits in masonry walls of building structures of 0.1 mm, 1 mm, 5 mm, 15 mm and 25 mm, respectively. Strain Impact Category 5 represents a predicted approximate crack width limit of greater than 25 mm. A detailed description of the Tilt and Strain Impact Categories is provided in Appendix E.

A summary of the maximum impacts that each rural building structure within the Study Area will experience, at any stage during or at the completion the proposed longwalls, is provided in Table 5.25.

Table 5.25 Count of Maximum Tilt and Strain Impacts for Rural Building Structures within the Study Area

Tilt Impact Category	Strain Impact Category						
	Category 0	Category 1	Category 2	Category 3	Category 4	Category 5	Total
Category A	14	1	1	0	0	0	**16**
Category B	0	0	0	0	0	0	**0**
Category C	0	0	1	0	0	1	**2**
Category D	0	1	1	7	2	10	**21**
Total	**14**	**2**	**3**	**7**	**2**	**11**	**39**

Preventive measures are generally not recommended for rural building structures unless the impact assessments are Category D for Tilt or Category 4 for Strain, or greater. This is due to the flexible types of construction of these structures.

There are 21 rural building structures which are assessed to experience a Category D tilt impact at some stage during, or at the completion of the proposed longwalls. Of these structures, eight are assessed to experience a Category D tilt impact at a transient stage, and the tilt impacts are assessed to reduce to Category C or less at the completion of all proposed longwalls.

All the rural building structures within the Study Area are of lightweight construction. Tilt generally does not have any significant impact on the stability of rural building structures, except where the tilts are very large, which can potentially induce eccentricities and, hence, greater loads into the wall bracing systems of the structures.

The rural building structures which are predicted to experience tilts greater than 30 mm/m at some stage during, or at the completion of the proposed longwalls are Structures Refs. A07b, A07c at Roxburgh South, Structures Refs. A08b, A08c, A08d at 550 Edderton Road, and Structures Refs. A10a, A10c, A10e, A10f, A10g at Belmont Homestead. Only Structures Refs. A07b, A10a and A10c are predicted to experience tilts of greater than 30 mm/m at the completion of all proposed longwalls.

There are 13 rural building structures assessed to experience a Category 4 or 5 strain impact, due to the extraction of the proposed longwalls, which are Structure Ref. A06b at Hospital, Structures Refs. A07b, A07c at Roxburgh South, Structures Refs. A08b, A08c, A08d at 550 Edderton Road, Structure Ref. A09a at 680 Edderton Road, and Structures Refs. A10a, A10c, A10d, A10e, A10f, A10g at Belmont Homestead.

All rural building structures within the Study Area are owned by Mt. Arthur Coal. It is recommended that all rural building structures should be inspected by a structural engineer, and that preventive measures are provided, where required, prior to each structure being mined beneath. It may be necessary that some rural building structures be demolished, or fenced off prior to being mined beneath.

The predictions and impact assessments for the rural building structures are based on longwalls having an overall void width of 285 metres. If the longwall widths were changed, the predictions at each structure may be higher or lower, depending on their relative position within the subsidence trough.

If the predictions were to be increased by factors of 1.25 to 5 times, the impacts on the rural building structures would increase accordingly. The assessed tilt and strain impacts for increased predictions for the rural building structures are provided in Table F.04, and are summarised in Table 5.26.

Table 5.26 Summary of Tilt and Strain Impacts for the Rural Building Structures within the Study Area for Increased Predictions

Increased Prediction	Number of Rural Building Structures with Tilt Impact Category for Increased Predictions				Number of Rural Building Structures with Strain Impact Category for Increased Predictions					
	Cat A	Cat B	Cat C	Cat D	Cat 0	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
x 1.25	20	1	4	14	13	3	3	4	5	11
x 1.50	19	2	1	17	13	2	4	2	5	13
x 1.75	16	4	1	18	12	3	3	2	5	14
x 2.00	16	3	2	18	12	2	2	3	3	17
x 5.00	12	1	2	24	10	1	2	3	2	21

5.15.3. Tanks

A total of 37 tanks (Structure Type T), which include the water and fuel tanks, have been identified within the Study Area. The tanks at Edderton Homestead just outside the Study Area have been included as part of this assessment. The locations of the tanks are shown in Drawings Nos. MSEC263-150 to MSEC263-156 and details are provided in Table F.03 in Appendix F. All tanks, apart from Tank A13t01, are owned by Mt. Arthur Coal.

Predictions of subsidence, tilt, and strain have been made at the centroid of each tank, as well as eight equally spaced points radially placed around the perimeter of each tank. The maximum predicted values of subsidence, tilt, and strain have been determined during, and at the completion the proposed series of longwalls within each seam.

The maximum predicted systematic subsidence, tilt, and strain for each tank are provided in Table F.04 in Appendix F. The maximum predicted total systematic tilts at the tanks, at any time during or after the extraction of the proposed longwalls, varies from less than 0.1 mm/m, to greater than 50 mm/m. The maximum predicted total systematic strains at the tanks, at any time during or after the extraction of the proposed longwalls, varies from less than 0.1 mm/m, to greater than 25 mm/m. The minimum radii of curvatures associated with the maximum predicted systematic strains vary from greater than 100 kilometres to less than 0.4 kilometres.

Tilt generally does not have any significant impact on the structural integrity or stability of tanks, except when the tilts are very large, which can potentially induce eccentricities into any supporting structures. The tanks within the Study Area are generally small and of flexible construction and, in most cases, are founded on a ground slab or the natural ground.

High tilts can affect the serviceability of tanks by altering the water or fuel levels in the tanks, which can in turn change the minimum level of water or fuel which can be released from the taps. The tanks within the Study Area are relatively small and, therefore, only very large tilts would have any significant impact on the serviceability of the tanks.

The tanks which are predicted to experience tilts greater than 30 mm/m at some stage during, or at the completion of the proposed longwalls, are Structures Refs. A07t01 to A07t04 at Roxburgh South, Structures Refs. A08t01 to A08t03 at 550 Edderton Road, and Structures Refs. A10t01 to A10t04 at Belmont Homestead. Only Structures Refs. A07t04, A08t01, A08t03, A10t01 and A10t02 are predicted to experience tilts greater than 30 mm/m at the completion of all proposed longwalls.

The predicted ground strains are unlikely to be fully transferred into the tanks where the tanks are founded on a ground slab or the natural ground. It is possible, however, that any buried pipelines associated with the tanks may be impacted by ground strains if they are anchored by the tank or other structures in the ground.

The tanks predicted to experience the greatest systematic strains at some stage during, or at the completion of the proposed longwalls, are Structure Refs. A07t01 to A07t04 at Roxburgh South, Structures Refs. A08t01 to A08t03 at 550 Edderton Road, and Structure Ref. A10t04 at Belmont Homestead.

All tanks, apart from Tank A13t01, are owned by Mt. Arthur Coal. It is recommended that all tanks should be inspected by a structural engineer and that preventive measures are provided, where required, prior to each tank being mined beneath.

5.15.4. Fences

There are a number of fences within the Study Area which are constructed in a variety of ways, generally using timber and metal materials. Wire fences could be affected by tilting of the fence posts and changes of tension in the fence wires due to strain as mining occurs. Fence post tilts of less than 10 mm/m are barely noticeable, and strains of less than 5 mm/m typically have little impact on wire tensions. However, this depends upon the existing tensions in the wires of the fences and their residual capacity to accept mining induced strains.

The predicted systematic tilts and strains due to the extraction of the proposed longwalls are greater than those which can be typically tolerated by fences. It is likely, therefore, that some of the fences would be impacted by the predicted subsidence movements and that some may need repairing as mining occurs. Impacted fences are relatively easy to rectify by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

Each longwall will affect a length of approximately 300 to 500 metres, and repairs at any time will be limited to the affected sections of fencing. The repairs will be progressive and, therefore, can be staged to suit the mining of each longwall in sequence.

5.15.5. Farm Dams

There are 90 farm dams that have been identified within the Study Area. The locations of the farm dams are shown in Drawing No. MSEC263-145 and details are provided in Table F.05 in Appendix F. The identified farm dams are typically earth dams established within the surface soils along the lines of natural watercourses.

Predictions of systematic subsidence, tilt, and strain have been made at the centroid and at the perimeter of each farm dam. The maximum predicted values of systematic subsidence, tilt, and strain have been determined during, and at the completion of the proposed series of longwalls within each seam.

A summary of the maximum predicted systematic subsidence, tilt, and strain at each farm dam, at the completion of the proposed series of longwalls within each seam, is provided in Table F.05. The maximum predicted systematic subsidence parameters at the farms dams, at the completion of the proposed series of longwalls within each seam, are also illustrated in Figs. G.05 to G.09 in Appendix G.

The maximum predicted systematic tilts at the farm dams vary from less than 0.1 mm/m, to greater than 50 mm/m. High tilts can reduce the storage capacity of farm dams and cause them to overflow. The potential for overflowing dams is dependent on the freeboard at the dam wall at the time of mining, and the direction of tilt relative to the dam. The predicted changes in freeboard at each farm dam has been conservatively determined by taking the maximum predicted tilt about the longest dimension of each dam, and these are summarised in Table F.05.

The majority of the farm dams which will be mined beneath are owned by Mt. Arthur Coal. There are, however, some privately owned farm dams and some Mt. Arthur Coal owned farm dams which are used by the tenants for agricultural purposes.

The maximum predicted systematic strains, tensile or compressive, at the farm dams varies from less than 0.1 mm/m, to greater than 25 mm/m. The minimum radii of curvatures associated with the maximum predicted systematic strains vary from greater than 100 kilometres, to less than 0.4 kilometres.

In addition to these systematic movements, the farm dams would experience some upsidence and closure movements associated with the valleys in which they are formed. As the valley heights of the dams are small, the valley related strains are typically much less than the systematic strains.

The farm dams within the Study Area are typically constructed of cohesive soils with reasonably high clay content, and are likely to be capable of withstanding tensile ground strains of up to 3 mm/m without impact. There are 68 farm dams which are predicted to experience systematic strains of 3 mm/m or greater.

It is expected, therefore, that some cracking and leakage of water may occur in the dam walls which are subjected to tensile strains greater than 3 mm/m, though, any cracking or leakages can be easily identified and repaired. Any loss of water from a farm dam would flow into the tributary in which the dam was formed. It is not expected, however, that any significant loss of water will occur from the dams.

There is a possibility that high concentrations of strain could occur at faults, fissures and other geological features, or points of weaknesses in the strata, and such occurrences could be coupled with localised stepping in the surface. If this type of phenomenon coincided with a dam wall, then, there is a possibility that a significant impact on the dam could occur, but the likelihood of this occurring is small.

All water retaining structures should be visually monitored during mining to ensure that they remain in a safe and serviceable condition. In the event that any of the private farm dams looses water as a result of mine subsidence, Mt. Arthur Coal would provide an alternative water supply to the affected property for the duration of the mining period, and the Mine Subsidence Board would repair the dam at the completion of mining.

5.15.6. Wells and Bores

There are a number of registered water bores identified within the vicinity of the Study Area, the locations of which are shown in Drawing No. MSEC263-146. A summary of the maximum predicted values of total systematic subsidence, tilt, and strain at the water bores, at any time during or at the completion of the proposed longwalls, is provided in Table F.06 in Appendix F.

There are three registered water bores within the Study Area which are privately owned, being Refs. GW029646 and GW029661 (2 off bores). A summary of the maximum predicted systematic subsidence parameters at the privately owned water bores are provided in Table 5.27.

Table 5.27 Maximum Predicted Total Systematic Subsidence, Tilt and Strain at the Privately Owned Water Bores due to the Extraction of the Proposed Longwalls

Bore ID	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Travelling or Total Tilt (mm/m)	Maximum Predicted Travelling or Total Tensile Strain (mm/m)	Maximum Predicted Travelling or Total Compressive Strain (mm/m)
GW 029646	1635	6.6	0.6	3.7
GW 029661 (A / B)	715	13	3.2	0.3

There are eight registered water bores within the Study Area which are owned by Mt. Arthur Coal. The maximum predicted systematic tilt at these bores, at any time during or at the completion of the proposed longwalls, varies from less than 0.1 mm/m, to greater than 50 mm/m. The maximum predicted systematic strains at these bores, at any time during or at the completion of the proposed longwalls, vary from less than 0.1 mm/m, to greater than 25 mm/m.

The 11 registered water bores within the Study Area are either located directly above, or immediately adjacent to the goaf areas of the proposed longwalls. It is likely, therefore, that differential horizontal displacements will occur at the different horizons within the strata at the bore locations, and this could result in the blockage, or reduced capacities of these bores. At the same time, it is possible that cracking and bed separation in the strata could result in the migration of water from near surface aquifers to other aquifers that lie beneath them.

The registered water bores adjacent to the Study Area are less likely to be affected by systematic subsidence impacts. These bores, however, may be affected by far-field horizontal movements, which can occur up to 2 or 3 kilometres from the proposed longwalls. The strains resulting from far-field horizontal movements, however, are generally very small and less likely to have an impact on the bores.

A detailed assessment of the impact of mine subsidence on the registered water bores is provided in the report by Mackie (2007). Any impacts on water bores can be readily managed until such time as the Mine Subsidence Board can re-establish them.

5.15.7. Windmills

The windmills within the Study Area are generally associated with the water bores, which are discussed in Section 5.15.6.

5.16. Mine Infrastructure

5.16.1. Impact Assessments for the MacDonalds Pit

The longwalls within the Glen Munro and Piercefield Seams are proposed to be mined directly beneath the highwall and low-walls in MacDonalds Pit. The MacDonalds Pit will be closed in accordance with Mt. Arthur Coal Mine Closure Plan, before the proposed longwalls are mined beneath it.

The MacDonalds Pit highwall provides access to the Blakefield Seam, however, no longwalls are proposed to be extracted from this seam as part of this assessment. It is likely that the stability of the highwall will be adversely affected by the extraction of the proposed longwalls beneath it. It is proposed that bund walls would be constructed at the top and bottom of the highwall, and that access to that section of the pit would be restricted, prior to mining beneath it. The lower sections of the highwall, which could become unstable during mining, could be restabilised by placing spoil against the face.

The MacDonalds Pit low-walls have slopes between 1 in 3 and 1 in 2. It is possible that soil slumping will occur down these slopes, as a result of the proposed longwalls mining beneath them, similar to that described in Section 5.7.1 for the natural steep slopes. The low-walls may also be affected by systematic tensile cracking which is discussed in Section 5.25.

5.16.2. Impact Assessments for the Belmont Pit

The longwalls within the Arrowfield, Bowfield, and Piercefield Seams are proposed to be mined directly beneath the highwall and low-walls in Belmont Pit. It is proposed that spoil will be placed within the pit which will provide some stabilisation to the lower sections of the highwall and the low-walls. The spoil is likely to consolidate as the result of subsidence, however, which is discussed in Section 5.16.4.

The greatest impact on the Belmont Pit highwall is predicted to occur during the extraction of the Arrowfield and Bowfield Seams, as the depths of cover are the shallowest. The Belmont Pit will be closed in accordance with the Mt. Arthur Coal Mine Closure Plan, before the proposed longwalls are mined beneath the pit. It is proposed that bund walls would be constructed at the top and bottom of the highwall, and that access to that section of the pit would be restricted, prior to mining beneath it. The lower sections of the highwall, which could become unstable during mining, could be restabilised by placing spoil against the face.

5.16.3. Impact Assessments for the Planned Belmont West Pit

It is planned that the Belmont Pit will be extended to form the Belmont West Pit. The planned highwall for the Belmont West Pit will provide access to the proposed longwalls within the Glen Munro Seam. The longwalls within the Arrowfield and Piercefield Seams are proposed to be mined directly beneath the highwall. The Belmont West Pit will be closed in accordance with the Mt. Arthur Coal Mine Closure Plan, before the proposed longwalls are mined beneath it.

It is likely that the stability of the planned highwall in the Belmont West Pit will be adversely affected by the extraction of the proposed longwalls beneath it. It is proposed that bund walls would be constructed at the top and bottom of the highwall, and that access to that section of the pit would be restricted, prior to mining beneath it. The lower sections of the highwall, which could become unstable during mining, could be restabilised by placing spoil against the face.

5.16.4. Predictions and Impact Assessments for the Spoil Heap within the Belmont Pit

The predicted subsidence parameters and contours provided in this report are at the natural ground surface. Additional subsidence will occur at the tops of any unconsolidated spoil heaps which are directly mined beneath by the proposed longwalls, due to the consolidation and lateral shift of the spoil heaps. A detailed discussion of the additional subsidence of unconsolidated spoil heaps is provided in Appendix D.5.

It is planned that spoil will be placed in the Belmont Pit, the location of which is shown in Drawing No. MSEC263-141. Fig. D. 11 in Appendix D provides an empirical relationship between the additional settlement at the tops of unconsolidated spoil heaps which are directly mined beneath. It is likely that this figure would provide an upper bound estimate for the spoil heap within the Belmont Pit, as the pit walls will provide lateral support to the spoil.

Longwalls PF103 to PF105 within the Piercefield Seam are proposed to mine directly beneath the planned spoil heap within the Belmont Pit. The maximum predicted subsidence (S) of the natural surface at the spoil heap is approximately 1400 mm, and the depth of cover (h) to the Piercefield Seam is 225 metres. The predicted additional subsidence of the top of the spoil heap within the Belmont Pit taken from Fig. D. 11 is, therefore, approximately 12 % of the height of the spoil heap.

5.17. Archaeological Sites

The locations, descriptions, and impact assessments for the archaeological sites within the Study Area are provided in the report by Umwelt (2007c). The impact assessments for the archaeological sites have been based on the subsidence predictions provided by MSEC.

5.18. Heritage Sites

The locations, descriptions, and impact assessments for the heritage sites within the Study Area are provided in the report by Umwelt (2007a). The impact assessments for the heritage sites have been based on the subsidence predictions provided by MSEC.

5.19. Survey Control Marks

There are a number of survey control marks located within the vicinity of the proposed longwalls, of which nine are located within the Study Area. The locations of the survey control marks are shown in Drawing No. MSEC263-147. A summary of the maximum predicted values of total systematic subsidence and horizontal movement at the survey control marks within the Study Area, after the extraction of the proposed series of longwalls within each seam, is provided in Table 5.28.

Table 5.28 Predicted Total Systematic Subsidence and Horizontal Movement at the Survey Control Marks after the Extraction of the Proposed Series of Longwalls within Each Seam

Survey Mark	Maximum Predicted Total Subsidence after the Extraction of the Proposed Series of Longwalls within Each Seam (mm)					Maximum Predicted Total Horizontal Movement after the Extraction of the Proposed Series of Longwalls within Each Seam (mm)				
	WH	GM	AF	BF	PF	WH	GM	AF	BF	PF
PM 46560	1560	1560	1560	1560	1560	20	20	20	20	20
PM 46565	< 5	< 5	< 5	< 5	10	< 5	< 5	< 5	< 5	5
PM 46566	1330	1330	1330	1330	1330	175	175	175	175	175
PM 74661	260	260	260	1535	2795	95	95	95	135	190
SS 20785	< 5	< 5	< 5	< 5	10	< 5	< 5	< 5	< 5	< 5
SS 24710	< 5	< 5	< 5	< 5	100	< 5	< 5	< 5	< 5	20
SS 94013	< 5	155	1930	1930	2290	< 5	15	35	35	50
SS 94014	< 5	1410	2155	2155	2335	< 5	45	80	80	105
TS 10524	< 5	< 5	< 5	< 5	100	< 5	< 5	< 5	< 5	20

The survey control marks that lie immediately outside the Study Area are also likely to experience either small amounts of subsidence and some small far-field horizontal movements as the proposed longwalls are mined. It is possible that other marks outside the immediate area could also be affected by far-field horizontal movements, up to 3 kilometres outside the Study Area, which is discussed in Section 5.24.

It will be necessary on completion of the proposed longwalls, when the ground has stabilised, to re-establish these marks. Consultation between Mt. Arthur Coal and the Department of Lands will be required throughout the mining period to ensure that these survey marks are reinstated at an appropriate time, as required.

5.20. Residential Establishments

5.20.1. Predictions and Impact Assessments for the Houses

There are ten houses that are located within the Study Area, all of which are owned by Mt. Arthur Coal. Nine are single-storey houses with lengths less than 30 metres (Type H1), and one is a single-storey house with a length greater than 30 metres (Type H2), being Edderton Homestead (Structure Ref. A12a). Although Edderton Homestead is only partly located within the Study Area, it has been included as part of these assessments. The locations of the houses within the Study Area are shown in Drawings Nos. MSEC263-150 to MSEC263-156 and details are provided in Table F.03 in Appendix F.

It should be noted that the houses labelled Cooks House and Hospital are located within the planned extension of the Belmont Pit, and are proposed to be removed prior to being mined beneath. The predictions and impact assessments for these houses provided in this section have been based on their current locations.

The houses on the Edinglassie and Rous Lench properties, which are located more than 1.3 kilometres outside the Study Area, could experience some small far-field horizontal movements as a result of the extraction of the proposed longwalls. These movements, however, tend to be bodily movements which are not associated with any significant strains. The houses on the Edinglassie and Rous Lench properties will not be impacted as a result of the extraction of the proposed longwalls.

Predictions of subsidence, tilt, and strain have been made at the centroids and at the vertices of each house within the Study Area. The maximum predicted values of systematic subsidence, tilt and strain have been determined during, and at the completion of the proposed series of longwalls within each seam.

The maximum predicted systematic subsidence, and the tilt and strain impact assessment for the houses within the Study Area are provided in Table F.04 in Appendix F. A summary of the assessed tilt and strain impacts for the houses within the Study Area is provided in Table 5.29.

Table 5.29 Summary of Tilt and Strain Impacts for Houses within the Study Area after the Extraction of the Proposed Series of Longwalls within Each Seam

Proposed Series of Longwalls	Tilt Impact Categories				Strain Impact Categories					
	Cat A	Cat B	Cat C	Cat D	Cat 0	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
Woodlands Hill Seam	7	0	1	2	7	0	0	0	1	2
Glen Munro Seam	6	0	1	3	5	0	0	0	1	4
Arrowfield Seam	3	2	2	3	3	0	1	1	1	4
Bowfield Seam	3	2	2	3	3	0	1	1	1	4
Piercefield Seam	3	1	2	4	3	0	1	0	1	5

Tilt Impact Categories A, B and C represent predicted tilts at the houses of up to 5 mm/m, 7 mm/m and 10 mm/m, respectively. Tilt Impact Category D represents predicted tilts of greater than 10 mm/m. Strain Impact Categories 0, 1, 2, 3 and 4 represent predicted approximate crack width limits in masonry walls of building structures of 0.1 mm, 1 mm, 5 mm, 15 mm and 25 mm, respectively. Strain Impact Category 5 represents a predicted approximate crack width limit of greater than 25 mm. A detailed description of the Tilt and Strain Impact Categories is provided in Appendix E.

A summary of the maximum impacts that each house within the Study Area will experience, at any stage during or at the completion of the proposed longwalls, is provided in Table 5.30.

Table 5.30 Count of Maximum Tilt and Strain Impacts for Houses within the Study Area

Tilt Impact Category	Strain Impact Category						
	Category 0	Category 1	Category 2	Category 3	Category 4	Category 5	Total
Category A	3	0	0	0	0	0	**3**
Category B	0	0	0	0	0	0	**0**
Category C	0	0	0	0	0	0	**0**
Category D	0	0	1	0	1	5	**7**
Total	**3**	**0**	**1**	**0**	**1**	**5**	**10**

Preventive measures are generally not recommended for houses unless the impact assessments are Category C for Tilt or Category 3 for Strain, or greater. All of the houses are of lightweight construction, therefore, it is possible that preventive measures would not be required unless the strain impact assessment was Category 4, or greater. In addition to this, many of the houses are constructed on brick piers which will reduce the magnitude of ground strains being transferred to the main structures.

There are seven houses which are assessed to experience a Category C or Category D tilt impact at some stage during, or at the completion of the proposed longwalls. It should be noted, however, that one of these houses, being House A08a, is assessed to experience a Category D tilt impact due to the travelling wave and is assessed to reduce to a Category B tilt impact at the completion of the proposed longwalls. A summary of the houses assessed to experience a Category C or Category D tilt impact is provided in Table 5.31.

Table 5.31 Summary of Houses Assessed to Experience Category C or Category D Tilt Impacts at Some Stage during the Extraction of the Proposed Longwalls

Structure Reference	Property	Maximum Tilt Impact due to the Proposed Longwall Travelling Waves	Maximum Tilt Impact at the Completion of the Proposed Series of Longwalls within Each Seam	Maximum Tilt Impact at the Completion of the Proposed Series of Longwalls within All Seams
A05a	Cooks House	Category B	Category D	Category D
A06a	Hospital	Category D	Category C	Category C
A07a	Roxburgh South	Category D	Category D	Category D
A08a	550 Edderton Road	Category D	Category B	Category B
A10b	Belmont Homestead	Category D	Category D	Category D
A12b	Edderton	Category D	Category C	Category C
A12c	Edderton	Category D	Category D	Category D

Tilt generally does not have any significant impact on the stability of houses, except where the tilts are very large, which can potentially induce eccentricities and, hence, greater loads into the wall bracing systems and into any supporting brick piers. It is recommended, therefore, that the houses listed in the above table should be inspected by a structural engineer, and that preventive measures are provided, where required, prior to each house being mined beneath.

The houses which are assessed to experience Category C and D tilts are also likely to experience serviceability problems including door swings and issues with gutter and wet area drainage. Some remedial measures may be required for the houses listed in Table 5.31 as the result of tilt.

There are six houses which are assessed to experience a Category 3 or greater strain impact. A summary of the assessed strain impacts for these houses is provided in Table 5.32.

Table 5.32 Summary of Houses Assessed to Experience Category 3 or Greater Strain Impacts due to the Extraction of the Proposed Longwalls

Structure Reference	Property	Maximum Strain Impact due to the Extraction of the Proposed Longwalls
A05a	Cooks House	Category 5
A07a	Roxburgh South	Category 5
A08a	550 Edderton Road	Category 5
A10b	Belmont Homestead	Category 5
A12b	Edderton	Category 5
A12c	Edderton	Category 4

It is expected that the actual impacts on the houses will be less than those provided in the above table, as all the houses within the Study Area are of light-weight construction, which are more flexible than masonry structures. In addition to this, many of the houses are founded on brick piers and, therefore, the ground strains will not be fully transferred into the main structures.

Structure Ref. A05a (Cooks House) is assessed to experience a Category 3 strain impact during the extraction of proposed Longwall AF103, and a Category 5 strain impact during the extraction of proposed Longwall PF103. The house is located within the planned extension of the Belmont Pit, however, and is proposed to be removed prior to being mined beneath.

Structure Ref. A07a (Roxburgh South) is assessed to experience a Category 5 strain impact during the extraction of proposed Longwall GM101, and will also be directly mined beneath by proposed Longwall AF202. The house is a single storey timber framed house founded on brick piers and a low level perimeter brickwall, with weatherboard cladding to the walls and an asbestos sheeted roof. It is recommended that the house should be inspected by a structural engineer before and after proposed Longwalls GM101 and AF202 mine beneath it, to assess the structural condition of the house, and to make recommendations for any required preventive or remedial works.

Structure Ref. A08a (550 Edderton Road) is assessed to experience a Category 5 strain impact during the extraction of proposed Longwall GM203, and will also be directly mined beneath by proposed Longwalls AF103 and PF104. The house is a single storey timber framed structure with weatherboard cladding to the external walls and a metal sheeted roof. The structure was only observed from a distance during the initial investigations, however, it is anticipated that the house is founded on brick piers. It is recommended that the house should be inspected by a structure engineer before and after the extraction of proposed Longwalls GM203, AF102 and AF103 mine beneath it, to assess the structural condition of the house and to make recommendations for any required preventive or remedial works.

Structure A10b (Belmont Homestead) is assessed to experience a Category 5 strain impact during the extraction of proposed Longwall WH105. The house is a single storey timber framed structure founded on brick piers and a low level perimeter brickwall, with fibresheet cladding to the walls and a metal sheeted roof. The options for the protection of this house include:-

1. Provide preventive works before, or during the extraction of proposed Longwall WH105 beneath the homestead. One method would be to temporarily remove the floor boards and provide packing between the brick piers and bearers as the homestead is mined beneath. The southern corner of the house would need to be packed approximately 400 mm higher than the northern corner at the completion of Longwall WH105,
2. Relocate the homestead to nearby Mt. Arthur Coal owned land, or
3. Undertake remedial works on the homestead after it has been mined beneath.

Structure Ref. A12b (Edderton) is assessed to experience a Category 5 strain impact during the extraction of proposed Longwall WH110. The house is a single storey timber framed structure founded on brick piers, with weatherboard cladding to the walls and a metal deck roof. It was observed during the initial inspections that a number of the brick piers supporting the house were damaged, tilted, or missing. It is likely, therefore, that preventive works will be required for the house prior to proposed Longwall WH110 mining beneath the structure. It is recommended that a structural engineer should inspect the structure before and after it is mined beneath, to assess the structural condition of the house and to make recommendations for any required preventive or remedial works.

Structure Ref. A12c (Edderton) is assessed to experience a Category 4 strain impact during the extraction of proposed Longwall WH110. The house is a single storey timber framed structure founded on brick piers, with fibro cladding to the walls and a metal deck roof. It is recommended that a structural engineer should inspect the structure before and after it is mined beneath, to assess the structural condition of the house and to make recommendations for any required preventive or remedial works.

The remaining houses are assessed to experience Category 2 or less strain impacts due to the extraction of the proposed longwalls. Edderton Homestead is also located outside the predicted total 20 mm subsidence contour and is unlikely, therefore, to experience any significant systematic subsidence movements.

It is likely, therefore, that these remaining houses will remain safe and serviceable throughout the mining period. It was observed during the initial investigations, however, that some of the houses were in a dilapidated condition. It is recommended, therefore, that all houses should be inspected by a structural engineer, prior to each house being mined beneath, to assess the existing structural condition of the houses and to make recommendations for any required preventive works.

The predictions and impact assessments for the houses are based on longwalls having an overall void width of 285 metres. If the longwall widths were changed, the predictions at each structure may be higher or lower, depending on their relative position within the subsidence trough.

If the predictions were to be increased by factors of 1.25 to 5 times, the impacts on the houses would increase accordingly. The assessed tilt and strain impacts for increased predictions for the houses are provided in Table F.04, and are summarised in Table 5.33.

Table 5.33 Summary of Tilt and Strain Impacts for the Houses within the Study Area for Increased Predictions

Increased Prediction	Number of Houses with Tilt Impact Assessment for Increased Predictions				Number of Houses with Strain Impact Assessment for Increased Predictions					
	Cat A	Cat B	Cat C	Cat D	Cat 0	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
x 1.25	3	0	1	6	3	0	1	0	0	6
x 1.50	3	0	1	6	3	0	1	0	0	6
x 1.75	3	0	0	7	2	1	1	0	0	6
x 2.00	3	0	0	7	2	1	0	1	0	6
x 5.00	3	0	0	7	1	1	1	0	1	6

5.20.2. The Heritage Wall at Edderton Homestead

The heritage wall at Edderton Homestead is located to the west of the homestead (Structure Ref. A12a). The maximum predicted tilts and strains at the heritage wall are similar to those at the homestead, as the maximum predicted parameters were determined within 20 metres of the homestead.

The wall is located outside the predicted total 20 mm subsidence contour resulting from the extraction of the proposed longwalls. It is unlikely, therefore, that there would be any significant systematic subsidence impacts on the wall, even if the predictions were increased by a factor of 5 times.

5.20.3. Non-Residential Building Structures

The predictions and impact assessments for non-residential building structures are provided in Sections 5.15.2 and 5.15.3.

5.20.4. Fences

The predictions and impact assessments for fences are provided in Section 5.15.4.

5.21. Likely Height of the Fractured Zone above the Proposed Longwalls

The background to sub-surface strata movements has been discussed in Section D.8 in Appendix D, and the following conclusions should be read in that context. The height of the fractured zone for single-seam extractions is dependent upon the angle of break (a), the width of the panel (W) and the spanning capacity of a competent stratum at the top of the fracture zone, span (w). These are illustrated in Fig. 5.3. From the mining geometry it can be shown that the height of the fractured zone equals the panel width (W) minus the span (w) divided by twice the tangent of the angle of break.

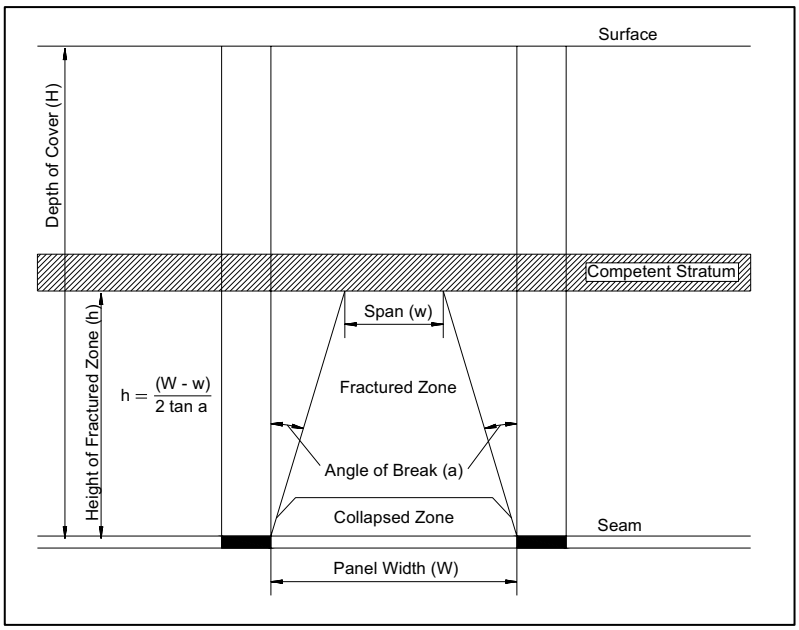

Fig. 5.3 Theoretical Model illustrating the Development and Limit of the Fractured Zone

Using this relationship, the theoretical height of the fractured zone for single-seam extractions, as a proportion of the width of the extracted panel, has been determined for a range of width-to-depth ratios. These values have been plotted in the graph shown in Fig. 5.4, together with the values that have been reported in literature. The red data points are those which have been reported in literature whilst the theoretical values are shown in green, magenta, and blue for angles of break of 17°, 20° and 23°, respectively.

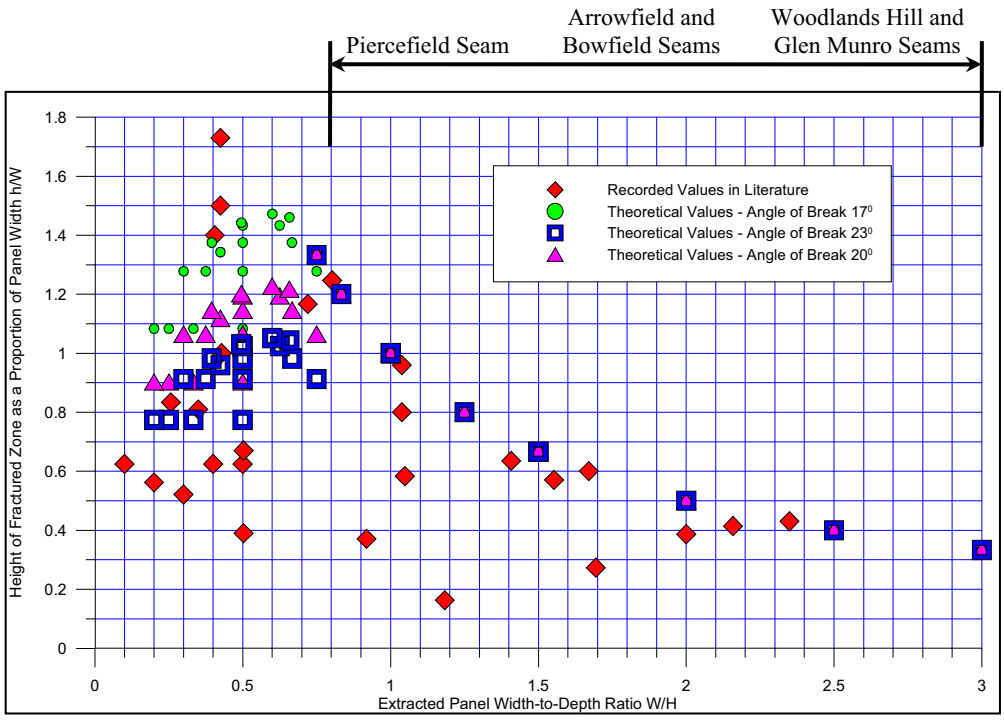

Fig. 5.4 Graph showing Height of Fractured Zone as a Proportion of Panel Width for different Width-to-Depth Ratios

It can be seen that the height of the fractured zone in the database is reasonably represented by the theoretical model using an angle of draw of 20°. Only three red data points appear above the magenta data points and these are the heights of the fractured zone over Longwall 2 at Ellalong Colliery and over Longwall 3 at Tahmoor Colliery, which were given by Holla (1986) and Holla and Buizen (1991).

In both of these cases, the apparent heights of the fractured zone were determined from extensometer readings which could have included horizontal shear as well as vertical dilation. The stated heights of the fractured zone at Tahmoor, which are the highest data points in the graph, are not supported by the measured vertical strains, which averaged only 0.6 mm/m in the top 160 metres of the overburden. A more realistic assessment is that the fractured zone extended only to the Bald Hill Claystone.

In some cases, it is likely that the upwards progression of the fractured zone was limited by the levels of vertical strain that could be developed, which is dependent upon the extracted seam thickness, the surface subsidence and the depth of cover.

The upper limit of the fractured zone for single-seam extractions will be reached when the strata above that zone are sufficiently strong to span the goaf area without significant bending or shear strains being developed. The upper sandstone strata within the Study Area are likely to be particularly strong and homogeneous and would be expected to be capable of spanning at least 35 metres.

The proposed longwalls within the Woodlands Hill and Glen Munro Seams are to be extracted first and, therefore, can be considered single-seam extractions. The sections of the proposed longwalls within the Arrowfield, Bowfield, and Piercefield Seams which extend well beyond the overlying longwalls can also be considered single seam extractions. The sections of the proposed longwalls within the Arrowfield, Bowfield and Piercefield Seams which mine beneath previously extracted longwalls are multi-seam extractions and, therefore, the method for determining the height of the fractured zone described in this section does not apply.

The height of the fractured zone above the proposed single seam longwall extractions can, therefore, be determined as the minimum depth of cover required to reduce the effective span of the strata to 35 metres, based on an average angle of break of 20°. The void widths of the proposed longwalls are 285 metres, apart from proposed Longwalls WH110 and GM302 which have void widths of 250 metres and 210 metres, respectively.

Based on a proposed longwall width of 285 metres, the predicted height of the fractured zone is 345 metres. It can be seen from Table 1.9, that the depths of cover to the proposed longwalls within the Woodlands Hill, Glen Munro, Arrowfield, and Bowfield Seams are less than 345 metres. It can also be seen from Drawing No. MSEC263-115, that the depth of cover to the proposed longwalls within the Piercefield Seam is generally less than 345 metres, apart from isolated locations above proposed Longwalls PF101, PF102, PF104, PF105, PF201, PF203 and PF204.

It is likely, therefore, that the fractured zones above the proposed single-seam extraction longwalls within each seam will extend to the surface. It is also likely that the fractured zones above the proposed multi-seam extraction longwalls within the Arrowfield, Bowfield and Piercefield Seams will extend up to the overlying seams and interact with the previously formed collapsed and fractured zones.

Where the depths of cover are less than 100 metres, it is also likely that the collapsed zone will extend near to the surface, resulting in irregular subsidence profiles. The likelihood and affect of irregular subsidence profiles is discussed in Section 5.22.

5.22. The Likelihood of Irregular Profiles

Wherever faults, dykes, or abrupt changes in geology are present near the surface, it is possible that irregularities in the subsidence profiles could occur. Similarly, where surface rocks are thinly bedded, and where cross-bedded strata exist close to the surface, it is possible for surface buckling to occur, leading to irregular movements.

The major geological structures which have been identified at seam level in the vicinity of the proposed longwalls are shown in Drawing No. MSEC263-131. Where large faults occur close to the surface, it is possible that a stepped subsidence profile would occur at the surface, and shearing would occur along the fault. A stepped subsidence profile is accompanied by locally higher tilts and ground strains.

Irregularities also occur in shallow mining situations, where the collapsed zone, which develops above the extracted longwalls, extends near to the surface. This type of irregularity is generally only seen where panel widths are supercritical and where the depths of cover are less than 100 metres, which occurs for the proposed longwalls within the Woodlands Hill, Glen Munro and Bowfield Seams. Where the depths of cover are less than 100 metres, it is likely that the subsidence profile will become irregular (ie: non-systematic), resulting in bumps and steps at the surface, which is accompanied by higher tilts and ground strains.

The level of irregular movement at varying depths of cover can be seen in the observed subsidence profiles over Longwalls 1 and E1 at South Bulga Colliery, which are shown in Fig. 5.5. The observed subsidence profiles along the MLS and LWE1 monitoring lines above the southern ends of Longwalls 1 and E1, respectively, having average depths of cover of 160 metres, are shown in the left of this figure. The observed subsidence profile along the MLM monitoring line above the northern end of Longwall 1, having an average depth of cover of 90 metres, is shown near the middle of the figure. The observed subsidence profile along the MLN monitoring line above the northern end of Longwall 1, having an average depth of cover of 45 metres, is shown in the right of this figure.

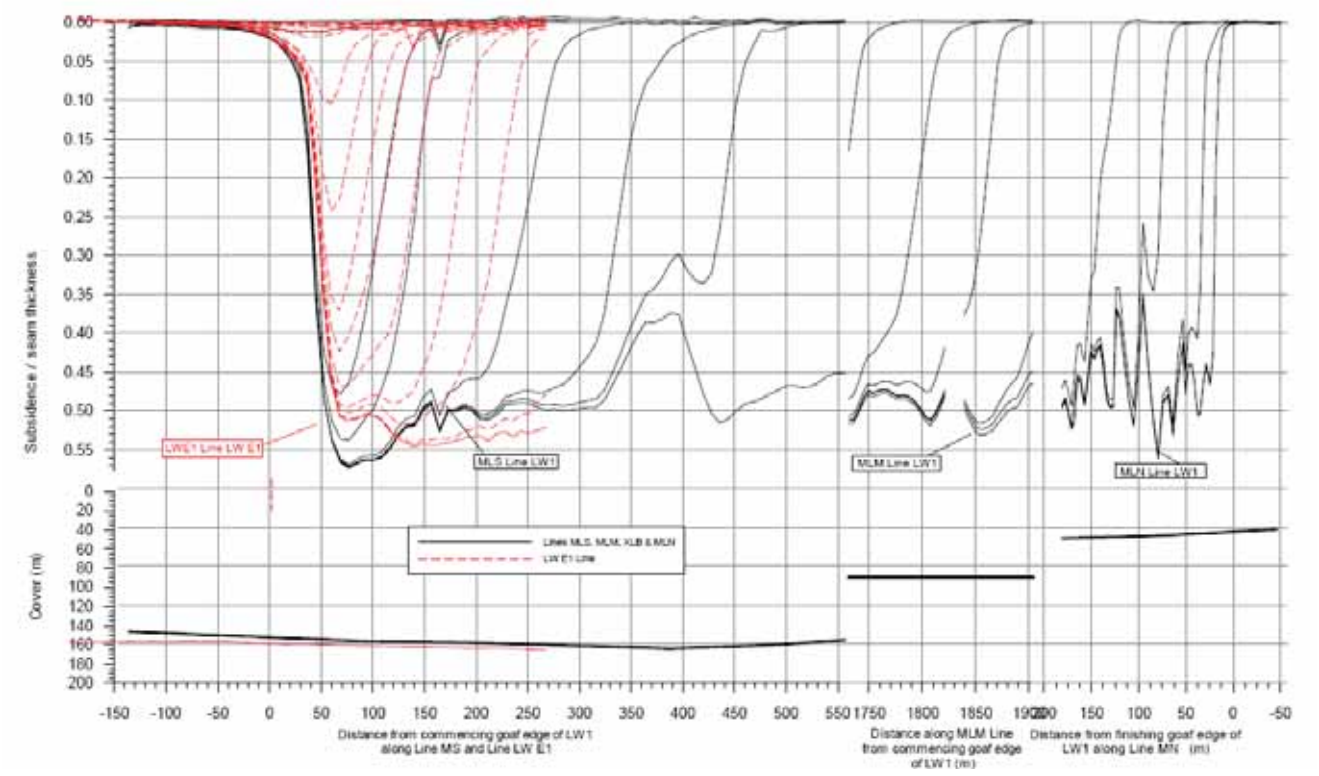

Fig. 5.5 Observed Subsidence Profiles over Longwalls 1 and E1 at South Bulga Colliery

The observed subsidence profiles are relatively smooth (ie: systematic) along the MLS and LWE1 monitoring lines, where the depths of cover are much greater than 100 metres. The observed subsidence profile is still relatively smooth along the MLM monitoring line, where the depth of cover is just less than 100 metres. The observed subsidence profile along the MLN line is very irregular (ie: non-systematic), where the depth of cover is less than 50 metres.

At the Mt. Arthur Underground Project, the level and extent of irregular subsidence movements are expected to occur at similar depths of cover as those observed at South Bulga Colliery. It is expected, therefore, that the observed subsidence profiles will be relatively smooth (ie: systematic), where the depths of cover are greater than 100 metres.

Irregular (ie: non-systematic) subsidence movements are expected to develop where the depths of cover are less than 100 metres. At depths of cover less than 50 metres, the observed subsidence profiles are likely to become very erratic, similar to those observed along the MLN line at South Bulga Colliery and shearing of the strata around the proposed longwall goaf edges could occur.

The locations within the Study Area where the depths of cover are less than 100 metres above the proposed longwalls are shown in Drawing No. MSEC263-315. The natural features and items of surface infrastructure which are located within these areas include:-

- Quarry Creek,
- Edderton and MacDonalds Roads,
- Drainage culverts and Bridges ER-B1 and ER-B2,
- 330/500 kV transmission line and the low voltage powerlines,
- Copper telephone cables,
- Farm dams,
- Water bores, and
- Rural building structures and houses.

The impacts resulting from irregular subsidence profiles are more likely to occur along Quarry Creek, Edderton Road, MacDonalds Road and the underground copper telephone cables. The reason for this is that these features extend continuously across the proposed longwalls and it is more likely, therefore, that a step or bump in the subsidence profile would be coincident with them. It is less likely that a step or bump in the subsidence profile would be coincident with an item of infrastructure which is at a discrete location above the proposed longwalls, which includes the drainage culverts, the bridges, the towers along the 330/500 kV transmission line, the poles along the low voltage powerlines, farm dams, water bores and building structures.

A stepped or irregular subsidence profile develops slowly and can be detected using subsidence monitoring or visual monitoring. Early detection allows for the implementation of preventive works or management strategies to protect the natural features and items of surface infrastructure from adverse impacts resulting from irregular subsidence profiles.

It is recommended that a subsidence monitoring line should be provided along Edderton Road, which would provide early detection for the road and underground copper cables. It is also recommended that subsidence monitoring should be provided along the 330/500 kV transmission line, due to the sensitivity and importance of this item of infrastructure. Visual monitoring can also be used to detect the development of a stepped subsidence profile at the remaining natural features and items of infrastructure.

5.23. Predicted Horizontal Movements

The predicted horizontal movements over the proposed longwalls are estimated by applying a factor to the tilt values. In the Hunter Coalfield a normal factor of 10 has been adopted, being the same factor as that used to determine strains from curvatures, and this has been found to give a reasonable correlation with measured data. We have found that this factor varies, and is higher at low tilt values and lower at high tilt values. The application of a 10 factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted tilt in the Study Area, during or at the completion of the proposed longwalls, is greater than 140 mm/m, which occurs during the extraction of the proposed series of longwalls within the Glen Munro Seams. These areas will experience the greatest horizontal movement towards the centre of the proposed longwalls. Applying a factor of 10 to this magnitude of tilt would provide a very conservative prediction of horizontal movement. It is likely that a factor of less than 4 would be applicable for a tilt of this magnitude and, therefore, the maximum predicted horizontal movement is approximately 500 mm.

Horizontal movements do not directly impact on natural features or items of surface infrastructure, rather impacts occur as a result of differential horizontal movements. Systematic strain is the rate of change of horizontal movement. The impacts of systematic strain on the natural features and items of surface infrastructure are addressed in Sections 5.2 to 5.20.

5.24. Predicted Far-Field Horizontal Movements

In addition to the systematic horizontal movements that have been predicted above and around the proposed longwalls, it is likely that some far-field horizontal movements will also be experienced as mining proceeds. These ground movements are believed to be the result of the redistribution of horizontal stresses in the strata around the collapsed zones above extracted longwalls. Such movements are predictable and occur whenever significant excavations occur at the surface or underground.

The in-situ horizontal stresses in the strata within the Study Area have already been affected by the open cut voids at the MacDonalds and Belmont Pits and also by the Saddlers Creek North and South Pits which are located east of the Study Area. As a result, the in-situ stresses in the strata around the proposed longwalls have already been partially redistributed. As the proposed longwalls are mined, the stresses in the strata above the proposed longwalls would be relaxed and redistributed around the collapsed zones above these longwalls.

The relationship between the observed incremental horizontal movements and distances from extracted longwalls is illustrated in Fig. D.30 in Appendix D. The relationship between the observed incremental horizontal movements and distances from extracted longwalls, where there was solid coal between the monitoring points and longwalls, is illustrated in Fig. D.31 in Appendix D.

It can be seen from these figures, that incremental far-field horizontal movements of up to 20 mm have been observed at distances of 2000 metres from longwall extractions. It should be noted, however, that at the larger distances from the longwall extractions, the measured movements contain larger proportions of survey error, in addition to valley related closure movements and movements along geological anomalies.

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the strata has been stress relieved by the first few longwalls, the potential for further movement is reduced. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

Any far-field horizontal movements that might occur would, nevertheless, be expected to be very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area and are accompanied by low levels of strain which are generally less than 0.1 mm/m. The impact of far-field horizontal movements on the natural features and items of surface infrastructure is expected to be insignificant.

5.25. The Likelihood and Extent of Surface Cracking

As subsidence occurs, surface cracks generally appear in the tensile zone, ie: within 0.1 to 0.4 times the depth of cover from the longwall perimeters. However, most cracks appear within 0.1 times the depth of cover from the longwall perimeters. The cracks are generally parallel to the longitudinal edges of the longwalls, except at the ends of the longwalls where the cracks are generally parallel to the ends of the longwalls.

At shallow depths of cover, it is also likely that smaller transient surface cracks will occur above and parallel to the moving extraction face, ie: at right angles to the longitudinal edges of the longwall, as the subsidence trough develops. This cracking, however, tends to be transient, since the tensile phase of the travelling wave, which causes the cracks to open up, is generally followed by a compressive phase, which closes them. It has been observed in the past, however, that surface cracks which occur during the tensile phase of the travelling wave do not fully close during the compressive phase, and tend to form compressive ridges at the surface.

At shallow depths of cover, therefore, surface cracking can potentially occur in any location above the extracted goaf areas of the proposed longwalls. The larger and more permanent cracks, however, are usually located in the final tensile zones around the perimeters of the longwalls.

The incidence of surface cracking is dependent on the location relative to the extracted longwall goaf edges, the depth of cover, the extracted seam thickness, and the thickness and inherent plasticity of the soils that overlie the bedrock. The surface soils above the proposed longwalls are generally weathered. The widths and frequencies of the cracks are also dependent upon the pre-existing jointing patterns in the bedrock. Large joint spacing can lead to concentrations of strain and possibly the development of fissures at rockhead, which are not necessarily coincident with the joints.

The largest surface cracks within the Study Area are expected to occur as the result of soil slumping down the steep slopes, which is discussed in Section 5.7.1. The surface cracks as the result of soil slumping at the "Northern Hills" and "Western Hills" are predicted to be typically in the order of 250 mm wide, but could be in the order of 500 mm wide where the slopes as the steepest.

Where the surface is relatively flat, the relationship between surface crack width and depth of cover, based upon measured data in the NSW Coalfields and observations over mines in the United Kingdom, is shown in Fig. D.12 in Appendix D. The upper blue line on the graph represents the upper-bound limit of the data in Australia, and the lower red line represents the upper-bound limit of the data measured at South Bulga Colliery. It can be seen that the crack width increases as the depth of cover reduces and that significant crack widths can develop at lower depths of cover.

The depths of cover are the shallowest above the proposed longwalls within the Woodlands Hill, Glen Munro and Bowfield Seams. The minimum depths of cover above these longwalls are less than 100 metres and the predicted surface crack widths are, therefore, typically in the order of 150 to 200 mm wide, but could be as large as 500 mm wide where the depths of cover are the shallowest. The predicted surface crack widths are smaller where the depths of cover are greater, or where the surface cracks result from the travelling wave. A summary of the relationship between depth of cover and typical predicted surface crack width is provided in Table 5.34.

Table 5.34 Relationship between Depth of Cover and Typical Predicted Surface Crack Width

Seams	Depth of Cover (m)	Typical Predicted Surface Crack Width in Final Tensile Zones adjacent to Goaf Edges (mm)	Typical Predicted Surface Crack Width due to Travelling Wave in Middle of Longwalls (mm)
WH, GM & BF	< 100	150 ~ 200	75 ~ 100
WH, GM, AF & BF	100 ~ 150	100 ~ 150	50 ~ 75
WH, GM, AF & BF	150 ~ 200	50 ~ 100	25 ~ 50
AF, BF & PF	> 200	< 50	< 25

The ranges of depths of cover shown in the above table are illustrated in Drawing No. MSEC263-315. The final tensile zones at the completion of the proposed longwalls are also shown in this drawing. Surface cracking which occurs within the final tensile zones during the extraction of the proposed longwalls will not be closed by the compressive phase of the longwall travelling wave. Surface cracking which occurs outside the final tensile zones will be partially reclosed by the compressive phase of the longwall travelling wave.

The surface cracks will tend to heal naturally, especially during rain events. If significant cracking is left untreated, however, it could form trip hazards for people and farm animals, or result in soil erosion on the steep slopes or in the drainage channels.

It is likely that the larger surface cracks which occur as the result of soil slumping at the "Northern Hills", and to a lesser extent at the "Western Hills", will require some remediation during and at the completion of mining, including the regrading, recompacting, and revegetating of the slopes. Where the terrain is flatter, it is likely that surface cracking between 50 mm and 100 mm would require infilling with soil or other suitable materials, and that surface cracking greater than 100 mm would require regrading and recompacting.

It is recommended that the natural surface is visually monitored during the extraction of the proposed longwalls, so that any significant cracking can be remediated, where required, by infilling, regrading, recompacting, and revegetating the surface. It is also recommended that test pits are dug in the locations of the largest surface cracks, to determine the profile of the cracks with depth, to aid in the remediation of these cracks.

It can be seen in Drawing No. MSEC263-112 that the depth of cover to the Glen Munro Seam is less than 50 metres in some locations. It is expected that tensile cracking larger than 500 mm wide will occur where the depths of cover are the shallowest. It is unlikely that the larger tensile cracks in these locations could be fully sealed and it is possible, therefore, that spontaneous combustion of the coal could occur where connection between the surface and seam remains. It is recommended that an assessment of the potential of spontaneous combustion of the coal within the Glen Munro Seam be undertaken by the appropriate specialists, and that suitable management strategies are implemented.

5.25.1. Observed Surface Cracking due to the Extraction of Beltana Longwall 1

Surface cracking was observed during the extraction of Beltana Longwall 1 within the Whybrow Seam. A survey was carried out by Bulga Coal Management (BCM) and its consultants, to determine the frequency and extent of cracking above the commencing end of Longwall 1 within the top of the ridge and the western slope of the ridge, where the depth of cover to the Whybrow Seam was approximately 175 to 185 metres. The width of Longwall 1 was 275 metres and the gradients of the slopes were generally less than 1 in 5.

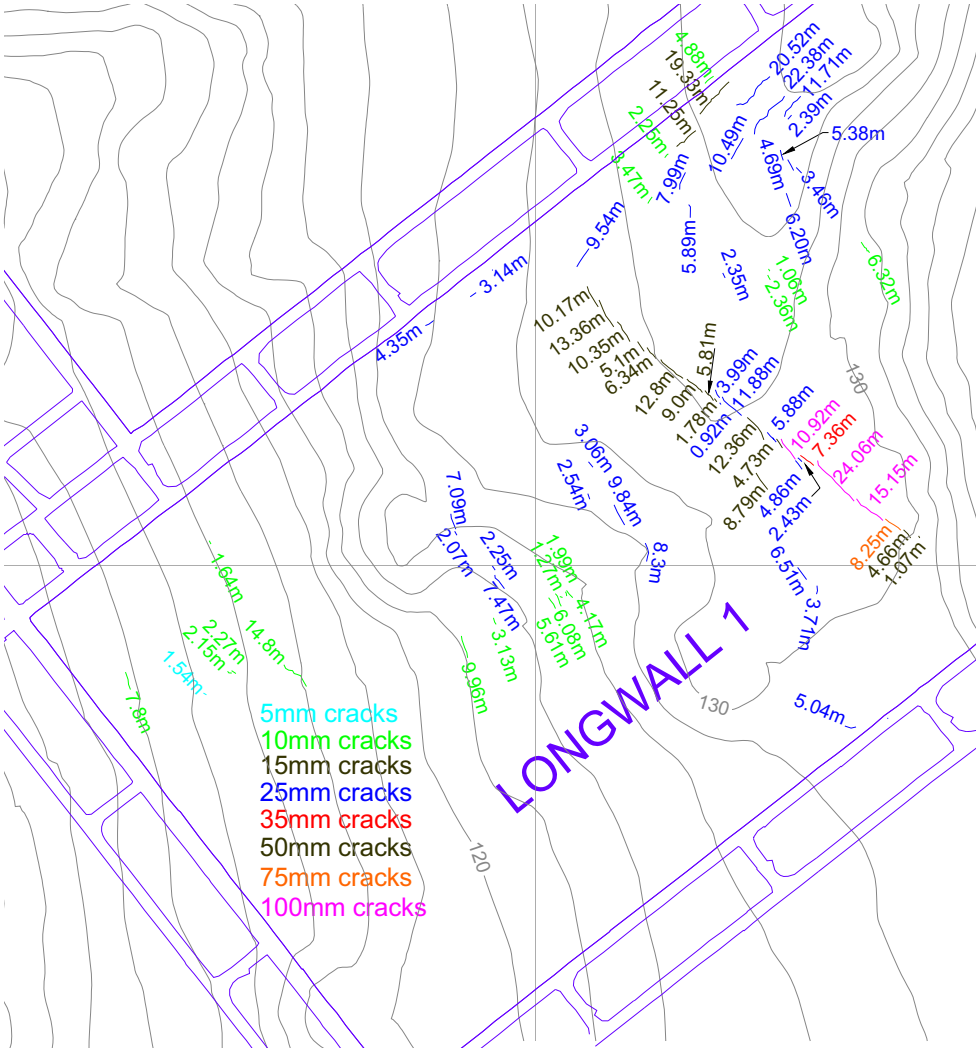

Fig. 5.6 Size, Length and Location of Surface Cracks above Longwall 1 at Beltana Mine

The results of this survey are shown in Fig. 5.6, which indicates the locations of the cracks that have been observed, the lengths of the cracks and the maximum widths of the cracks. The cracks occurred within 412 metres of the commencing end of the longwall and are distributed over the full width of the longwall. The area of the surveyed section of the longwall is 112,476 m^2. It can be seen from the survey data that noticeable cracks are infrequent occurrences and that only a very small part of the surface area was affected by cracking. This is consistent with experience elsewhere in the NSW Coalfields at similar depths of cover.

Several trial pits were excavated to determine the nature and the depths of the cracks and it was found that the cracks up to 25 mm width were relatively shallow, penetrating to approximately 350 mm to 400 mm below the surface and reducing in width as the depth increased. For example, Fig. 5.7 shows a 10 mm wide crack of approximately 350 mm depth.

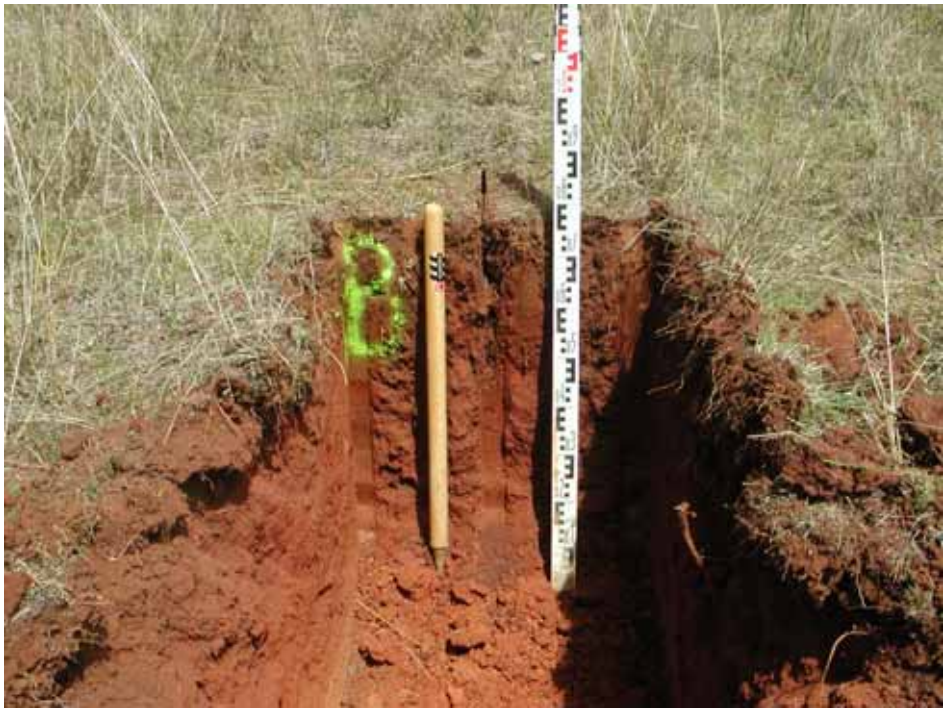

Fig. 5.7 Test Pit Excavated across one of the Narrower Cracks

The wider cracks were found to extend more than 1 metre below the soil surface, again reducing in width as the depth increased. The nature of the cracks is typical of cracking above longwall panels due to the curvature of the subsidence profile at a depth of cover of approximately 200 metres.

Such cracks generally occur just inside and parallel to the perimeter of the longwall, with additional cracking across the longwall at intervals due to the progressive subsidence wave that follows the retreat of the longwall face. The widths and spacing of the cracks, generally, indicate ground curvatures and strains that are in keeping with those that have been predicted, with maximum strains of the order of 5 mm/m.

The wider cracks at the top of the ridge are, however, unusual and are wider than would have been expected, based upon the predicted longitudinal curvatures and strains. An examination of these wider cracks was carried out by BCM on 7th November 2003, to determine the most likely cause. Test pits were excavated across the cracks to the top of the weathered Fordwich Sill, which was found to lie at approximately 1.6 to 3.8 metres below the surface.

The cracks extended through chocolate soils, red duplex soils and semi-weathered sill materials to the weathered sill, reducing in width as the depth increased, as shown in Fig. 5.8. Two of the cracks were found to coincide with natural joints in the weathered sill, which had closed in one case to less than 10 mm. The joints coincided with a defined valley in the top of the rock.

Fig. 5.8 Test Pit Excavated across one of the Wider Cracks

It seems likely therefore that the wider cracks at the head of the ridge were formed during the tensile phase, as the longwall face retreated, and were induced by pre-existing joints in the Fordwich Sill. The joints at rockhead were later closed during the compressive phase, but the soils above rockhead failed to close, probably due to downslope movement that had occurred during the tensile phase and slippage of the soils at the interface with the sill.

A summary of the findings from the survey of cracks above the commencing end of Longwall 1 is provided in Table 5.35. For simplicity the cracks have been categorised as 0 to 10 mm, 10 to 25 mm, 25 to 50 mm and 50 to 100mm in width. It can be seen that within the surveyed area of 112,476 m^2 there were 72 cracks with a total length of 494 m and a total area of 17.7 m^2. 62% of the cracks were less than 25 mm width and 88% were less than 50 mm width. The total area of the cracks was very small relative to the overall area that was surveyed, with less than 0.016 % of the surface being affected by noticeable cracking.

It should be noted that this figure is based upon the assumption that the maximum crack width within the stated range applies over the total length of the cracks within the range. This is, therefore, a very conservative assessment, which could be significantly overstated. It nevertheless serves to indicate that only a small proportion of the surface was subjected to significant cracking.

Table 5.35 Analysis of Surface Cracks above the Commencing End of Longwall 1

Observed Cracks	Crack Width (mm)				
	0 to 10	10 to 25	25 to 50	50 to 100	Totals
Number of cracks	19	34	15	4	72
Total length (metres)	83	239	114	58	494
Area of the cracks (square metres)	0.8	5.7	5.6	5.6	17.7
Proportion of surface area cracked (%)	0.0007	0.005	0.005	0.005	<0.02
Proportion of total crack length (%)	17	45	26	12	100

5.26. The Potential Impacts of Ground Vibration on Structures due to Mining

The settlement of the ground resulting from systematic subsidence is generally a gradual and progressive movement, the effect of which is not apparent to an observer at the surface. The major breakage and collapse of strata into the voids left by extraction of the seam occur in the layer immediately above the seam. Above that level, the breakage and collapse of the strata reduces to become a bending and sagging of the upper layers of rock with less sudden and much smaller movements occurring. In some instances, the movements can be concentrated at faults or other points of weakness in the strata with minor stepping at the surface.

Any major collapse below ground would result in some vibration in the layers of rock above it, which might be felt as a minor effect at the surface. Vibrations resulting from the collapse of strata into the goaf are also more readily observed where the underlying strata layers are thick and relatively uniform, and where the overlying soil is relatively thin.

It is possible as the proposed longwalls are mined and the strata subsides, for some vibrations to be felt at the surface directly above or close to the proposed longwalls, where the depths of cover are less than 100 metres. The levels of vibration would, however, generally be very low and would generally not be of sufficient amplitude to result in structural impact.

5.27. The Potential for Noise at the Surface due to Mining

It would be very unusual for noise to be noticed at the surface due to longwall mining at depths greater than 100 metres. As systematic subsidence occurs and the near surface rocks are affected by tensile and compressive strains, the rocks open up at joints and planes of weakness, and displace due to rotation and shear.

Generally the movements are gradual and cannot be detected by an observer at the surface. These movements are also generally shielded by the more plastic surface soils which tend to distribute the strains more evenly and insulate against any sounds from below.

In some cases, the stresses in the rock can build up to the point that the rock suddenly shears to form a new fracture and if the rock is exposed or has only a thin covering of surface soil, the noise resulting from the fracturing can be heard at the surface. Normally the background level of noise in the countryside is high enough to ensure that the sound is not noticed, although in the stillness of night, it might occasionally be noticed when it occurs in close proximity. The impact due to noise at the surface resulting from the extraction of the proposed longwalls is predicted to be insignificant.

5.28. Estimation of the Reliability of the Systematic Subsidence Predictions

The Incremental Profile Method should provide realistic, if not conservative predictions of subsidence, tilt, curvature, and strain over the proposed longwalls within the Woodlands Hill, Glen Munro, Arrowfield, Bowfield and Piercefield Seams. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

Empirical methods of subsidence prediction are generally accepted as providing predictions of maximum subsidence to an accuracy of ±10 % to ±15 %. It was indicated by Dr Lax Holla, in his paper entitled, "Reliability of Subsidence Prediction Methods for use in Mining Decisions in New South Wales" (1991, Ref. 26), that the accuracy of predictions of maximum subsidence, made using the Department's Empirical Method, generally ranged from +8 % to -11 %. Only four of the 14 examples referred to in the paper had a maximum predicted subsidence less than the maximum observed subsidence, based on the information from seven different collieries in the Southern and Newcastle Coalfields. When the predictive graphs used in the Incremental Profile Method have been calibrated to local data, even greater accuracies have been found to be possible in predicting the maximum values of the subsidence parameters.

The prediction of subsidence parameters at a specific point is more difficult. Based upon a large number of comparative analyses, however, it has been concluded that the vertical subsidence predictions for single seam extractions, obtained using the Incremental Profile Method, should generally be conservative where the geology is consistent and the model has been calibrated to local data. Where subsidence is predicted at points beyond the goaf edge, which are likely to experience very low values of subsidence, the predictions should generally be accurate to within 50 mm of subsidence.

The tilts and systematic curvatures can be predicted to the same level of accuracy, but the measured curvatures and strains can vary considerably from the predicted systematic values for the following reasons:-

- Variations in local geology can affect the way in which the near surface rocks are displaced as subsidence occurs. In the compression zone, the surface strata can buckle upwards or can fail by shearing and sliding over their neighbours. If localised cross bedding exists, this shearing can occur at relatively low values of stress. This can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zone, existing joints can be opened up and new fractures can be formed at random, leading to localised concentrations of tensile strain.
- Where a thick surface layer of soil, clay or rock exists, the underlying movements in the bedrock are often transferred to the surface at reduced levels and the measured strains are, therefore, more evenly distributed and hence more systematic in nature than they would be if they were measured at rockhead.
- Strain measurements can sometimes give a false impression of the state of stress in the ground. For example:
    - buckling of the near-surface strata can result in localised cracking and apparent tensile strain in areas where overall, the ground is in fact being compressed, because the actual values of the measured strains are dependent on the locations of the survey pegs.
    - where joints open up or cracks develop in the tensile phase and fail to close in the compressive phase, as they sometimes do if they are subsequently filled, the ground can appear to be in tension when it is actually in compression.
- Sometimes, survey errors can also affect the measured strain values and these can result from movement in the benchmarks, inaccurate instrument readings, or disturbed survey pegs. In these circumstances it is not surprising that the predicted systematic strain at a point does not match the measured strain.
- In sandstone dominated environments, much of the earlier ground movements can be concentrated at the existing natural joints, which have been found to be at an average spacing of 7 to 15 metres.

It is also recognised that the ground movements above a longwall panel can be affected by the gradients of the surface and the coal seam, the direction of mining and the presence of dykes within the panel, which can result in a lateral shift in the subsidence profile.

The prediction of strain at a point must be considered within an appropriate confidence interval, but the Incremental Profile Method approach does allow a more realistic assessment of the subsidence impacts to be made. An assessment based upon applying the maximum predicted strains at every point would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

The comparison between predicted and observed subsidence movements will be undertaken during the extraction of the proposed longwalls. The subsidence predictions made using the Incremental Profile Method can be refined based on the monitoring data obtained during mining. Further refinement can also be made to the predictions where local monitoring data close to the Study Area becomes available.

5.29. Testing of the Incremental Profile Method

5.29.1. Comparison with Subsidence Predictions from the SCT Numerical Model

The predictions made using the Incremental Profile Method were compared to those obtained from the Strata Control Technology (SCT) numerical model. A comparison was made for a single panel within the Piercefield Seam for a single seam extraction, having a void width of 283 metres, depth of cover of 310 metres, and an extracted seam thickness of 3 metres. A flat surface and seam were assumed in the Incremental Profile Method for the purpose of the comparison. The predicted subsidence profiles for the single panel obtained from each method are overlaid in Fig. 5.9.

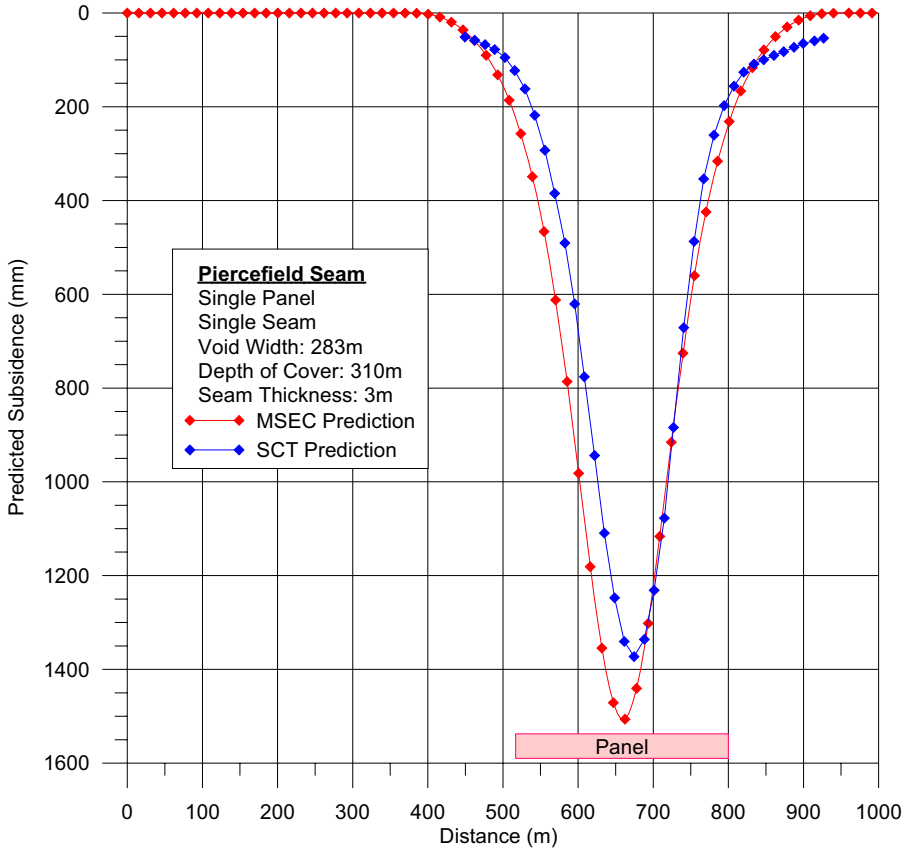

Fig. 5.9 Comparison of Predicted Subsidence for a Single Panel within the Piercefield Seam

It can be seen that the maximum predicted subsidence and the predicted profiles obtained using each method are very similar. The maximum predicted subsidence obtained using the Incremental Profile Method is slightly higher than that obtained from the SCT numerical model. The small offset between the maximum predicted subsidence for each model is likely to be the result of topographical features.

The subsidence profiles and multi-seam factors used in the Incremental Profile Method will be further refined during future assessments, based on the results from the SCT numerical model. The maximum predicted subsidence over the proposed longwalls is unlikely to be refined, however, the shapes of the predicted profiles over the chain pillars and adjacent goaf areas for multi-seam extraction conditions may be refined based on the latest information.

Numerical modelling of proposed multi-seam mining by SCT (2006c) has identified that the maximum predicted subsidence in each seam would be up to 60 % of the proposed mining height. In comparison, the Incremental Profile Method has utilised an overall prediction of 67.5 % of the proposed mining height for a single supercritical panel. The maximum predicted subsidence as a percentage of extraction height is greater for a series of panels for multi-seam conditions, which is discussed in Section 4.6. In practical terms, these assessment levels are very similar, with the Incremental Profile Method being slightly more conservative, ie: predicting a slightly greater level of subsidence than the numerical modelling.

5.29.2. Testing of the Incremental Profile Method against Longwall 1 at the Dendrobium Mine

The predicted subsidence movements were compared to the observed subsidence movements for Longwall 1 in Area 1 at Dendrobium Mine. The longwall is the first panel in a series and has a void width of 245 metres, and an overall length of 1750 metres. The longwall was extracted from the Wongawilli Seam, having depths of cover varying between 170 and 320 metres, and an extraction height of 3.3 to 3.4 metres. The south-eastern end of the longwall is located beneath previously extracted workings within the Bulli Seam and, therefore, is subject to multi-seam interactions.

Conventional mine subsidence surveying could not be undertaken for Longwall 1, however, the surface levels in Area 1 were determined by aerial laser scans before, and at the completion of this longwall. The contours of observed changes in surface level were determined by taking the difference between the surface levels before and after mining, and are shown in Fig. 5.10.

The accuracy of surface levels interpreted from the aerial laser scans are generally in the order of ±150 mm. The accuracy of the observed changes in surface level, which are the differences in heights between the two aerial laser scans are, therefore, in the order of ±300 mm. There is also a larger scatter in the observed surface levels from the aerial laser scans which result from heights being measured off natural features including trees, undergrowth, and rocks. The scatter resulting from these features, however, can be smoothed to a certain extent.

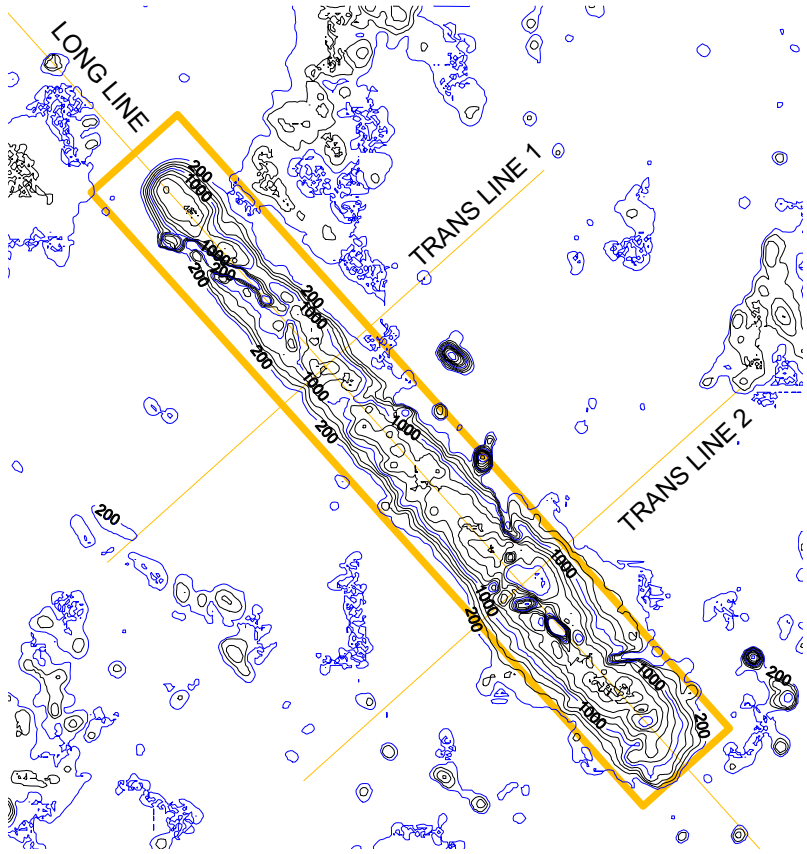

Fig. 5.10 Observed Change in Surface Level Contours based on Aerial Laser Scans

It should also be noted that the contours of observed changes in surface level, developed from the aerial laser scans, show the changes in heights of points at fixed Eastings and Northings. This differs from the usual observed subsidence contours where the changes in heights are made for the same surface point, regardless of how much that point has moved horizontally. That is the usual or traditional subsidence contours include both the vertical and horizontal components of fixed points on the surface. Horizontal movements are traditionally included in the subsidence profiles, as monitoring data is generally based on the movements of ground pegs, which are fixed to the surface.

The contours of observed changes in surface level, developed from the aerial laser scans, can be confusing in locations of steep terrain, such as at cliffs, as the surface moves horizontally towards the centre of the goaf as the ground subsides, and the level changes at fixed Eastings and Northings can be dramatic, and do not provide a realistic indication of the actual subsidence at a point. Where the ground is reasonably level, however, the contours of changes in surface level should provide a good indication of the actual subsidence.

The profiles of observed changes in surface level and the predicted subsidence, due to the extraction of Longwall 1, were compared along one longitudinal line and two transverse lines and are shown in Fig. 5.11. The locations of the longitudinal and transverse lines are shown in Fig. 5.10.

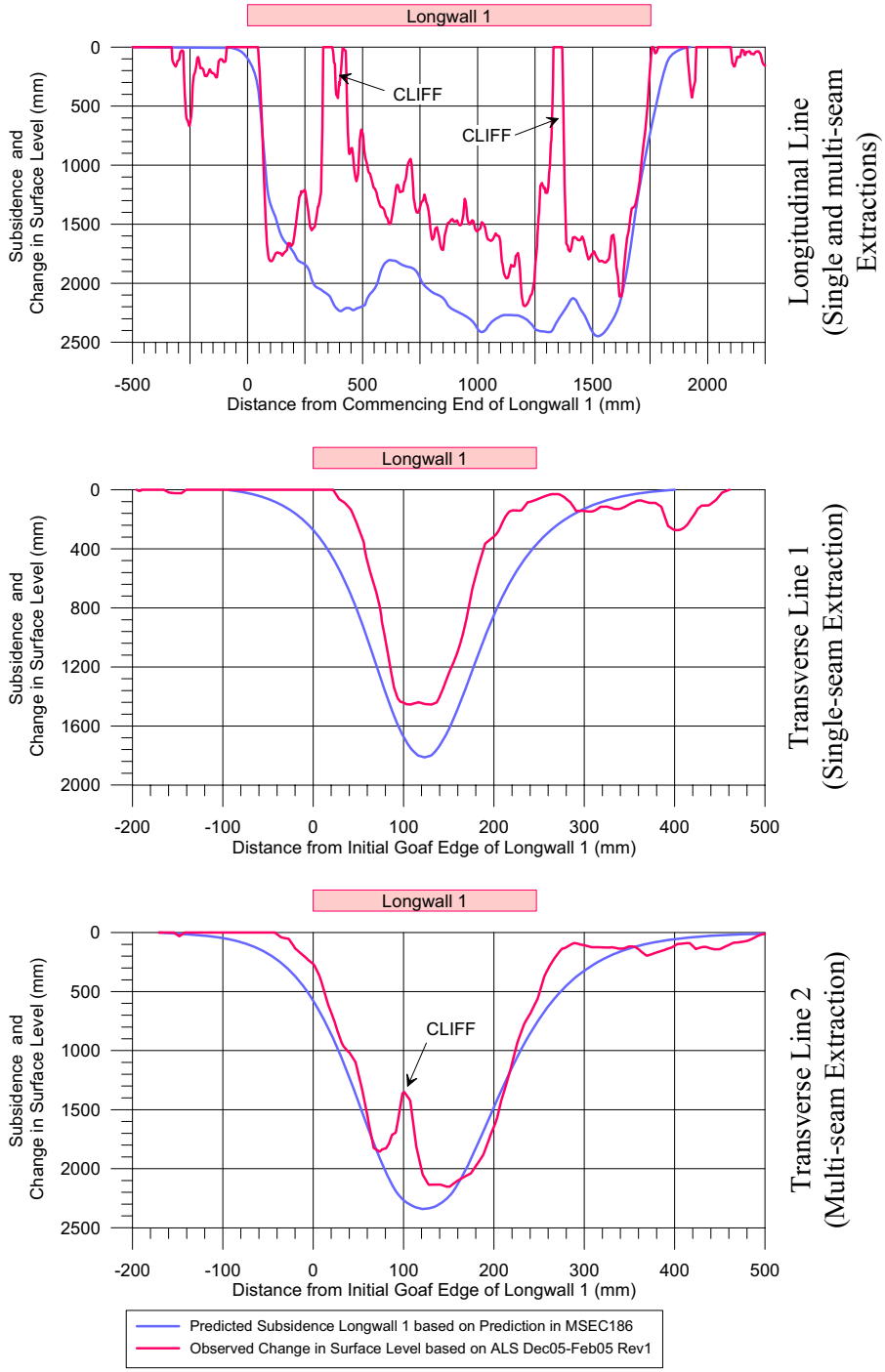

Fig. 5.11 Profiles of Observed Changes in Surface Level and Predicted Subsidence due to the Extraction of Longwall 1

It can be seen from Fig. 5.11, that the predicted subsidence is generally greater than the observed changes in surface level. The locations where the observed changes in surface level are greater than the predicted subsidence are generally adjacent to, or outside the goaf, and the differences are generally within the order of accuracy of the aerial laser scans.

The comparison along Transverse Line 1 is for a single-seam extraction, and the comparison along Transverse Line 2 is for a multi-seam extraction. The comparisons along the Longitudinal Line vary from a single-seam extraction at the north-west corner of the longwall (left side of the graph) to a multi-seam extraction at the south-east corner of the longwall (right side of the graph). It can be concluded from these comparisons, therefore, that the Incremental Profile Method provided relatively good and generally conservative subsidence predictions for Longwall 1 at Dendrobium Mine.

5.29.3. Testing of the Incremental Profile Method against Longwall 1 at the Beltana Mine

The predicted subsidence profiles, obtained using the Incremental Profile Method, have also been compared against the measured subsidence survey results after the extraction of Longwall 1 within the Whybrow Seam in Beltana Central Mining Area, where the geology and depths of cover are similar to those at the project.

A graph comparing the predicted and measured subsidence profiles along the monitoring line at the Longwall 2 Ridge Cross Line is shown in Fig. 5.12. It can be seen that the predicted subsidence, tilts and strains were comparable to those observed, however, there was a slight lateral shift between the predicted and observed results. This lateral shift is typically accounted for in the impact assessments by predicting the maximum subsidence parameters within a 20 metre radius of an isolated natural feature as described in Section 0.

Graphs comparing the predicted and measured subsidence profiles along the monitoring lines at the Optical Fibre Cross Line, West Charlton Road Cross Line and East Fence Cross Line are shown in Fig. 5.13, Fig. 5.14 and Fig. 5.15, respectively. It can be seen that the predicted subsidence, tilts and strains closely match the observed profiles, and generally provide slightly conservative results. The slight lateral shift between the predicted and observed results have been accounted for in the impact assessments as described above.

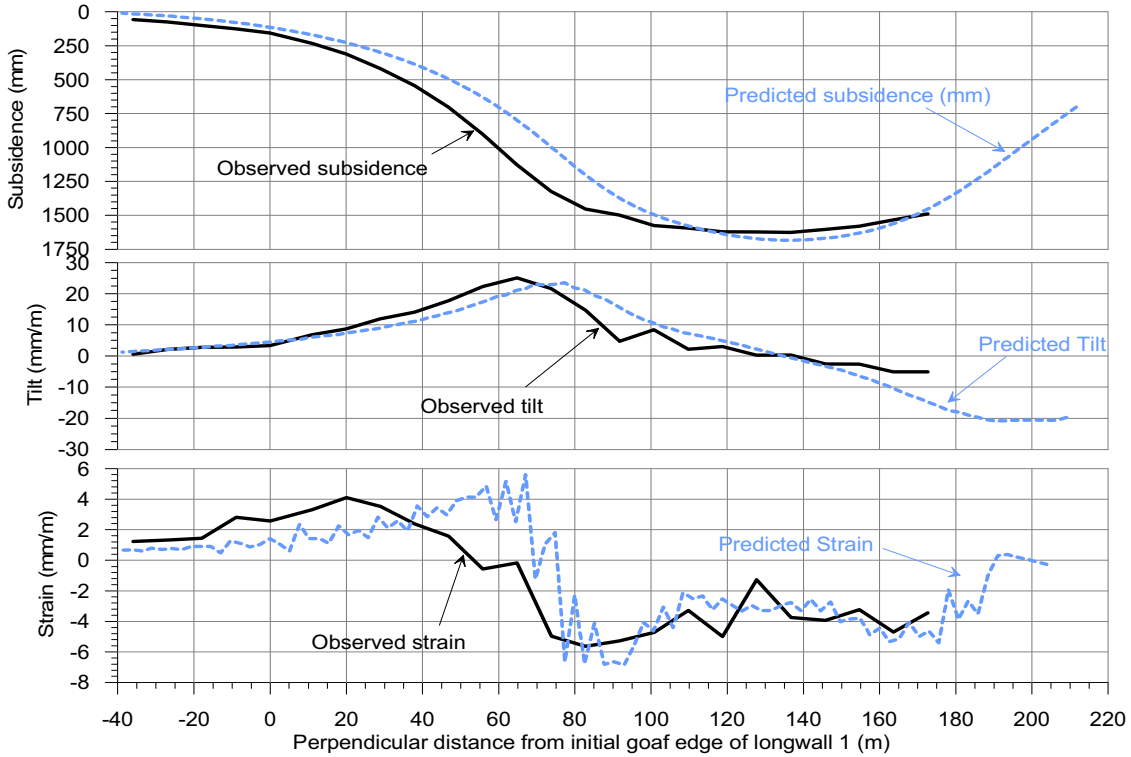

Fig. 5.12 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – Ridge Cross Line

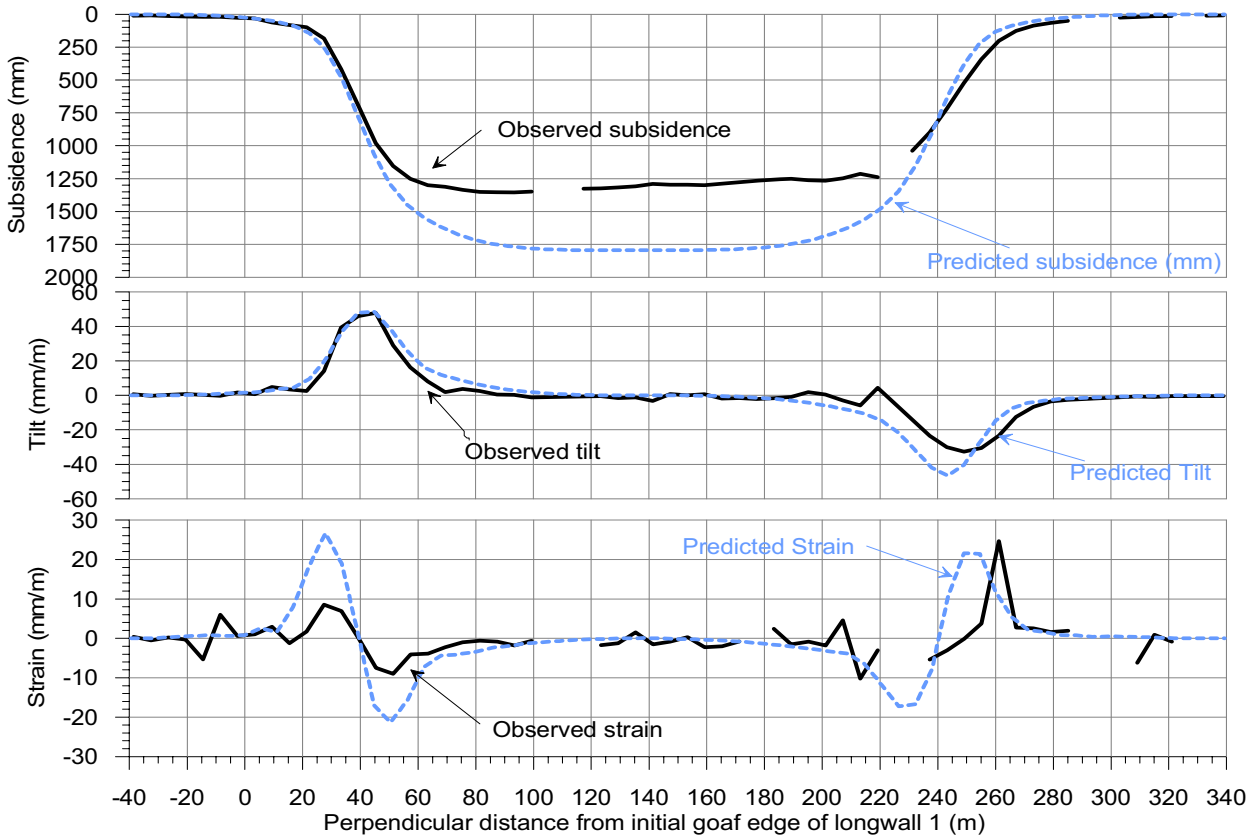

Fig. 5.13 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – Optical Fibre Cross Line

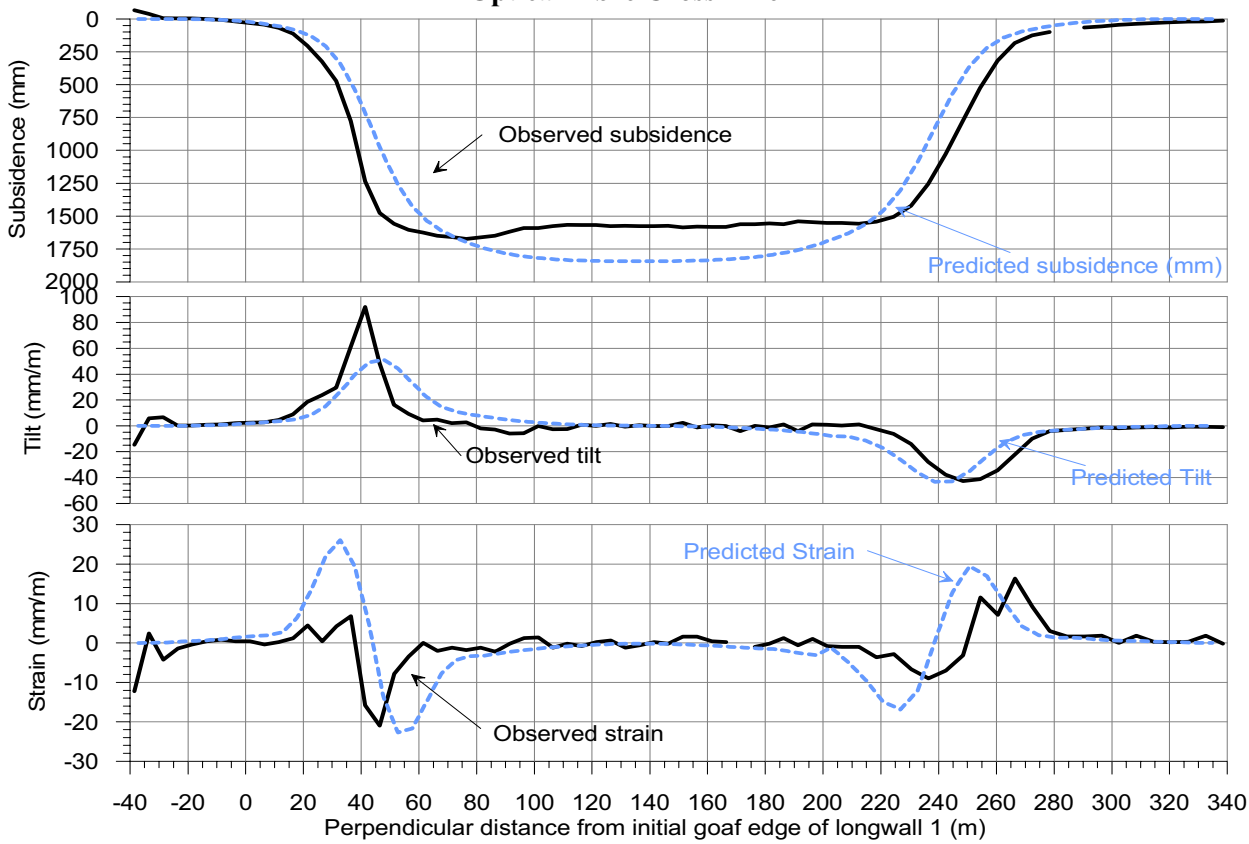

Fig. 5.14 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – West Charlton Road Cross Line

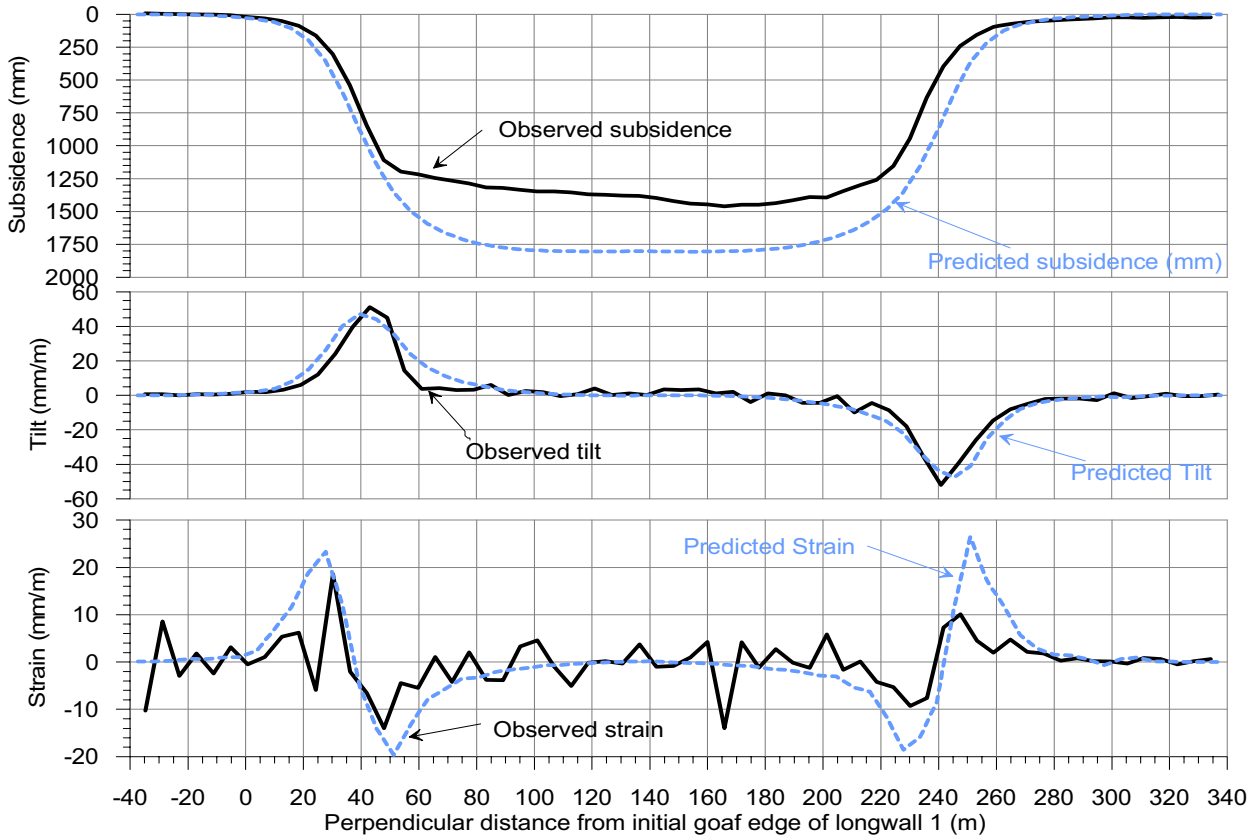

Fig. 5.15 Beltana Mine Monitoring Results after extraction of Longwall 1 in Whybrow Seam – East Fence Cross Line

APPENDICES

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Some of the mining terms used in the report are defined below:-

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections.
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S_{max}.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Multi-seam prediction factor	The proportional increase in the predicted subsidence between single and multi-seam mining conditions.
Overlap adjustment factor	A factor that defines the ratio between the maximum incremental subsidence of a panel and the maximum incremental subsidence of that panel if it were the first panel in a series.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.
Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar.

Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points.
Sub-critical area	An area of panel smaller than the critical area.
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel.
Super-critical area	An area of panel greater than the critical area.
Tilt	The difference in subsidence between two points divided by the horizontal distance between the points.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	A reduction in the expected subsidence at a point, being the difference between the predicted subsidence and the subsidence actually measured.

The structure classifications used in this report are defined below:-

C Commercial
D Dams
H1 Single storey houses with a maximum plan dimension less than 30 metres
H2 Single storey houses with a maximum plan dimension greater than 30 metres
P Pools
R Other non-residential structures
T Tanks

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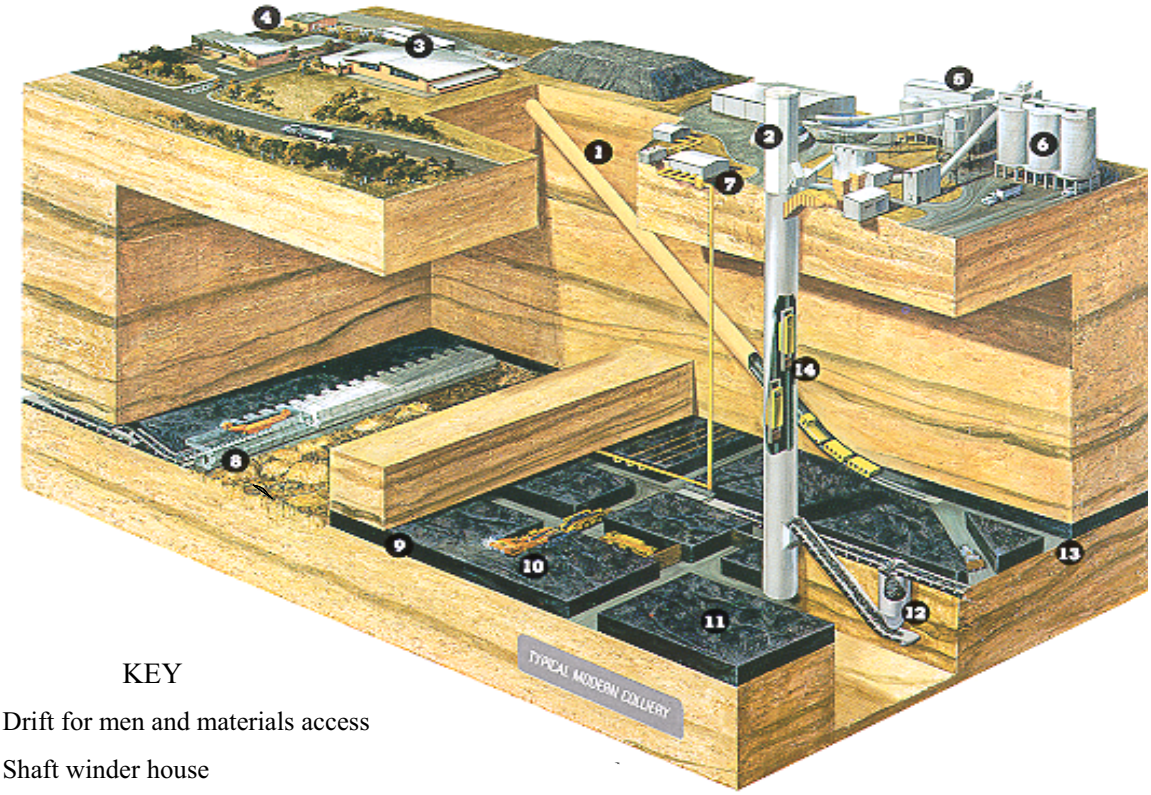
APPENDIX C. INTRODUCTION TO LONGWALL MINING AND SUBSIDENCE

C.1. The Longwall Mining Process

Fig. C.1, below, shows a cutaway diagram of a typical longwall mine. The main features of the mine are indicated in the key below the diagram. The longwall face is indicated by the number 8 in the diagram.



KEY

1. Drift for men and materials access
2. Shaft winder house
3. Bathhouse and administration building
4. Workshops
5. Coal preparation plant
6. Coal storage bins
7. Gas drainage system
8. Longwall face equipment
9. Coal seam
10. Continuous miner unit
11. Coal pillar
12. Underground coal bin
13. Main roadway or heading
14. Coal skips to carry coal to the surface

Fig. C.1 Cutaway View of a Typical Longwall Mine

In longwall mining, a panel of coal, typically around 150 to 300 metres wide, 1000 to 3500 metres long and 2 to 5 metres thick, is totally removed by longwall shearing machinery, which travels back and forth across the coalface. A typical section through a coal face is shown in Fig. C.2 and a photograph of typical longwall face equipment is shown in Fig. C.3. The shearer cuts a slice of coal from the coalface on each pass and a face conveyor, running along the full length of the coalface, carries this away to discharge onto a belt conveyor, which carries the coal out of the mine.

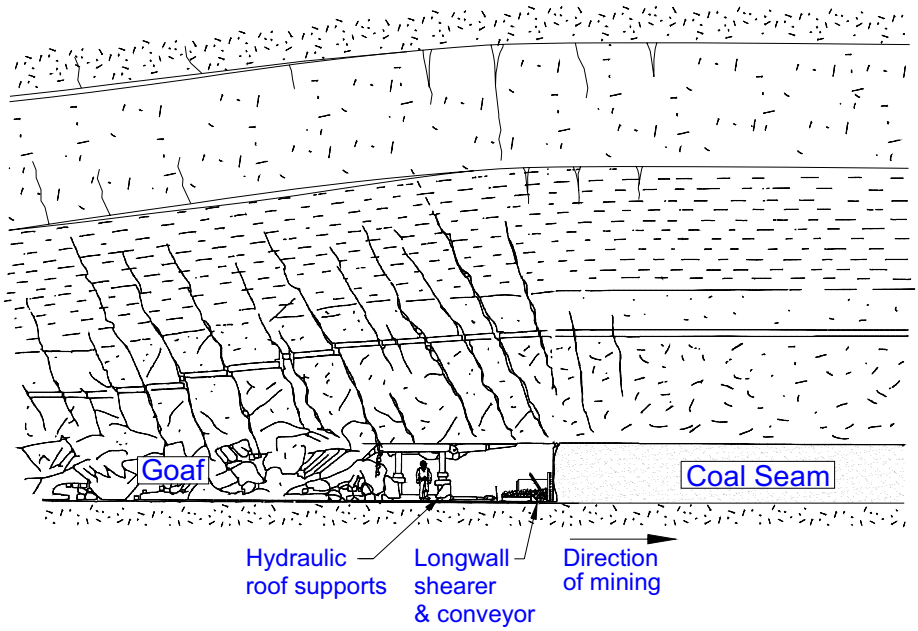


Fig. C.2 Cross Section of a Typical Longwall Face

The area immediately in front of the coalface is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata and provide a working space for the shearing machinery and face conveyor. After each slice of coal is removed, the hydraulic roof supports, the face conveyor and the shearing machinery are moved forward. Fig. C.3 shows the arrangement of machinery on a typical longwall face, with the hydraulic roof supports on the left hand side and the coal face on the right hand side of the picture. The drum in the background is the rotating cutting head of the coal shearer and the chain conveyor can be seen in the foreground.

Fig. C.3 Typical Longwall Face Equipment

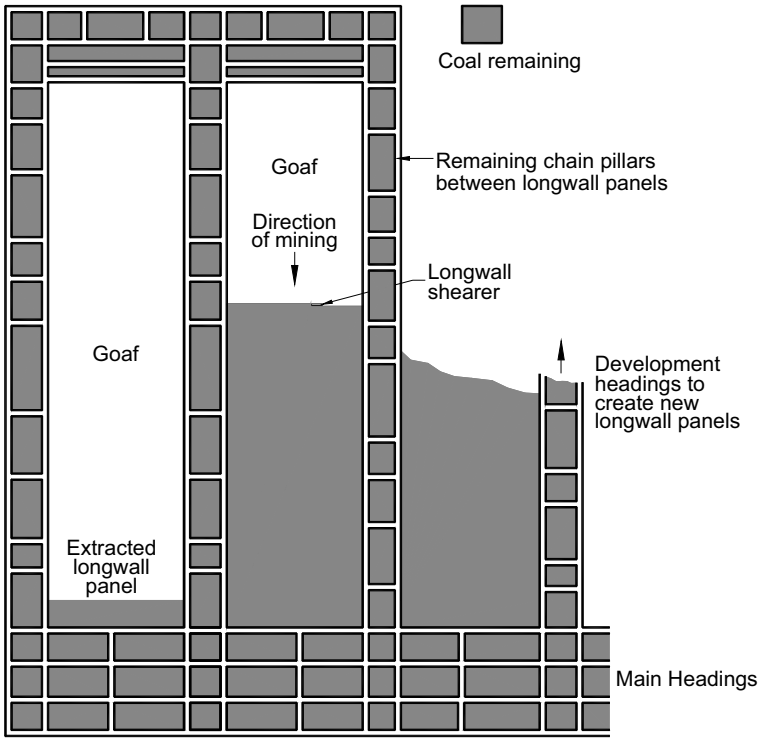


Fig. C.4 Typical Plan View of a Series of Longwall Panels

Fig. C.4 shows a typical layout of a group of longwalls. Before the extraction of a longwall panel commences, continuous mining equipment extracts coal to form roadways (known as headings) around the longwall panel. These roadways form the mine ventilation passages and provide access for people, machinery, electrical supply, communication systems, water pump out lines, compressed air lines and gas drainage lines. The roadways, which provide access from the mine entrance to the longwalls, are referred to as the main headings. Once the main headings have been established additional roadways, known as development headings, are driven on both sides of the longwall panel and are connected together across the end of the longwall.

The longwall face equipment is established at the end of the panel that is remote from the main headings and coal is extracted within the panel as the longwall equipment moves towards the main headings. This configuration is known as retreat mining. Typically, a longwall face retreats at a rate of 50 metres to 100 metres per week, depending on the seam thickness and mining conditions. The coal between the development headings and between the main headings is left in place as pillars to protect the roadways as mining proceeds. The pillars between the development headings are referred to as chain pillars.

When coal is extracted using this method, the roof immediately above the seam is allowed to collapse into the void that is left as the face retreats. This void is referred to as the goaf. Miners working along the coalface, operating the machinery, are shielded from the collapsing strata by the canopy of the hydraulic roof supports. As the roof collapses into the goaf behind the roof supports, the fracturing and settlement of the rocks progresses through the overlying strata and results in sagging and bending of the near surface rocks and subsidence of the ground above, as illustrated in Fig. C.2.

If the width of an extracted panel of coal is small and the rocks above the seam are sufficiently strong, it is possible that the roof will not collapse and hence no appreciable subsidence will occur at the surface. However, to maximise the utilisation of coal resources and for other economic reasons, wide panels of coal are generally extracted and, in most cases, the roof is unable to support itself.

Longwall panel widths between 250 metres and 300 metres are becoming common as collieries strive towards more cost-efficient production and some collieries are now considering longwall widths of 400 metres or more.

C.2. The Development of Subsidence.

C.2.1. Subsidence Mechanisms.

As the immediate roof strata, i.e. the rocks immediately above the seam, collapse into the goaf, the rocks above them lose support and sag to fill the void beneath them. The mechanism progresses towards the surface and the affected width increases so that at the surface, an area somewhat larger than the extracted panel of coal undergoes settlement. Fig. C.5 shows a typical subsidence profile above an extracted longwall panel and it can be seen that the majority of the subsidence occurs over the centre of the longwall and tapers off around the perimeter of the longwall. The subsidence is typically less than the thickness of coal extracted underground.

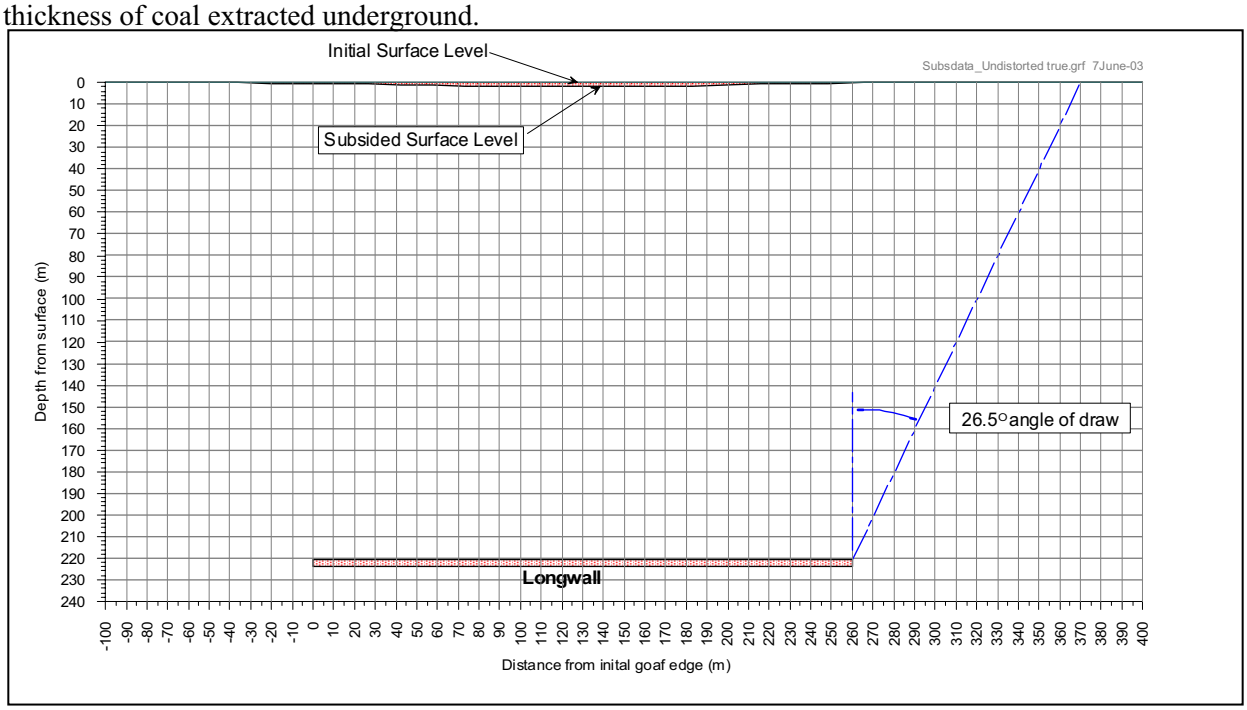


Fig. C.5 Typical Subsidence Profile Drawn to a True Scale

The angle at which the subsidence spreads out towards the limit of subsidence, at the surface, is referred to as the angle of draw. The angle of draw depends upon the strength of the strata and the depth of cover to the coal seam and typically lies between 10 and 35 degrees from the vertical, depending on how the limit of subsidence is defined.

It is generally accepted that subsidence of less than 20 mm will have negligible effect on surface infrastructure and this is generally adopted as the cut-off point for determination of the angle of draw. In the Coalfields of NSW, if local data is not available, the cut-off-point is taken as a point on the surface defined by an angle of draw of 26.5 degrees from the edge of the extraction, i.e. a point on the surface at a distance of half the depth of cover from the goaf edge. Where local data exists and it can be shown that the angle is generally less than 26.5 degrees, then, the lower angle of draw can be used.

The subsidence of the surface is considerably less than the thickness of coal removed, due to the voids that are left within the collapsed strata. The extent of the settlement at the surface is therefore dependent upon the strength and nature of the rocks overlying the coal seam and is a direct function of their capacity to bridge over the voids.

When a panel has a width that is small, relative to the depth of the seam below the surface, the fractured rocks have a tendency to bridge over the goaf by arching between the solid abutments on each side of the panel, thus reducing the amount of subsidence.

As the panel width is increased, however, the overlying rocks are less able to arch over the goaf and a limiting panel width is reached where no support is available and maximum subsidence occurs. This limiting panel width is referred to as the critical width and is usually taken to be 1.4 times the depth of cover. It does, however, depend upon the nature of the strata.

Where several panels are mined in a series and chain pillars are left between the panels, the maximum subsidence does not occur unless each panel is, at least, of critical width. The chain pillars crush and distort as the coal is removed from both sides of them, but, usually, they do not totally collapse and, hence, the pillars provide a considerable amount of support to the strata above them.

Where large super-critical areas are extracted, the maximum possible subsidence is typically 55% to 65% of the extracted seam thickness, but, because chain pillars are normally left in place, and provide some support, this maximum possible subsidence is rarely reached.

Research has shown that the incremental subsidence of a second or subsequent panel in a series is greater than the subsidence of an individual isolated panel of identical geometry. Because the subsidence effects above a panel extend beyond its goaf edges, these effects can overlap those of neighbouring panels.

Where the width to depth ratios of the panels in a series are sub-critical, which is normally the case in the Southern Coalfield, the amount of subsidence in each panel is determined by the extent of these overlaps, which are further influenced by the widths of the chain pillars. In this situation, the first panel in a series will generally exhibit the least subsidence and the second and subsequent panels will exhibit greater subsidence due to disturbance of the strata caused by mining the preceding panels and consequential redistribution of stresses within the strata.

The subsidence at the surface does not occur suddenly but develops progressively as the coal is extracted within the area of influence of the extracted panel. In many cases, when the cover over the coal seam is deep, a point on the surface will be affected by the extraction of several adjacent panels.

When extraction of coal from a panel is commenced, there is no immediate surface subsidence, but as the coal within the panel is extracted and the resulting void increases in size, subsidence develops gradually above the goaf area. As mining continues, a point is reached within the panel where a maximum value of subsidence occurs and despite further mining beyond this point, within the panel, this level of subsidence is not increased.

As further adjacent panels are extracted, additional subsidence is experienced, above the previously mined panel or panels. However, a point is also reached where a maximum value of subsidence is observed over the series of panels irrespective of whether more panels are later extracted.

The subsidence effect at the surface occurs in the form of a wave, which moves across the ground at approximately the same speed as the longwall face retreats within the longwall panel. The extraction of each panel creates its own wave as the panels are mined in sequence.

The development of subsidence at any point on the surface of the ground can be seen to be a very complex mechanism and the cumulative effect of a number of separate movements.

C.2.2. Subsidence Parameters

Subsidence, tilt, horizontal displacement, curvature and strain are the subsidence parameters normally used to define the extent of the surface movements that will occur as mining proceeds and generally form the basis for the assessment of the impacts of subsidence on surface infrastructure. These parameters are illustrated in Fig. C.6. which shows a typical subsidence profile drawn to an exaggerated vertical scale.

Subsidence

Subsidence usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements can in many cases be greater than the vertical subsidence, where the subsidence is small. The amplitude of subsidence is usually expressed in millimetres.

Tilt

Tilt is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. The sign of tilt is not important, but the convention usually adopted is for a positive tilt to indicate the ground increasing in subsidence in the direction of measurement.

The maximum tilt, or the steepest portion of the subsidence profile, occurs at the point of inflection in the subsidence trough, where the subsidence is roughly equal to one half of the maximum subsidence. Tilt is usually expressed in millimetres per metre.

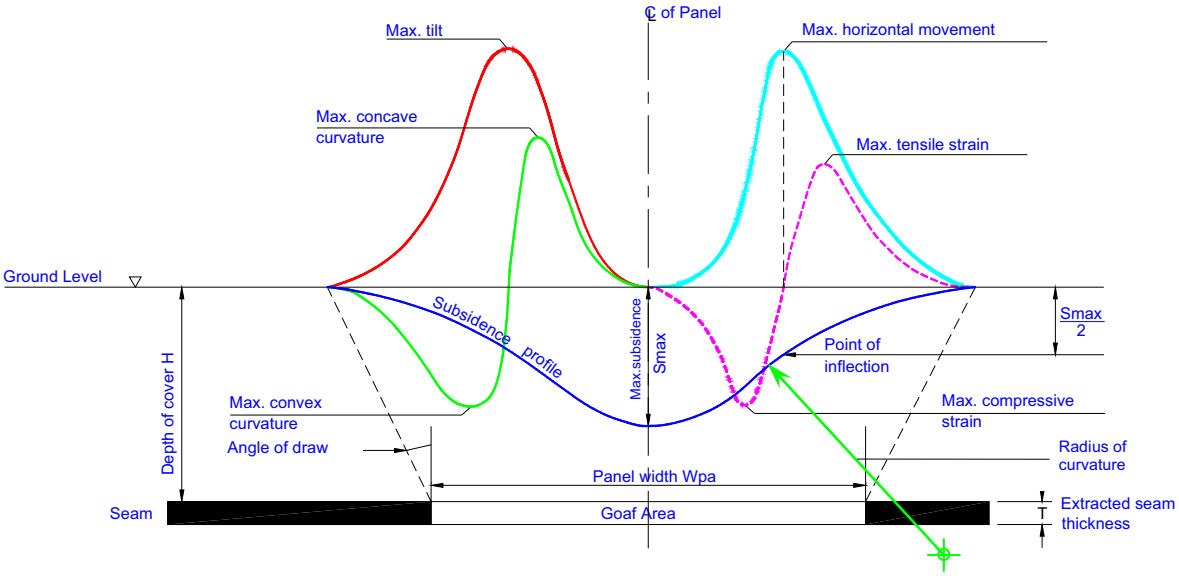


Fig. C.6 Subsidence Parameter Profiles above a Single Longwall Panel

Horizontal Displacement

The horizontal component of subsidence, or horizontal displacement, is greatest at the point of maximum tilt and declines to zero at the limit of subsidence and at the point of maximum subsidence. Horizontal displacement is usually expressed in millimetres.

Curvature

Curvature is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the radius of curvature with the units of 1/km, or km^{-1}, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in kilometres.

Curvature is convex or 'hogging' over the goaf edges and concave or 'sagging' toward the bottom of the subsidence trough. The convention usually adopted is for convex curvature to be positive and concave curvature to be negative.

Strain

Strain is caused by bending and differential horizontal movements in the strata. Measured strain is determined from monitored survey data by calculating the horizontal change in length of a section of a subsidence profile and dividing this by the initial horizontal length of that section.

If the section has been extended, the ground is in tension and the change in length and the resulting strain are positive. If the section has been shortened, the ground is in compression and the change in length and the resulting strain are negative.

The unit of measurement adopted for strain is millimetres per metre. The maximum strains coincide with the maximum curvature and hence the maximum tensile strains occur towards the sides of the panel whilst the maximum compressive strains occur towards the bottom of the subsidence trough.

C.2.3. Subsidence Impacts at the Surface

The most significant impacts on surface infrastructure are experienced during the development of the subsidence trough, when maximum ground movements normally occur.

As the subsidence wave approaches a point on the surface, the ground starts to settle, is displaced horizontally towards the mined void and is subjected to tensile strains, which build from zero to a maximum over the length of convex or hogging curvature, as shown in Fig. C.7.

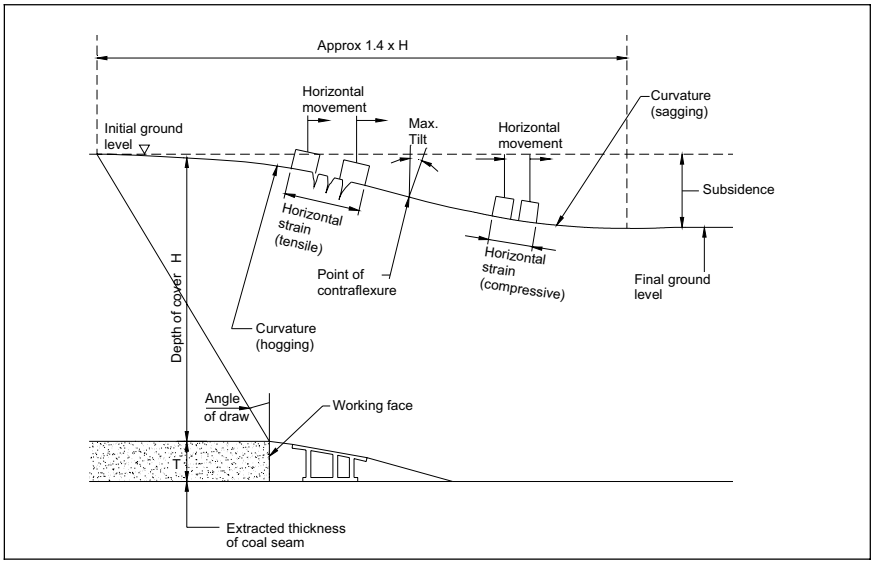


Fig. C.7 Development of a Subsidence Trough (to an exaggerated vertical scale)

The position of maximum hogging curvature is the position of maximum tensile strain. When vertical subsidence is approximately half of the maximum subsidence, i.e., as the face passes under the surface point, the ground reaches its maximum horizontal displacement and the strain reduces to zero again.

As the longwall face moves further away from the surface point the settlement continues, horizontal displacement reduces and the ground is subjected to compressive strains, which build from zero to a maximum over the length of concave or sagging curvature and then decline to zero as maximum subsidence is reached. The position of maximum sagging curvature is the position of maximum compressive strain. When the subsidence is complete, the ground is commonly left with no horizontal displacement and little residual tilt or strain.

Between the tensile and compressive zones is the point of inflection, which is the point at which maximum tilt and maximum horizontal displacement occurs. For critical extraction conditions, it is also the point at which the subsidence is, approximately, equal to half the maximum subsidence.

As the longitudinal wave passes, the transverse subsidence profile gradually develops and is completed as maximum subsidence is reached. The transverse subsidence profiles over each side of the panel are similar in shape to the longitudinal subsidence profile and have the same distribution of tilts, curvatures and strains. Most of the points on the surface will thus be subjected to three-dimensional movements, with tilt, curvature and strain in both the transverse and longitudinal directions. The impact of subsidence on surface infrastructure is therefore dependent upon its position within the trough.

The above sequence of ground movements, along the length of a panel, only applies to surface structures if they are located at a point where the maximum subsidence is likely to occur. Elsewhere, the impacts, in the both the transverse and longitudinal direction are reduced.

If a structure is located on the perimeter of the subsidence trough, it will only be slightly affected, will suffer little settlement and will have little residual tilt or strain.

A structure or surface feature on the side of the trough between the tension and compression zones will experience some subsidence, and will be left with residual horizontal displacement and tilt, but will be subjected to lower curvatures and strains. Structures or surface features located at the positions of maximum curvature and strain would generally suffer the greatest impact.

As each panel within a series is extracted in turn, an incremental subsidence trough is formed above it. If the width-to-depth ratios of the panels are low, the incremental subsidence troughs overlap at the surface and the resulting subsidence at any point, in these circumstances, is a combination of the effects of a number of panels.

A point on the surface may then be subjected to a series of subsidence waves, which occur as each panel is extracted, and the duration of these impacts will depend upon the position of the point relative to each of the subsidence troughs that are formed.

APPENDIX D. METHODS OF SUBSIDENCE PREDICTION

D.1. The Prediction of Subsidence Parameters

D.1.1. Alternative Methods of Prediction

Several alternative methods have been used in the past to predict subsidence parameters, including:

- Graphical Methods, such as the National Coal Board Method used in the U.K.
- Profile Function Methods.
- Influence Function Methods.
- Numerical Modelling Methods.
- Empirical Methods.

Profile function methods seek to define the shape of the subsidence profile using a single mathematical formula. These are generally only applicable to single panels, since they assume the profiles to be symmetrical and fail to recognise the way in which subsidence profile shapes are modified over adjacent and previously longwall goaf areas.

Influence function methods predict subsidence profiles based on the theory of an area of influence around a point of extraction. These methods can be applied to a wide range of mining geometries, but are more difficult to calibrate and check than profile function methods.

Numerical modelling techniques have been developed in recent years using finite element and discrete element models such as FLAC, UDEC and FLOMEC. These are particularly useful tools for investigating strata mechanisms and hydrological impacts, but have not been found to produce sufficiently accurate predictions of mine subsidence parameters.

Empirical methods can be developed for the prediction of subsidence parameters whenever a large database of measured subsidence parameters is available. These methods can be advantageously employed over a wide range of mining geometries, taking into account local variations in strata lithology. Other modelling methods can also be successful where sufficient local data is available for model calibration. To be successful, all methods of prediction have to be checked against measured data and calibrated to reflect local geology.

An empirical approach has generally been adopted in the coalfields of New South Wales, and this has been expanded in recent years by the development of the Incremental Profile Method. The Standard Empirical methods and the Incremental Profile Method are described in the following sections. Further information on alternative methods of subsidence prediction can be found in Kratzsch (1983) and Whittaker and Reddish (1989).

D.1.2. Standard Empirical Methods

At collieries in New South Wales, the maximum subsidence of the surface has generally been predicted using empirical methods. In the past, subsidence predictions were based upon the methods outlined in the Subsidence Engineers Handbook, first published by the National Coal Board of the United Kingdom in 1965 and revised in 1975. This involved the use of a series of graphs derived from numerous field observations in British mines, which allowed the shapes of the subsidence, tilt and strain profiles to be predicted.

The method gave good results when applied to British mining situations, but when the method was adopted in Australia, it became clear that the field observations differed considerably from predicted values and were generally much less than theory would suggest.

This is because the strata that overlie the coal seams in British coalfields differ from those that occur in the coalfields of Australia and because the subsidence measurements in British coalfields were in some cases affected by multi-seam mining. The rocks in Britain are generally less competent and less able to bridge the extracted voids and, therefore, for a given seam thickness, the maximum subsidence is greater than it would normally be for the same mining geometry in Australian conditions.

An intensive research program was therefore undertaken by the then New South Wales Department of Mineral Resources (DMR) to develop a predictive model that was more appropriate for Australian conditions. It was noted that the subsidence behaviour varied significantly between the Southern Coalfield, the Newcastle Coalfield and the Western Coalfield of New South Wales. Subsidence data from collieries in New South Wales were therefore studied separately for the three coalfields. The work resulted in three publications which provide guidelines for the prediction of mine subsidence parameters in each coalfield. The handbook for the Southern Coalfield was completed in 1975 (Holla, 1975) and the handbooks for the Newcastle and Western Coalfields were completed in 1987 (Holla, 1987a) and 1991 (Holla, 1991a) respectively. It should be noted that the method of prediction given in the New South Wales handbooks is only applicable to single, isolated panels.

Additional research by Dr L. Holla of the DMR led to the publishing of a paper (Holla, 1988) which included a graph which can be used to predict the maximum subsidence above a series of longwall panels, for critical extraction conditions. This graph is reproduced as Fig. D.1, where S_{max} is the maximum subsidence, T is the seam thickness and H is the depth of cover.

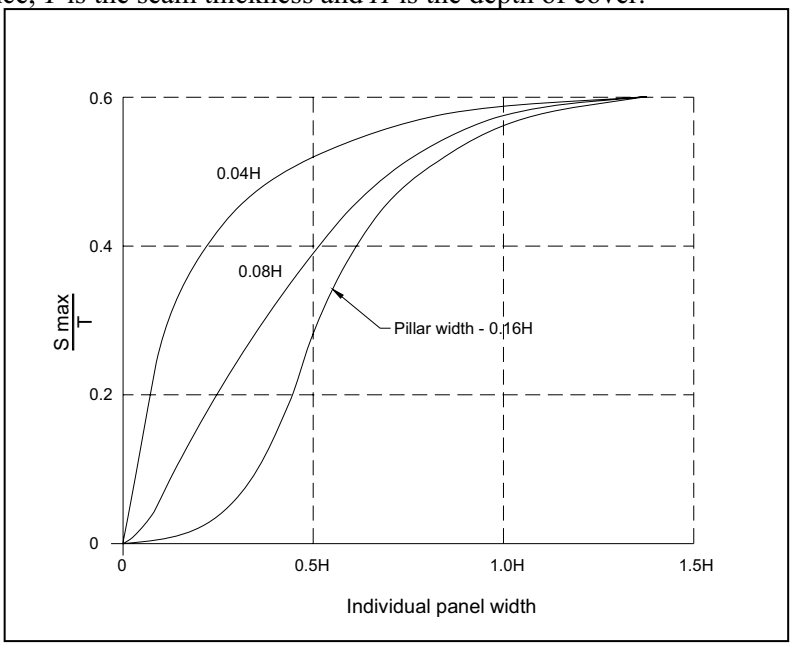


Fig. D.1 Graph for the Prediction of Maximum Subsidence over a Series of Panels for Critical Extraction Conditions (after Holla, 1988)

Following further study, a revised handbook was produced by the DMR for the Southern Coalfield in 2000 (Holla and Barclay). This later handbook included graphs that allow prediction of the maximum subsidence over a series of longwall panels. The handbook can also be used to establish an approximate subsidence profile and to predict the maximum tilt, curvature and strain above a mined area, for single panels.

When the width of an extracted panel, the depth of cover, and the extracted seam thickness are known, the following parameters can be predicted:

The maximum subsidence value

- The location of the inflection point
- The average goaf edge subsidence
- The limit of subsidence

Once these parameters have been determined, an appropriate subsidence profile can be produced as a line of best fit between the points of maximum subsidence, inflection, goaf edge subsidence and limit of subsidence. This method thus allows the approximate shape of subsidence profile to be determined for a single isolated panel.

The predicted maximum tensile strain, compressive strain and tilt can be determined from the maximum subsidence and depth of cover, using, respectively, factors obtained from the graphs shown in Figs. 4.6, 4.7 and 4.10 of the DMR handbook (Holla and Barclay, 2000). The predicted maximum curvatures can be derived from the predicted maximum strains using the graph shown in Fig. 4.9 of the handbook.

The limit of subsidence is determined from the depth of cover and the angle of draw. The DMR recommends a practical angle of draw of 26.5° for general use in the Southern Coalfield, and hence the limit of subsidence would generally be positioned at half the depth of cover from the perimeter of the extracted area.

Whilst the DMR method normally provides reasonable predictions of the maximum subsidence above a series of longwall panels, it does not predict the subsidence profiles across a series of panels and does not allow the variations in tilt, curvature and strain to be determined across a series of longwalls. This method therefore could not be used to provide the detailed predictions required for this study. However, it was used to provide a check on the accuracy of the maximum predicted subsidence parameters which have been obtained using the Incremental Profile Method.

D.1.3. The Incremental Profile Method

The Incremental Profile Method was developed by Mr A.A. Waddington and Mr. D.R. Kay during the course of a study for BHP Collieries Division, the Water Board and AGL during the latter part of 1994 (Waddington and Kay, 1995). The purpose of the study was to develop an empirical method which could be used to predict the subsidence, tilts, curvatures and strains likely to be experienced as longwall mining occurred at Appin and Tower Collieries, and to assess the likely effects of mining on surface infrastructure.

The first step in the development of the model was to study detailed records of subsidence movements which had been observed over previous longwalls at Appin and Tower Collieries and over longwalls at neighbouring mines, including Tahmoor, West Cliff, Cordeaux and South Bulli Collieries. The measured subsidence data was plotted in a variety of ways to establish whether or not any regular patterns of ground behaviour could be found. The most significant patterns were illustrated in the shapes of the observed incremental subsidence profiles measured along survey lines located transversely across the longwalls.

The incremental subsidence profile for each longwall was derived by subtracting the initial subsidence profile (measured prior to mining the longwall) from the final subsidence profile (measured after mining the longwall). The incremental subsidence profile for a longwall therefore shows the change in the subsidence profile caused by the mining of the individual longwall.

The consistency in the shapes of the incremental subsidence profiles led to the development of the Incremental Profile Method. This consistency can be observed in the typical incremental subsidence profiles presented in Fig. D.2.

The Incremental Profile Method of prediction is based upon predicting the incremental subsidence profile for each longwall in a series of longwalls and then adding the respective incremental profiles to show the cumulative subsidence profile at any stage in the development of a series of longwalls.

The incremental subsidence profiles are also used to derive incremental tilts, systematic curvatures and systematic strains which can be added to show the transient and final values of each parameter as a series of longwalls are mined.

Profiles can be predicted in both the transverse and longitudinal directions, thus allowing the subsidence, tilts, systematic curvatures and systematic strains to be predicted at any point on the surface above a series of longwalls. The method also explains the development of undulations that occur within the subsidence trough and allows the magnitude of both transient and residual tilts and curvatures within the trough to be determined.

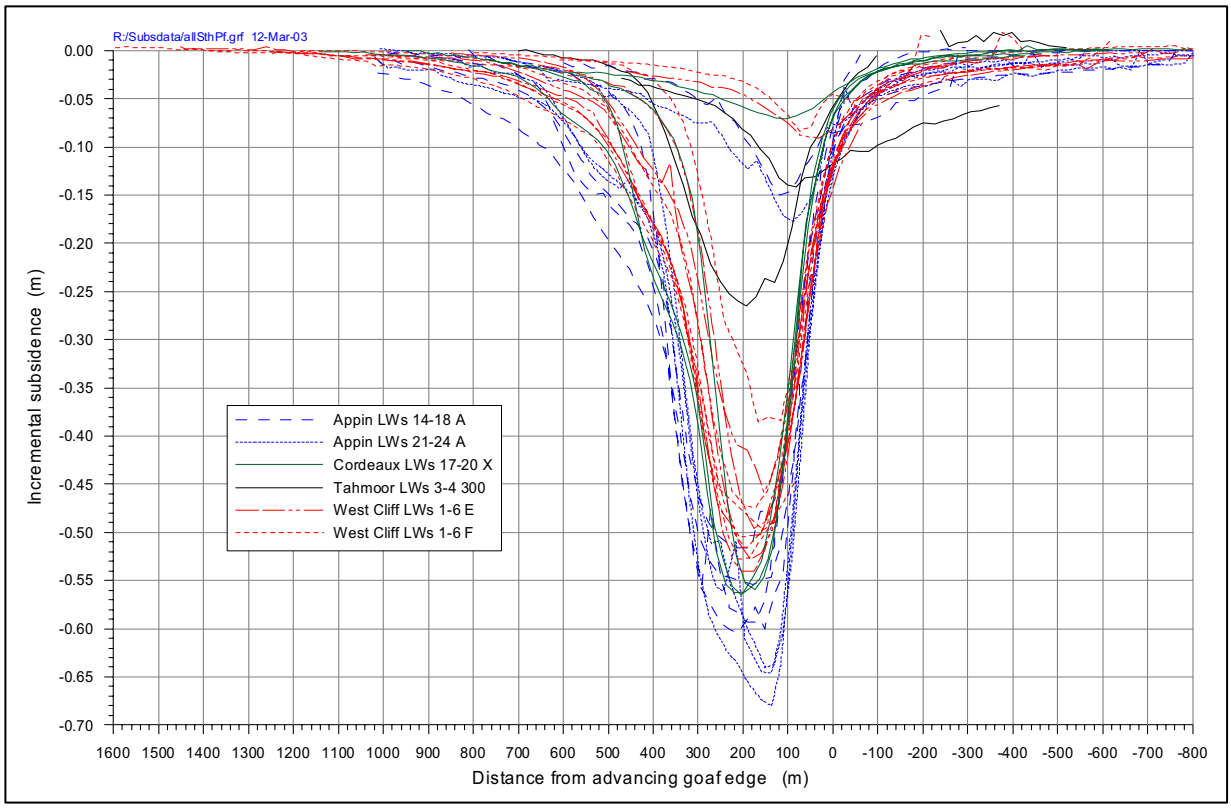


Fig. D.2 Typical Incremental Subsidence Profiles – NSW Southern Coalfield

The model was initially tested by comparing the predicted values of subsidence, tilt, curvature and strain against the measured values for a number of longwalls at Appin, Cordeaux, Tahmoor and West Cliff Collieries. Following that study, the method was used to analyse and predict subsidence over other longwall panels at Appin, South Bulli, Bulli, Corrimal, Tahmoor, Teralba, North Cliff, Metropolitan, Tower and West Cliff Collieries. These studies found that the shapes of the measured incremental profiles conformed to the patterns and magnitudes observed during the initial 1994 study.

During 1996 and 1997, the method was extended for use in the Newcastle Coalfield. The shapes of incremental profiles over extracted longwall panels at Cooranbong, West Wallsend, Newstan, Teralba, and Wyee Collieries were studied and a subsidence model was developed for the Cooranbong Life Extension Project. These studies have shown that the shapes of the incremental profiles in the southern part of the Newcastle Coalfield conform to the patterns observed in the Southern Coalfield. Since that study, the method has been used to analyse and predict subsidence over other longwall panels at West Wallsend, Cooranbong, Wyong and South Bulga Collieries.

The collection of additional data has allowed further refinement of the method and the database now includes more than 475 measured examples. A wide range of longwall panel and pillar widths and depths of cover is included within the database and hence, the shapes of the observed incremental profiles in the database reflect the behaviour of typical strata over a broad spectrum.

Further research during the last few years has identified the shapes of the incremental profiles in a number of multi-seam situations. These profiles are generally greater in amplitude than the single seam profiles and differ in shape from the standard profiles over single seams.

The incremental profiles have been modelled in two halves, the point of maximum subsidence being the point at which the two halves of the profile meet. A library of mathematically defined profile shapes has been established, which allows the incremental profiles to be modelled, depending on the width to depth ratio of the longwall and the position of the longwall in the series.

The mathematical formulae that define the profile shapes are of the form given in Equation 1 below. The library of profile shapes simply comprises the values *a* to *k* in these formulae.

$$y = \frac{a + cx + ex^2 + gx^3 + ix^4 + kx^5}{1 + bx + dx^2 + fx^3 + hx^4 + jx^5} \qquad \text{Equation 1}$$

Different formulae apply, with unique *a* to *k* values, for first, second, third, fourth, and fifth or subsequent panels in a series, and for different width-to-depth ratios, within the range 0.3 to 5.0. For second, third, fourth and fifth or subsequent panels, the left and right hand sides of the profiles have different formulae.

The library of profile shapes thus contains a to k values for 693 different half-profile shapes for single-seam mining situations. In addition the library contains 236 different half-profile shapes for a range of multi-seam mining situations. A selection of model incremental subsidence profiles for various width-to-depth ratios is shown in Fig. D.3, below.

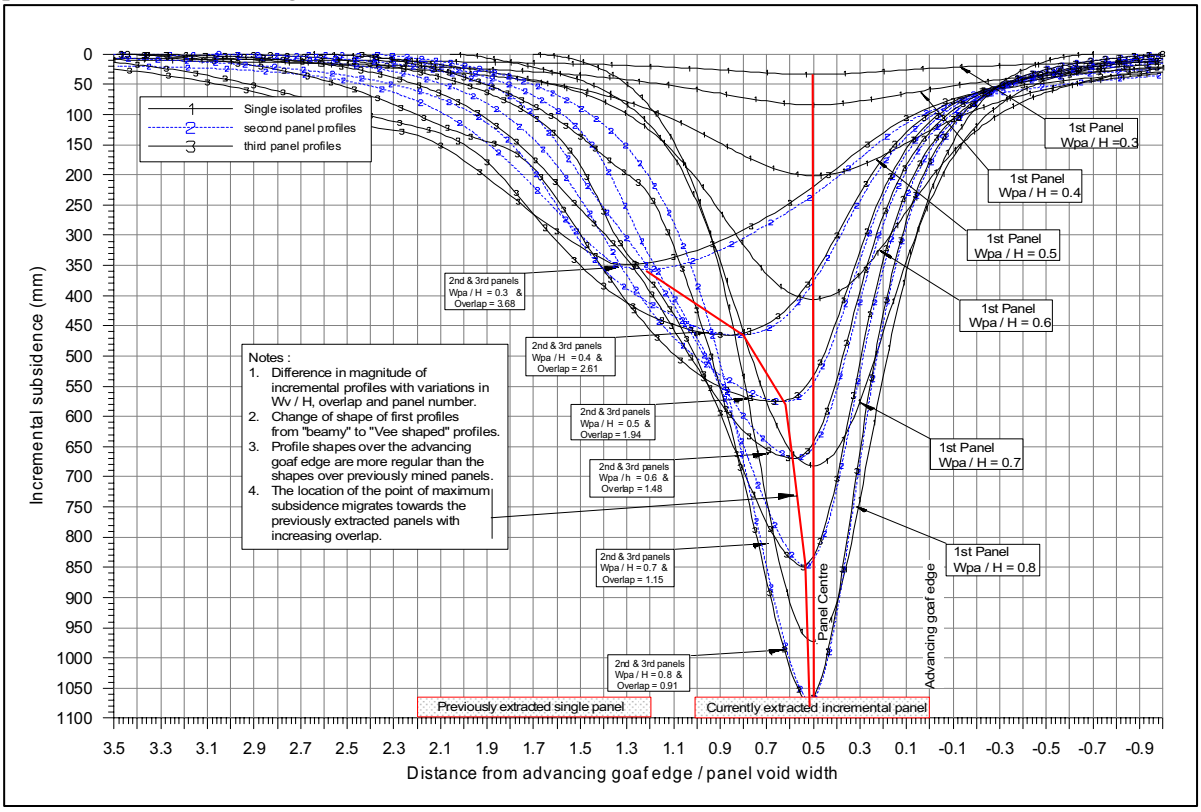


Fig. D.3 Incremental Subsidence Profiles obtained using the Incremental Profile Method

The method has a tendency to over-predict the subsidence parameters because a conservative approach was adopted in preparing the graph that is used for predicting the maximum incremental subsidence. Fig. D.4 shows the maximum incremental subsidence, expressed as a proportion of seam thickness, versus panel width-to-depth ratio.

Since this graph is used to determine the amplitude of the incremental subsidence profile, any over-prediction of the maximum subsidence value also leads to over-predictions of the tilt, curvature and strain values. Once the geometry of a longwall panel is known, the shapes of the two halves of the incremental subsidence profile of the panel can be determined from the appropriate formulae to provide a smooth non-dimensional subsidence profile across the longwall.

The actual incremental profile is obtained by multiplying vertical dimensions by the maximum incremental subsidence value and horizontal dimensions by the local depth of cover. Smooth tilt and curvature profiles are obtained by taking the first and second derivatives of the subsidence profile. Strain profiles are obtained directly from the curvature profiles.

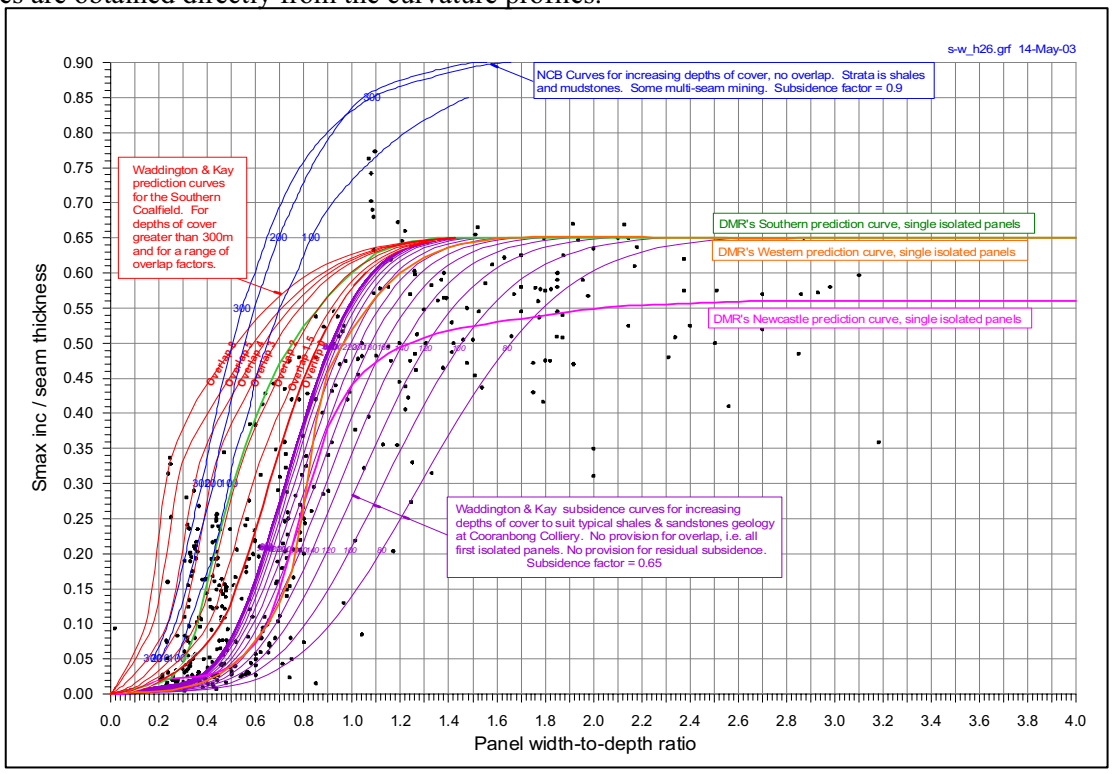


Fig. D.4 Prediction Curves for Maximum Incremental Subsidence

It can be seen from Fig. D.3 and Fig. D.4 that, as panel width to depth ratio (W/H) decreases, the magnitude of the incremental subsidence profile is reduced and the position of the point of maximum subsidence moves closer to the previously extracted panels. It has been found that the amplitude and position of the incremental profile relative to the maingate of the longwall is determined by a factor known as the overlap factor. This overlap factor is derived empirically as a function of the panel width, pillar width and depth of cover.

In order to determine strain values from the curvature profiles, it is necessary to select an empirical relationship that will generally provide conservative results. The NCB Subsidence Engineers Handbook (1975) adopts a relationship in which the reciprocal radius of curvature, K, is equal to strain squared divided by 0.024.

This relationship does not provide a good fit when strains derived from predicted curvatures, are compared with measured values. However, if a linear relationship of strain = 15 × curvature is chosen, then a closer fit is achieved between predicted and observed data from the Southern Coalfield. This equates to the bending strain in a beam of 30 metres depth, bending about its centre line. The relationship of 15 × curvature is also reasonably close to the graph of radius of curvature versus maximum strain given in Fig. 4.9 of the DMR's handbook for the Southern Coalfield (Holla and Barclay, 2000), for depths of cover between 300 metres and 400 metres. It will, however, give lower values of strain for greater depths. A factor of 10 has been found to be more applicable in the Hunter and Newcastle Coalfields.

Predicted horizontal displacements in the direction of the prediction line (normal to the longwall), can be derived by accumulating the predicted strains multiplied by the bay lengths, after distributing any displacement closure errors over all bay lengths in proportion to the predicted strains. Alternatively, the predicted horizontal ground movement profiles can be derived by applying a proportionality factor to the predicted tilt profiles, which they resemble in both magnitude and direction.

Experience has shown that the subsidence and tilt profiles predicted using the Incremental Profile Method usually match the systematic observed profiles reasonably accurately. It is not possible to match the predicted and observed curvature and strain profiles to the same standard, due to the large amount of scatter generally found in the measured data. The range of systematic strains is, however, adequately predicted.

The scatter in the strains is caused by random variations in stratigraphy, rock strength, fracture characteristics and spacing of joints which dictate the way in which the near surface rocks will respond as subsidence occurs. The scatter sometimes results in anomalous peaks of strain, though in many cases these peaks can be predicted.

It should be remembered that the predicted strains obtained using the Incremental Profile Method are the systematic strains, which can, in some cases, be exceeded by local anomalous peaks of strain. In the Incremental Profile Method, such anomalous peaks of strain are dealt with statistically.

The Incremental Profile Method provides a greater understanding of the mechanism of subsidence over a series of panels and allows a detailed prediction of subsidence parameters to be made for any point on the subsidence profile.

Other benefits of the Incremental Profile Method are as follows:

The method can be used even where the seam thicknesses, pillar and panel widths and depths of cover vary from panel to panel across a series of longwalls. This is possible because the total subsidence predictions are an accumulation of incremental subsidence profiles for each longwall, based on their individual panel and pillar widths, the seam thickness and depth of cover and the position of each longwall within the series of longwalls.

- After superimposing the influence of the incremental subsidence profiles for each longwall it has been found, in the syntheses carried out to date, that the total subsidence profiles are predicted quite accurately.
- Because the total subsidence profiles are well represented, this method provides improved predictions of tilts, and general background or 'systematic' curvatures and strains.
- The method can be used to model the effects of alternative mine layouts with different pillar and panel configurations and to compare the impact of tilts, curvatures and strains for each alternative.
- By varying the proposed widths of panels and pillars, it is possible to show the variations in the predicted magnitude of the maximum total subsidence and the shape of the subsidence trough.

Because of the inherent advantages of the Incremental Profile Method, this method has been used to make the detailed subsidence predictions for this project.

D.1.4. Typical Subsidence Predictions

Typical predicted incremental and cumulative total subsidence, tilt and strain profiles over a series of longwalls are shown in Fig. D.5. It can be seen that the subsidence parameters vary throughout the subsidence trough.

Subsidence profiles are generally prepared along a series of parallel prediction lines, orientated at right angles to the centrelines of the longwalls. The prediction lines are generally positioned 25 metres to 100 metres apart, depending on the depth of cover and generally cover the full area of the longwalls, extending outwards as far as the limit of subsidence.

When the predicted subsidence profiles have been developed along each of the prediction lines, the predicted subsidence data is used to develop a three-dimensional model of the subsidence trough, from which subsidence contours are derived.

A typical longwall layout showing predicted subsidence contours over a series of four longwalls is illustrated in Fig. D.6. The variations in these contours reflect the changes in seam thickness and depths of cover from place to place over the area of the longwalls.

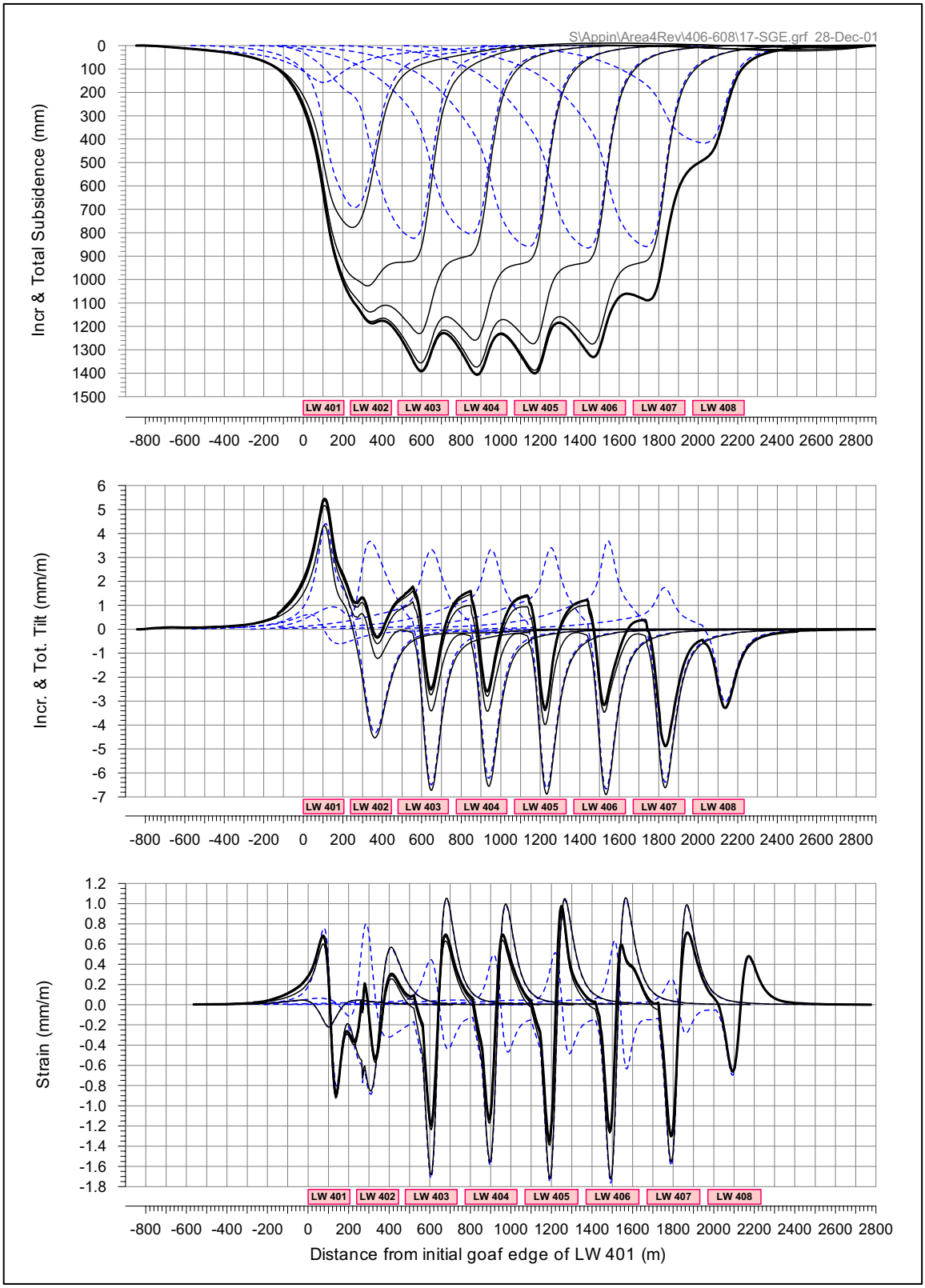


Fig. D.5 Typical Predicted Incremental and Total Subsidence, Tilt and Strain Profiles

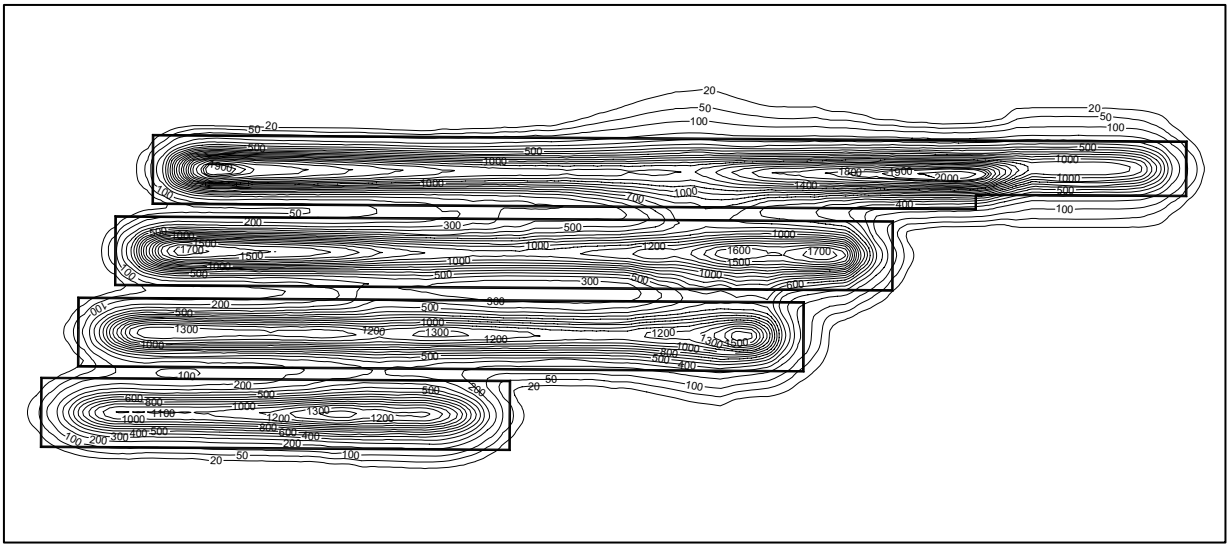


Fig. D.6 Typical Predicted Subsidence Contours over a Series of Longwalls

D.2. Timing and Direction of Predicted Tilts and Strains

It is generally found that the maximum tilts and strains at any point within a mined area are aligned in the transverse direction across the longwalls and occur after the longwalls are extracted. However, there are cases when the maximum tilts and strains are not aligned in the transverse directions. There are also instances where the maximum tilts and strains at a particular point occur during the extraction of a particular longwall and are later reduced by extraction of subsequent longwalls. Treatment of these cases is discussed below.

D.2.1. Travelling, Transient and Final Subsidence Parameters

The Incremental Profile Method allows subsidence parameters to be predicted at any point on the surface when the longwall face is at any position in a panel, and hence for any:

- **travelling** scenario, *during* extraction of a longwall,
- **transient** scenario, *following* the extraction of *each* longwall, or
- **final scenario, following the extraction of all longwalls in a series.**

This is particularly relevant for assessing the impacts of curvature and strain on an item of surface infrastructure, which can be greater at a travelling stage than on completion of mining a particular longwall or all longwalls in a series.

A review of subsidence data from several collieries in the Southern Coalfields, in particular West Cliff Colliery, has indicated that the magnitude of the observed travelling strains in the longitudinal direction are generally smaller than the observed transient or final longitudinal strains over the ends of the longwalls. Using the Incremental Profile Method, the travelling strains at any point in the subsidence trough can be determined by taking into account the maximum predicted longitudinal strains over the ends of each longwall, the maximum predicted incremental subsidence value for the longwall and the predicted subsidence at the point of interest.

D.2.2. Tilts and Strains in the Transverse and Longitudinal Directions

The predicted maximum tilts and strains within the mined areas are, generally, those which are aligned in the transverse direction across the longwalls. However, at the ends of the longwalls, the maximum tilts and strains are at right angles to the subsidence contours, which can be aligned in various directions relative to the longwalls. Also, in some cases, the travelling wave that occurs during the extraction of each longwall can produce travelling longitudinal tilts and strains which can be greater than the transverse values. These cases typically occur at those points within the subsidence trough at which maximum subsidence is developed.

At points where it is found that longitudinal tilts and strains are greater than those in the transverse direction, it is extremely rare for these tilts and strains to be greater at a transient stage than on completion of mining. There may be isolated cases where the maximum tilts and strains are aligned in a diagonal direction to the orthogonal axes of the longwalls. In such cases, the magnitude of these tilts and strains will exceed the transverse and longitudinal values by a small proportion only and are unlikely to influence the final assessment of potential impact or development of management plans to mitigate this potential impact.

D.3. Statistical Analysis of Curvature and Strain

The peak values of curvature and strain that have frequently been noted along measured monitoring lines have generally been found to be localised effects associated with escarpments, river valleys, creek alignments or geological anomalies. Consequently, many of them are predictable.

Higher values of measured strain can also arise from buckling of near-surface strata at shallow depths of cover, from disturbance of survey pegs and from survey errors. There are, therefore, some anomalies that can not be predicted and it has to be accepted that there is a small risk of peak values of strain and curvature occurring, at some point, in addition to the predicted systematic background strains and the predictable local peaks. It is preferable to deal with such anomalies on a statistical basis and wherever measured records are available, frequency analyses should be prepared in order to determine the likely incidence of such occurrences.

A histogram of measured strains at South Bulga Colliery, where the depth of cover to the Whybrow Seam varies between 40 metres and 160 metres, is shown in Fig. D.7. It can be seen that 90% of the measured strains were between 1.0 mm/m, tensile, and 2.5 mm/m, compressive. Approximately 9% of tensile strains were in the range 2.5 mm/m to 17 mm/m, whilst 9% of compressive strains were in the range 1.0 mm/m to 12.5 mm/m. Only 1% of strains exceeded 17 mm/m, compressive, or 12.5 mm/m, tensile.

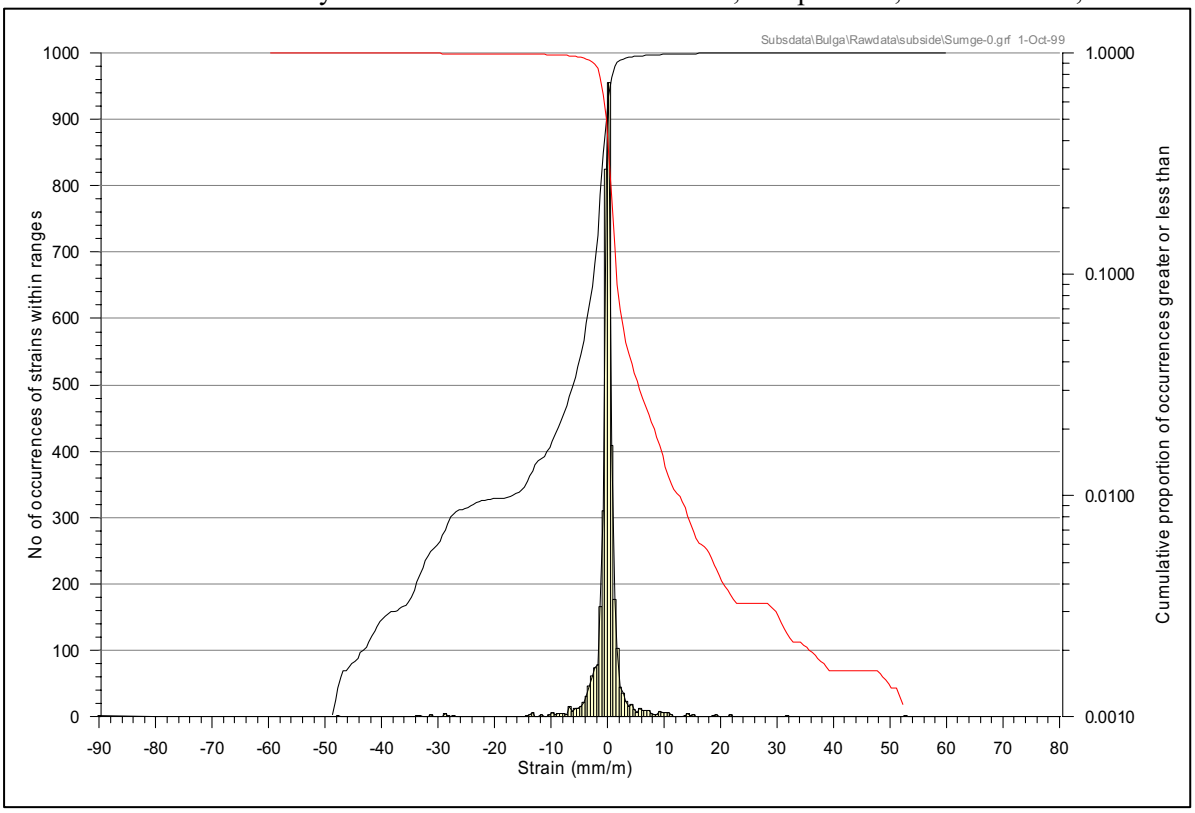


Fig. D.7 Graph showing Histogram of Strain Occurrences at South Bulga Colliery

D.4. Adjustment of the Incremental Profile Method for Multi-Seam Mining Areas

D.4.1. Introduction

As discussed by Kratzsch (1983), a rock mass that has been undermined many times can be regarded as an accumulation of generally loose blocks of stone. The movement of the non-cohesive blocks within the rock mass are less dependent on the properties of those blocks, and more dependent on stochastic movement processes.

After extracting the longwalls in the Woodlands Hill and the Glen Munro Seams, the overlying strata will become more fragmented, particularly within and immediately above the longwall goaf regions, and higher stress conditions will be created in the strata above and below the remaining chain pillars in these seams. The subsidence movements, due to extraction of the longwalls in the Arrowfield, Bowfield and Piercefield Seams, will be affected by the changed strata conditions above the Woodlands Hill and Glen Munro Seams.

The difference in strata behaviour will depend on the:-

- Magnitude of the subsidence caused by mining the overlying seam,
- Degree of fragmentation or the proportion of voids left in the overlying strata, due to mining the overlying seam,
- State of stress in the remaining pillars,
- Relative positions of the overlying and underlying pillars, and
- Interburden thicknesses between the seams.

As a consequence of the changed strata conditions, the magnitudes and shapes of the subsidence profiles above the multi-seam extractions will differ from those over the single seam extractions.

D.4.2. Literature Review on Subsidence Impacts caused by Multi-Seam Mining

It is generally accepted that the magnitude of subsidence caused by multi-seam mining is greater than for single seam extractions of the same thickness, but, in addition, the shapes of the resulting subsidence profiles are flatter and wider. In order to calibrate the Incremental Profile Method for use in multi-seam mining cases, a detailed literature study was undertaken into available local and overseas subsidence prediction methods and monitoring data from multi-seam cases.

Most of the available literature was found in the United Kingdom and United States of America, and many of the published papers discussed ground control and mine safety issues resulting from the mining of longwalls both under and over previously extracted seams.

Considerable discussion was focussed on comparing the state of stress and stability of the pillars, the differences between stacking or staggering the pillars in overlying and underlying seams and the height of the collapsed zone above the extracted seam. Papers including observed subsidence survey data, in multi-seam mining cases, in Australia, have been written by Kapp, Holla and Holt, and these papers are discussed below.

Kapp (1985) advised that more subsidence would occur from mining a seam in multi-seam mining conditions than would occur under single-seam conditions. He reported that the subsidence measured after longwall mining at South Bulli Colliery was greater than the extracted seam thickness due to the additional effect of the collapse of pillar remnants in the overlying seam, which had been extracted by bord and pillar extraction methods. Similar observations were made at Wyee Colliery by Holla and Thompson (1988).

A more graphic example was given in the case of the longwalls at South Bulli Colliery of the Southern Coalfield as discussed by Kapp (1982). These longwalls were mined in the Balgownie Seam below pillar stooks which remained in old workings in the Bulli Seam, only 10 metres above the longwalls. The observed subsidence was in some cases greater than the thickness of the seam mined in the longwalls due to the additional effect of the collapse of pillar remnants in the Bulli Seam."

Holla and Thompson (1992) discussed the observed ground movements due to the extraction of two longwall panels at Newstan Colliery that were located on top of each other. Longwall 6 was extracted first in the Great Northern Seam and Longwall 8 was extracted one year later in the Fassifern Seam. Both panels were shallow, with depths of cover between 50 metres and 65 metres, and the panel width in both cases was more than three times the depth of cover. The tailgate of Longwall 8 was located directed below the tailgate of Longwall 6.

A maximum subsidence of 2 metres, which was 60 % of the extracted seam thickness, was observed after mining the Great Northern Seam. A maximum subsidence of 3.2 metres, which was 100 % of the extracted seam thickness, was observed after mining the Fassifern Seam. The interburden thickness was 15 metres, which the authors concluded was less than the height of the collapse zone above the extraction in the Fassifern Seam.

Holt (1996, 2001), on the other hand, advised that, based upon his observations in the Hunter Valley, an "additive" approach could be used and that multi-seam predictions could be made by treating each seam as a single seam and adding the results together.

Waddington Kay & Associates (2001), in its report to the Commission of Inquiry into the proposed Dendrobium Mine, provided monitored subsidence data from the mining of Longwalls 1 to 6 in the Wongawilli Seam at Kemira Colliery, which were 30 metres below bord and pillar workings in the Bulli Seam at Mount Kembla and Kemira Collieries.

The old mine workings in the Bulli Seam at Mount Kembla and Kemira Collieries were fully extracted except for a number of very small pillars, sometimes referred to as stooks, which were left in place to temporarily support the roof. It is reasonable to assume that these stooks would have collapsed as the longwalls in the Wongawilli Seam were extracted, allowing further settlement and consolidation of the strata above the Bulli Seam to occur. It is conjectured that the cracking or fragmentation of the strata above the Bulli Seam, due to the earlier mining, would also have resulted in greater subsidence as the Wongawilli Seam was mined, due to the reduction in the shearing capacity of the cracked strata.

The additional ground movement is dependent upon the thickness of the seam to be extracted, the thickness of the interburden between the seams, the methods of mining, the percentage of extraction in the previously mined seams, and the amount of subsidence caused by mining the previously mined seams as a proportion of the extracted seam thicknesses.

D.4.3. Available Multi-Seam Subsidence Monitoring Data from NSW Coalfields

Subsidence survey data were available from the following multi-seam mining cases:

- Newstan Colliery Longwall 8 in the Fassifern Seam - below LW6 in the Great Northern Seam
- Newstan Colliery Longwalls 1, 2, 3 and 4 - below extracted pillar workings
- Wyee Colliery Longwalls 1, 2, 3, 4, 7 and 9 - below extracted pillar workings
- John Darling Colliery Longwall 1 - below extracted pillar workings
- Teralba Colliery Longwalls 6, 7, 8 and 9 - below extracted pillar workings
- Kemira Colliery Longwalls 1 to 6 - below extracted pillar workings

This data has been analysed in order to develop a series of multiplying factors that can be applied to the predicted maximum incremental subsidence for a single seam to allow for the multi-seam effects of the overlying seams, which is discussed in Section D.4.4. It has also been used to assist in developing a series of incremental subsidence profile shapes, which can be used to model incremental subsidence profiles in multi-seam mining cases, which is discussed in Section D.4.5.

The maximum observed incremental subsidence in the available data from multi-seam longwall cases is shown in Fig. D.8. It can be seen that the Newstan Colliery Longwall 8 case provided a significantly greater observed maximum incremental subsidence as a proportion of the extracted seam thickness, compared to the other cases, primarily due to its extremely shallow depth of cover and small interburden thickness. The conditions at Newstan Longwall 8 are significantly different to those found at the Mt. Arthur Underground Project, and this result has, therefore, been discarded for the purposes of this report. The South Bulli - Balgownie Seam case, however, reported by Kapp (1985), may also have experienced a similar ratio of maximum observed incremental subsidence to extracted seam thickness.

It can be noted from Fig. D.8 that the magnitudes of the maximum incremental subsidence from multi-seam mining cases are generally greater than single seam cases. For each case, a prediction was made using the standard Incremental Profile Method for single seams and the observed multi-seam subsidence values were, on average, 10% higher than the predicted single seam cases.

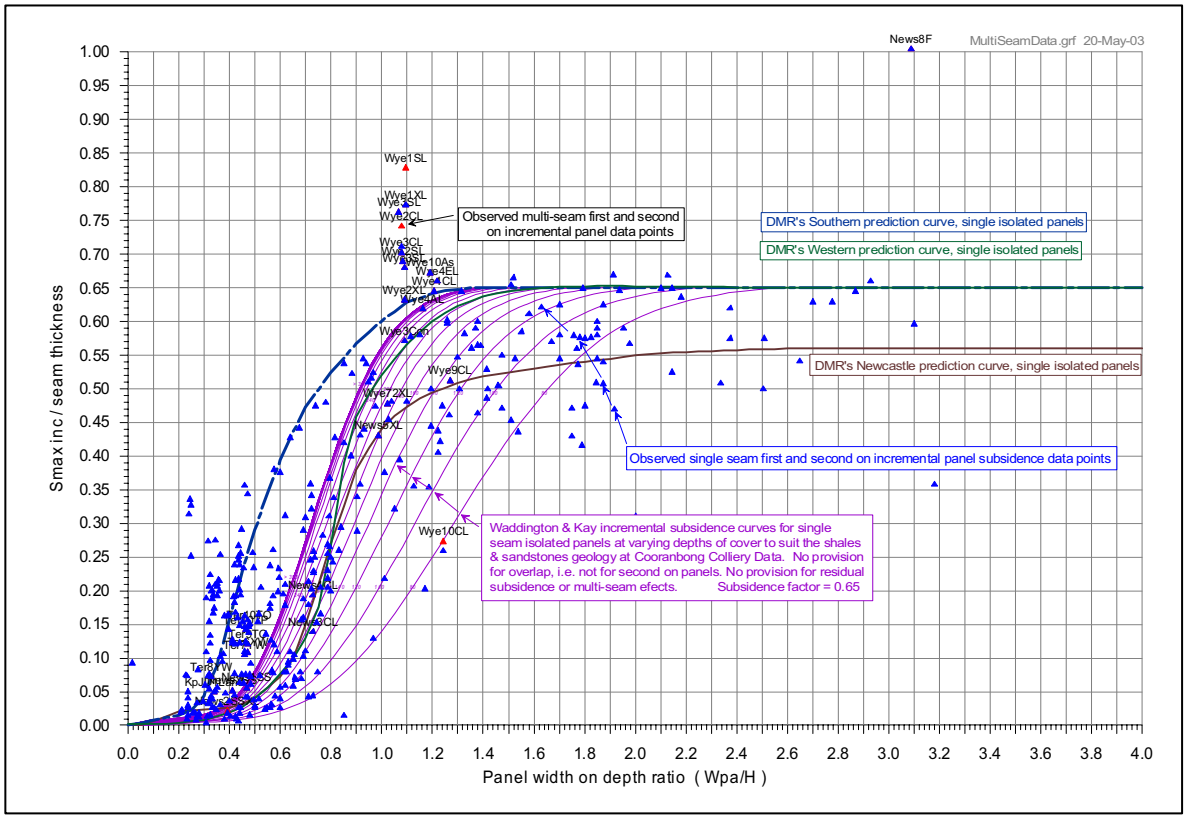


Fig. D.8 Review of Maximum Incremental Subsidence from Multi-Seam Cases

D.4.4. Method of Multi-Seam Subsidence Predictions for the Mt. Arthur Underground Project

Based upon an extensive review of multi-seam mining literature, subsidence predictions and measured subsidence levels, MSEC has developed multiplying factors that can be applied to the predicted maximum incremental subsidence for a single seam to allow for the multi-seam effects of the overlying seams.

A summary of the multi-seam prediction factors for single longwall panels having an interburden thickness between 20 and 50 metres is shown in Table D. 1. A summary of the multi-seam prediction factors for single longwall panels having an interburden thickness between 80 and 110 metres is shown in Table D. 2.

Table D. 1 Multi-Seam Prediction Factors for Single Longwall Panels having an Interburden Thickness between 20 and 50 metres

Predicted Subsidence Factor for Single seam (*Smax/T*) (%)	Overlying pillared areas (stable)		
	Extra Subs Factor (%)	Incr. Subs Factor (%)	Multiplying Factor for Single Panels
5	5	10	2.00
10	5	15	1.50
15	5	20	1.33
20	5	25	1.25
25	5	30	1.20
30	5	35	1.17
35	5	40	1.14
40	5	45	1.13
45	5	50	1.11
50	5	55	1.10
55	5	60	1.09
60	5	65	1.08
65	5	70	1.08

Table D. 2 Multi-Seam Prediction Factors for Single Longwall Panels having an Interburden Thickness between 80 and 110 metres

Predicted Subsidence Factor for Single seam (*Smax/T*) (%)	Overlying pillared areas (stable)		
	Extra Subs Factor (%)	Incr. Subs Factor (%)	Multiplying Factor for Single Panels
5	2.5	7.5	1.50
10	2.5	12.5	1.26
15	2.5	17.5	1.17
20	2.5	22.5	1.12
25	2.5	27.5	1.10
30	2.5	32.5	1.08
35	2.5	37.5	1.07
40	2.5	42.5	1.06
45	2.5	47.5	1.06
50	2.5	52.5	1.05
55	2.5	57.5	1.05
60	2.5	62.5	1.04
65	2.5	67.5	1.04

It can be seen from these tables that the multi-seam prediction factors for single longwall panels are smaller for the higher depths of interburden. The interburden thicknesses between the proposed longwalls in successive seams at the project vary between 60 metres and 190 metres, with average interburden thicknesses varying between 70 and 90 metres. The multi-seam prediction factors provided in Table D. 2 for single longwall panels are, therefore, more relevant to the proposed longwalls at the project.

The multi-seam prediction factors for a series of longwall panels are greater than those provided in the above tables due the ongoing subsidence over the chain pillars, reactivation of previously extracted longwalls and reactivation of the goafs above the preceding multi-seam longwalls, which is illustrated by the long tails of the multi-seam subsidence profiles shown in Fig. D. 9.

The maximum predicted subsidence for a series of supercritical longwalls for multi-seam conditions, such as the longwalls within the Arrowfield and Bowfield Seams, are 70 to 75 % of the extraction height. The multi-seam factors for the longwalls in these seams are, therefore, between 1.08 and 1.15.

The maximum predicted subsidence for a series of subcritical longwalls for multi-seam conditions , such as the longwalls within the Piercefield Seam, are even greater, as these longwalls would not normally achieve full subsidence for single-seam conditions and, therefore, have a greater potential for reactivation of the above goafs under multi-seam conditions. The multi-seam factors for the longwalls within the Piercefield Seam are, therefore, between 1.10 and 1.40.

The multi-seam prediction factors are based upon a limited amount of measured data and do not necessarily represent an upper-bound case. It is possible, therefore, that observed subsidence parameters may be greater than those predicted in this report, although it is unlikely that the predictions will be substantially exceeded. It is also possible that the observed subsidence parameters could be less than predicted.

It is recommended that monitoring be undertaken during the mining of the longwalls so that the proposed multi-seam prediction factors can be reviewed and revised to reflect the local conditions. It is noted that the majority of the land and surface infrastructure above the proposed longwalls are owned by Mt. Arthur Coal, and that the low density of surface features will allow the calibration of the model to observed data, prior to many of these features being affected by multi-seam subsidence affects.

D.4.5. Review of Incremental Subsidence Profile Shapes for Multi-Seam Mining

A review of incremental subsidence profile shapes in multi-seam mining situations was carried out for this project and Fig. D. 9 shows a comparison between the observed multi-seam incremental profiles and the predicted single-seam incremental profiles for the same longwalls. This exercise confirmed that multi-seam incremental profile shapes were wider and flatter than single-seam incremental profile shapes for the same panel width-to-depth ratio. Study of the multi-seam profiles enabled the development of a method for the prediction of the incremental subsidence profiles in the multi-seam areas of this project.

Fig. D. 9 shows the observed multi-seam incremental subsidence profiles plotted in a normalised form, that is, subsidence values divided by the maximum observed subsidence value, versus the distance from the maingate of the incremental panel divided by the panel width.

Fig. D. 10 shows the model multi-seam incremental profiles for a range of panel width-to-depth ratios that have been fitted over the available observed multi-seam incremental subsidence profiles, and these profile shapes have been used when predicting subsidence profiles for the multi-seam areas of this project.

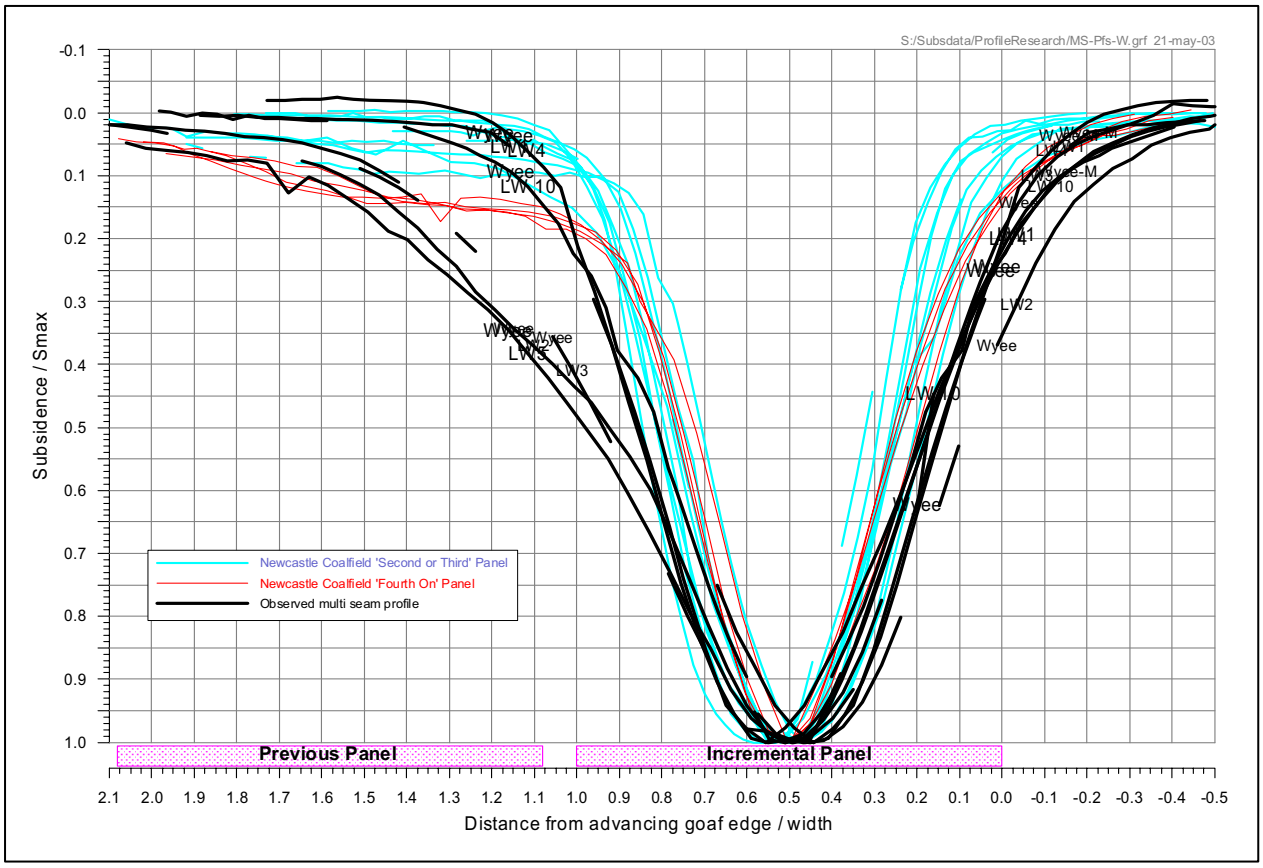


Fig. D. 9 Comparison between Single and Multi-Seam Incremental Subsidence Profiles

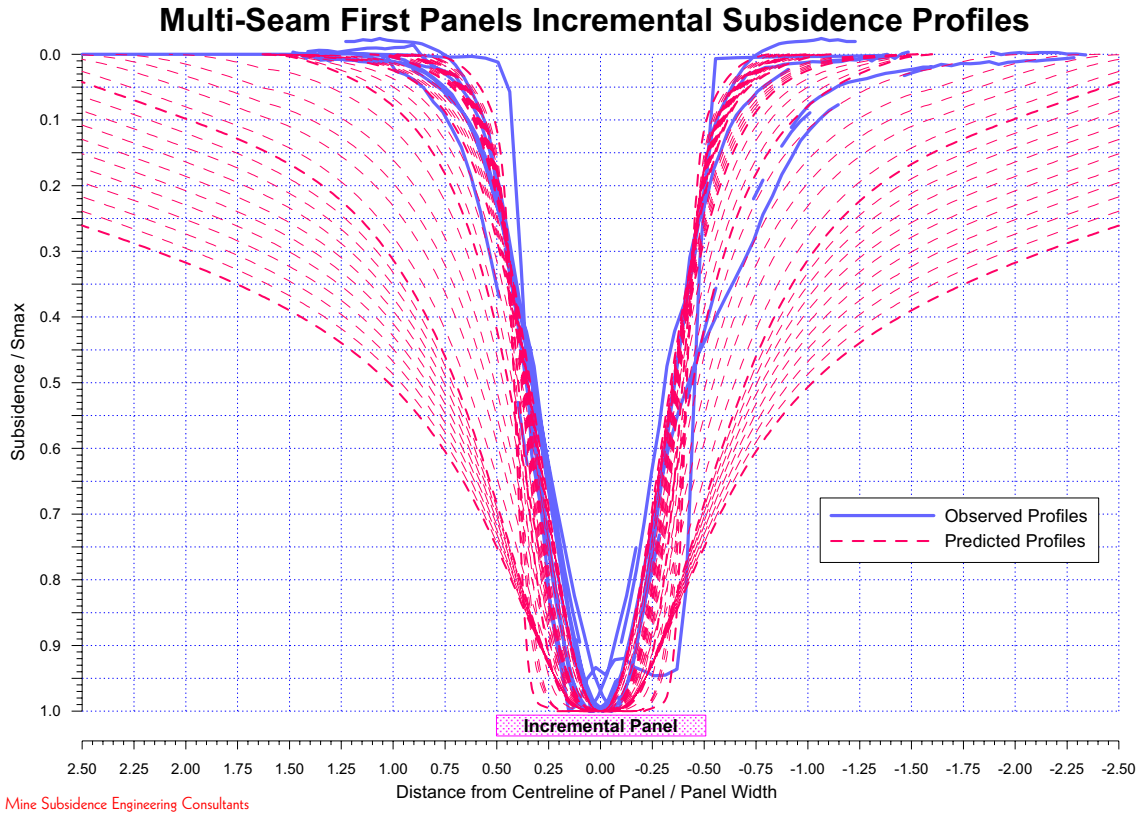


Fig. D. 10 Observed and Predicted Multi-Seam Incremental Profiles

The multi-seam incremental profiles in Fig. D. 10 are representative of the data currently available for observed multi-seam mining cases in Australia, which are relevant for this project. As this data set is limited, a reasonably conservative approach has been taken in developing the model. It is, however, possible that observed subsidence profiles may vary from those predicted in this report, although it is unlikely that the actual profiles will be substantially different from those that have been predicted.

D.5. Increased Predicted Ground Movements due to the Settlement of Overburden Spoil Heaps

The Incremental Profile Method is used to predicted subsidence at the natural surface level, and does not include additional settlement which may occur in spoil heaps located above extracted longwalls. The settlement of an unconsolidated spoil heap is additional to the predicted subsidence contours obtained provided in this report. In addition to this, the stability of an unconfined spoil heap may be affected by the subsidence and settlement which occurs when it is undermined.

A literature review was carried out in order to determine whether any empirical data might be available on the settlement of spoil heaps as they are undermined. Research in the United Kingdom has revealed that:-

- The subsidence profile that develops on a spoil heap is wider and deeper than both the predicted profile and the profile that develops on adjacent natural ground, due to additional settlement or consolidation of the spoil heap material,
- The magnitude of this settlement depends upon the extent, dimensions and rate of mine working, upon the geology of the site and upon the initial density of the spoil,
- The magnitude of the settlement is greatest over the worked-out area of the coal,
- The modified subsidence profile results in strain and tilt profiles that differ correspondingly from those predicted, and
- The initiation of ground movement due to an approaching longwall mine working is detected sooner on a spoil heap than on the adjacent natural ground.

In summary, mine subsidence can affect the stability of spoil heaps by:-

- Altering the shear strength of the spoil,
- Altering the internal and surface drainage of both the spoil heap and its foundation,
- Causing an increase in pore pressures in both the spoil heap and its foundation,
- Modifying the geometry of the spoil heap slope, and
- Inducing movement along old planes of failure.

Research work on spoil heap settlement was also referred to by Whittaker and Reddish (1989):

"Several other field investigations were carried out in the U.K. coalfields in order to monitor the general character of surface deformational behaviour of spoil heaps subjected to the effects of mining subsidence. The purpose of these studies was to compare the response of spoil heaps to undermining and relate these to anticipated movements as predicted by standard subsidence calculation procedures, Forrester and Whittaker (1976). Standard subsidence measuring methods were applied to collate data on the deformational behaviour of the spoil heaps.

The following general conclusions were drawn by Forrester and Whittaker (1976) on undermining spoil heaps:-

1. Spoil heap subsidence was observed to be greater than predicted in both magnitude and extent; maximum subsidence was observed to be as much as 67% greater than that for natural ground. Predicted magnitudes were generally low estimates.
2. Spoil heaps responded earlier to the effects of subsidence than the natural ground.
3. Observed maximum surface strains were greater for spoil heap structures than for natural ground.

4. The incidence of surface cracking was not covered by the standard prediction procedures; cracks on the surface of the tip were observed to occur when the observed tensile ground strain exceeded 3 mm/m. Compression humps became apparent on the spoil heap at compressive strain magnitudes of the order of 10 mm/m.
5. The presence of a mine spoil heap resulted in the area of influence of mining subsidence increasing, with angles of draw of up to 45° being more representative than the 26½° value for natural ground.
6. Mine spoil heaps were observed to respond gradually with uniform development of ground movement during the period of mining subsidence.
7. Typical displacement features observed, were those of excess settlement at the crest and heave at the toe of a mine spoil heap under the influence of mining subsidence.

A tentative linear relationship is indicated by these results and this is shown in Fig. D. 11. The results suggest that there is a relationship between excess settlement per unit spoil heap height and the *S/H* ratio. The relationship shown in this figure has been used to predict the settlement of any overburden spoil heaps for this project.

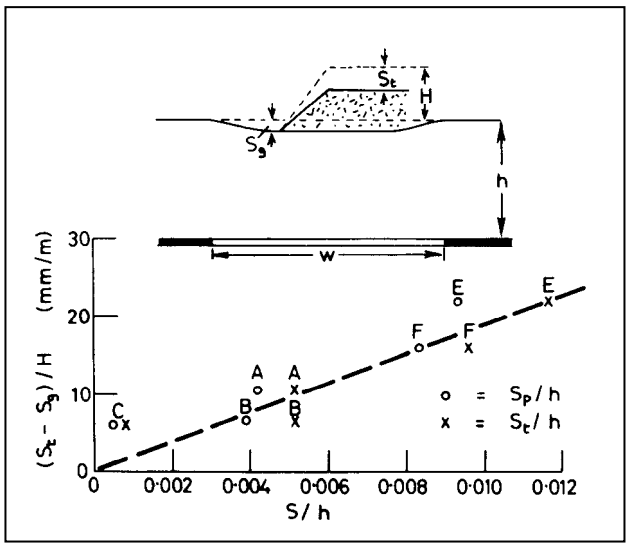


Fig. D. 11 Relationship between Excess Settlement of Mine Spoil Heap and the S/H Ratio. (From Whittaker and Reddish, 1989)

D.6. Surface Cracking

As subsidence occurs, cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeter. It is also possible that cracking could occur in other locations at right angles to the longitudinal centreline of the longwall as the longwall is mined and the subsidence trough develops. However, this cracking is likely to be transient, since the tensile phase, which results in the cracks opening up, is generally followed by a compressive phase that closes them.

Surface tensile fracturing in exposed sandstone is likely to occur coincident with the maximum tensile strains, but fracturing could also occur due to buckling of surface beds that are subject to compressive strains. Fracture widths tend to increase as the depth of cover reduces and significant cracking would normally be expected where the depth of cover is less than 250 metres.

Noticeable cracks are less likely to occur at low levels of strain, i.e. where the strains are less than 2 mm/m. Kratzsch (1983) indicated that tension cracks had been recorded in Germany, at strains of 3 mm/m to 7 mm/m. Whittaker and Reddish (1989) indicated, however, that noticeable cracking had been recorded in the United Kingdom, in Triassic Sandstone, at strains less than 2 mm/m.

Fig. D.12 shows the relationship between the depth of cover and the width of surface cracks, based upon measured data in the NSW Coalfields and observations over mines in the United Kingdom. The upper blue line on the graph represents the upper-bound limit of the data in Australia and the lower red line represents the upper-bound limit of the data measured at South Bulga Colliery. It can be seen that the crack width increases as the depth of cover reduces and that significant crack widths can develop at lower depths of cover.

As subsidence movements were monitored over Longwalls 1 to 4 at South Bulga Colliery, it was noted that cracking had occurred generally over the area of the longwalls. The depth of cover over the longwalls varied between 40 metres and 157 metres and the seam thickness varied between 2.25 metres and 2.6 metres. The strata above the seam in this location were generally sandstones or fine-grained sedimentary rocks.

The maximum subsidence was approximately 1400 mm. Tilts reached maximum values of approximately 55 mm/m, transversely across the longwalls, and 250 mm/m, along the longwalls, due to buckling of the strata at shallow depths of cover. Measured strains varied between 54 mm/m, tensile, and 110 mm/m, compressive.

As expected, the extent of cracking and the widths of the cracks were both greater at the shallower depths of cover. Cracks up to 30 mm wide were recorded where the depth of cover was 155 metres and cracks up to 150 mm wide were recorded where the depth of cover was only 40 metres. Some compressive buckling was also noted at the shallower depth of cover.

Discussion on the likely incidence of cracking over the proposed longwalls at the proposed Mt. Arthur Underground Project is provided in Sections 5.25and 5.25.1 of this report and should be read in context with the above observations.

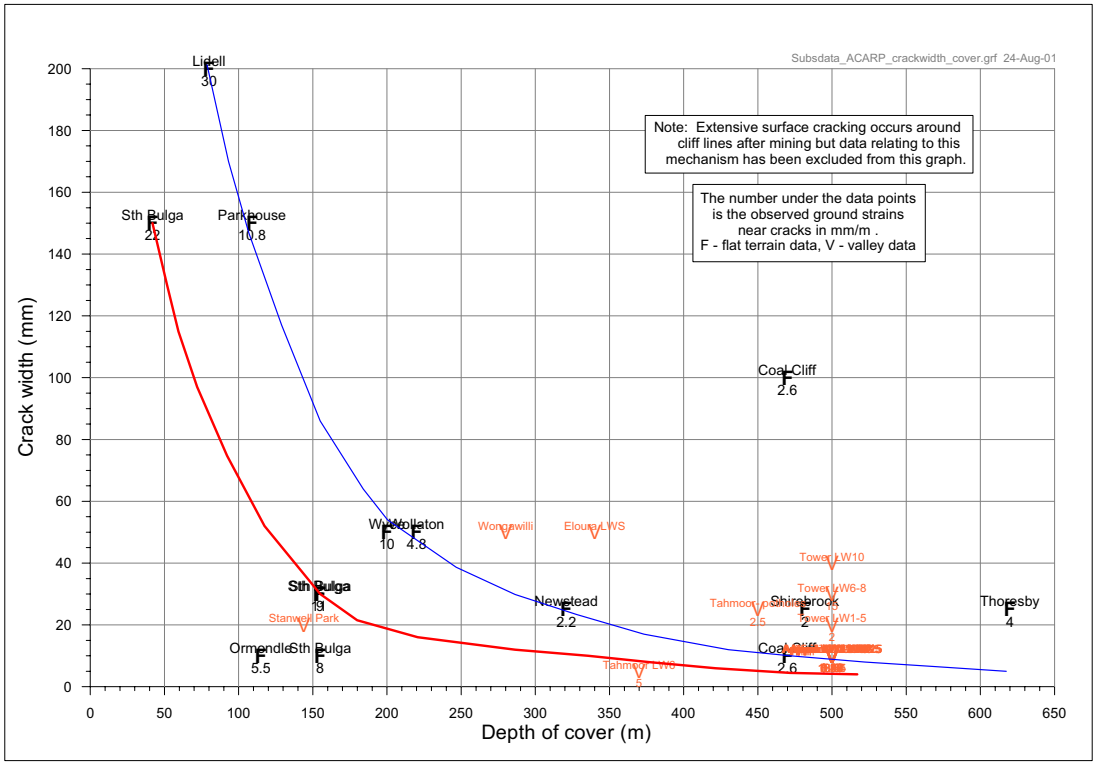


Fig. D.12 Relationship between Crack Width and Depth of Cover

D.7. Additional Mining-Induced Ground Movements caused by Topographic or Geological Factors

D.7.1. Analysis of Ground Displacements from Measured Survey Data

When longwalls are extracted beneath steeply incised terrain, the ground movements that occur around the longwalls are very complex, particularly within a high stress regime, and these complex movements result from a number of distinct mechanisms. During research by MSEC, previously known as Waddington Kay & Associates, it was found that measured movements were often a combination of some or all of the following components:

Normal mining-induced horizontal movements of points on the surface, around an extracted panel, as subsidence occurs, which are generally directed towards the centre of the extracted goaf area.

- Upsidence and closure of creeks, gullies, river valleys and gorges due to valley bulging, which results from the redistribution of pre-existing in-situ stresses, as mine subsidence occurs.
- Predominantly horizontal displacements of surface strata due to release and redistribution of pre-existing regional in-situ stresses as the extracted goaf areas increase in size within a local mining area.
- Mass slippage movements in a downhill direction due to topographic factors.
- Differential movements of the strata on opposite sides of a fault line.
- Continental drift, which is known to change the positions of points on the Australian Plate by moving them approximately 70 mm each year towards the northeast.

Study of data collected over longwalls in the Southern Coalfield during the last twenty years has led to the development of methods that can now be used for the prediction of some of these components which are discussed in this section. Valley related movements are less obvious in the Hunter and Newcastle Coalfields and are usually more difficult to resolve from observed monitoring data. The reason for this is that the systematic movements in the Hunter and Newcastle Coalfields are generally much larger than those in the Southern Coalfield, and these movements tend to overshadow any valley related movements which may occur, especially in smaller, less incised valleys.

In developing predictive methods, it is advantageous if the measured data can be broken down into its various components prior to analysis. This is not an easy task, however, because in most cases the measured survey movements are relative movements rather than absolute movements and in all cases they are total movements. When analysing the closures that have been measured in creeks and river valleys due to valley bulging, however, it appears that many of the other components have little or no effect on the closure measurements.

Mass slippage down steep slopes, due to mining is a relatively rare occurrence and is due to the instability of surface soils in particular locations. Where steep slopes exist and can be affected by mining it is prudent to study the geology of the site and the nature of the surface soils so that any unstable areas can be identified. It is possible that some of the data studied by MSEC could have been affected by this mechanism, but if so it will have led to overstatement of closure movements.

Differential movements on opposite sides of a fault line are equally rare occurrences and there are only a few known major faults in the Study Areas. There is no evidence to indicate that any of the measured data used in developing the predictive methods have been affected by differential movements at faults.

In analysing the valley closure data, no allowance was made for differential movements caused by regional horizontal stress redistribution or continental drift, because the differential movements in the two sides of a valley, as a result of these mechanisms, would be negligible.

In the steep-sided Cataract and Nepean River Gorges it was found that the closures in the sides of the gorges were almost mass movements with little differential shear displacement between different horizons in the strata. Almost all of the closure, therefore, occurred in the bases of the gorges. Because the gorge bases are relatively narrow, the differential mining-induced horizontal movement, due to differential tilting in the sides of the gorges, was relatively small in comparison with the closure movements.

In the vee-shaped valleys, a large proportion of the closure occurred in the bases of the valleys, coupled with localised concentration of compressive strain, but in some cases, part of the closure was noted to occur at horizons above the bases of the valleys.

This observation from measured data was supported by numerical modelling work by CSIRO, which indicates that in vee-shaped valleys some of the shearing occurs along weaker horizons in the valley sides. The closure movements are, therefore, spread over a greater width than those measured in the gorges.

It is possible that some of the measured closure data from vee-shaped valleys could have been affected by differential systematic mining-induced horizontal movements in the valley sides. In some cases these differential movements could have caused the sides of the valley to open and the measured closure, being the sum of the two movements, could, therefore, be less than the actual closure caused by valley bulging.

The extent to which the data might have been affected in this way is difficult to determine. This is because many of the surveys that were carried out in the past did not measure the absolute movements of the ground in three dimensions. In these cases the closures have been calculated from the strains.

The method that has been developed for the prediction of closure is, therefore, based upon the overall closure of the valley recognising that, in the case of vee-shaped valleys, some of the movement will occur in the valley sides.

When predicting closures in vee-shaped valleys it would be prudent to ignore the impacts of differential mining-induced horizontal movements in the valley sides, if those movements result in a reduction in the predicted closures.

D.7.2. Normal Mining Induced Horizontal Ground Movements

The 'normal' horizontal component of subsidence, sometimes referred to as horizontal displacement, can be predicted, in flat terrain, i.e. where steep slopes or surface incisions do not influence ground movement patterns. As discussed in Section D.1.3, the magnitude and direction of horizontal displacements can be determined, approximately, from the predicted tilt profiles, by applying the strain-curvature factor. These subsidence induced horizontal displacements are generally directed towards the centre of the mined longwall panel as shown in Fig. D.13.

As also discussed in Section D.1.3, the appropriate strain-curvature factor for the Hunter Coalfield is 10. If the predicted tilt at a point is 2 mm/m, for example, then the predicted horizontal ground displacement will be approximately 20 mm, directed towards the centre of the mined goaf.

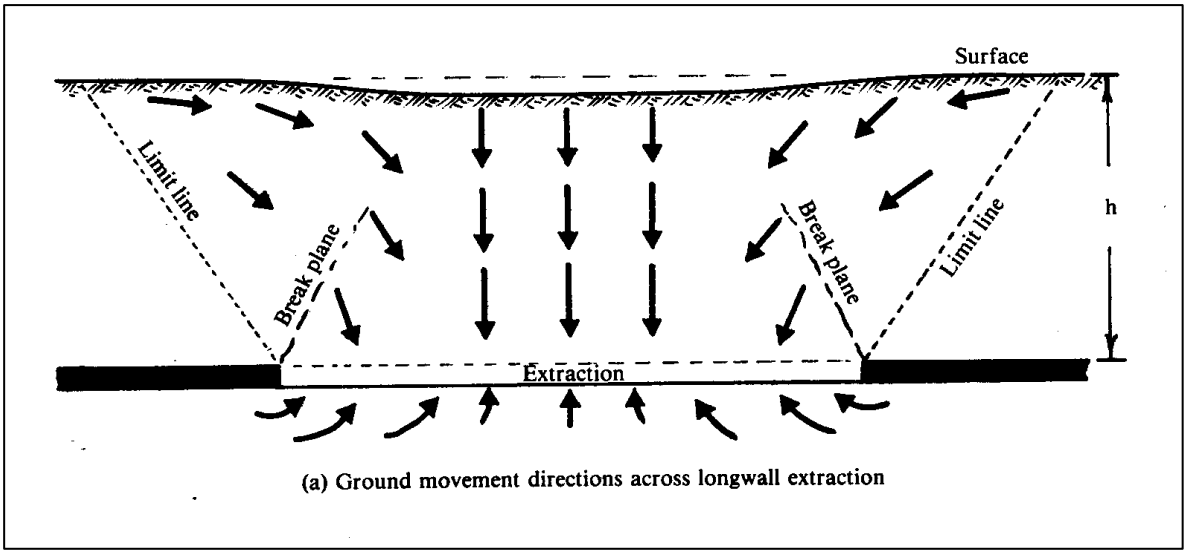


Fig. D.13 Normal Mining Induced Movements above an Extracted Area (after Whittaker, Reddish and Fitzpatrick, 1985)

This method is only approximate and, whilst it tends to be conservative where the tilts are high, it tends to underestimate the horizontal movements where the tilts are low. Where the tilt is low, however, the 'normal' horizontal displacement is generally very small, even though it could be many times greater than the vertical subsidence at the same point. The tilts reduce with increasing distance from the goaf edge of the longwall, and at the edge of the subsidence trough, where the tilts approach zero, any small horizontal displacement at that point could be infinitely greater than the tilt. When large horizontal displacements are measured outside the goaf area, they are more likely to be a result of far-field movements, as discussed in Section D.7.9.

D.7.3. Upsidence and Closure due to Mining beneath Gorges, River Valleys and Creeks

When creeks and river valleys are affected by mine subsidence, the observed subsidence in the base of the creek or river is generally less than the level that would normally be expected in flat terrain. This reduced subsidence is due to the floor of the valley buckling upwards. This phenomenon is referred to as valley bulging and results from the redistribution of, and increase in, the horizontal stresses in the strata immediately below the base of the valley as mining occurs. Valley bulging is a natural phenomenon, resulting from the formation and ongoing development of the valley, as indicated in Fig. D.14, but the process is accelerated by mine subsidence. The phenomenon appears to be triggered, to varying degrees, whenever mining occurs beneath or adjacent to escarpments, gorges, river valleys, creeks or other surface incisions.

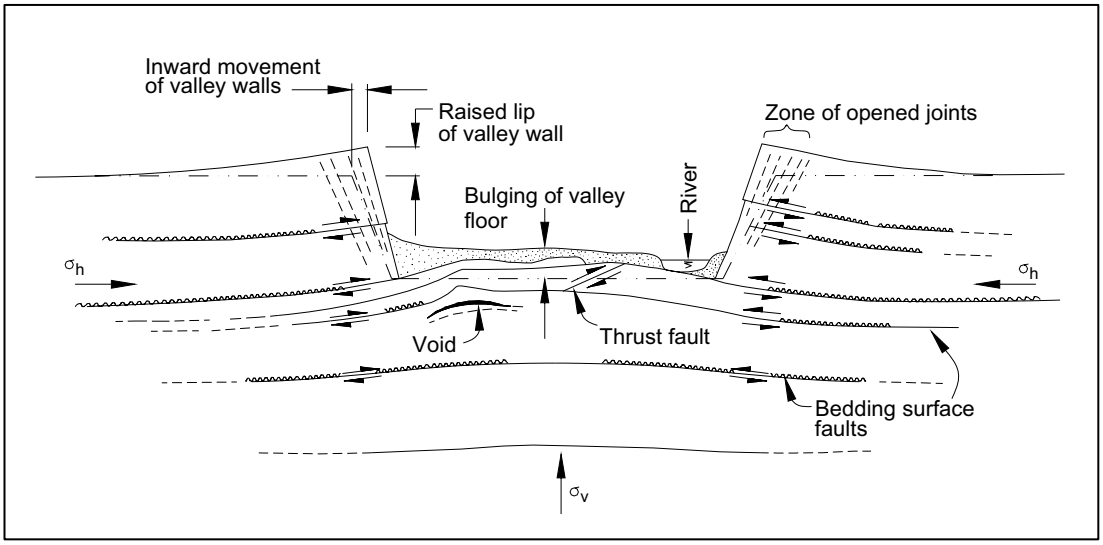


Fig. D.14 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

The local reduction in subsidence, which is referred to as 'upsidence', is generally accompanied by localised changes in tilt and curvature leading to high compressive strain in the centre of the valley and horizontal closure of the valley sides. In the case of escarpments and wide river gorges the movements may be limited to the cliffs that are closest to the extracted area.

The phenomenon is clearly seen when subsidence profiles are plotted to an exaggerated vertical scale, when the upsidence can be seen as a localised upwards spike in an otherwise smooth subsidence profile, coincident with a creek alignment. A typical example is illustrated in Fig. D.15, which shows the measured subsidence profiles over Longwalls 1 to 6 at West Cliff Colliery, along a survey line known as the E-Line. The upsidence spike in the subsidence profile, between Longwalls 2 and 3, can be seen to coincide with the alignment of a local creek, leading to a reduced subsidence of approximately 200 mm coupled with a local concentration of compressive strain.

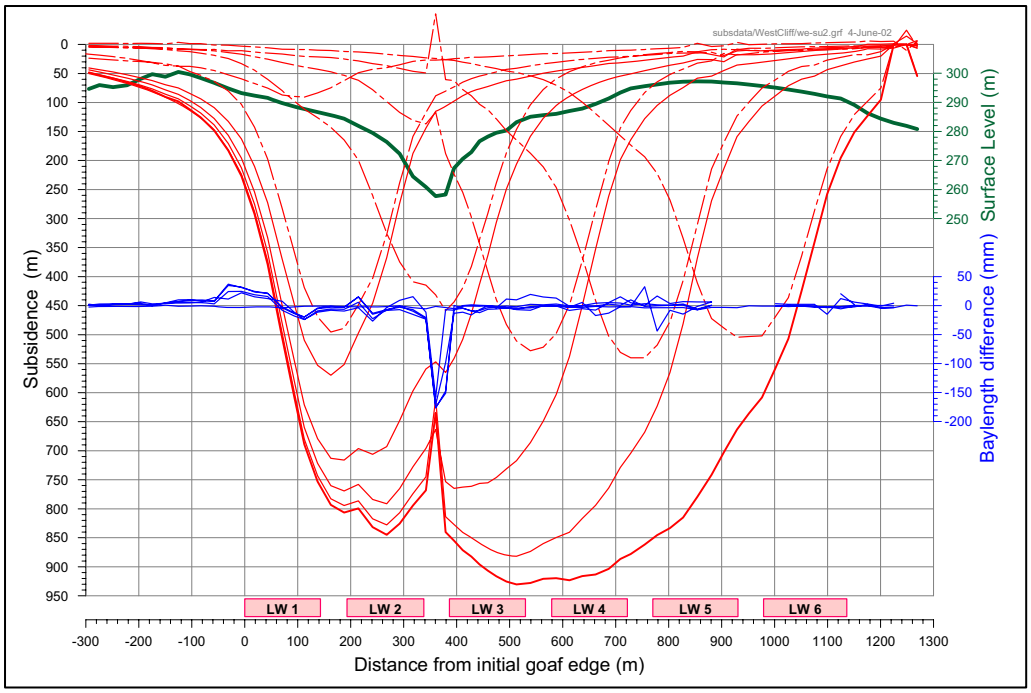


Fig. D.15 Measured Subsidence Profiles over Longwalls 1 to 6 at West Cliff Colliery

In most cases studied, the upsidence effects extend outside the valley and include the immediate cliff lines and the ground beyond them. For example, monitoring within the Cataract Gorge, at Tower Colliery, as Longwalls 8 and 10 were mined, revealed that the upsidence extended up to 300 metres from the centre of the Gorge, on both sides of the Gorge. In that case, the magnitude of the upsidence was greater than the subsidence leading to an overall uplift in the base of the Gorge, consequently leaving it above its original pre-mining level.

In other cases, within creek alignments, upsidence has been observed well outside an extracted panel, apparently due to a beam within the near-surface strata rotating and pivoting as a seesaw, as one end of it rises and the other subsides. However, in these cases, the measured upsidence and strains were less than would be expected to arise from the compressive buckling mechanism described above.

Based upon the empirical evidence, upsidence and closure movements can be expected in cliffs and in the sides of valleys, whenever longwalls are mined beneath or adjacent to them. Such movements, however, tend to be smaller outside the goaf areas and tend to reduce with increasing distance outside the goaf edge. The movements are incremental and increase as each longwall is mined in sequence, and consequently the movements resulting from the mining of one longwall can be spread over several longwalls.

Methods of prediction have been developed for closure and upsidence, as detailed in the ACARP *Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems* (Waddington Kay and Associates, 2002).

The methods used to determine the predicted upsidence and closure for gorges, creek and river valleys were developed using empirical data from the Southern Coalfield. The data was mainly taken from the Nepean and Cataract River Valleys, which are large and steeply incised when compared to many of the valleys within the Hunter and Newcastle Coalfields. It is expected, therefore, that the methods used to determine predicted upsidence and closure movements will provide conservative results for smaller, less incised creek and river valleys within the Hunter and Newcastle Coalfields.

D.7.4. The Prediction of Closure in Creeks and River Valleys

A method has been developed for prediction of closure across creeks and river valleys which is based upon measured data over a wide range of cases, with valley depths varying from 27 metres to 74 metres. This data was mainly collected from collieries in the Southern Coalfield where the valleys are incised into flat lying sedimentary deposits and where the in-situ horizontal stresses are high. However, valley closure has also been observed in other locations and with lower valley depths.

The method is expected to give superior results in areas with geology and stress regimes similar to those from which it was derived. The method is based upon upper-bound measured values and it is anticipated that the method will over-predict in most cases, especially in areas of lower stress. Further research is required to determine how pre-existing in-situ horizontal stress and variations of local geology specifically influence the closure movements.

The method of valley closure prediction was first fully described in the report tilted “Report on ACARP Research Project No C9067 Research into the Impacts of Mine Subsidence on the Strata and Hydrology of River Valleys and Development of Management Guidelines for Undermining Cliffs, Gorges and River Systems” that was published by Waddington Kay & Associates in 2002. Since then new observations of closure have permitted minor improvements to the method of prediction that allow for the detailed prediction of distribution of closure movement profiles across a valley and allow more realistic upper bound predictions when predicting closure and upsidence at large distances from the lateral and longitudinal edges of longwall panels. The minor modifications in the prediction curves are shown on the following figures.

The method for the prediction of closure is based upon a series of graphs that show the interrelationships between closure and a number of contributory factors. The interrelationships between the factors are illustrated in the following figures.

Fig. D.16 shows a graph of closure plotted against the transverse distance from a point in the bottom of the valley to the maingate of the longwall divided by the width of the panel plus the width of the pillar.

Fig. D.17 shows a longitudinal distance adjustment factor plotted against the longitudinal distance from a point in the bottom of the valley to the nearest end of the longwall in metres.

Fig. D.18 shows a valley depth adjustment factor plotted against valley depth.

Fig. D.19 shows an incremental subsidence adjustment factor plotted against the maximum incremental subsidence of the panel.

The graphs provide the original and the revised upper bound prediction curves, which are predominantly based upon closure data from the Cataract and Nepean Gorges, where the maximum incremental subsidence was approximately 410 mm and the depth of gorge was approximately 68 metres. The observed raw data values were "normalised" to account for variations in positions of the monitored creeks with respect to the panel edges and for variations in the magnitude of the maximum incremental subsidence over the mined panel and for variations in the valley depths. Large adjustment factors had to be applied to some of the raw observed data points and, where the raw data point is smaller than the survey tolerance, this magnification is also applied to the survey errors. Accordingly judgement was required to determine where to fit the new prediction curves, which are found to be above 90% of the adjusted observed closure data.

The closure is initially predicted from the graph shown in Fig. D.16 and the value so obtained is adjusted with reference to the graphs shown in Fig. D.17 to Fig. D.19, depending on the position of the bottom of the valley relative to the end of the longwall, the valley depth and the maximum incremental subsidence of the longwall.

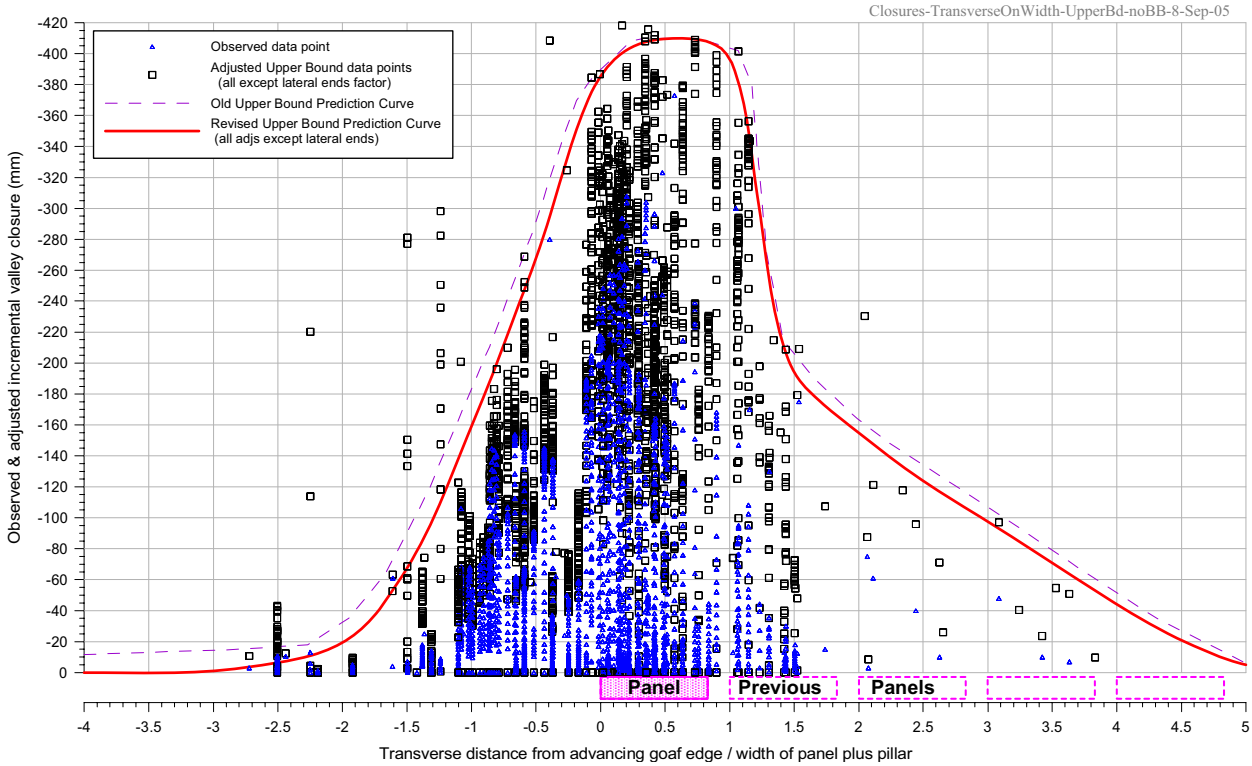


Fig. D.16 Valley Closure versus Distance from the Maingate of the Longwall relative to the Width of the Panel plus the Width of the Pillar

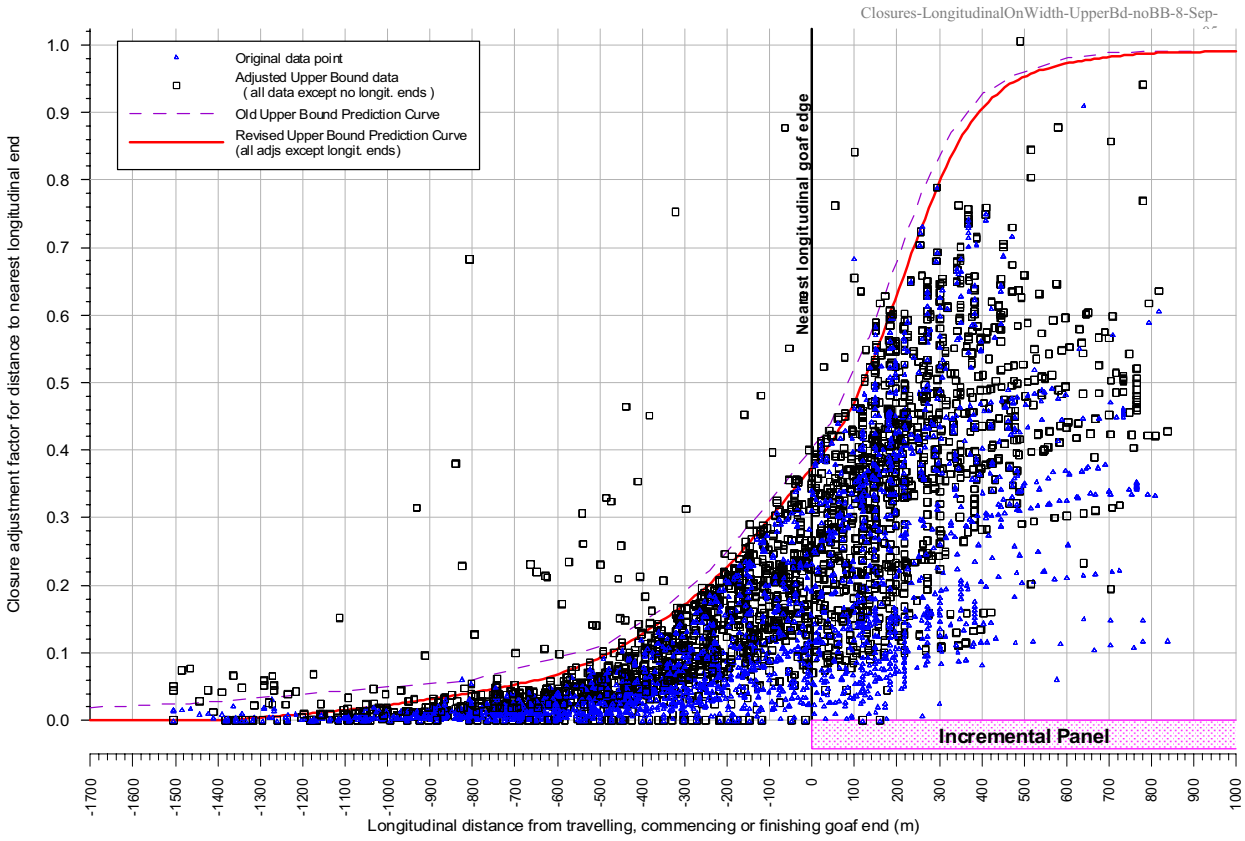


Fig. D.17 Valley Closure Adjustment Factor versus Longitudinal Distance

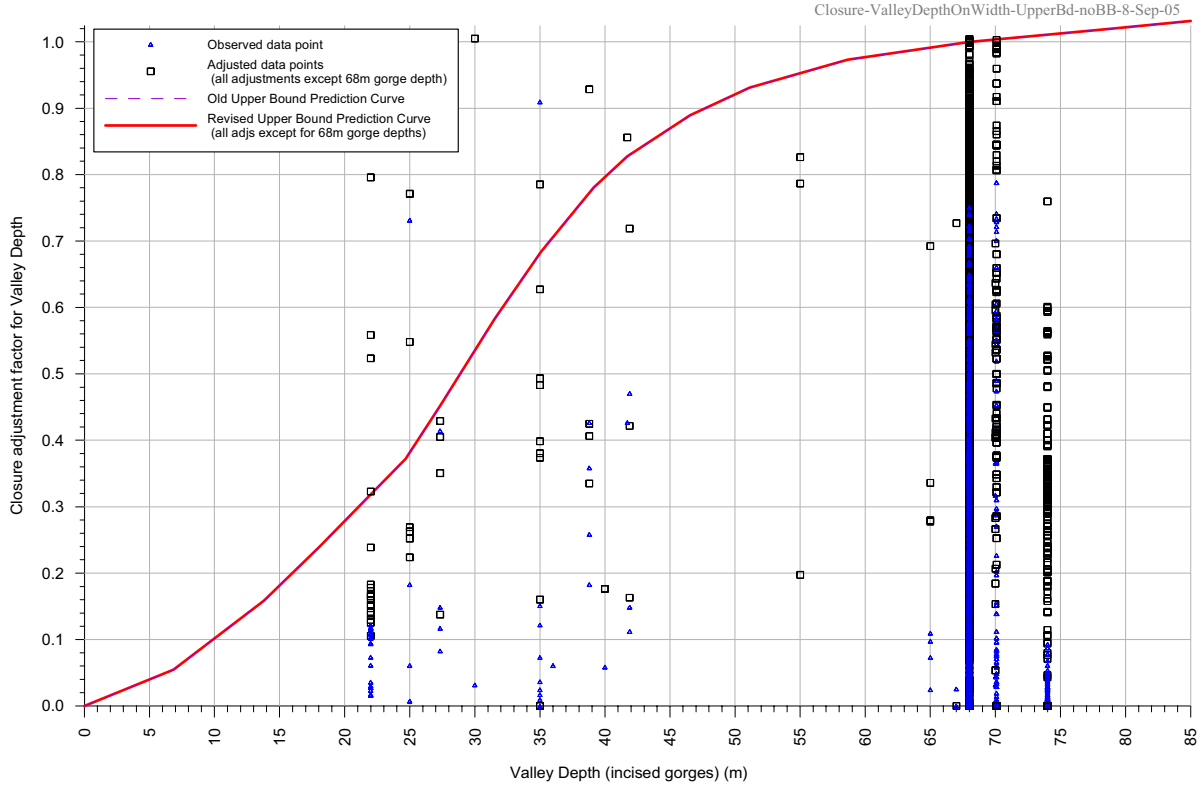


Fig. D.18 Valley Closure Adjustment Factor versus Valley Depth

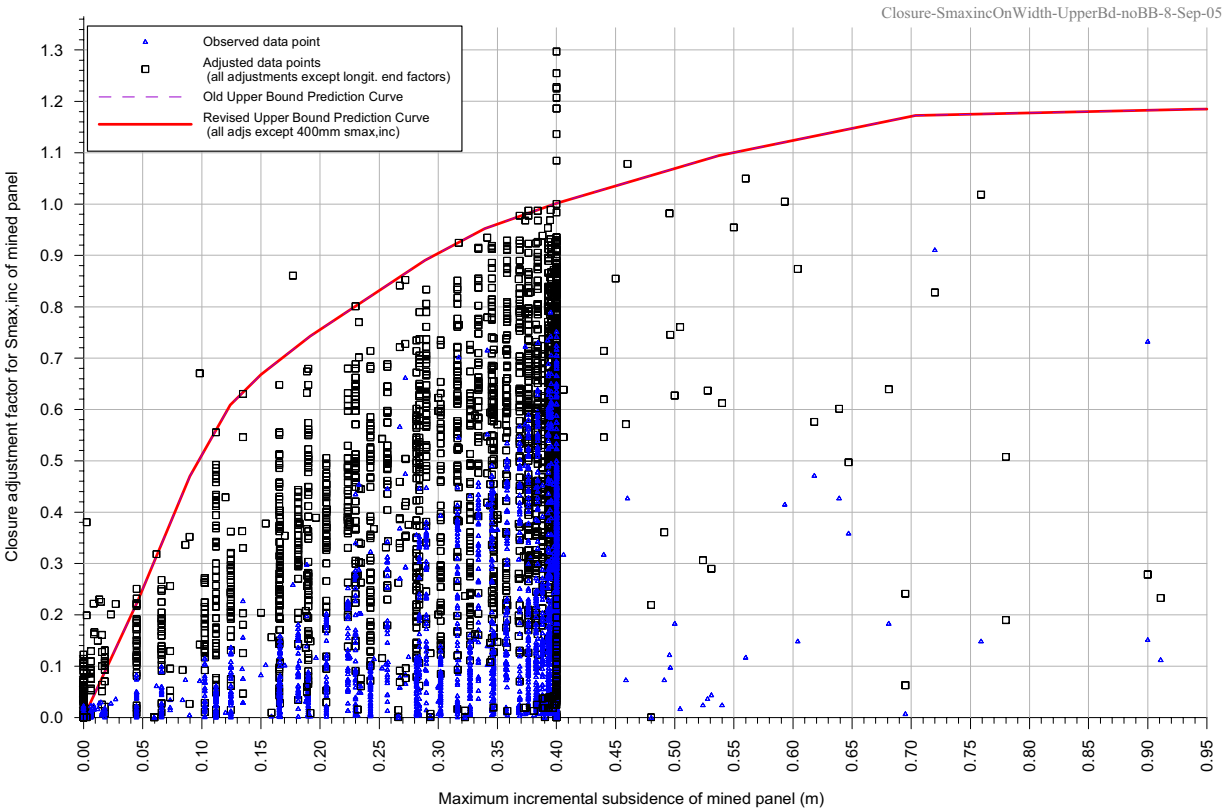


Fig. D.19 Valley Closure Adjustment Factor versus Maximum Incremental Subsidence

Fig. D.20 shows the distance measurement convention used to define the location of the point in the creek for which closure and upsidence predictions are required.

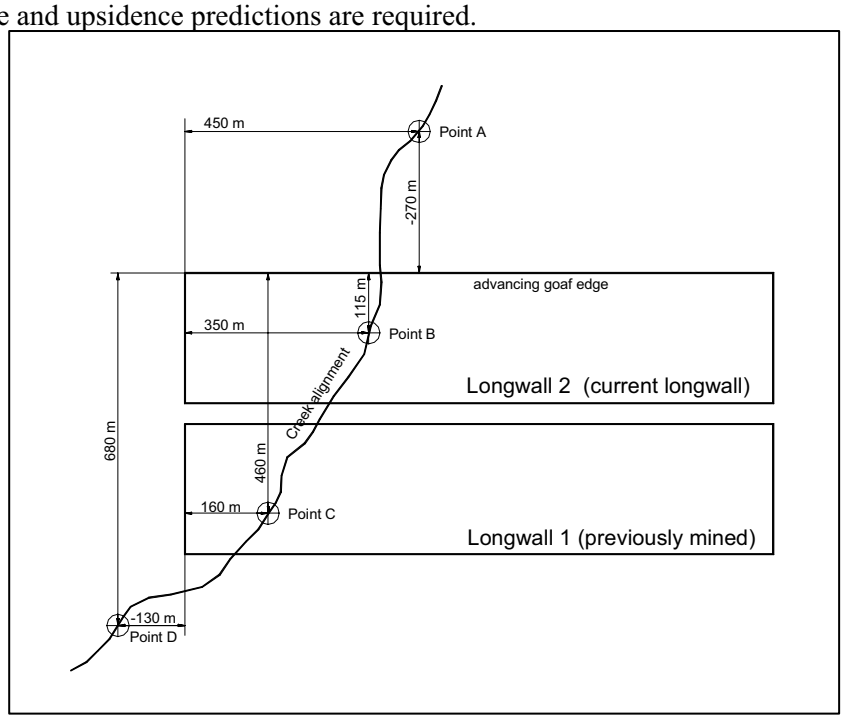


Fig. D.20 Distance Measurement Convention for Closure and Upsidence Predictions

The transverse distances plotted in Fig. D.16 are the distances measured at right angles to the maingate of the longwall expressed as a proportion of the width of the panel plus the width of the pillar. The transverse distances for points A, B, C and D in Fig. D.20 are -270 metres, 115 metres, 460 metres and 680 metres, respectively, distances outside the goaf being negative.

The longitudinal distances plotted in Fig. D.17 are the distances from the nearest end of the longwall, measured parallel to the longitudinal centreline of the longwall. These distances for points A, B, C and D in Fig. D.20 are 450 metres, 350 metres, 160 metres and -130 metres, respectively, distances outside the goaf again being negative.

To make a prediction of closure at a point in the base of a creek or river valley, it is necessary to know the distance of the point from the advancing edge of the longwall, the longitudinal distance from the nearest end of the longwall, the valley depth, the maximum incremental subsidence of the panel that is being mined and the panel and pillar widths.

D.7.5. The Prediction of Upsidence in Creeks and River Valleys

The method developed for the prediction of upsidence in creeks and river valleys is similar to that described above for the prediction of closure. The method is based upon measured data over a wide range of cases, with valley depths varying from 8 metres to 87 metres. The data was mainly collected from collieries in the Southern Coalfield where the valleys are incised into flat lying sedimentary deposits and where the in-situ horizontal stresses are high.

The method of prediction would therefore be expected to give superior results in areas with similar geology and similar stress regimes. The method has also been modified based on new data received since the ACARP report was published in 2002. The method is based upon upper-bound measured values and it is anticipated that the method will over-predict in most cases, especially in areas of lower stress. Again, further research is required to determine how pre-existing in-situ horizontal stress and local variations in geology specifically influence the upsidence movements.

The prediction of upsidence is based upon a series of graphs that show the interrelationships between upsidence and a number of contributory factors. The interrelationships between the factors are illustrated in the following figures.

Fig. D.21 shows the graph of upsidence plotted against the transverse distance from a point in the bottom of the valley to the maingate of the longwall divided by the width of the panel plus the width of the pillar.

Fig. D.22 shows a longitudinal distance adjustment factor plotted against the longitudinal distance from a point in the bottom of the valley to the nearest end of the longwall in metres.

Fig. D.23 shows a valley depth adjustment factor plotted against valley depth.

Fig. D.24 shows an incremental subsidence adjustment factor plotted against the maximum incremental subsidence of the panel.

The graphs provide the original and the revised upper bound values, which are mainly based upon upsidence data from the Cataract Gorge, where the maximum incremental subsidence was approximately 350 mm and the depth of gorge was approximately 70 metres.

The transverse distances plotted in Fig. D.21 are the distances measured at right angles to the maingate of the longwall, expressed as a proportion of the width of the panel plus the width of the pillar. Fig. D.20 shows the distance measurement convention used to define the location of the point in the creek for which closure and upsidence predictions are required.

To make a prediction of upsidence at a point in the base of a creek or river valley, it is necessary to know the distance of the point from the advancing edge of the longwall, the longitudinal distance from the nearest end of the longwall, the valley depth, the maximum incremental subsidence of the panel that is being mined and the panel and pillar widths.

The initial prediction of upsidence is made using the upper-bound curve in Fig. D.21, for the relevant transverse distance divided by panel plus pillar width. The value of upsidence is then adjusted by multiplying it by the factors obtained from the upper-bound graphs from Fig. D.22 to Fig. D.24.

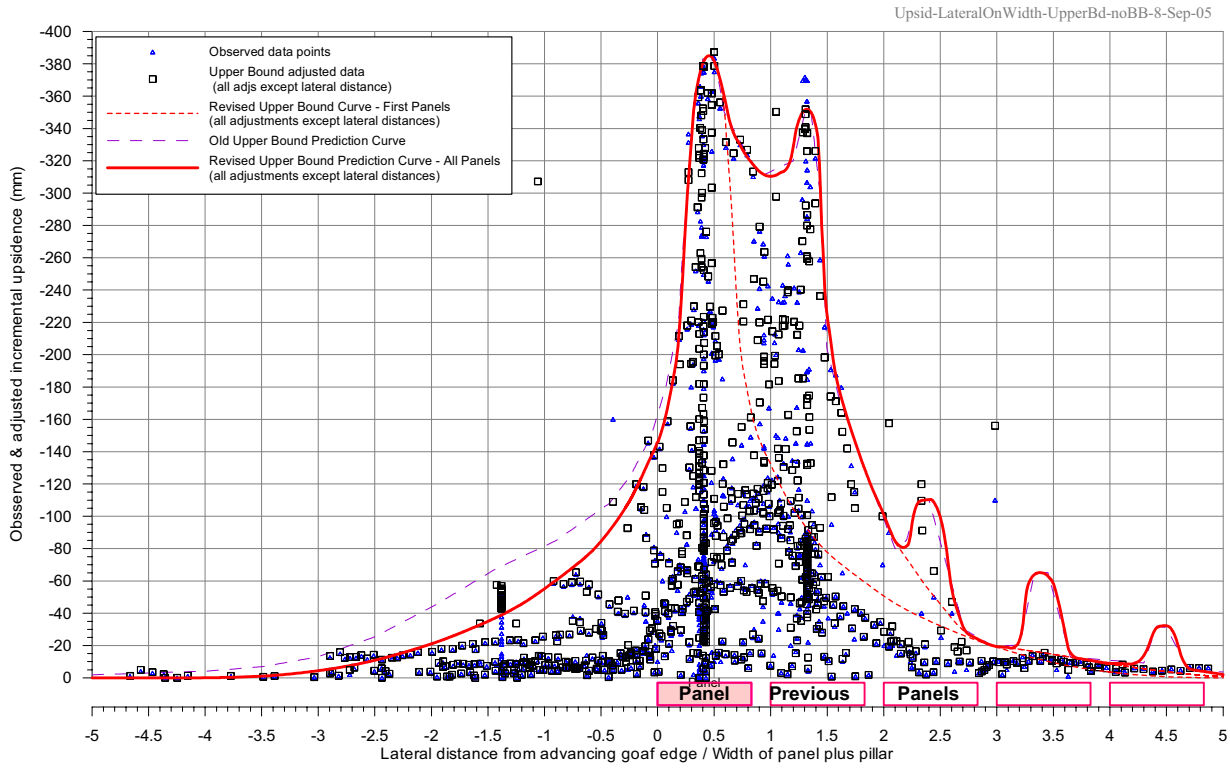


Fig. D.21 Upsidence versus Distance from the Maingate of the Longwall relative to the Width of the Panel plus the Width of the Pillar

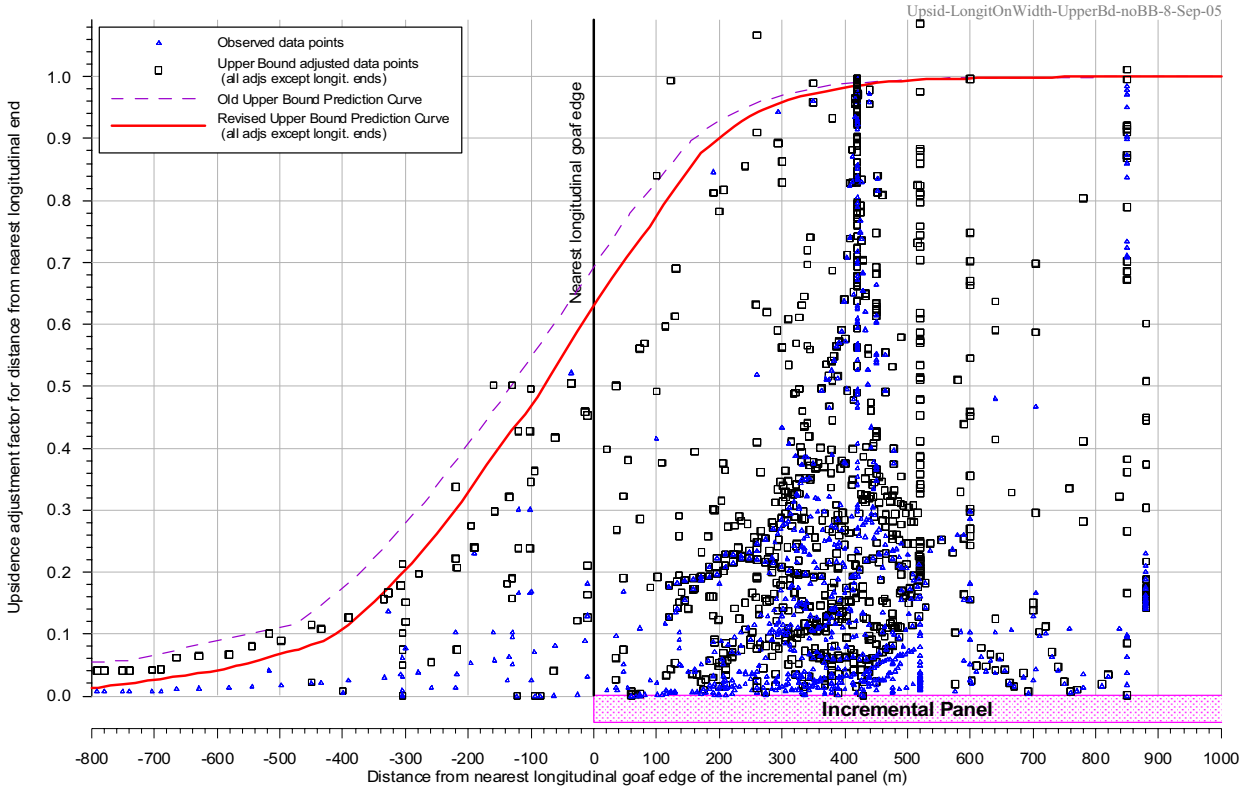


Fig. D.22 Upsidence Adjustment Factor versus Longitudinal Distance

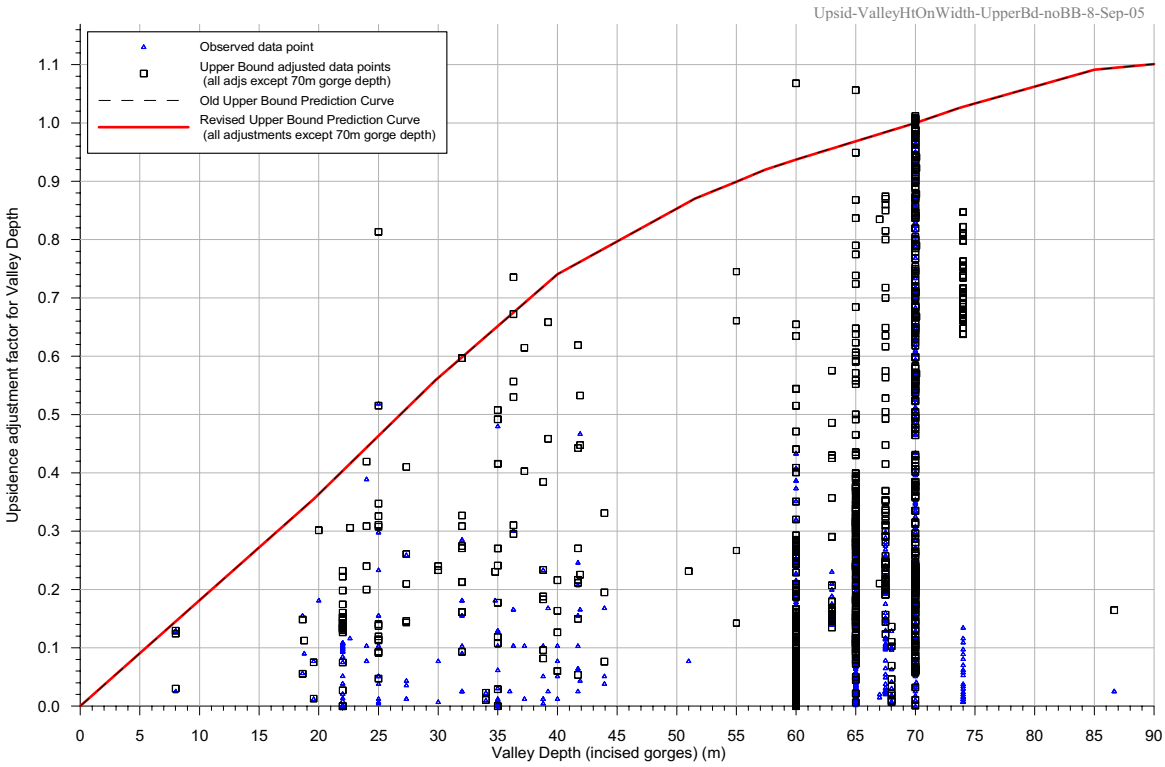


Fig. D.23 Upsidence Adjustment Factor versus Valley Depth

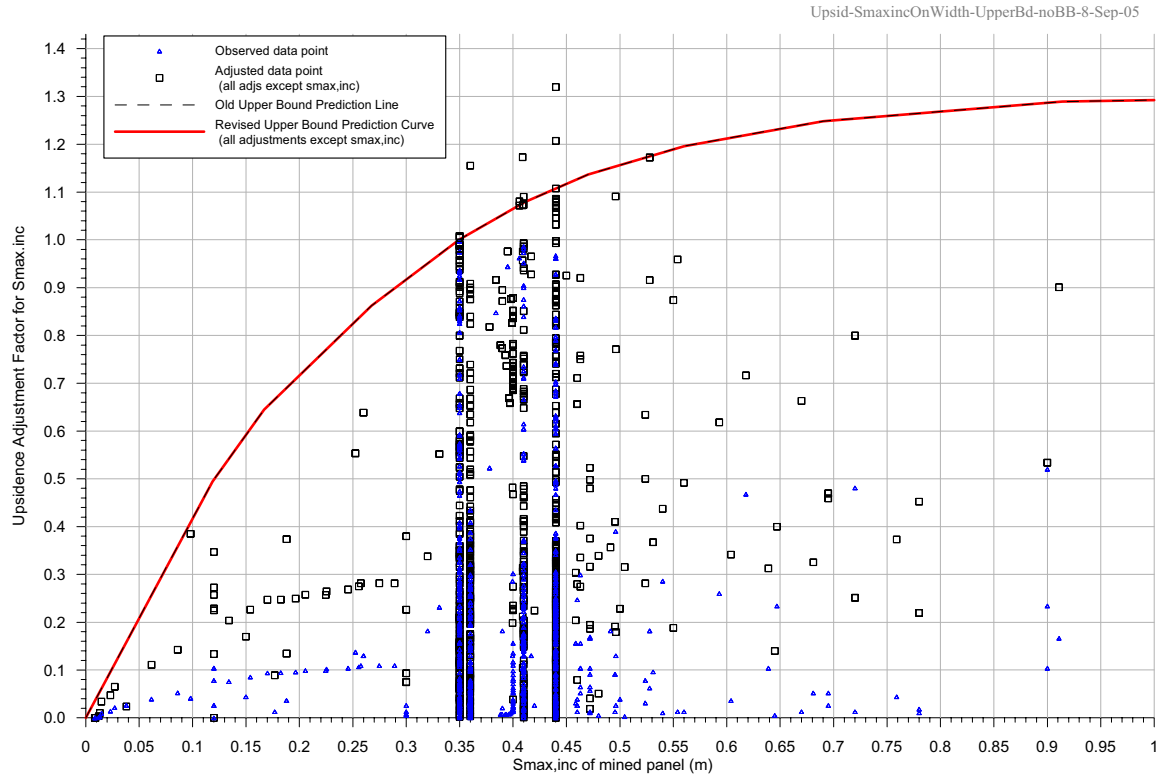


Fig. D.24 Upsidence Adjustment Factor versus Maximum Incremental Subsidence

D.7.6. The Lateral Distribution of Upsidence

Upsidence is the result of two separate mechanisms, namely, valley bulging and buckling of the strata in the base of the valley. The maximum upsidence occurs in the base of a creek or river valley, where the strata buckling occurs, but the upsidence effect spreads outwards under the sides of the valley for a considerable distance due to valley bulging.

For example, in the Cataract Gorge above Longwall 8 at Tower Colliery, whilst the upsidence in the base of the gorge was 350 mm, the upsidence in the cliffs was around 100 mm and the upsidence effect extended for a distance of 300 metres on each side of the gorge.

Fig. D.25 shows idealised profiles of upsidence across the Cataract gorge, both along the goaf edge of a longwall and along the centreline of the longwall. It can be seen that the lateral spread of the upsidence was greater where the amplitude of the upsidence was greater. Further research is required in order to develop a more definitive method for the prediction of upsidence profiles, but in the meantime it seems reasonable to model the profiles on the upper measured profile shown in Fig. D.25. An approximate profile can be obtained by scaling both the width and amplitude of the profile in proportion to the predicted upsidence value. It should be noted, however, that the predicted profile can only be approximated since the actual buckling will depend upon local geology and might not be centrally positioned in the bottom of the valley or gorge.

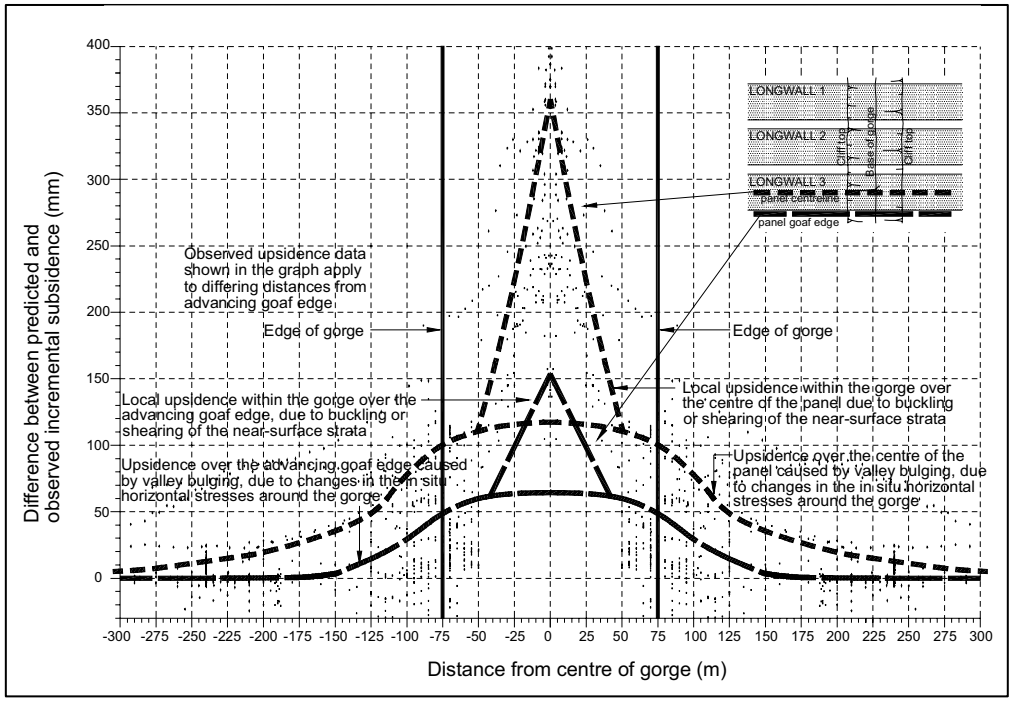


Fig. D.25 Idealised Upsidence Profiles across the Cataract Gorge

D.7.7. The Prediction of Compressive Strains in Creeks and River Valleys

The method of prediction for compressive strain due to closure was developed as part of the ACARP study (2002). The method provides an indication of the maximum compressive strains that might be experienced as a result of mining by adopting an upper bound relationship between observed closure and maximum compressive strain. This relationship is shown in Fig. D.26. The predicted closure, obtained using the method described in Section D.7.4, is the overall closure across the valley.

The predicted strain is the average strain over a bay length of 20 metres and is assumed to occur within the lowest part of the valley. The closure of this bay can, therefore, be determined from the predicted strain. The closure over this bay length can be greater than the overall closure of the valley, due to expansion in the valley sides as the horizontal stresses are relieved.

It is believed that the closure and strain are both driven by the in-situ horizontal stress and it is reasonable to assume that the compressive strains will reduce as the in-situ stress reduces. Since the graph in Fig. D.26 has been based on data that is primarily from observations at Tower Colliery, where the in-situ stress is particularly high, it is expected that the graph will generally be conservative and could over-predict strains by 100% in some cases, particularly where the predicted levels of strain are low. The data spread in the graph shows the variations that have occurred in practice and provides a guide to the potential range of strains that might occur in a particular case.

Since the completion of the ACARP study, an examination of observed ground movements suggest that the predictive method is mainly applicable for creeks and valleys that are located directly above extracted longwalls. However, it has been found that observed maximum compressive strains are substantially less in locations that are not directly above extracted longwalls. An upper bound relationship between compressive strain and lateral and longitudinal distance from longwalls is provided in Fig. D.27 and Fig. D.28. It is hoped that further analysis of observed ground movements will be conducted in the future, so that the method for predicting maximum compressive strains can be improved.

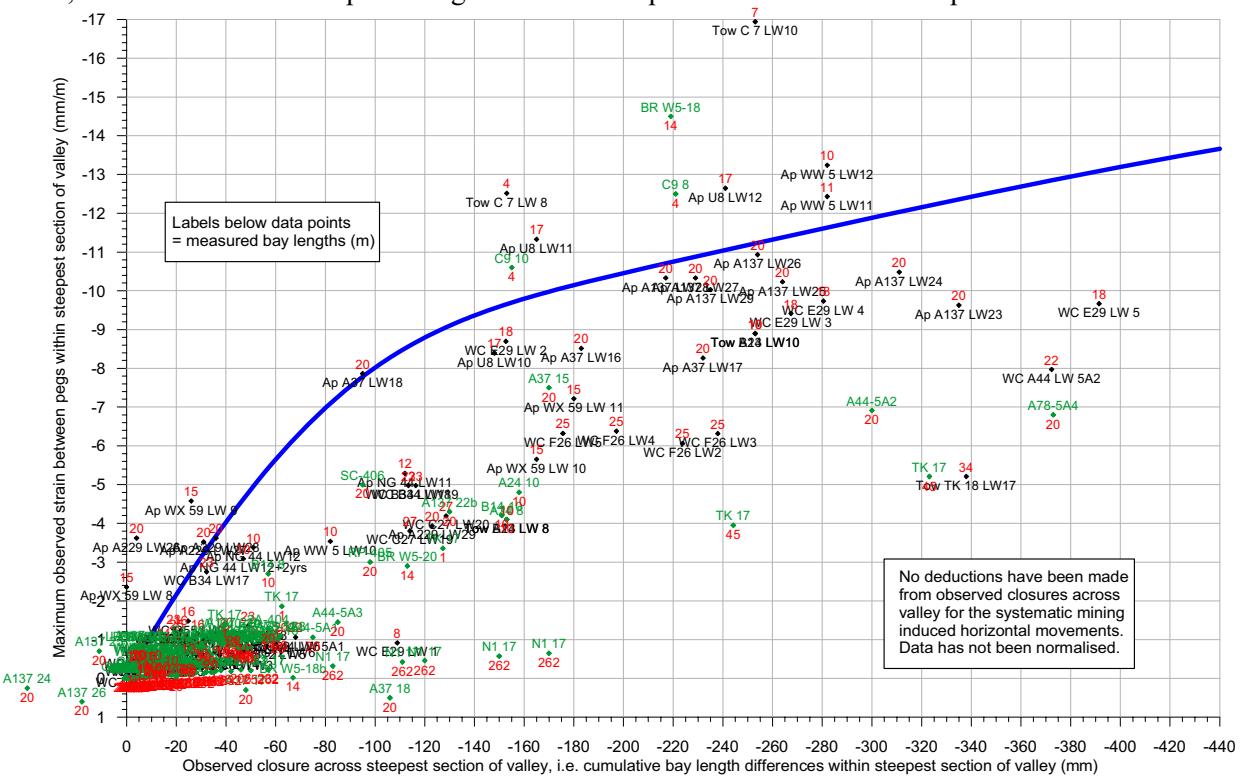


Fig. D.26 Graph of Maximum Compressive Strain versus Valley Closure

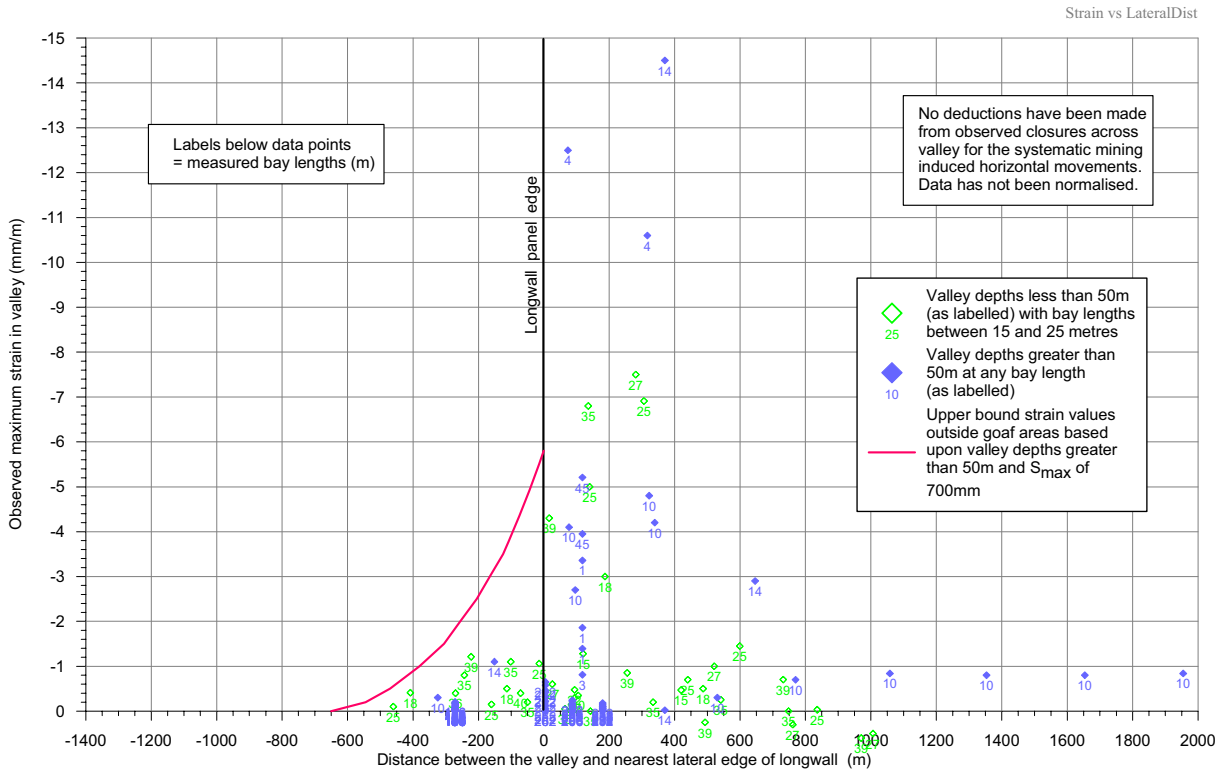


Fig. D.27 Graph of Maximum Compressive Strain versus Lateral Distance

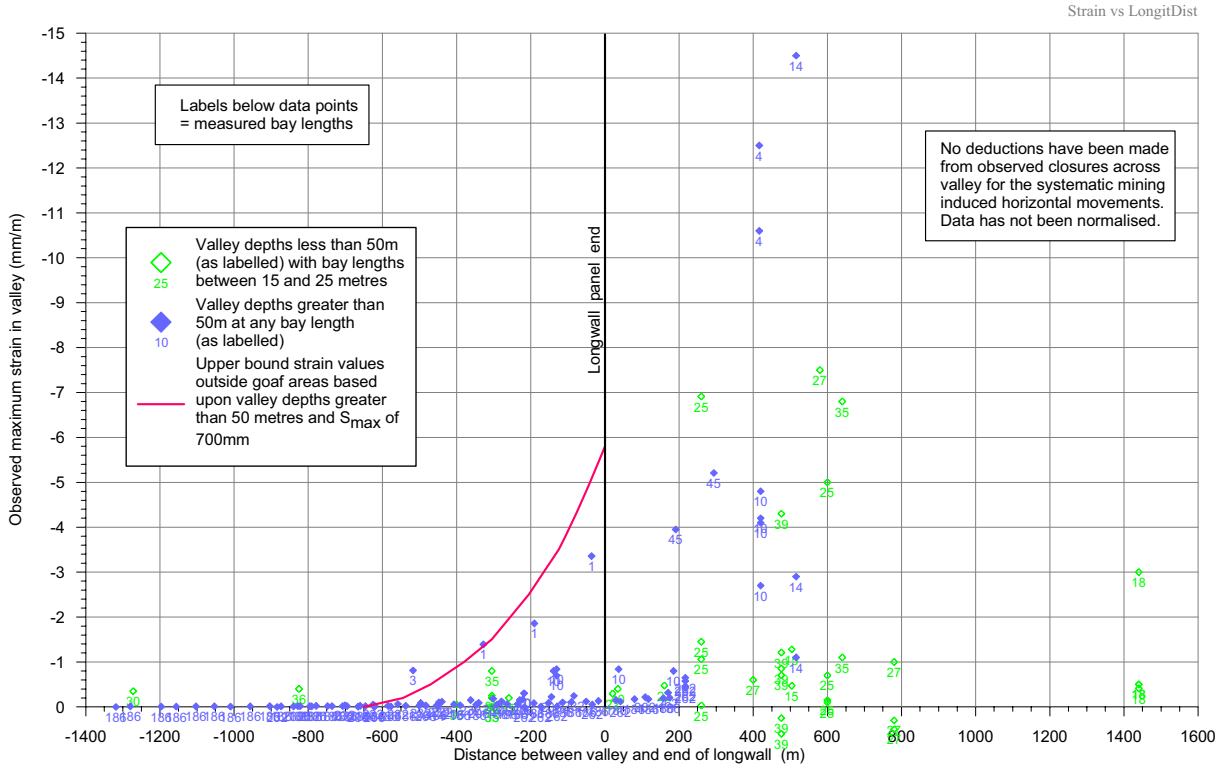


Fig. D.28 Graph of Maximum Compressive Strain versus Longitudinal Distance

D.7.8. Irregular Subsidence Profiles

D.7.8.1. Definition of an Anomaly

An anomaly is defined as a significant irregular or non-systematic ground movement, which was not expected to occur. Small fluctuations in survey lines are not categorised as anomalies as these rarely affect surface features and are often within survey tolerance.

Systematic subsidence movements due to longwall extraction are particularly easy to identify as longwalls are regular in shape and the extracted coal seams are relatively uniform in thickness. Systematic subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata collapsing into a void.

As a general rule, the smoothness of the profile is governed by the depth of cover and lithology of the overburden. Where the depth of cover is greater than 400 metres, such as in the Southern Coalfield, the subsidence profiles along monitoring lines are generally smooth. Where the depth of cover is less than 100 metres, such as in the Hunter and Newcastle Coalfields, the subsidence profiles along monitoring lines are not generally smooth.

Even where the subsidence profiles are smooth, at locations with a high depth of cover, however, localised non-systematic ground movements have been observed along monitoring lines on some occasions. The causes behind the majority of these movements can be interpreted and are outlined in Section D.7.8.2. These include valley upsidence and closure, the influence of geological structures and issues related to the installation or surveying of monitoring lines.

Even though it is possible to attribute a reason behind most non-systematic ground movements, there remain some movements that still cannot be explained. These are termed “anomalies”, and their presence can sometimes impact surface features. Suggested reasons for some of these movements are discussed later in the report. In summary, it is believed that these anomalies are a result of the reaction of near-surface strata to increased horizontal compressive stress due to mine subsidence.

While the causes of anomalies are not yet fully understood, it is hoped that they will be better understood as the development of mine subsidence knowledge progresses. This may then allow these movements to be predicted, so that surface features can be better protected in the future.

D.7.8.2. Method of Identification of Anomalies along Monitoring Lines

Anomalies have been identified from observed subsidence profiles by a process of elimination. If a cause behind an irregularity in a subsidence, tilt or strain profile cannot be determined, the irregularity is recorded as an anomaly. All significant irregularities in the subsidence, tilt and strain profiles have been identified along each monitoring line, and the cause of each irregularity has been described and recorded. The most common causes of irregular or non-systematic movements are listed below.

- Valley upsidence and closure
- Geological Structures
- Change in direction of monitoring line
- Bumped pegs
- Damaged pegs
- Survey Line Discontinuities
- Survey Errors

D.7.8.3. Potential Causes of Anomalies

There are a number of possible causes of anomalies, the majority of which are due to local near-surface geology.

Upsidence and closure in unknown "hidden" creeks which have been filled in by geological processes or by infrastructure development. This cause could be eliminated by examination of topography and lithology records.

- The possible presence of an unknown fault, dyke or other geological structure.
- Buckling due to increased horizontal stress concentrations, similar to those experienced in valleys.
- Buckling due to cross bedding or blocky behaviour of the near surface strata.
- Rotation of near-surface strata over the goaf edge.
- The presence of a stronger stratum capable of forming a natural corbel at the goaf edge.

It is observed that the major observed anomalies have behaved in a similar manner. The anomalies show an upwards bulge, or upsidence in the subsidence profile, coupled with a local concentration of compressive strain. In some cases, a localised surface "wrinkle" has formed at the point of maximum compression.

It is generally considered that the ground within the subsidence trough is in tension close to the edge of the longwall and in compression close to the centre of the longwall. This, however, is only true for the immediate surface of the bedrock. The strata behaves as a series of distinct beds of varying strengths that separate due to shearing along planes of weakness as subsidence occurs. The strata can therefore be looked upon as a series of relatively thin slabs laying one upon the other.

The underside of the uppermost stratum, following subsidence, is in compression close to the goaf edge and in tension close to the centre of the longwall, contrary to what the upper surface of the stratum is experiencing. It is these changes in stress between the upper surface of one layer and the lower surface of the layer above it that results in the shearing between the beds and the resulting bed separation.

In the Hunter and Newcastle Coalfields, the in-situ horizontal stresses in the strata can be greater than the vertical stresses, even close to the surface. The strata are being compressed on all sides, with the exception of the surface, which is not vertically constrained. As subsidence occurs and the normal collapse mechanisms initiate, the strata above and close to the longwall move inwards to fill the void. This allows the strata outside the subsidence trough to expand towards the goaf area.

At the same time, the horizontal stresses in the strata are redistributed above and below the seam causing increases in stress above the collapse zone, which results in elastic shortening, horizontally, and elastic expansion, vertically. The strata on each side of the collapse zone expands towards the goaf and are partially stress relieved resulting in vertical shortening of the strata and increased subsidence movements well outside the angle of draw.

This redistribution of horizontal stress extends for a considerable distance outside the goaf area, with measurable displacements almost three kilometres away. It is believed that this expansion towards the longwall goaf areas, due to the relaxation of in-situ horizontal stress in the strata is the cause both of the far-field horizontal displacements and the unusually high vertical subsidence displacements that sometimes occur beyond the angle of draw.

All of the subsidence mechanisms are driven by in-situ stresses and gravitational forces, which are compressive. None of the driving forces behind the subsidence-induced movements are tensile. Generally, when the strata are vertically confined, they behave systematically. The irregularities that occur in subsidence profiles are therefore a surface phenomenon that is driven by compressive forces.

The surface strata can be likened to an ice flow, in which the individual blocks of ice are displaced due to the pressures exerted on them by their neighbours and by the underlying currents in the water beneath them. The blocks can buckle upwards or one block can shear and ride over the top of its neighbour. In some cases the blocks can be forced upwards to form arches or ridges. Not all movements are in the vertical plane and in some circumstances horizontal shearing can occur as one block slides past another, being propelled by a greater force and facing less resistance than its neighbour.

It is conjectured that the major anomalies that have been recorded were due to arching and buckling of near-surface strata as mining resulted in bed separation. It is also possible that shearing in underlying cross-bedded strata could initiate the anomaly, but there has been no stepping in the surface, which suggests that the near-surface strata have buckled rather than sheared.

It is interesting to note that the most likely place for compressive buckling to occur at the surface is where the surface is convex, or hogging. This is because the tendency in that situation is for the rocks to buckle upwards when compressed horizontally and to fail in bending tension or in shear. Where the strata are concave, or sagging, the underlying strata restrain the buckling and, generally, failure would occur only when the applied horizontal stresses exceeded the compressive strength of the strata, which is much greater than its tensile or shear resistance.

The in-situ horizontal stress increases in intensity with depth, but the stresses still exist close to the surface. The stresses are distributed throughout the strata according to the stiffness of each unit and the weaker strata attract a smaller proportion of the stress than the stronger strata. The way in which the surface strata will behave is, therefore, dependent upon the nature of the surface and near-surface rocks.

As mining occurs, subsidence and redistribution of in-situ horizontal stress results in bed separation and each stratum, particularly those at the surface, which are less confined by the weight of the rocks above them, becomes an independent and relatively slender compression member.

In this situation, very little eccentricity of loading or curvature of the member is required to initiate arching, followed by buckling. The initial buckling is a result of the in-situ horizontal stress and the movement is exacerbated as subsequent longwalls are mined and the longwalls get closer to the anomaly.

The increased subsidence over the goaf was initially difficult to understand, because it was anticipated that subsidence would be reduced in the high stress regime. A possible explanation, for the increased subsidence, is that the strata in the collapse zone had already been partially stress relieved by the adjacent goaf areas and thus offered less horizontal confinement, therefore allowing greater subsidence to occur.

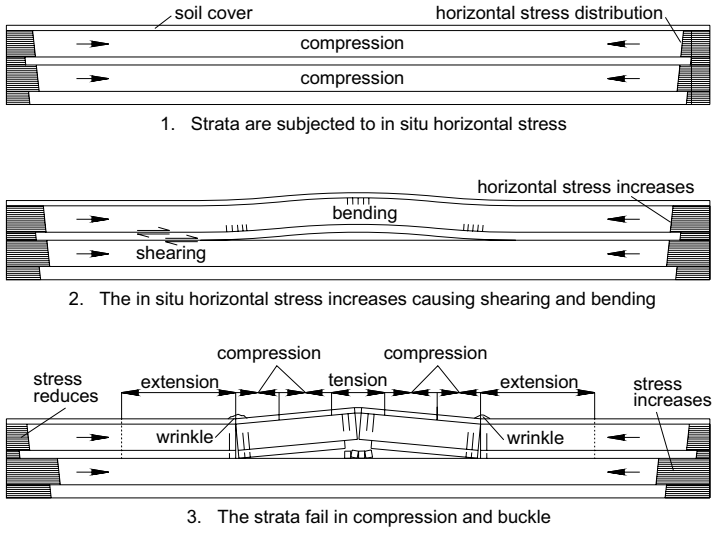


Fig. D.29 Strata Buckling Mechanism due to In-situ Horizontal Stress

The way in which buckling develops is illustrated in Fig. D.29. The phenomenon starts as bed separation occurs in the near-surface strata, due to shearing between beds as the in-situ stresses in the strata are redistributed. The stress in a particular stratum results in bending occurring, either due to eccentricity of loading or curvature of the stratum and the stratum arches upwards.

As the subsidence impact increases, the stratum starts to crack on its convex surfaces as the rock fails in bending tension. If the mining-induced stress continues to increase and the tensile fractures continue to develop to the full depth of the stratum, the stratum eventually fails in compression and buckles upwards. The buckling releases the horizontal confining stress in the stratum on both sides of the buckle and allows the stratum to expand horizontally and locally relieve the compressive stress. The stress relief in the surface stratum transfers additional stress into the strata below it and this can result in progressive failure and buckling through a number of strata, until the buckling of a stratum is prevented by the weight of the rocks above it.

When buckling occurs, the resultant strains measured at the surface can vary considerably from the predicted systematic strains and can alternate between compressive and tensile, even though the strata are consistently being compressed. It is this erratic behaviour of the surface strata that results in the scatter in measured strain profiles. The measurement of strain does not differentiate between a real extension of an unstressed stratum under applied bending stress and the expansion of a stratum due to compressive stress relief. The measured strains can therefore give a false impression of the state of stress in the surface strata.

It is probable that the most substantial impact to building structures in the Southern Coalfield is due to the buckling of surface strata under the influence of in-situ horizontal stress. Generally the underlying systematic levels of tensile and compressive strain are too low to result in significant impact and the worst impact has been associated with anomalous behaviour of the strata, where curvatures, strains and tilts have been increased.

D.7.9. The Prediction of Incremental Far-Field Horizontal Movements

In addition to the 'normal' and topographically related movements, far-field (ie: regional) movements have also been recorded in a number of cases, at considerable distances from the longwall goaf areas. Such movements have often been several times higher than the vertical subsidence movements measured at the same locations.

It has been conjectured that these far-field movements are caused by redistribution of the stresses in the strata between the seam and the surface due to the regional mining activity. The direction of such movements would tend to be towards the active mining, but the direction of movement could also be dependent upon the scale and proximity of adjacent goaf areas.

It has been suggested by some authors that the far-field movements are generally aligned with the principal horizontal in-situ stress direction. However, it seems more reasonable to suggest that the movements will be directed from areas of high stress towards areas where the confining stresses have been reduced by mining activity, thus allowing expansion of the strata to occur. The stresses within the strata are generally compressive in all directions and until mining occurs the stresses are in equilibrium, the balance being controlled by the shear resistance within and between strata units. As mining occurs, the equilibrium is disturbed and the stresses have to achieve a new balance by shearing through the weaker strata units and by expanding into areas of greatest dilation, i.e. towards the goaf areas, where the confining stresses have been relieved.

An empirical database of observed far-field horizontal movements has been compiled using monitoring data primarily from the Southern Coalfield of New South Wales in Australia. The monitoring data was collected from Collieries including Appin, Bellambi, Dendrobium, Tower and West Cliff. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwall. At low levels of far-field horizontal movements, however, there was a high scatter in the orientation of the observed movements.

Fig. D.30 shows the observed incremental far-field horizontal movements, resulting from the extraction of a single longwall, relative to the distance from the longwall. It can be seen from this figure that incremental far-field horizontal movements of up to 20 mm have been observed at distances of 2000 metres from extracted longwalls.

Fig. D.31 shows the observed incremental far-field horizontal movements, resulting from the extraction of a single longwall, relative to the distance from the longwall, for cases where there was solid coal between the longwall and the monitoring points. It can be seen by comparing Fig. D.30 and Fig. D.31, that the magnitudes of observed incremental far-field horizontal movements are generally less where there is solid coal between the longwalls and monitoring points.

The maximum movements tend to occur when the second and third longwalls are mined in a series, and tends to decline as subsequent longwalls are mined. This is possibly due to the fact that once the strata has been stress relieved by the first few longwalls, the potential for further movement is reduced.

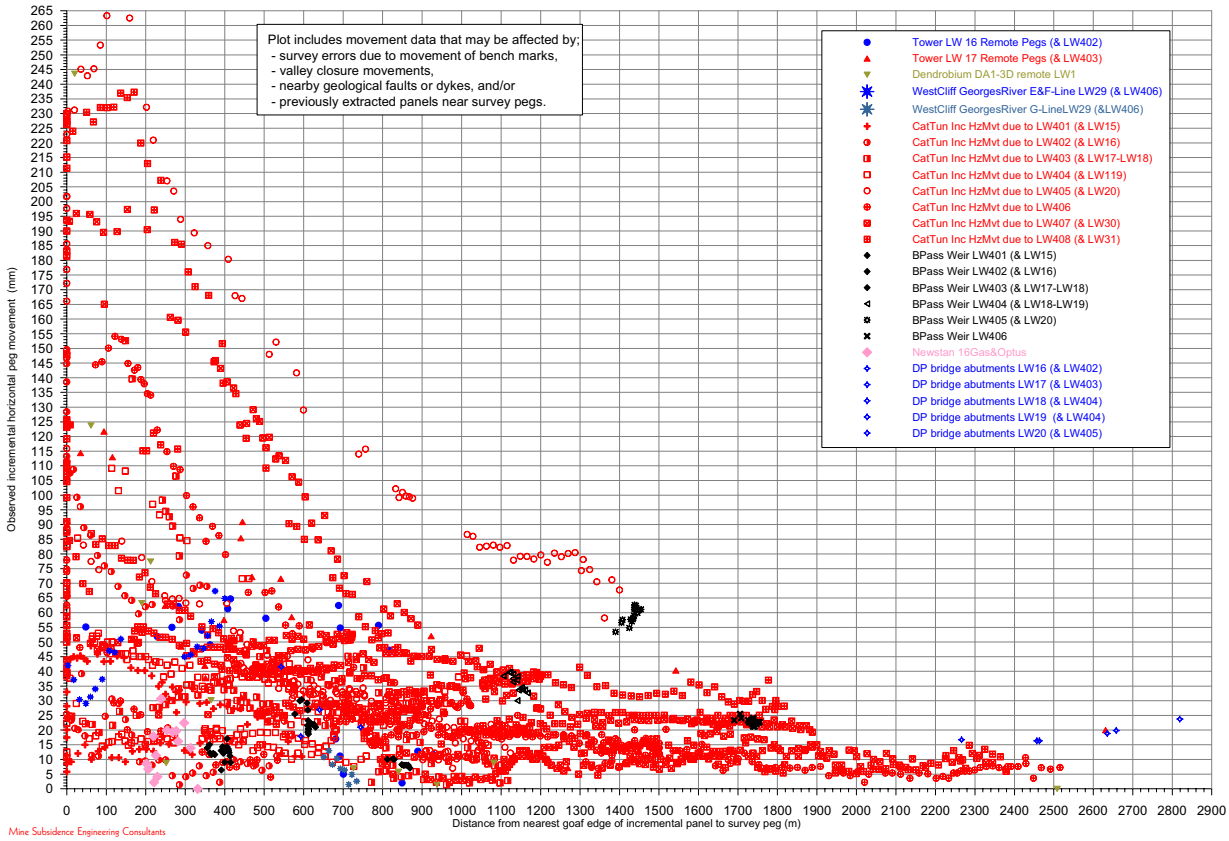


Fig. D.30 Observed Incremental Far-Field Horizontal Movements

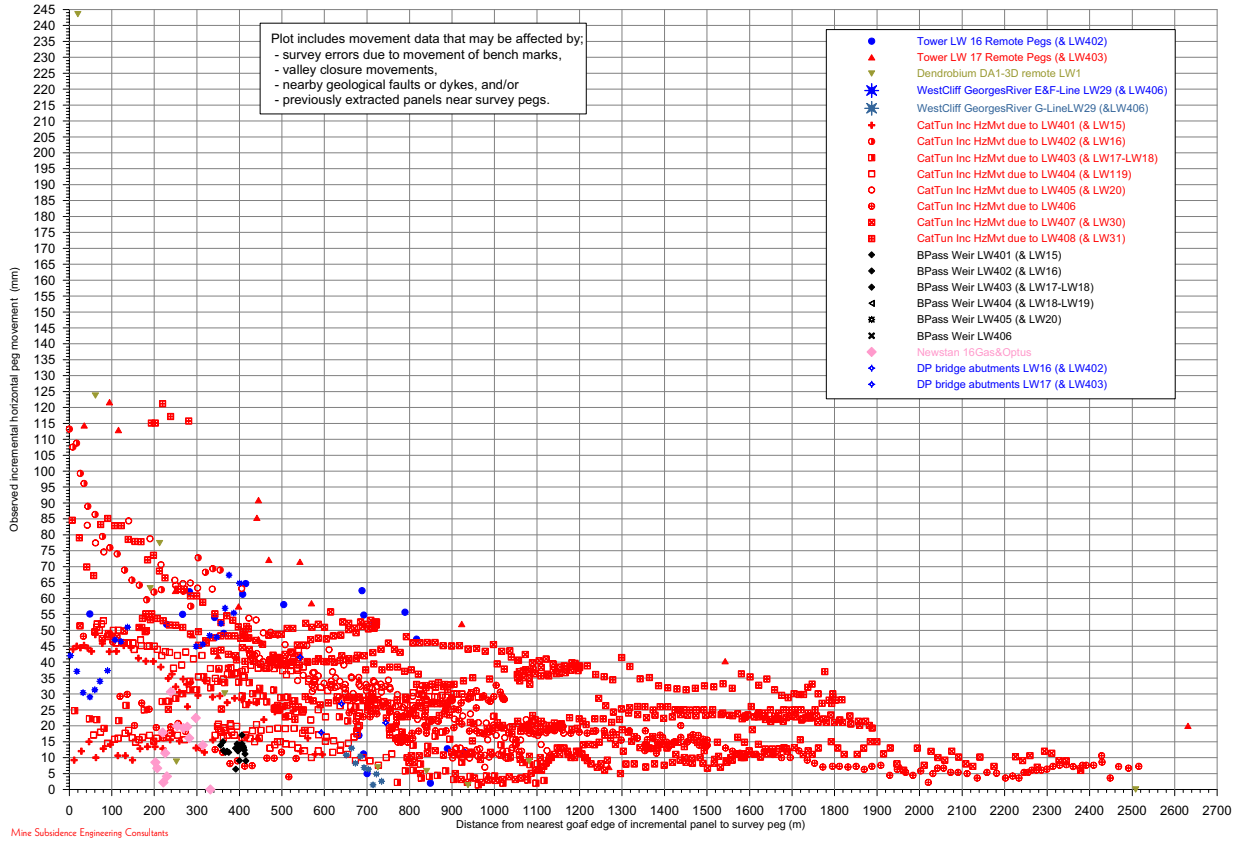


Fig. D.31 Observed Incremental Far-Field Horizontal Movements with Solid Coal between the Monitoring Points and Mined Longwall

D.8. Sub-Surface Strata Movements above Extracted Panels of Coal

D.8.1. Collapse Mechanisms

Before the strata above an underground excavation are disturbed, all points beneath the surface are under compression from the weight of the overburden, and from pre-existing in-situ horizontal stresses, and are in a state of equilibrium. The extraction of panels of coal, by continuous miner or longwall mining operations, creates voids, which upset the balance of forces in the strata, causing displacements to occur until a new state of equilibrium is reached.

The overall force field in the strata, outside and around the extracted void, remains unchanged and the stresses have to readjust locally around the void to achieve this new state of equilibrium. The void provides the compressed rock with a space into which it can expand, and in so doing relieve the stresses that initiated the movement.

Because the extracted voids are generally much wider than the height of the seam, the initial movements tend to be vertical displacements of the roof and floor of the void, movements of the roof being assisted to a greater extent by gravity. Once the vertical movement occurs, generally by failure of the immediate roof strata, the strata outside the void, which are no longer constrained by the roof strata can relieve some of their stress by expanding horizontally into the goaf area. A state of equilibrium is achieved when the desire of the strata to expand is balanced by the frictional shear forces, developed by the weight of the overburden, which tend to resist the expansion.

The collapse of the immediate roof strata will generally be followed by the collapse of the rocks above them, unless the remaining overburden strata are sufficiently strong and homogeneous to span over the width of the void. Failure generally occurs due to the separation of an individual stratum along a bedding plane, which, being unable to carry the loads imposed by the weight of the overburden and the horizontal compressive stress, shears or buckles in bending and falls into the goaf.

The collapse progresses upwards until a stronger and more homogeneous strata beam is reached with the capacity to bridge the void. Such strata beam could be a thicker homogeneous rock of a particular type, such as a massive sandstone or conglomerate layer, or could be a combination of rock strata, which, acting together as a laminated beam, have sufficient strength to span the void. The height at which the progressive collapse of the strata towards the surface is arrested, i.e. the height of the fractured zone, is dictated by the width of the extracted void and the nature of the overburden strata.

The mechanism of collapse and the subsidence at the surface is further complicated by the cantilevering of the strata from the abutments on each side of the void and the elastic compression of the coal pillars and the strata above and below them.

After failure of the immediate roof, the lateral expansion of the strata at the abutments into the extracted void tends to form natural corbels, which support the strata above them and reduce the effective span. As the collapse progresses upwards the corbels extend further and further towards the centre of the goaf and form an irregular cantilever of strata at each abutment which transfer the weight of the overburden strata above the collapsed zone into the abutments. The angle, measured from the vertical, at which these corbels extend into the goaf area, is referred to as the angle of break.

The cantilevering strata and the overburden above the collapse zone span between the abutments and sag across the void and are partially supported by the collapsed rocks beneath them. At the same time, because the loads on the abutments are increased by the spanning strata, elastic compression occurs in the abutment coal pillars and in the strata above and below the pillars, causing settlement over the pillars. This settlement above the pillars is greatest where the depth of cover is high and the width to depth ratio of the extracted panel is relatively small. At higher width to depth ratios the settlement over the pillars reduces, because the strata collapses more freely into the goaf and less load is shed to the abutments. Additional settlement over the pillars occurs due to the lateral expansion of the strata at the abutments and the resultant vertical dilation caused by horizontal stress relief.

These separate mechanisms combine to cause subsidence at the surface, which extends over the extracted void and beyond the edges of the void to the limit of subsidence. Vertical subsidence at the surface is generally less than the thickness of the extracted coal seam, because the collapsed strata and the sagging strata above the collapsed zone contain a significant number of voids.

Rocks within the collapsed zone tend to fail by blocky delamination from the strata above them and collapse into the void in an irregular manner, which causes bulking of the collapsed strata to occur. Sometimes this can be sufficient to choke off the collapsed zone and prevent further progression of the collapsed zone towards the surface. In other cases it is possible that significant voids could be left at the top of the collapsed zone beneath a competent strata beam.

Above the collapsed zone is the fractured zone in which the strata are subject to significant vertical displacement and bending, which result in fracturing, joint opening, shearing on bedding planes and bed separation. The more competent rocks tend to span over the gaps beneath them, whilst weaker rocks tend to sag onto the stronger rocks beneath them. This results in vertical bed separation and void formation beneath the more competent strata with increased horizontal permeability. In this zone, it is possible that cracks could extend for the full depth of a stratum, thus increasing vertical permeability and connectivity between near surface aquifers and the mine workings.

Above the fractured zone is the constrained zone, in which the strata tend to sag and bend without failing and are laterally constrained by the horizontal in-situ stresses within the strata. In this zone, the bending of the strata results in the development of shear stresses at the interfaces between adjacent beds, causing horizontal displacements along the bedding planes and increased horizontal permeability. At low curvatures it is likely that some strata would crack on their convex surfaces, though the tension cracks would not penetrate the full depth of a stratum and hence would not provide hydraulic connectivity to the underlying strata. In the constrained zone, it is therefore possible that the horizontal permeability could increase due to subsidence, without an increase in vertical permeability.

Above the constrained zone is the surface zone, which comprises vertically unconfined strata and alluvial soils that essentially follow the bedrock movements downwards, but can still experience tensile cracking and surface buckling due to ground curvatures and strains.

D.8.2. Angle of break

The extent to which the corbels develop at the abutments and cantilever into the collapse zone is dependent upon the strength and thickness of the strata in the immediate roof and overburden, the locations of pre-existing joints and faults and the level of in-situ horizontal stress. The units that are thicker, stronger and more homogeneous will tend to cantilever further than those which are thinly bedded, weaker and more frequently jointed. The angle of break is therefore dependent upon local geology. It can also be affected by the choice of mining method and the speed of mining.

In a sequence of rocks comprising sandstones, conglomerates, shales, claystones and mudstones of moderate thickness it would appear, from the literature that has been reviewed, that the angle of break will be somewhere between 17^0 and 23^0. Based upon an angle of break of 17^0 the collapse zone would only extend through to the surface if the width to depth ratio was greater than 0.6 and if there was no significant stratum to span the void and arrest the upward development of the collapse zone at some horizon in the sequence. At an angle of break of 23^0, the width to depth ratio would have to exceed 0.84.

D.8.3. Variations in Terminology used to describe Strata Displacement Zones

A study of the various papers and texts that are listed in the references in Appendix B, reveals that the terminology used by different authors to describe the strata displacement zones above an extracted panel is inconsistent. Forster (1995) noted that most studies had recognised four separate zones, with some variations in the definitions of each zone. Peng and Chiang (1984) as illustrated in Fig 8.4.1 of the text book by Peng, which is reproduced in Fig. D.32, below, had recognised only three zones, namely the caved zone, the fractured zone and the continuous deformation zone. McNally et al (1996) also recognised three zones, which they referred to as the caved zone, the fractured zone and the elastic zone.

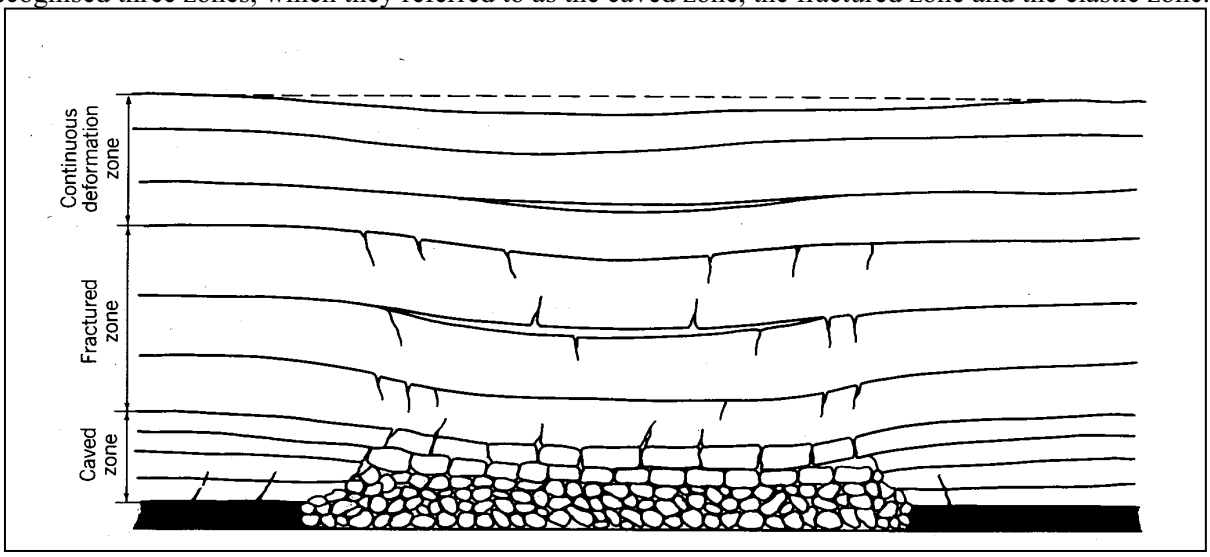


Fig. D.32 Zones in the Overburden According to Peng and Chiang (1984)

Kratzsch (1983) identified four zones, namely the immediate roof, the main roof, the intermediate zone and the surface zone. For the purpose of this study, the following zones, as described by Singh and Kendorski (1981) and proposed by Forster (1995), have been adopted. These are further illustrated in Fig. D.33.

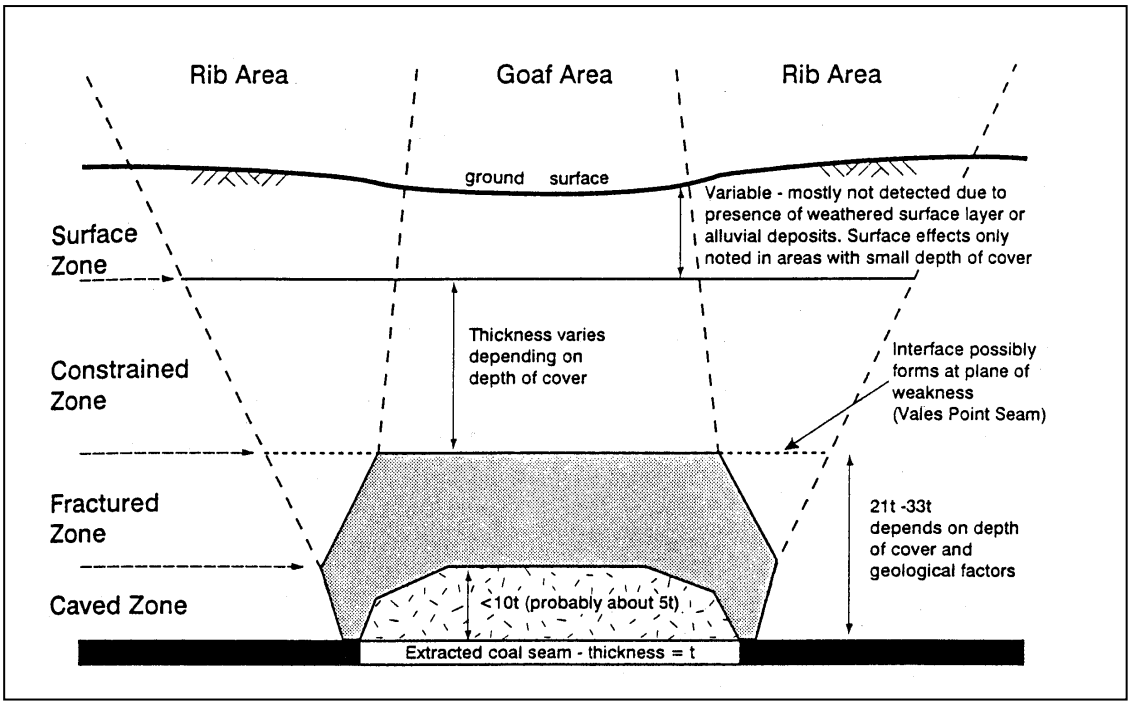


Fig. D.33 Zones in the Overburden according to Forster (1995)

Caved or collapsed Zone. (Some authors note primary and secondary caving zones.) Comprises loose blocks of rock detached from the roof and occupying the cavity formed by mining. Can contain large voids

- *Disturbed or Fractured Zone*. (Some authors include the secondary caving zone.) Basically in-situ material lying immediately above the caved zone which has sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation.
- *Constrained or Aquiclude Zone*. (Also called the Intermediate Zone.) Comprises confined rock strata above the disturbed zone which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present as well as discontinuous vertical cracks (usually on the underside of thick strong beds). Weak or soft beds in this zone may suffer plastic deformation.
- *Surface Zone*. Unconfined strata at the ground surface in which mining induced tensile and compressive strains may result in the formation of surface cracking or ground heaving.

D.8.4. Permeability, Vertical Dilation and Collapse and Fracture Zones

The likely heights of the collapsed, fractured and constrained zones have been provided by various authors and these have been reviewed during the course of preparing this report. Generally, the height of the caved zone has been indicated to fall within the range 1.5 to 14 times the extraction height, with the majority of cases in the range 5 to 10 times the extracted height. Forster concluded that the maximum height would be less than 10 times and probably around 5 times the extraction height.

The height of the fractured zone has been indicated to lie within the range 10 to 105 times the extracted height, though Holla and Buizen (1991) indicated that the height of the fractured zone over Longwall 3 at Tahmoor Colliery extended to a height of 143 times the extracted seam thickness, based upon extensometer readings. Forster (1995) concluded that the height of the fractured zone should be taken as 21 to 33 times the extracted height of the seam.

An alternative method of measuring the heights of the collapsed and fractured zones is to express the height as a function of the extracted width. This method appears to be favoured by some authors, though definitive relationships have yet to be determined. The height of the disturbed zone, being the overall height of the collapsed and fractured zones, has generally been found to vary from 0.16 to 1.4 times the extracted width. A height of 1.73 times the extracted width was indicated by Holla and Buizen (1991) over Longwall 3 at Tahmoor Colliery, based upon extensometer readings.

Some of the difficulties in establishing the heights of the various zones of disturbance above an extracted panel stem from the imprecise definitions of the fracture and constrained zones and the interpretation of extensometer readings. The definition of constrained zone is based upon the assumption that bed separation in this zone will increase horizontal permeability without increasing vertical permeability. It is possible for considerable dilation to occur as differential bending of the strata layers occurs, but this is not considered to be the same kind or extent of fracturing that is to be found in the fractured zone, where vertical permeability is likely to be affected by bending or shear induced vertical fractures.

Where vertical dilation is measured by extensometer readings, it is possible that bed separation in the constrained zone could be misinterpreted as fracturing in the fractured zone. The measurement of vertical tensile strain is of some assistance in identifying the extent of the strata disturbance at different horizons, but where bed separation occurs in the constrained zone a large vertical strain at that point can be confined by low vertical strains above and below the point.

The interpretation of extensometer readings has to be undertaken with care, particularly where the extensometers are limited in depth and do not penetrate the full depth of the overburden. The researchers at the University of New South Wales (1984) noted that since there had been no direct permeability measurements, it was difficult to establish a relationship between the vertical strain variation and the permeability of the strata.

Another issue with regard to extensometer readings that should be highlighted is that the extensometers were affected by horizontal shear and displacement, which resulted in total extension readings that were greater than the extracted thickness of coal. Quite clearly the extensions included horizontal movements between strata units at particular horizons and such movements would give a totally wrong impression of the vertical strains between anchors.

D.8.5. Relationship between Vertical Dilation Heights and Mining Geometry

The effect of mining geometry on the heights of the collapse and fractured zones is not well documented. Theory would suggest that the height of the collapse zone would be directly related to the width of the extraction, the height of extraction, the depth of cover and the nature of the rocks in the overburden. Where the panel width-to-depth ratio is high and the depth of cover is shallow, it is clear that the fractured zone can extend from seam to surface. This is clearly indicated in the extensometer readings from boreholes above shallow areas of extraction, where the vertical strains close to the surface are as high as they are close to seam level.

This was apparent in the results of the extensometer readings above Longwall 2 at Invincible Colliery, where the longwall width was 135 metres, the height of extraction was 2.7 metres and the depth of cover was 116 metres. The width-to-depth ratio of the panel was, therefore, 1.16. In this case, the collapsed zone extended to approximately 9 times the extracted seam thickness above the seam roof. Above the collapsed zone, the vertical strain was almost linear through to the surface at approximately 8 mm/m, indicating that the fractured zone extended to the full depth of the overburden.

It was also apparent in the movements of the strata above Longwall 11 at Angus Place Colliery. In that case, the longwall width was 211 metres, the height of extraction was 2.47 metres and the depth of cover was 263 metres. The width-to-depth ratio of the panel was, therefore, 0.8. Bhattacharyya and Zang (1993) estimated that the height of the collapsed zone was 25 metres, or 10 times the extracted seam height. Above the collapsed zone, the vertical strain was almost linear through to the surface at approximately 5.6 mm/m, indicating that the fractured zone extended to the full depth of the overburden.

The extent of the collapsed zone has generally been defined with reference to the extracted seam thickness and the height to which collapse occurs before the bulking of the collapsed rocks chokes off further vertical progression of the collapsed zone. The extent of the fractured zone above the collapsed zone would appear to be more dependent upon the width of the extraction and the angle of break. The vertical strain would appear to be dependent upon the extracted seam thickness, the amount of subsidence and the depth of cover.

It is reasonable to suppose that as the width to depth ratio reduces, the height of the fractured zone would also reduce. Conversely, the height of the fractured zone would be expected to increase as the width-to-depth ratio increased.

APPENDIX E. CLASSIFICATION OF DAMAGE TO BUILDING STRUCTURES

E.1. Introduction

The major mining-induced ground movements and subsidence parameters that are used to assess the impacts of subsidence on building structures are discussed in the following sections. The classification system for impact levels due to subsidence induced ground movements are also explained.

E.2. Mining Induced Ground Movements

E.2.1. Vertical Subsidence

Vertical, rigid body, subsidence has little or no effect on buildings or other surface structures where the subsidence occurs uniformly. The structures are, naturally, left at a lower level but normally this has little or no adverse effect upon them. Drainage systems and services to a building normally subside with the building and impact only results when differential subsidence occurs.

E.2.2. Horizontal Displacement

Horizontal displacements due to mining subsidence occur in such a way that points on the surface generally move towards the centre of the subsidence trough. Where one part of a structure is moved differently relative to other parts, then the structure experiences tensile stretching or compressive squashing. Differential horizontal movements give rise to strains but uniform horizontal movement of a surface structure would not normally have any adverse effect as the ground and structure move together.

E.2.3. Tilt

Ground tilt does not generally lead to structural impact. Severe tilts, however, may cause serviceability problems, such as doors tending to close themselves, or drainage problems, resulting from changes in the slopes of roof gutters, wet area floors and external paved areas. Single storey buildings usually remain serviceable when the residual tilts are less than 7 mm/m, although taller structures can be more sensitive to tilt. Swimming pools and large water storage tanks are also sensitive to tilting and, in some cases, are more sensitive than residential buildings.

E.2.4. Curvature

Curvature resulting from differential tilting is one of the major causes of impact to buildings and structures. Normally, curvature is defined as the reciprocal of the radius of curvature but it can also be defined by a deflection ratio for a particular length of structure, or by the radius of curvature itself. The deflection ratio is the maximum vertical displacement occurring between two points along a structure, expressed as a fraction of the horizontal distance between them.

An acceptable, or allowable, deflection ratio is that which can be tolerated by a structure without impairing its structural adequacy or serviceability, despite visible cracking that may occur in the superstructure. It is therefore a measure of the resistance of a structure to bending and shear strain.

Allowable deflection ratios are given in the Australian Standard AS 2870 (1996) for different types of construction and these, together with ratios established in research by various authors, are discussed in Sections 4.5 to 4.8. Cracking in rendered walls will normally be more apparent than in face brickwork and the allowable deflection ratios are therefore reduced for structures with rendered walls.

Modern brick structures are generally built with vertical joints at frequent intervals to allow for thermal expansion and other building movements. These structures can normally accommodate some curvature without damage but older brick structures, which were not designed to accommodate such movements, are more likely to be adversely affected.

E.2.5. Horizontal Strain

As discussed in Section 4.2.2, differential horizontal movements give rise to ground strains, however, most of the horizontal movements are proportional to ground curvature. Within the subsidence trough, convex or hogging curvature is accompanied by tensile strain and concave or sagging curvature is accompanied by compressive strain. Both tensile and compressive strains can cause cracking in a building structure but tensile strains are more difficult to accommodate since almost all components of a structure are weaker in tension than compression.

High levels of tensile strain cause stepped cracking in brickwork and masonry, cracking in plaster wall linings, pulled joints in plumbing and separation at joints in paving and roadways. High levels of compressive strain are characterised by crushing and spalling of faces in brickwork and masonry, closure of door and window openings, shear fractures, buckling of pipes, wall linings, floors, ceilings and external paving.

The transfer of ground strains into the structure occurs through friction on the underside of the foundations and ground pressure on the sides of the foundations. The transfer is thus dependent upon the configuration and type of foundation and its orientation to the subsidence trough.

The transfer of strain is also dependent upon the types of soil that are immediately below the foundation. Buildings founded on rock can, in some cases, experience a full transfer of strain whilst those founded on clay or sandy soils generally only attract a proportion of the ground strain. The transfer is a function of soil to foundation interaction and, in many cases, shearing of the soil layers reduces the transfer of strain.

Colwell and Thorne (1991), in their paper that referred to the monitoring of subsidence movements at a house above Longwall 3 at West Wallsend Colliery, indicated that the strains transferred into the walls of a brick veneer home were an order of magnitude less than those measured in the ground.

Horizontal tensile strains will affect all types of structure to the same degree once they have been cracked, since any increase in strain will tend to increase the width of the existing cracks rather than develop new ones.

E.2.6. Strain and Curvature Combinations

In practice, structural impact results from combinations of ground curvature and strain. The ground movements are generally three dimensional, adding the further complication of twisting in a structure. As subsidence occurs, the foundations settle and deform to match the subsided shape of the ground, the deformations being concentrated mainly at weak joints in the structure.

New cracks are generally formed where the shear or tensile strength of structural elements is exceeded. The cracking patterns depend upon the extent of the vertical displacements, the length to height ratio of the walls, the structural capacity of the building elements, and the shear strength and stiffness of the foundations.

In masonry and brickwork, the cracks generally follow the mortar joints either vertically or diagonally in steps. Bending and shear cracks can also occur due to curvature and strain along a wall. Once the cracks have formed, further ground deformations and extensions will be consumed in extending or expanding the cracks.

Where buildings are founded on sandy soils or clays and the ground strains are not fully transmitted into the structure, the level of impact is mostly dictated by curvature rather than horizontal strain.

Generally, the worst impacts will result from a combination of convex (hogging) curvature and tensile strain, rather than concave (sagging) curvature and compressive strain. The impact assessments, given in Chapter 6, have reviewed each combination, but are based upon the worst combination of the bending and horizontal tensile strains, which have been predicted to occur at each structure as the longwalls are mined. For each longwall panel, the travelling and transient strains at each structure have both been considered, and the maximum of these strains was used in the impact assessment for the structure.

E.3. Effect of Building Structure Type

The design and configuration of buildings and the materials of which they are built will determine the effects which mining subsidence will have upon them and the extent to which they will be affected. The bending strains resulting from ground curvature will affect different types of buildings in different ways.

A full masonry building of, for example, 15 metres in length, can tolerate a maximum differential foundation movement of 10 mm before damage occurs, whilst a timber framed building can tolerate a differential movement of 50 mm due to its greater flexibility.

A well designed building on foundations that allow for differential movement of the superstructure, constructed of flexible materials, with proper attention to the design of movement joints, will suffer less than a rigid brick structure on concrete strip foundations.

Buildings founded upon clay strata will not, normally, be subjected to the total horizontal ground strain. Buildings on piled foundations, on the other hand, would be affected to a greater extent due to lateral earth pressure on the piles and if the piles are rigidly connected to the building foundations this could result in a greater level of strain being applied to the building superstructure. Foundations built directly onto bedrock are more likely to transmit the total amount of ground strain into the building causing greater levels of impact.

Buildings that have raft foundations, built on a layer of sand and provided with a sliding membrane, often allow the ground to move without causing damage to the superstructure. Other buildings that are founded on stumps or short brick piers will generally allow the ground to move with only slight impact to the building above. These buildings also provide easy access for temporary and permanent adjustment of the piers and the structure.

The length of the building is also an important factor, since longer buildings will experience greater extension due to direct ground strain and bending strain, and the levels of impact will consequently be increased.

For many long structures, however, the maximum predicted strain will only apply over part of the length of the structure. In normal circumstances, therefore, the movements caused by mine subsidence will not be fully transmitted to the buildings and structures on the surface. However, a cautious approach is normally adopted and impact assessments are generally carried out assuming full transfer of displacements and strains from the ground into the structures. This approach was adopted in the present study.

E.4. Damage Thresholds on Building Structures

Much has been written on the subject of impact to buildings resulting from ground movements and the way in which different types of building, with different forms of construction, are likely to respond to applied curvatures and strains.

In 1974, Burland and Wroth prepared a thorough review of published papers to that date and recorded the findings of various researchers, which are summarised below. They presented the results to a conference of the British Geotechnical Society on the Settlement of Structures. Most of the literature referred to by the authors related to impact resulting from differential settlement or curvature rather than horizontally induced mining strains but it is nevertheless useful in establishing guidelines for determination of the effects of mine subsidence.

Burland and Wroth concluded that for brickwork and blockwork, in cement mortar, the critical tensile strain lay in the range 0.5 mm/m to 1.0 mm/m and for reinforced concrete in the range 0.3 mm/m to 0.5 mm/m. Below these levels, no cracking was apparent.

To place this in context with normal building movements, it is worth noting that strains likely to occur in clay brickwork, due to thermal expansion and contraction, can be of the order of 0.2 mm/m to 0.3 mm/m for a temperature differential of 30°C. Expansion of brickwork due to brick growth can also be of this order of magnitude.

The expansion and contraction of concrete structures, due to changes in temperature or moisture content, can be twice as high as for clay bricks. British Standards permit shrinkage strains of 0.3 mm/m to 0.9 mm/m in walls and panels.

Fig. 11 of the paper by Burland and Wroth compares the relative sag and hog for load-bearing walls and frame buildings, as determined by various researchers, and provides further guidance on the relationship between impact levels, deflection ratios and length to height ratios. The authors' view was that allowable deflection ratios for hogging structures should be less than for sagging structures.

The methods used to define the threshold levels for differential movement and strain varied from author to author and Burland and Wroth clarified the terminology, to enable direct comparisons to be made. Some statements concerning levels of impact were rather subjective and it was not easy to compare 'severe' by Littlejohn, with 'substantial' from Cheney and Burford and 'considerable' from Bjerrum. The relative values of strain provided some assistance in making comparisons.

It is clear that mining induced curvatures and strains will in some cases cause significant impact to building structures unless they are designed to accommodate these movements.

E.5. Allowable Deflection Ratios

Various authors in Australia have considered the effects of differential movement of buildings and many papers have been published which contain valuable data. This information has been incorporated in compiling Table E.1, which shows allowable deflection ratios for various types of building. The table has been extended to show the equivalent radii of curvature, for buildings of different length, at the allowable deflection ratios.

Bray and Branch (1988) provided a table showing allowable deflection ratios and limiting radii of curvature for different types of construction. Dr Lax Holla (1987b) also published a table of allowable deflection ratios, which was derived from a paper by Woodburn (1979), entitled Interaction of Soils, Footings and Structures.

Australian Standard, AS 2870 - 1996, provides guidance on the allowable deflection ratios for various types of structure, to be used in the design of foundations for domestic buildings and also gives tolerable levels of differential vertical movement in foundations.

Granger (1991) gives tolerable values of deflection ratio and maximum acceptable deflections for reinforced and articulated brick walls. The deflection ratio for brick veneer of 1:600 has been assumed to apply to normal face brickwork and the lower allowable deflection ratio of 1:800 has been adopted for rendered masonry, which is more susceptible to impact.

Where different authors have stated slightly different values, the lower ratio has been assumed in compiling Table E.1. Allowable deflection ratio, for a particular type of building, has been taken to mean the deflection ratio which would cause only slight impact if applied to a building of that type.

Not all structures, however, will be situated at the position of maximum curvature. The curvature and strain will vary considerably throughout the longwall area and the levels of impact on buildings and structures will be dependent upon their positions within the subsidence troughs.

E.6. Classification of Impact Levels to Walls

The 'National Coal Board Classification of Subsidence Damage' for building structures, was given in Table 8 of the *Subsidence Engineers Handbook*, which was published by the National Coal Board, in 1975. The scale of damage was classified by description and was related to specific changes in the lengths of building structures.

The National Coal Board classification would appear to have been in use in 1962, when it was referred to, in a slightly amended form, in a paper presented to the Institution of Structural Engineers by J.D. Geddes (1962). This descriptive classification of impact was adopted and extended by the Department of the Environment, of the U.K., in 1981, at which time the impact categories were linked to crack width, rather than to specific changes in the length of a structure. The classification, in this form, was shown in Table 8.5 of a book titled *Ground Movements and their Effect on Structures* (Geddes, 1984).

Table E.1 Allowable Deflection Ratios for Building Structures

Form of Construction		Allowable Deflection Ratio	Length in Metres			
			10	20	30	40
Loadbearing walls			**Acceptable Radius of Curvature in Kilometres**			
1	Solid masonry, rendered	1:4000	5.00	10.00	15.00	20.00
2	Solid masonry	1:3000	3.75	7.50	11.25	15.00
Non-loadbearing or lightly loaded walls			**Acceptable Radius of Curvature in Kilometres**			
3	Solid masonry, rendered	1:2000	2.50	5.00	7.50	10.00
4	Solid masonry	1:1500	1.87	3.75	5.62	7.50
5	Articulated masonry, rendered	1:800	1.00	2.00	3.00	4.00
6	Articulated masonry	1:600	0.75	1.50	2.25	3.00
7	Reinforced articulated masonry, rendered	1:600	0.75	1.50	2.25	3.00
8	Reinforced articulated masonry	1:400	0.50	1.00	1.50	2.00
9	Masonry veneer, rendered	1:800	1.00	2.00	3.00	4.00
10	Masonry veneer	1:600	0.75	1.50	2.25	3.00
11	Articulated masonry veneer, rendered	1:600	0.75	1.50	2.25	3.00
12	Articulated masonry veneer	1:500	0.62	1.25	1.87	2.50
13	Reinforced articulated masonry veneer, rendered	1:400	0.50	1.00	1.50	2.00
14	Reinforced articulated masonry veneer	1:300	0.38	0.75	1.12	1.50
15	Timber or steel clad in fibro or weatherboard	1:300	0.38	0.75	1.12	1.50
16	Steel or concrete frame with brick infill	1:1000	1.25	2.50	3.75	5.00
17	Steel or concrete frame without infill	1:500	0.62	1.25	1.87	2.50

The same classification has been incorporated, with some minor revisions to the wording, within Appendix C of Australian Standard, AS 2870 - 1996. Table C1 in the standard shows the classification of impact with reference to walls, related to crack width, and Table C2 gives a classification of impact with reference to concrete floors, related to both crack width and differential vertical movement.

The Australian Standard Classification, reproduced from Table C1, is presented in Table E.2 and has been used in this report as the basis for describing levels of impact to building structures, resulting from mine subsidence. The classification has, however, been extended to include a Category 5, which corresponds to the Very Severe Damage Category of the National Coal Board Classification and represents crack widths greater than 25 mm.

Table E.2 Classification of Impact with Reference to Walls

Impact Category	Description of typical impact to walls and required repair	Approximate crack width limit
0	Hairline cracks.	< 0.1 mm
1	Fine cracks which do not need repair.	0.1 mm to 1.0 mm
2	Cracks noticeable but easily filled. Doors and windows stick slightly.	1 mm to 5 mm
3	Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather-tightness often impaired	5 mm to 15 mm, or a number of cracks 3 mm to 5 mm in one group
4	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window or door frames distort. Walls lean or bulge noticeably. Some loss of bearing in beams. Service pipes disrupted.	15 mm to 25 mm but also depends on number of cracks
5	As above but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken with distortion. If compressive damage, severe buckling and bulging of the roof and walls.	> 25 mm

E.7. Classification of Impact Levels due to Tilt

There is no standard method for classifying the level of impact caused by tilt. However, Australian Standard AS 2870 - 1996 indicates that local deviations in vertical or horizontal slope of more than 1 in 100, (10 mm/m), will normally be clearly visible and that slopes greater than 1 in 150 (approximately 7 mm/m) are undesirable.

However, it is recognised that structures are constructed to varying levels of accuracy. As reported by Burton (1995), research commissioned by the Mine Subsidence Board in 1991 indicated that a sample of 83 dwellings built at Woodrising in the preceding ten years in areas unaffected by mining, had a mean deviation from level of 2.39 mm/m, with a maximum deviation of 8.7 mm/m. The Mine Subsidence Board, in its *Annual Review* (1992), published further details of the research project. Fig. E.1 shows the distribution of measured tilts arising from this and other pre-mining surveys, and indicates that 21% of 156 houses had tilts of more than 4 mm. The maximum tilt measured at a building prior to mining was 15 mm/m, with nine cases being reported between 9 mm/m and 15 mm/m. The acceptable change in tilt, due to mining, will thus vary from case to case and will be dependent upon the tilts existing before mining occurs.

The Mine Subsidence Board has adopted the policy that tilts caused by mine subsidence, which affect serviceability, constitute impact that is to be compensated. When the tilts are between 4 mm/m and 7 mm/m, the Board recognises that the tilt, in some instances, could cause problems to roof drainage and wet area floors and, in those circumstances, would expect to carry out remedial works. It is also possible that some adjustment could be required to doors and windows.

Where the tilt is greater than 7 mm/m and the roof drainage, wet area floors or pools can not be correctly graded or levelled without major structural work, then the Board would consider jacking the building to level. If, in extreme cases, the tilt caused impact to a building structure that could not be repaired economically, the Board, depending on the merits of each case, may be prepared to demolish the structure and rebuild it, or negotiate with the owner to pay monetary compensation, or purchase the property.

There appears to be a consensus that final overall tilts in buildings which are less than 7 mm/m are tolerable and that tilts above 10 mm/m are undesirable. Overall tilts in buildings less than 5 mm/m would generally have negligible impact on building structures though this level of tilt could affect swimming pools and could possibly affect roof, floor or land drainage systems, where existing gradients are less than normal design requirements.

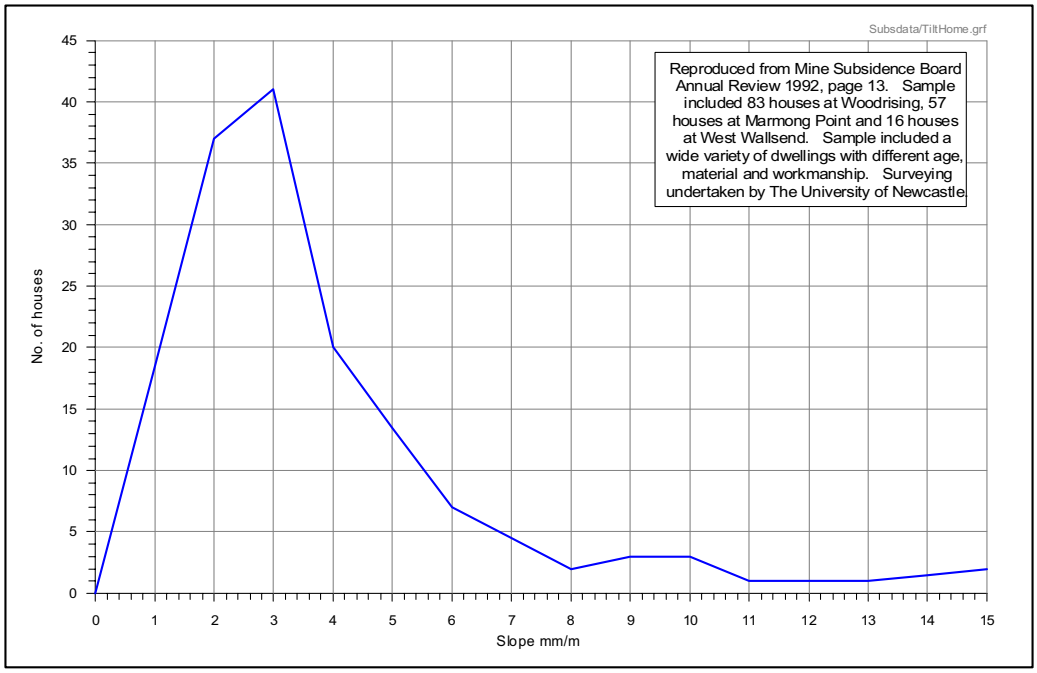


Fig. E.1 Tilts of Surveyed Dwellings located outside Mine Subsidence Areas

The impact classification shown in Table E.3, was developed by Waddington Kay & Associates. This has generally been accepted for a number of previous projects and Commissions of Inquiry. It is noted, however, that the Mine Subsidence Board consider jacking houses for Category C levels of tilt.

Table E.3 Classification of Impact with Reference to Tilt

Impact Category	Mining Induced Ground Tilt (mm/m)	Description
A	< 5	Unlikely that remedial work will be required.
B	5 to 7	Adjustment to roof drainage and wet area floors might be required.
C	7 to 10	Minor structural work might be required to rectify tilt. Adjustments to roof drainage and wet area floors will probably be required and remedial work to surface water drainage and sewerage systems might be necessary.
D	> 10	Considerable structural work might be required to rectify tilt. Jacking to level or rebuilding could be necessary in the worst cases. Remedial work to surface water drainage and sewerage systems might be necessary.

E.8. Classification of Impact due to Ground Strains

In 1975, the National Coal Board, in the *Subsidence Engineers Handbook*, published a graph showing the relationship between impact, horizontal ground strain and the length of a building structure. It was based upon empirical data obtained from studying the effects of subsidence along 165 observation lines at numerous collieries in the U.K.

It has been generally accepted as providing a reasonable basis for assessing the levels of impact that are likely to result from mining subsidence and has been adopted in other countries around the world. When used in Australia for the prediction of impact, it has been shown to provide reasonable agreement with observed impact levels (Holla, 1988 and 1995; Bray and Branch, 1988).

The graph is reproduced, in an extended form, in Fig. E.2 and illustrates the various impact categories, shown in Table E.2. These are separated by lines that represent specific extensions to the length of a structure. These extensions, which define the various categories of impact, were originally published in Table 8 of the *Subsidence Engineers Handbook* (NCB, 1975). It follows that the strain values referred to in Fig. E.2, should be seen as those occurring in the building structure. Normally these are taken to be the mining-induced horizontal ground strains. However, ground strains should be converted into structure strains by adding or subtracting the effect of mining-induced hogging or sagging curvature in the structure.

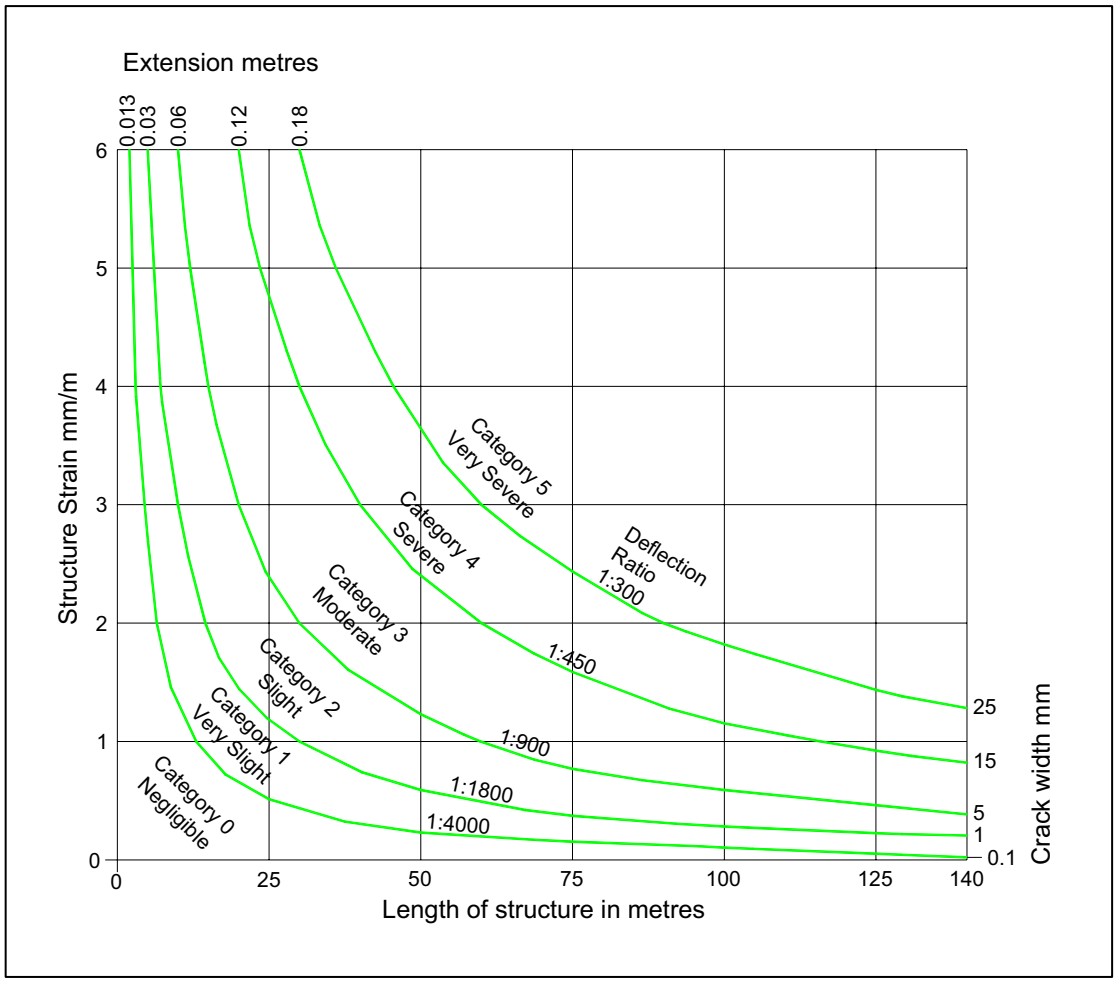


Fig. E.2 Impact Classification with Deflection Ratios for Two Storey Brick Structures

The impact categories shown in Fig. E.2 relate to typical two-storey brick or masonry building structures, which were the norm in mining areas in the U.K. Brick veneer homes and timber framed structures, with fibro or weatherboard cladding, which are commonly built in Australia, are not normally found in the mining areas of the U.K. The impact classifications are, therefore, somewhat conservative for these more typical Australian structures.

As previously discussed, the horizontal ground strains are associated with ground curvatures and both contribute to the strain which is experienced by a building structure. Often the horizontal strain is only partially transferred into the building and the curvature, which causes bending strain, provides the greater contribution to the total strain.

The bending strain in a building structure, resulting from hogging curvature of the ground, is dependent upon the height of the building, H, and the radius of curvature of the ground, R, and can be expressed simply as strain = H/R, as shown in Fig. E.3.

In this calculation, it is assumed that the curvature of the ground, at foundation level, is transferred into the structure by differential settlement of the foundations and that the structure bends to accommodate the curvature. It is assumed that hogging curvature will result in bending about the underside of the foundation. In practice, some shearing may take place in the structure and the calculated bending strain might not be fully developed.

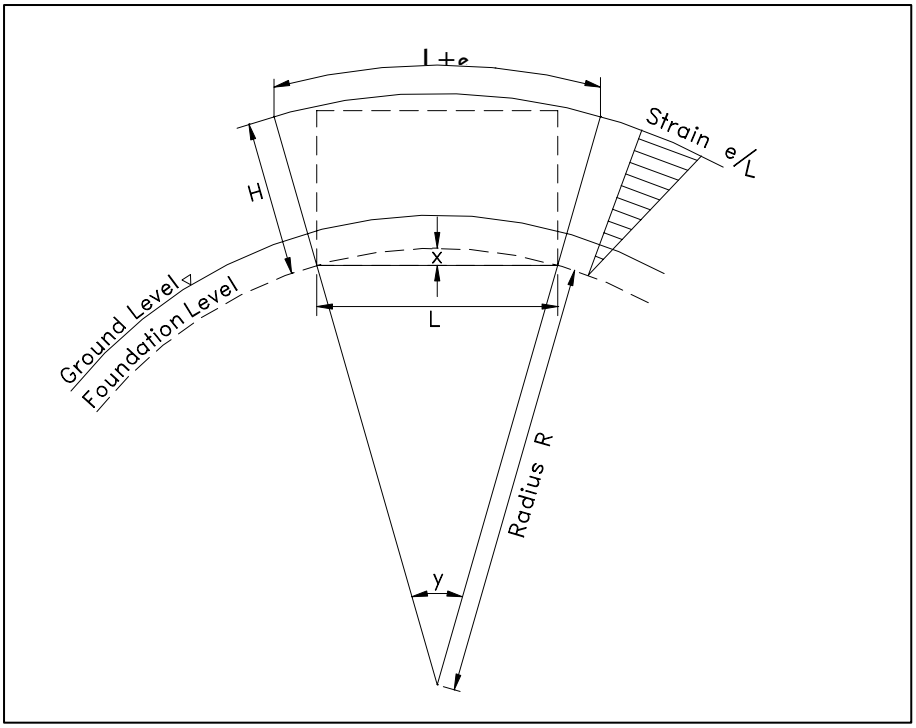
In the sagging mode, some resistance to bending will occur in the lower part of the wall. Normally slippage will occur at damp course level but, if no damp course exists, the foundations or ground slab will provide resistance. The effective neutral axis will therefore be in the lower part of the wall but its location will vary from structure to structure. In general, it seems reasonable to assume that walls, subjected to concave, or sagging, curvature, will bend about their centre line.

To determine the tensile strains in a building structure, the horizontal tensile ground strains have been added to the tensile bending strains, which are determined from a structure height measured from the underside of the foundation. To determine the compressive strains in a building structure, the compressive bending strains, determined from the mid-height of a structure, have been deducted from the horizontal compressive ground strains. This combined strain has then been used in predicting impact intensity from Fig. E.2.

In practice, much of the horizontal ground strain could be lost in the transfer. The impact assessments, provided in Chapter 6, are therefore cautious assessments that represent the worst possible scenario based upon the predicted subsidence parameters.

E.9. The Relationship between Impact Classification and Allowable Deflection Ratio

The elongation of a structure, due to curvature of the ground is directly related to the deflection ratio of a structure, as shown in Fig. E.3.



Note: Curvature exaggerated for clarity

Fig. E.3 Symbols used in the Analysis of Structures Bending by Hogging

From the geometry of a circle it can be shown that:

elongation of structure, e = deflection ratio × 8 H Equation 2

The relationship between the elongation of a structure, due to bending, and the deflection ratio is therefore dependent upon the height of the structure.

From the curve shown in Fig. E.2, a two-storey building with a height of 6.75 metres represents an extension of 0.03 metres for an impact category between 1 and 2. This can be related to a deflection ratio using the formula given above.

Hence, $$\text{Deflection Ratio} = \frac{\text{elongation}}{8H} = \frac{0.03}{54} = \frac{1}{1800}$$ Equation 3

Using the method above, the deflection ratios have been calculated for other values of extension and these have been shown in Fig. E.2. The calculations indicate that for two-storey brick structures, with a height of 6.75 metres, the upper limit of impact for Category 2 represents a deflection ratio of 1:900. Similarly, the upper limits of Impact Categories 3 and 4 are represented by deflection ratios of 1:450 and 1:300, respectively.

It is reasonable to assume that the level of impact at a deflection ratio of less than 1:4000 would be negligible for a two storey brick structure. A curve has been included in Fig. E.2, based upon this value of deflection ratio, in order to provide a division between Impact Categories 0 and 1.

E.10. Relationship between Impact Classification and Crack Width

The deflection ratios and maximum crack widths which separate each Impact Category, for two-storey brick structures of 6.75 metres height, are shown in Fig. E.2. Based upon these factors, Fig. E.4 has been produced, to show the relationship between the inverse of deflection ratio and the maximum crack width.

The impact categories given in Table E.2 are related to maximum crack widths and these have been shown for each of the categories in Fig. E.2. Impact Category 0 relates to a maximum crack width of less than 0.1 mm, which would not be visible, and hence represents negligible impact. Categories 1 to 4 relate to maximum crack widths of 1 mm, 5 mm, 15 mm and 25 mm respectively. Category 5 has been added to represent crack widths greater than 25 mm.

In a paper presented by P.F. Walsh (1991), a graph was published showing the relationship between crack widths and inverse deflection ratios for single storey, brick veneer houses, subject to reactive clay movements. The graph was reproduced from a paper which was published in 1981 by D.A. Cameron and P.F. Walsh, and is based upon actual deflections and crack widths.

This graph has been added to Fig. E.4 to show the comparison between the theoretical relationships and measured results and a very close agreement can be seen. The classification of impact with reference to both extension and crack width would, therefore, appear to have some scientific basis.

It can be seen from Table E.1, that all other types of building structure have an allowable deflection ratio greater than that of brick structures. A timber-framed building, for example, has an allowable deflection ratio of 1:300 compared with 1:2000 for lightly loaded rendered brickwork. Rendered brick veneer structures have an allowable ratio of 1:800.

The effect of bending strains on building structures is dependent upon their flexibility and their capacity to absorb curvature by shearing. The level of impact caused to a building, by curvature of the ground, therefore reduces as the allowable deflection ratio increases.

The use of the graphs in Fig. E.2 to predict the levels of impact to buildings of flexible construction would, therefore, be an over-cautious approach and would result in excessively conservative assessments. The management strategies have therefore been adjusted for sheds and other light structures to compensate for this conservatism.

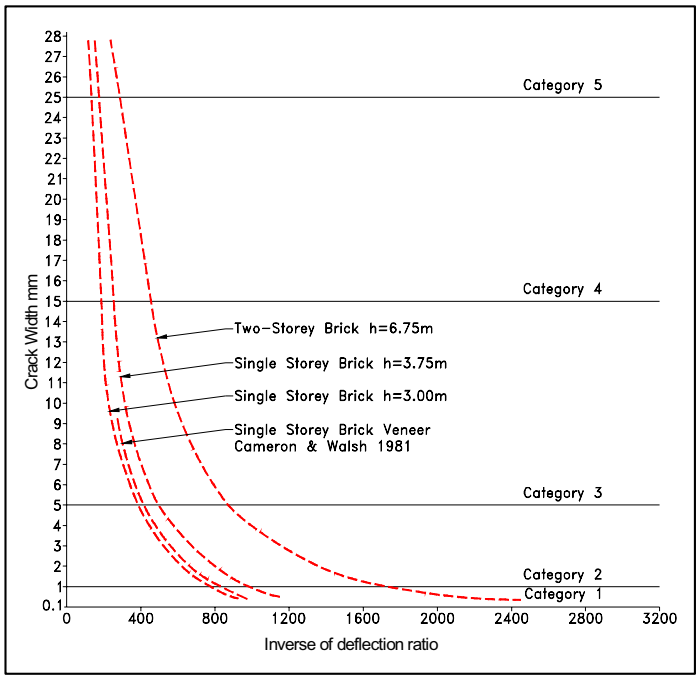


Fig. E.4 Variation of Crack Width with Deflection Ratio for Brick Structures

APPENDIX F. TABLES

Table F.01 - 330/500 kV Transmission Line (TL 73/74) - Predicted Subsidence, Tilt and Strain at the Tower Locations

Incremental Subsidence due to each Longwall

Tower	MGA Easting	MGA Northing	Inc Subs due to WH101 (mm)	Inc Subs due to WH102 (mm)	Inc Subs due to WH103 (mm)	Inc Subs due to WH104 (mm)	Inc Subs due to WH105 (mm)	Inc Subs due to WH106 (mm)	Inc Subs due to GM205 (mm)	Inc Subs due to AF101 (mm)	Inc Subs due to AF102 (mm)	Inc Subs due to BF201 (mm)	Inc Subs due to BF202 (mm)	Inc Subs due to BF203 (mm)	Inc Subs due to PF201 (mm)	Inc Subs due to PF202 (mm)	Inc Subs due to PF203 (mm)	Inc Subs due to PF204 (mm)
38	291423	6416822	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	291874	6416439	0	0	0	0	0	0	0	92	0	0	0	0	0	0	0	0
36	292221	6416143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	292670	6416099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	293117	6416056	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	293522	6416018	0	0	0	0	0	0	0	0	0	0	0	0	328	0	0	0
32	293979	6415970	0	0	0	0	0	0	0	0	0	77	0	0	954	73	0	0
31	294339	6415934	0	0	0	0	0	0	0	0	0	1679	0	0	105	754	59	0
30	294577	6415909	790	52	0	0	0	0	0	0	0	1238	19	0	8	1222	110	0
29	295211	6415844	44	178	24	0	0	0	0	0	0	0	1849	244	0	127	708	46
28	295719	6415770	0	1943	110	0	0	0	0	0	0	0	36	1845	0	3	818	300
27	296165	6415705	0	0	2032	93	0	0	0	0	0	0	0	555	0	0	42	1043
26	296542	6415650	0	0	83	173	43	0	0	0	0	0	0	7	0	0	2	627
25	296987	6415586	0	0	0	1985	110	0	0	0	0	0	0	0	0	0	0	11
24	297348	6415533	0	0	0	0	1894	63	0	0	0	0	0	0	0	0	0	0
23	297841	6415462	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
22	298260	6415400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	298704	6415336	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Maximum:	790	1943	2032	1985	1894	63	0	92	0	1679	1849	1845	954	1222	818	1043

Total Subsidence after each Longwall

(Note: Total subsidence includes time effects)

Tower	MGA Easting	MGA Northing	Total Subs after WH101 (mm)	Total Subs after WH102 (mm)	Total Subs after WH103 (mm)	Total Subs after WH104 (mm)	Total Subs after WH105 (mm)	Total Subs after WH106 (mm)	Total Subs after GM205 (mm)	Total Subs after AF101 (mm)	Total Subs after AF102 (mm)	Total Subs after BF201 (mm)	Total Subs after BF202 (mm)	Total Subs after BF203 (mm)	Total Subs after PF201 (mm)	Total Subs after PF202 (mm)	Total Subs after PF203 (mm)	Total Subs after PF204 (mm)
38	291423	6416822	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	291874	6416439	0	0	0	0	0	0	0	92	92	92	92	92	92	92	92	92
36	292221	6416143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	292670	6416099	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	293117	6416056	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	293522	6416018	0	0	0	0	0	0	0	0	0	0	0	0	328	328	328	328
32	293979	6415970	0	0	0	0	0	0	0	0	0	77	77	77	955	989	989	989
31	294339	6415934	0	0	0	0	0	0	0	0	0	1679	1679	1679	1743	2480	2539	2539
30	294577	6415909	790	842	842	842	842	842	842	842	842	1751	1767	1767	1771	2992	3100	3100
29	295211	6415844	44	178	201	201	201	201	201	201	201	201	2010	2213	2213	2307	2991	3039
28	295719	6415770	0	1943	2051	2051	2051	2051	2051	2051	2051	2051	2086	3878	3878	3881	4699	4931
27	296165	6415705	0	0	2032	2122	2122	2122	2122	2122	2122	2122	2122	2635	2635	2635	2677	3637
26	296542	6415650	0	0	83	193	216	216	216	216	216	216	216	223	223	223	225	884
25	296987	6415586	0	0	0	1985	2093	2093	2093	2093	2093	2093	2093	2093	2093	2093	2093	2103
24	297348	6415533	0	0	0	0	1894	1957	1957	1957	1957	1957	1957	1957	1957	1957	1957	1957
23	297841	6415462	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
22	298260	6415400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	298704	6415336	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Maximum:	790	1943	2051	2122	2122	2122	2122	2122	2122	2122	2122	3878	3878	3881	4699	4931

Table F.01 - 330/500 kV Transmission Line (TL 73/74) - Predicted Subsidence, Tilt and Strain at the Tower Locations

Travelling Tilt East-West during each Longwall

(+ve = Tilt to the East & -ve = Tilt to the West)

Tower	MGA Easting	MGA Northing	Travel Tilt E/W during WH101 (mm/m)	Travel Tilt E/W during WH102 (mm/m)	Travel Tilt E/W during WH103 (mm/m)	Travel Tilt E/W during WH104 (mm/m)	Travel Tilt E/W during WH105 (mm/m)	Travel Tilt E/W during WH106 (mm/m)	Travel Tilt E/W during GM205 (mm/m)	Travel Tilt E/W during AF101 (mm/m)	Travel Tilt E/W during AF102 (mm/m)	Travel Tilt E/W during BF201 (mm/m)	Travel Tilt E/W during BF202 (mm/m)	Travel Tilt E/W during BF203 (mm/m)	Travel Tilt E/W during PF201 (mm/m)	Travel Tilt E/W during PF202 (mm/m)	Travel Tilt E/W during PF203 (mm/m)	Travel Tilt E/W during PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	-3.3	-0.2	0.0	0.0
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-9.7	0.0	0.0	-0.3	-2.5	-0.2	0.0
30	294577	6415909	-26.5	-1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.4	-0.1	0.0	0.0	-4.1	-0.4	0.0
29	295211	6415844	-1.2	-5.0	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-10.2	-1.3	0.0	-0.4	-2.3	-0.2
28	295719	6415770	0.0	-42.8	-3.4	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-10.6	0.0	0.0	0.0	-2.7	-1.0
27	296165	6415705	0.0	0.0	-29.6	-1.9	0.0	0.0	0.0	0.0	0.0	0.0	-2.8	0.0	0.0	0.0	-0.1	-3.1
26	296542	6415650	0.0	0.0	-1.5	-3.2	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.8
25	296987	6415586	0.0	0.0	0.0	-32.9	-2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	297348	6415533	0.0	0.0	0.0	0.0	-47.3	-2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	297841	6415462	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Minimum:	-26.5	-42.8	-29.6	-32.9	-47.3	-2.4	0.0	-0.4	0.0	-9.7	-10.2	-10.6	-3.3	-4.1	-2.7	-3.1

Travelling Tilt North-South during each Longwall

(+ve = Tilt to the North & -ve = Tilt to the South)

Tower	MGA Easting	MGA Northing	Travel Tilt N/S during WH101 (mm/m)	Travel Tilt N/S during WH102 (mm/m)	Travel Tilt N/S during WH103 (mm/m)	Travel Tilt N/S during WH104 (mm/m)	Travel Tilt N/S during WH105 (mm/m)	Travel Tilt N/S during WH106 (mm/m)	Travel Tilt N/S during GM205 (mm/m)	Travel Tilt N/S during AF101 (mm/m)	Travel Tilt N/S during AF102 (mm/m)	Travel Tilt N/S during BF201 (mm/m)	Travel Tilt N/S during BF202 (mm/m)	Travel Tilt N/S during BF203 (mm/m)	Travel Tilt N/S during PF201 (mm/m)	Travel Tilt N/S during PF202 (mm/m)	Travel Tilt N/S during PF203 (mm/m)	Travel Tilt N/S during PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	-1.1	-0.1	0.0	0.0
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.3	0.0	0.0	-0.1	-0.8	-0.1	0.0
30	294577	6415909	-9.3	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.5	0.0	0.0	0.0	-1.4	-0.1	0.0
29	295211	6415844	-0.4	-1.8	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.4	-0.5	0.0	-0.1	-0.8	-0.1
28	295719	6415770	0.0	-15.0	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-3.6	0.0	0.0	-0.9	-0.3
27	296165	6415705	0.0	0.0	-10.4	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	0.0	0.0	0.0	-1.0
26	296542	6415650	0.0	0.0	-0.5	-1.1	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6
25	296987	6415586	0.0	0.0	0.0	-11.6	-0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	297348	6415533	0.0	0.0	0.0	0.0	-16.6	-0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	297841	6415462	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Minimum:	-9.3	-15.0	-10.4	-11.6	-16.6	-0.9	0.0	-0.1	0.0	-3.3	-3.4	-3.6	-1.1	-1.4	-0.9	-1.0

Table F.01 - 330/500 kV Transmission Line (TL 73/74) - Predicted Subsidence, Tilt and Strain at the Tower Locations

Cumulative Tilt East-West after each Longwall

(+ve = Tilt to the East & -ve = Tilt to the West)

Tower	MGA Easting	MGA Northing	Total Tilt E/W after WH101 (mm/m)	Total Tilt E/W after WH102 (mm/m)	Total Tilt E/W after WH103 (mm/m)	Total Tilt E/W after WH104 (mm/m)	Total Tilt E/W after WH105 (mm/m)	Total Tilt E/W after WH106 (mm/m)	Total Tilt E/W after GM205 (mm/m)	Total Tilt E/W after AF101 (mm/m)	Total Tilt E/W after AF102 (mm/m)	Total Tilt E/W after BF201 (mm/m)	Total Tilt E/W after BF202 (mm/m)	Total Tilt E/W after BF203 (mm/m)	Total Tilt E/W after PF201 (mm/m)	Total Tilt E/W after PF202 (mm/m)	Total Tilt E/W after PF203 (mm/m)	Total Tilt E/W after PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5	1.5	1.5
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	-3.1	-2.9	-2.9	-2.9
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.2	1.4	1.6	1.6
30	294577	6415909	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	2.8	3.2	3.2	3.2	4.7	4.9	4.9
29	295211	6415844	-0.3	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.1	1.4	1.4	0.9	2.2	2.4
28	295719	6415770	0.0	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.4	-7.8	-7.8	-7.9	-10.4	-9.7
27	296165	6415705	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	-2.7	-2.7	-2.7	-2.8	-1.7
26	296542	6415650	0.0	0.0	-0.7	-0.3	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-2.4
25	296987	6415586	0.0	0.0	0.0	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.5
24	297348	6415533	0.0	0.0	0.0	0.0	10.2	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
23	297841	6415462	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum:	5.6	5.6	5.6	5.6	10.2	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
		Minimum:	-0.3	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.4	-7.8	-7.8	-7.9	-10.4	-9.7

Cumulative Tilt North-South after Each Longwall

(+ve = Tilt to the North & -ve = Tilt to the South)

Tower	MGA Easting	MGA Northing	Total Tilt N/S after WH101 (mm/m)	Total Tilt N/S after WH102 (mm/m)	Total Tilt N/S after WH103 (mm/m)	Total Tilt N/S after WH104 (mm/m)	Total Tilt N/S after WH105 (mm/m)	Total Tilt N/S after WH106 (mm/m)	Total Tilt N/S after GM205 (mm/m)	Total Tilt N/S after AF101 (mm/m)	Total Tilt N/S after AF102 (mm/m)	Total Tilt N/S after BF201 (mm/m)	Total Tilt N/S after BF202 (mm/m)	Total Tilt N/S after BF203 (mm/m)	Total Tilt N/S after PF201 (mm/m)	Total Tilt N/S after PF202 (mm/m)	Total Tilt N/S after PF203 (mm/m)	Total Tilt N/S after PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.3	-4.3	-4.3	-4.3
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.9	-1.9	-1.9	8.5	7.6	7.6	7.6
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.8	-1.8	-1.8	-0.5	-4.8	-5.2	-5.2
30	294577	6415909	-18.6	-19.0	-19.0	-19.0	-19.0	-19.0	-19.0	-19.0	-19.0	-10.4	-10.7	-10.7	-10.6	-14.5	-15.2	-15.2
29	295211	6415844	1.1	-0.6	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	1.3	-0.8	-0.8	0.6	-3.4	-3.8
28	295719	6415770	0.0	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	30.2	26.7	26.7	26.8	34.3	32.2
27	296165	6415705	0.0	0.0	-1.4	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	6.4	6.4	6.4	6.8	3.3
26	296542	6415650	0.0	0.0	2.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	6.8
25	296987	6415586	0.0	0.0	0.0	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.9
24	297348	6415533	0.0	0.0	0.0	0.0	-31.3	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9
23	297841	6415462	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum:	1.1	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	29.5	30.2	26.7	26.7	26.8	34.3	32.2
		Minimum:	-18.6	-19.0	-19.0	-19.0	-31.3	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9	-31.9

Table F.01 - 330/500 kV Transmission Line (TL 73/74) - Predicted Subsidence, Tilt and Strain at the Tower Locations

Travelling Tensile Strain during each Longwall

(+ve = Tensile Strain)

Tower	MGA Easting	MGA Northing	Travel Tension during WH101 (mm/m)	Travel Tension during WH102 (mm/m)	Travel Tension during WH103 (mm/m)	Travel Tension during WH104 (mm/m)	Travel Tension during WH105 (mm/m)	Travel Tension during WH106 (mm/m)	Travel Tension during GM205 (mm/m)	Travel Tension during AF101 (mm/m)	Travel Tension during AF102 (mm/m)	Travel Tension during BF201 (mm/m)	Travel Tension during BF202 (mm/m)	Travel Tension during BF203 (mm/m)	Travel Tension during PF201 (mm/m)	Travel Tension during PF202 (mm/m)	Travel Tension during PF203 (mm/m)	Travel Tension during PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.2	0.0	0.0
30	294577	6415909	22.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.3	0.0	0.0
29	295211	6415844	0.9	3.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.2	0.0	0.0	0.2	0.0
28	295719	6415770	0.0	35.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.2	0.1
27	296165	6415705	0.0	0.0	22.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.2
26	296542	6415650	0.0	0.0	0.7	1.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
25	296987	6415586	0.0	0.0	0.0	30.1	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	297348	6415533	0.0	0.0	0.0	0.0	42.1	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	297841	6415462	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum:	22.8	35.1	22.9	30.1	42.1	2.4	0.0	0.0	0.0	1.5	1.5	1.6	0.3	0.3	0.2	0.2

Travelling Compressive Strain during each Longwall

(-ve = Compressive Strain)

Tower	MGA Easting	MGA Northing	Travel Comp. during WH101 (mm/m)	Travel Comp. during WH102 (mm/m)	Travel Comp. during WH103 (mm/m)	Travel Comp. during WH104 (mm/m)	Travel Comp. during WH105 (mm/m)	Travel Comp. during WH106 (mm/m)	Travel Comp. during GM205 (mm/m)	Travel Comp. during AF101 (mm/m)	Travel Comp. during AF102 (mm/m)	Travel Comp. during BF201 (mm/m)	Travel Comp. during BF202 (mm/m)	Travel Comp. during BF203 (mm/m)	Travel Comp. during PF201 (mm/m)	Travel Comp. during PF202 (mm/m)	Travel Comp. during PF203 (mm/m)	Travel Comp. during PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	-0.3	0.0	0.0	0.0
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.4	0.0	0.0	0.0	-0.2	0.0	0.0
30	294577	6415909	-27.6	-1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.1	0.0	0.0	0.0	-0.3	0.0	0.0
29	295211	6415844	-1.1	-4.3	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.4	-0.2	0.0	0.0	-0.2	0.0
28	295719	6415770	0.0	-28.9	-3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	0.0	0.0	-0.2	-0.1
27	296165	6415705	0.0	0.0	-25.0	-1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	-0.2
26	296542	6415650	0.0	0.0	-0.8	-1.7	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
25	296987	6415586	0.0	0.0	0.0	-28.4	-1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	297348	6415533	0.0	0.0	0.0	0.0	-34.2	-3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	297841	6415462	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Minimum:	-27.6	-28.9	-25.0	-28.4	-34.2	-3.0	0.0	0.0	0.0	-1.4	-1.4	-1.5	-0.3	-0.3	-0.2	-0.2

Table F.01 - 330/500 kV Transmission Line (TL 73/74) - Predicted Subsidence, Tilt and Strain at the Tower Locations

Cumulative Tensile Strain after each Longwall

(+ve = Tensile Strain)

Tower	MGA Easting	MGA Northing	Total Tension after WH101 (mm/m)	Total Tension after WH102 (mm/m)	Total Tension after WH103 (mm/m)	Total Tension after WH104 (mm/m)	Total Tension after WH105 (mm/m)	Total Tension after WH106 (mm/m)	Total Tension after GM205 (mm/m)	Total Tension after AF101 (mm/m)	Total Tension after AF102 (mm/m)	Total Tension after BF201 (mm/m)	Total Tension after BF202 (mm/m)	Total Tension after BF203 (mm/m)	Total Tension after PF201 (mm/m)	Total Tension after PF202 (mm/m)	Total Tension after PF203 (mm/m)	Total Tension after PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.7
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	0.9	1.5	1.6	1.6	1.6
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	294577	6415909	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	4.7	4.5	4.5	4.6	3.8	3.9	3.9
29	295211	6415844	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	1.5	1.5	1.7	1.8	1.8
28	295719	6415770	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	296165	6415705	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.5	0.0
26	296542	6415650	0.0	0.0	1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	2.8
25	296987	6415586	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	297348	6415533	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	297841	6415462	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Maximum:	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2	4.7	4.5	4.5	4.6	3.8	3.9	3.9

Cumulative Compressive Strain after each Longwall

(-ve = Compressive Strain)

Tower	MGA Easting	MGA Northing	Total Comp. after WH101 (mm/m)	Total Comp. after WH102 (mm/m)	Total Comp. after WH103 (mm/m)	Total Comp. after WH104 (mm/m)	Total Comp. after WH105 (mm/m)	Total Comp. after WH106 (mm/m)	Total Comp. after GM205 (mm/m)	Total Comp. after AF101 (mm/m)	Total Comp. after AF102 (mm/m)	Total Comp. after BF201 (mm/m)	Total Comp. after BF202 (mm/m)	Total Comp. after BF203 (mm/m)	Total Comp. after PF201 (mm/m)	Total Comp. after PF202 (mm/m)	Total Comp. after PF203 (mm/m)	Total Comp. after PF204 (mm/m)
38	291423	6416822	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	291874	6416439	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	292221	6416143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	292670	6416099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	293117	6416056	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	293522	6416018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	293979	6415970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	294339	6415934	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.5	-1.5	-1.5	-1.2	-1.0	-1.0	-1.0
30	294577	6415909	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.2	-3.6	-3.6	-3.5	-3.8	-3.8	-3.8
29	295211	6415844	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	295719	6415770	0.0	-15.3	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.4	-15.3	-16.5	-16.5	-16.5	-16.4	-16.3
27	296165	6415705	0.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	-0.1
26	296542	6415650	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	296987	6415586	0.0	0.0	0.0	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3
24	297348	6415533	0.0	0.0	0.0	0.0	-16.5	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6
23	297841	6415462	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	298260	6415400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	298704	6415336	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Minimum:	0.0	-15.3	-15.4	-15.4	-16.5	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6	-16.6

Table F.02 - 330/500 kV Transmission Line (TL 73/74) - Predicted Changes in Bay Lengths between Adjacent Towers

Maximum Change In Bay Length during the Extraction of Each Longwall

(+ve / -ve = Increase / decrease in the distance between adjacent towers at the level of the highest cables)

Tower	MGA Easting	MGA Northing	Level of Highest Cables (m)	Original Bay Length (m)	Change in Bay Length during WH101 (mm)	Change in Bay Length during WH102 (mm)	Change in Bay Length during WH103 (mm)	Change in Bay Length during WH104 (mm)	Change in Bay Length during WH105 (mm)	Change in Bay Length during WH106 (mm)	Change in Bay Length during GM205 (mm)	Change in Bay Length during AF101 (mm)	Change in Bay Length during AF102 (mm)	Change in Bay Length during BF201 (mm)	Change in Bay Length during BF202 (mm)	Change in Bay Length during BF203 (mm)	Change in Bay Length during PF201 (mm)	Change in Bay Length during PF202 (mm)	Change in Bay Length during PF203 (mm)	Change in Bay Length during PF204 (mm)	Maximum Increase in Bay Length (mm)	Maximum Decrease in Bay Length (mm)	Maximum Percentage Increase in Bay Length (%)	Maximum Percentage Decrease in Bay Length (%)
38	291423	6416822	60.6																					
37	291874	6416439	57.6	592	0	0	0	0	0	0	0	42	113	113	113	113	113	113	113	113	113	0	0.0	0.0
36	292221	6416143	68.6	456	0	0	0	0	0	0	0	-42	-113	-113	-113	-113	-113	-113	-113	-113	0	-113	0.0	0.0
35	292670	6416099	51.6	451	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
34	293117	6416056	57.6	449	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
33	293522	6416018	50.1	407	0	0	0	0	0	0	0	0	0	0	0	0	-2	113	113	113	113	-2	0.0	0.0
32	293979	6415970	57.4	460	0	0	0	0	0	0	0	0	0	-5	50	50	-319	-386	-360	-360	50	-386	0.0	-0.1
31	294339	6415934	52.9	362	0	0	0	0	0	0	0	0	0	-556	3	3	332	187	358	376	376	-556	0.1	-0.2
30	294577	6415909	51.6	239	-1329	365	470	470	470	470	470	470	470	482	196	215	252	165	251	262	482	-1329	0.2	-0.6
29	295211	6415844	71.6	638	1224	-749	-468	-407	-407	-407	-407	-407	-407	140	-1016	-311	-143	-17	-404	-190	1224	-1016	0.2	-0.2
28	295719	6415770	59.1	514	114	-2854	-1140	-980	-980	-980	-980	-980	-980	-980	-189	-1516	-920	-864	-1066	-1290	114	-2854	0.0	-0.6
27	296165	6415705	54.4	451	0	3238	-627	835	956	956	956	956	956	956	980	1295	574	576	862	707	3238	-627	0.7	-0.1
26	296542	6415650	54.4	381	0	0	1658	-142	-90	-36	-36	-36	-36	-36	-36	257	216	216	228	153	1658	-142	0.4	0.0
25	296987	6415586	54.4	450	0	0	125	-1827	-242	-136	-136	-136	-136	-136	-136	-131	-130	-130	-129	75	125	-1827	0.0	-0.4
24	297348	6415533	57.6	365	0	0	0	2066	-2190	1000	1165	1165	1165	1165	1165	1165	1165	1165	1165	1171	2066	-2190	0.6	-0.6
23	297841	6415462	59.1	498	0	0	0	0	2509	-845	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	2509	-1011	0.5	-0.2
22	298260	6415400	57.6	423	0	0	0	0	4	2	2	2	2	2	2	2	2	2	2	2	4	0	0.0	0.0
21	298704	6415336	54.4	449	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
		Maximum:		638	1224	3238	1658	2066	2509	1000	1165	1165	1165	1165	1165	1295	1165	1165	1165	1171	3238	0	0.7	0.0
		Minimum:		239	-1329	-2854	-1140	-1827	-2190	-980	-1011	-1011	-1011	-1011	-1016	-1516	-1011	-1011	-1066	-1290	0	-2854	0.0	-0.6

Maximum Change In Bay Length at the Completion of Each Longwall

(+ve / -ve = Increase / decrease in the distance between adjacent towers at the level of the highest cables)

Tower	MGA Easting	MGA Northing	Level of Highest Cables (m)	Original Bay Length (m)	Change in Bay Length after WH101 (mm)	Change in Bay Length after WH102 (mm)	Change in Bay Length after WH103 (mm)	Change in Bay Length after WH104 (mm)	Change in Bay Length after WH105 (mm)	Change in Bay Length after WH106 (mm)	Change in Bay Length after GM205 (mm)	Change in Bay Length after AF101 (mm)	Change in Bay Length after AF102 (mm)	Change in Bay Length after BF201 (mm)	Change in Bay Length after BF202 (mm)	Change in Bay Length after BF203 (mm)	Change in Bay Length after PF201 (mm)	Change in Bay Length after PF202 (mm)	Change in Bay Length after PF203 (mm)	Change in Bay Length after PF204 (mm)	Maximum Increase in Bay Length (mm)	Maximum Decrease in Bay Length (mm)	Maximum Percentage Increase in Bay Length (%)	Maximum Percentage Decrease in Bay Length (%)
38	291423	6416822	60.6																					
37	291874	6416439	57.6	592	0	0	0	0	0	0	0	113	113	113	113	113	113	113	113	113	113	0	0.0	0.0
36	292221	6416143	68.6	456	0	0	0	0	0	0	0	-113	-113	-113	-113	-113	-113	-113	-113	-113	0	-113	0.0	0.0
35	292670	6416099	51.6	451	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
34	293117	6416056	57.6	449	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
33	293522	6416018	50.1	407	0	0	0	0	0	0	0	0	0	0	0	0	113	113	113	113	113	0	0.0	0.0
32	293979	6415970	57.4	460	0	0	0	0	0	0	0	0	0	50	50	50	-380	-360	-360	-360	50	-380	0.0	-0.1
31	294339	6415934	52.9	362	0	0	0	0	0	0	0	0	0	3	3	3	278	363	376	376	376	0	0.1	0.0
30	294577	6415909	51.6	239	465	470	470	470	470	470	470	470	470	189	215	215	250	260	262	262	470	0	0.2	0.0
29	295211	6415844	71.6	638	-493	-425	-407	-407	-407	-407	-407	-407	-407	-183	-264	-146	-143	-306	-185	-171	0	-493	0.0	-0.1
28	295719	6415770	59.1	514	38	-962	-980	-980	-980	-980	-980	-980	-980	-980	-939	-920	-920	-871	-1265	-1210	38	-1265	0.0	-0.2
27	296165	6415705	54.4	451	0	930	945	956	956	956	956	956	956	956	978	574	574	577	815	845	978	0	0.2	0.0
26	296542	6415650	54.4	381	0	0	-81	-50	-36	-36	-36	-36	-36	-36	-36	216	216	216	226	-77	226	-81	0.1	0.0
25	296987	6415586	54.4	450	0	0	66	-122	-136	-136	-136	-136	-136	-136	-136	-130	-130	-130	-128	65	66	-136	0.0	0.0
24	297348	6415533	57.6	365	0	0	0	146	1142	1165	1165	1165	1165	1165	1165	1165	1165	1165	1165	1172	1172	0	0.3	0.0
23	297841	6415462	59.1	498	0	0	0	0	-988	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	0	-1011	0.0	-0.2
22	298260	6415400	57.6	423	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0.0	0.0
21	298704	6415336	54.4	449	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
		Maximum:		638	465	930	945	956	1142	1165	1165	1165	1165	1165	1165	1165	1165	1165	1165	1172	1172	0	0.3	0.0
		Minimum:		239	-493	-962	-980	-980	-988	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1011	-1265	-1210	0	-1265	0.0	-0.2

Table F.03 - Mount Arthur Underground Project - Details of Building Structures

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Property Name	Type	Description	Owner	Built	Footings	Floor	Walls	Roof	Maximum Plan Dimension (m)	Height (m)
A05a	294574.8	6418023.7	Cooks House	H1	House	MAC		Brick walls & piers	Timber	Timber frame & weatherboard	Metal	14.5	3.8
A05b	294570.7	6418036.5	Cooks House	R	Garage	MAC		Slab on Ground	Concrete	Timber frame & weatherboard	Metal	5.3	3.8
A05t01	294588.7	6418043.4	Cooks House	T	Tank	MAC		-	Metal	Metal	Metal	5.9	3.0
A05t02	294572.3	6418011.9	Cooks House	T	Tank	MAC		-	Metal	Metal	Metal	4.8	2.5
A06a	294534.5	6417816.2	Hospital	H1	House	MAC		Concrete piers	Timber	Timber frame & metal sheet	Metal	9.1	3.8
A06b	294564.1	6417811.6	Hospital	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	20.3	3.0
A06c	294562.1	6417798.9	Hospital	R	Chicken pen	MAC		-	Earth	Metal frame & metal sheet	Metal	4.5	2.5
A06d	294528.4	6417871.4	Hospital	R	Shed	MAC		-	Earth	Timber frame & metal sheet	-	6.2	2.5
A06t01	294532.7	6417822.2	Hospital	T	Tank	MAC		-	Metal	Metal	Metal	1.5	2.5
A06t02	294535.7	6417822.1	Hospital	T	Tank	MAC		-	Metal	Metal	Metal	1.5	2.5
A06t03	294529.5	6417811.0	Hospital	T	Tank	MAC		-	Metal	Metal	Metal	1.8	2.5
A07a	292916.5	6419058.8	Roxburgh South	H1	House	MAC		Brick walls & piers	Timber	Timber frame & weatherboard	Asbestos	21.3	3.8
A07b	292959.8	6419039.7	Roxburgh South	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	18.6	5.0
A07c	293024.3	6419016.7	Roxburgh South	R	Shed	MAC		-	Earth	Metal frame & metal sheet	Metal	13.7	2.5
A07d	292971.3	6419306.4	Roxburgh South	R	Shed	MAC		-	Earth	Metal frame & metal sheet	Metal	16.3	5.0
A07e	293207.6	6419648.7	Roxburgh South	O	Weather station	MAC		-	-	-	-		
A07t01	292946.6	6419037.4	Roxburgh South	T	Tank	MAC		-	Metal	Metal	Metal	5.0	2.5
A07t02	293016.8	6419015.9	Roxburgh South	T	Tank	MAC		-	Metal	Metal	Metal	2.7	2.5
A07t03	293016.6	6419011.8	Roxburgh South	T	Tank	MAC		-	Metal	Metal	Metal	3.4	2.5
A07t04	292990.0	6419055.3	Roxburgh South	T	Desiel Tanks (2 off)	MAC		-	Metal	Metal frame on metal stilts	Metal	5.1	2.5
A08a	293947.8	6417520.7	550 Edderton Rd	H1	House	MAC		Brick walls & piers	Timber	Timber frame & weatherboard	Metal	14.6	3.8
A08b	293924.1	6417524.3	550 Edderton Rd	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	8.8	2.5
A08c	293903.9	6417523.2	550 Edderton Rd	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	10.0	4.0
A08d	293885.5	6417524.4	550 Edderton Rd	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	10.5	2.5
A08t01	293763.7	6417305.7	550 Edderton Rd	T	Tank	MAC		-	Fibreglass	Fibreglass	Fibreglass	7.4	2.5
A08t02	293936.4	6417538.7	550 Edderton Rd	T	Tank	MAC		-	Metal	Metal	Metal	4.3	2.5
A08t03	293800.8	6417325.8	550 Edderton Rd	T	Tank	MAC		-	Metal	Metal	Metal	2.0	2.5
A09a	294416.0	6416100.9	680 Edderton Rd	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	13.6	3.0
A09b	294408.4	6416102.8	680 Edderton Rd	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	6.6	3.0
A09c	294442.5	6416052.6	680 Edderton Rd	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	10.6	2.5
A09t01	294421.3	6416095.9	680 Edderton Rd	T	Tank	MAC		-	Metal	Metal on timber frame	Metal	2.9	2.5
A09t02	294421.7	6416106.3	680 Edderton Rd	T	Tank	MAC		-	Metal	Metal	Metal	3.4	2.5
A09t03	294402.7	6416109.3	680 Edderton Rd	T	Tank	MAC		-	Metal	Metal	Metal	3.4	2.5
A09t04	294402.2	6416113.6	680 Edderton Rd	T	Tank	MAC		-	Metal	Metal	Metal	3.4	2.5
A09t05	294442.3	6416045.4	680 Edderton Rd	T	Tank	MAC		-	Metal	Metal	Metal	2.9	2.5
A10a	296331.1	6415183.2	Belmont Homestead	R	Shed	MAC	1935	-	Timber	Timber frame	Metal	10.0	3.8
A10b	296322.4	6415173.6	Belmont Homestead	H1	House	MAC	1935	Brick walls & piers	Timber	Timber frame & fibresheet	Metal	9.7	3.8
A10c	296317.6	6415200.6	Belmont Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame & metal sheet	Metal	8.0	3.8
A10d	296344.3	6415221.8	Belmont Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame & metal sheet	Metal	8.9	3.8
A10e	296571.7	6415142.0	Belmont Homestead	R	Shed	MAC		Timber piers	Timber	Timber frame & metal sheet	Metal	25.8	6.0
A10f	296518.2	6415120.0	Belmont Homestead	R	Dorm Accomodation	MAC		Brick & concrete piers	Timber	Timber frame & fibro	Metal	23.8	3.8
A10g	296524.1	6415168.2	Belmont Homestead	R	Outhouse (Ruins)	MAC		Slab on Ground	Concrete	Timber	-	5.6	1.0
A10h	296327.4	6415186.6	Belmont Homestead	-	Chimney	MAC		Brick	-	Brick	-	3.7	3.8
A10t01	296312.4	6415183.7	Belmont Homestead	T	Tank	MAC		Slab on Ground	Concrete	Metal	Metal	5.2	2.5
A10t02	296324.9	6415188.4	Belmont Homestead	T	Tank	MAC		Slab on Ground	Concrete	Metal	Metal	2.1	2.5
A10t03	296544.3	6415301.1	Belmont Homestead	T	Tank	MAC		-	Metal	Metal	Metal	8.7	2.5
A10t04	296581.5	6415163.2	Belmont Homestead	T	Tank	MAC		-	Metal	Metal	Metal	8.7	2.5
A11a	293964.7	6416593.5	TSR - HRLPB	H1	House	MAC		Brick piers	Timber	Timber frame & weatherboard	Metal	7.5	3.8
A12a	295692.7	6413016.8	Edderton Homestead	H2	House	MAC	Prior 1915	Brick walls & piers	Timber	Timber frame & weatherboard	Metal	34.6	3.8
A12b	295683.4	6413192.0	Edderton Homestead	H1	House	MAC		Brick piers	Timber	Timber frame & weatherboard	Metal	12.5	4.8

Table F.03 - Mount Arthur Underground Project - Details of Building Structures

Structure Reference	Centroid MGA Easting	Centroid MGA Northing	Property Name	Type	Description	Owner	Built	Footings	Floor	Walls	Roof	Maximum Plan Dimension (m)	Height (m)
A12c	295755.0	6413190.9	Edderton Homestead	H1	House	MAC		Brick & timber piers	Timber	Timber frame & fibro	Metal	13.2	3.8
A12d	295881.6	6413122.5	Edderton Homestead	H1	House	MAC		Timber piers	Timber	Timber frame & weatherboard	Metal	9.6	3.8
A12e	295707.6	6413085.1	Edderton Homestead	R	Garage	MAC		Slab on Ground	Concrete	Timber frame & weatherboard	Metal	23.0	3.8
A12f	295765.8	6413081.4	Edderton Homestead	R	Shed	MAC		-	Earth	Timber frame & weatherboard	Metal	13.7	3.8
A12g	295789.3	6413081.4	Edderton Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame & weatherboard	Metal	13.7	3.8
A12h	295763.0	6413053.8	Edderton Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame & weatherboard	Metal	6.1	3.8
A12i	295833.9	6413060.1	Edderton Homestead	R	Shed	MAC		Timber piers	Timber	Timber frame & metal sheet	Metal	10.6	5.0
A12j	295848.8	6413044.7	Edderton Homestead	R	Shed	MAC		-	Earth	Timber frame	Metal	11.2	3.8
A12k	295858.9	6413090.6	Edderton Homestead	-	Weather station	MAC		-	Earth	Wire fence	-	5.2	1.5
A12l	295887.5	6413144.4	Edderton Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame & metal sheet	Metal	3.7	3.8
A12m	295754.4	6413118.3	Edderton Homestead	R	Shed	MAC		-	Earth	Timber frame	Metal	8.5	3.0
A12n	295713.1	6413198.9	Edderton Homestead	R	Garage	MAC		Slab on Ground	Concrete	Timber frame & metal sheet	Metal	7.6	3.8
A12o	295681.4	6412953.1	Edderton Homestead	-	Tennis court	MAC		-	Earth	Wire fence	-	16.0	3.0
A12p	295733.5	6412906.1	Edderton Homestead	H1	House	MAC		Brick piers	Timber	Timber frame & weatherboard	Metal	9.7	3.8
A12q	295859.2	6413130.1	Edderton Homestead	R	Silo	MAC		Slab on Ground	Concrete	Metal	Metal	4.4	5.0
A12r	295689.2	6413035.0	Edderton Homestead	R	Pavement & Awning	MAC		Slab on Ground	Concrete	Brick	Metal	7.1	3.0
A12s	295694.9	6413218.9	Edderton Homestead	R	Kennel	MAC		-	Earth	Metal	Metal	5.2	2.0
A12t	295770.5	6413017.4	Edderton Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame & weatherboard	Metal	5.0	3.0
A12u	295733.7	6413000.9	Edderton Homestead	R	Laundry	MAC		Slab on Ground	Concrete	Concrete	Concrete	9.8	3.8
A12v	295739.5	6412997.4	Edderton Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame	Metal	2.9	2.5
A12w	295798.2	6412995.3	Edderton Homestead	R	Shed	MAC		-	Timber	Timber frame & metal sheet	Metal	9.4	2.5
A12x	295792.1	6413001.6	Edderton Homestead	R	Shed	MAC		Slab on Ground	Concrete	Timber frame & weatherboard	Metal	3.2	2.5
A12y	295803.0	6413002.2	Edderton Homestead	R	Shed	MAC		-	Earth	Timber frame & metal sheet	Metal	3.5	2.5
A12z	295815.7	6413009.8	Edderton Homestead	R	Stable	MAC		-	Earth	Timber frame & metal sheet	Metal	6.1	2.5
A12aa	295825.1	6413007.0	Edderton Homestead	R	Silo	MAC		Timber sleepers	Metal	Metal	Metal	6.1	3.8
A12t01	295689.1	6413039.5	Edderton Homestead	T	Tank	MAC		Slab on Ground	Metal	Metal	Metal	2.4	3.0
A12t02	295710.0	6412980.9	Edderton Homestead	T	Tank	MAC		-	Concrete	Concrete	Concrete	5.5	2.5
A12t03	295727.1	6412898.9	Edderton Homestead	T	Tank	MAC		-	Polymer	Polymer	Polymer	3.5	2.5
A12t04	295732.3	6412899.2	Edderton Homestead	T	Tank	MAC		-	Polymer	Polymer	Polymer	3.5	2.5
A12t05	295736.7	6412895.5	Edderton Homestead	T	Tank	MAC		-	Polymer	Polymer	Polymer	3.5	2.5
A12t06	295758.9	6413078.7	Edderton Homestead	T	Tank	MAC		-	Concrete	Concrete	Metal	4.1	3.0
A12t07	295767.5	6413052.4	Edderton Homestead	T	Tank	MAC		-	Metal	Metal	Metal	2.7	2.5
A12t08	295875.6	6413124.4	Edderton Homestead	T	Tank	MAC		Timber frame	Metal	Metal	Metal	1.8	2.5
A12t09	295891.9	6413124.8	Edderton Homestead	T	Septic Tank	MAC		-	Concrete	Concrete	Concrete	1.8	2.5
A12t10	295675.3	6413193.8	Edderton Homestead	T	Septic Tank	MAC		-	Concrete	Concrete	Concrete	2.5	2.5
A12t11	295681.4	6413202.3	Edderton Homestead	T	Tank	MAC		Slab on Ground	Metal	Metal	Metal	2.8	2.5
A12t12	295681.6	6413198.7	Edderton Homestead	T	Tank	MAC		Slab on Ground	Metal	Metal	Metal	2.8	2.5
A12t13	295751.6	6413182.9	Edderton Homestead	T	Tank	MAC		Slab on Ground	Metal	Metal	Metal	2.0	2.5
A12t14	295733.8	6412979.9	Edderton Homestead	T	Septic Tank	MAC		-	Concrete	Concrete	Concrete	11.7	2.5
A12t15	295883.3	6413227.0	Edderton Homestead	T	Tank	MAC		-	Metal	Metal	Metal	11.2	2.5
A13t01	293148.4	6414678.8	Wolfgang	T	Tank	Wolfgang		-	Metal	Metal	Metal	5.0	2.5

Table F.04 - Mount Arthur Underground Project - Predictions and Impact Assessments for Building Structures

Structure Name	Structure Type	Structure Centroid MGA Easting (m)	Structure Centroid MGA Northing (m)	Maximum Structure Plan Dimension (m)	Structure Height (m)	Maximum Predicted Subsidence due to WH (mm)	Maximum Predicted Subsidence due to WH+GM (mm)	Maximum Predicted Subsidence due to WH+GM+AF (mm)	Maximum Predicted Subsidence due to WH+GM+AF +BF (mm)	Maximum Predicted Subsidence due to WH+GM+AF +BF+PF (mm)	Maximum Predicted Travel Tilt during the Extraction of WH Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of GM Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of AF Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of BF Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of PF Longwalls (mm/m)	Maximum Predicted Total Tilt due to WH (mm/m)	Maximum Predicted Total Tilt due to WH+GM (mm/m)	Maximum Predicted Total Tilt due to WH+GM+AF (mm/m)	Maximum Predicted Total Tilt due to WH+GM+AF+BF (mm/m)	Maximum Predicted Total Tilt due to WH+GM+AF+BF +PF (mm/m)	Tilt Impact Assessment at the Completion WH	Tilt Impact Assessment at the Completion WH+GM	Tilt Impact Assessment at the Completion WH+GM+AF	Tilt Impact Assessment at the Completion WH+GM+AF+BF	Tilt Impact Assessment at the Completion WH+GM+AF+BF +PF
A05a	H1	294575	6418024	14.489	3.750	0	0	282	282	1731	0.0	0.0	1.8	0.0	5.3	0.0	0.0	7.1	7.1	29.2	Category A	Category A	Category C	Category C	Category D
A05b	R	294571	6418036	5.253	3.750	0	0	153	153	1411	0.0	0.0	0.9	0.0	4.7	0.0	0.0	2.2	2.2	25.8	Category A	Category A	Category A	Category A	Category D
A05t01	T	294589	6418043	5.900	3.000	0	0	151	151	1404	0.0	0.0	0.9	0.0	4.7	0.0	0.0	2.2	2.2	25.4	-	-	-	-	-
A05t02	T	294572	6418012	4.800	2.500	0	0	373	373	1834	0.0	0.0	2.6	0.0	5.4	0.0	0.0	10.2	10.2	17.0	-	-	-	-	-
A06a	H1	294534	6417816	9.138	3.750	0	0	1515	1515	2427	0.0	0.0	12.2	0.0	2.1	0.0	0.0	6.4	6.4	9.2	Category A	Category A	Category B	Category B	Category C
A06b	R	294564	6417812	20.294	3.000	0	0	1487	1487	2373	0.0	0.0	12.0	0.0	2.4	0.0	0.0	15.3	15.3	14.8	Category A	Category A	Category D	Category D	Category D
A06c	R	294562	6417799	4.549	2.500	0	0	1371	1371	2195	0.0	0.0	11.1	0.0	2.5	0.0	0.0	17.8	17.8	16.8	Category A	Category A	Category D	Category D	Category D
A06d	R	294528	6417871	6.233	2.500	0	0	1559	1559	2792	0.0	0.0	12.6	0.0	3.7	0.0	0.0	0.4	0.4	7.4	Category A	Category A	Category A	Category A	Category C
A06t01	T	294533	6417822	1.500	2.500	0	0	1519	1519	2436	0.0	0.0	12.2	0.0	1.9	0.0	0.0	4.1	4.1	7.9	-	-	-	-	-
A06t02	T	294536	6417822	1.500	2.500	0	0	1516	1516	2431	0.0	0.0	12.2	0.0	1.9	0.0	0.0	4.2	4.2	8.0	-	-	-	-	-
A06t03	T	294529	6417811	1.800	2.500	0	0	1491	1491	2368	0.0	0.0	12.0	0.0	2.1	0.0	0.0	6.2	6.2	9.1	-	-	-	-	-
A07a	H1	292916	6419059	21.310	3.750	0	1638	3572	3572	3572	0.0	> 50	15.6	0.0	0.0	0.0	0.0	> 50	> 50	> 50	Category A	Category D	Category D	Category D	Category D
A07b	R	292960	6419040	18.578	5.000	0	2060	3960	3960	3960	0.0	> 50	15.3	0.0	0.0	0.0	0.0	33.1	32.7	32.7	Category A	Category D	Category D	Category D	Category D
A07c	R	293024	6419017	13.660	2.500	0	2072	3945	3945	3945	0.0	> 50	14.3	0.0	0.0	0.0	0.0	0.1	10.4	10.4	Category A	Category A	Category D	Category D	Category D
A07d	R	292971	6419306	16.306	5.000	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A07e	O	293206	6419649	0.000	0.000	0	0	0	37	37	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	1.5	1.5	-	-	-	-	-
A07t01	T	292947	6419037	5.000	2.500	0	2031	3948	3948	3948	0.0	> 50	15.4	0.0	0.0	0.0	0.0	23.8	23.2	23.2	23.2	-	-	-	-	-
A07t02	T	293017	6419016	2.700	2.500	0	2071	3926	3926	3926	0.0	> 50	14.2	0.0	0.0	0.0	0.0	0.1	7.5	7.5	7.5	-	-	-	-	-
A07t03	T	293017	6419012	3.400	2.500	0	2071	3910	3910	3910	0.0	> 50	14.1	0.0	0.0	0.0	0.0	0.1	8.9	8.9	8.9	-	-	-	-	-
A07t04	T	292990	6419055	5.134	2.500	0	1991	3912	3912	3912	0.0	> 50	15.2	0.0	0.0	0.0	0.0	43.7	43.4	43.4	43.4	-	-	-	-	-
A08a	H1	293948	6417521	14.558	3.750	0	1728	2679	2679	3773	0.0	> 50	6.0	0.0	3.9	0.0	0.0	1.2	5.6	6.0	Category A	Category A	Category B	Category B	Category B
A08b	R	293924	6417524	8.759	2.500	0	1746	2789	2789	3751	0.0	> 50	6.9	0.0	3.6	0.0	0.0	1.4	8.5	8.5	Category A	Category A	Category C	Category C	Category A
A08c	R	293904	6417523	10.004	4.000	0	1767	2885	2885	3825	0.0	> 50	7.5	0.0	3.5	0.0	0.0	1.5	10.3	10.3	Category A	Category A	Category D	Category D	Category B
A08d	R	293886	6417524	10.459	2.500	0	1782	2979	2979	3899	0.0	> 50	8.2	0.0	3.3	0.0	0.0	1.4	11.8	11.8	Category A	Category A	Category D	Category D	Category C
A08t01	T	293764	6417306	7.400	2.500	0	996	2868	2868	4224	0.0	> 50	11.8	0.0	3.9	0.0	0.0	43.0	45.1	45.1	> 50	-	-	-	-	-
A08t02	T	293936	6417539	4.300	2.500	0	1713	2846	2846	3779	0.0	> 50	7.7	0.0	3.3	0.0	0.0	1.3	10.7	10.7	6.3	-	-	-	-	-
A08t03	T	293801	6417326	2.000	2.500	0	1622	3375	3375	4749	0.0	> 50	11.9	0.0	4.0	0.0	0.0	> 50	> 50	> 50	> 50	-	-	-	-	-
A09a	R	294416	6416101	13.582	3.000	0	0	0	130	803	0.0	0.0	0.0	0.9	2.6	0.0	0.0	0.0	4.3	7.9	Category A	Category A	Category A	Category A	Category C
A09b	R	294408	6416103	6.626	3.000	0	0	0	91	813	0.0	0.0	0.0	0.6	2.9	0.0	0.0	0.0	3.3	8.1	Category A	Category A	Category A	Category A	Category C
A09c	R	294443	6416053	10.823	2.500	0	0	0	1018	1730	0.0	0.0	0.0	7.0	1.9	0.0	0.0	0.0	25.6	22.1	Category A	Category A	Category A	Category D	Category D
A09t01	T	294421	6416096	2.900	2.500	0	0	0	132	775	0.0	0.0	0.0	0.9	2.3	0.0	0.0	0.0	4.4	5.0	-	-	-	-	-
A09t02	T	294422	6416106	3.400	2.500	0	0	0	84	777	0.0	0.0	0.0	0.6	2.7	0.0	0.0	0.0	3.1	7.2	-	-	-	-	-
A09t03	T	294403	6416109	3.400	2.500	0	0	0	51	869	0.0	0.0	0.0	0.4	3.1	0.0	0.0	0.0	2.1	9.2	-	-	-	-	-
A09t04	T	294402	6416114	3.400	2.500	0	0	0	38	915	0.0	0.0	0.0	0.3	3.3	0.0	0.0	0.0	1.7	9.9	-	-	-	-	-
A09t05	T	294442	6416045	2.900	2.500	0	0	0	1058	1767	0.0	0.0	0.0	7.3	1.5	0.0	0.0	0.0	25.6	22.4	-	-	-	-	-
A10a	R	296331	6415183	10.021	3.750	1696	1696	1696	1696	1696	38.0	0.0	0.0	0.0	0.0	43.3	43.3	43.3	43.3	43.3	Category D	Category D	Category D	Category D	Category D
A10b	H1	296322	6415174	9.652	3.750	1783	1783	1783	1783	1783	39.9	0.0	0.0	0.0	0.0	39.4	39.4	39.4	39.4	39.4	Category D	Category D	Category D	Category D	Category D
A10c	R	296318	6415201	7.950	3.750	908	908	908	908	908	20.3	0.0	0.0	0.0	0.0	31.1	31.1	31.1	31.1	31.0	Category D	Category D	Category D	Category D	Category D
A10d	R	296344	6415222	8.886	3.750	492	492	492	492	492	10.9	0.0	0.0	0.0	0.0	13.5	13.5	13.5	13.5	13.4	Category D	Category D	Category D	Category D	Category D
A10e	R	296572	6415142	25.842	6.000	2109	2109	2109	2109	2109	> 50	0.0	0.0	0.0	0.0	2.9	2.9	2.9	2.9	2.9	Category A	Category A	Category A	Category A	Category A
A10f	R	296516	6415120	23.787	3.750	2110	2110	2110	2110	2110	> 50	0.0	0.0	0.0	0.0	2.9	2.9	2.9	2.9	2.9	Category A	Category A	Category A	Category A	Category A
A10g	R	296524	6415168	5.613	1.000	2105	2105	2105	2105	2105	> 50	0.0	0.0	0.0	0.0	1.3	1.3	1.3	1.3	1.3	Category A	Category A	Category A	Category A	Category A
A10h	-	296327	6415187	3.721	3.750	1454	1454	1454	1454	1454	32.6	0.0	0.0	0.0	0.0	43.4	43.4	43.4	43.4	43.4	-	-	-	-	-
A10t01	T	296312	6415184	5.167	2.500	1416	1416	1416	1416	1416	31.7	0.0	0.0	0.0	0.0	43.3	43.3	43.3	43.3	43.3	-	-	-	-	-
A10t02	T	296325	6415188	2.100	2.500	1359	1359	1359	1359	1359	30.4	0.0	0.0	0.0	0.0	43.3	43.3	43.3	43.3	43.3	-	-	-	-	-
A10t03	T	296544	6415301	8.700	2.500	308	308	308	308	308	6.7	0.0	0.0	0.0	0.0	6.0	6.0	6.0	6.0	5.9	-	-	-	-	-
A10t04	T	296582	6415163	8.700	2.500	2109	2109	2109	2109	2109	> 50	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	-	-	-	-	-
A12a	H2	295693	6413017	34.580	3.750	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12b	H1	295683	6413192	12.498	4.750	1437	1437	1437	1437	1437	24.8	0.0	0.0	0.0	0.0	9.5	9.5	9.5	9.5	9.5	Category C	Category C	Category C	Category C	Category C
A12c	H1	295755	6413191	13.193	3.750	1271	1271	1271	1271	1271	20.7	0.0	0.0	0.0	0.0	22.2	22.2	22.2	22.2	22.2	Category D	Category D	Category D	Category D	Category D
A12d	H1	295882	6413122	9.637	3.750	12	12	12	12	12	0.2	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	Category A	Category A	Category A	Category A	Category A
A12e	R	295708	6413085	23.002	3.750	73	73	73	73	73	1.3	0.0	0.0	0.0	0.0	2.9	2.9	2.9	2.9	2.9	Category A	Category A	Category A	Category A	Category A
A12f	R	295766	6413081	13.681	3.750	13	13	13	13	13	0.2	0.0	0.0	0.0	0.0	0.7	0.7	0.7	0.7	0.7	Category A	Category A	Category A	Category A	Category A
A12g	R	295789	6413081	13.671	3.750	4	4	4	4	4	0.1	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	Category A	Category A	Category A	Category A	Category A
A12h	R	295763	6413054	6.076	3.750	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12i	R	295834	6413060	10.633	5.000	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12j	R	295849	6413045	11.243	3.750	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12k	-	295859	6413091	5.220	1.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12l	R	295887	6413144	3.672	3.750	43	43	43	43	43	0.7	0.0	0.0	0.0	0.0	1.9	1.9	1.9	1.9	1.9	Category A	Category A	Category A	Category A	Category A
A12m	R	295754	6413118	8.507	3.000	132	132	132	132	132	2.2	0.0	0.0	0.0	0.0	4.4	4.4	4.4	4.4	4.4	Category A	Category A	Category A	Category A	Category A
A12n	R	295713	6413199	7.584	3.750	1414	1414	1414	1414	1414	23.7	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	10.4	Category D	Category D	Category D	Category D	Category D
A12o	-	295681	6412953	15.993	3.000	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12p	H1	295734	6412906	9.735	3.750	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12q	R	295859	6413130	4.400	5.000	34	34	34	34	34	0.5	0.0	0.0	0.0	0.0	1.5	1.5	1.5	1.5	1.5	Category A	Category A	Category A	Category A	Category A
A12r	R	295689	6413035	7.101	3.000	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12s	R	295695	6413219	5.184	2.000	1458	1458	1458	1458	1458	24.5	0.0	0.0	0.0	0.0	2.2	2.2	2.2	2.2	2.2	Category A	Category A	Category A	Category A	Category A
A12t	R	295770	6413017	5.008	3.000	1450	1450	1450	1450	1450	25.2	0.0	0.0	0.0	0.0	22.2	22.2	22.2	22.2	22.2	Category D	Category D	Category D	Category D	Category D
A12u	R	295734	6413001	9.832	3.750	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12v	R	295739	6412997	2.911	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12w	R	295798	6412995	9.354	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12x	R	295792	6413002	3.189	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12y	R	295803	6413002	3.464	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Category A	Category A	Category A	Category A	Category A
A12z	R	295816	6413010	6.080	2.500	1458	1458	1458	1458	1458	25.8	0.0	0.0	0.0	0.0	22.2	22.2	22.2	22.2	22.2	Category D	Category D	Category D	Category D	Category D
A12aa	R	295825	6413007	6.080	3.750	1458	1458	1458	1458	1458	25.9	0.0	0.0	0.0	0.0	22.2	22.2	22.2	22.2	22.2	Category D	Category D	Category D	Category D	Category D
A12t01	T	295689	6413040	2.400	3.000	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12t02	T	295710	6412981	5.523	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12t03	T	295727	6412899	3.500	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12t04	T	295732	6412899	3.500	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12t05	T	295737	6412896	3.500	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12t06	T	295759	6413079	4.100	3.000	6	6	6	6	6	0.1	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	-	-	-	-	-
A12t07	T	295768	6413052	2.700	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12t08	T	295876	6413124	1.800	2.500	11	11	11	11	11	0.2	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	-	-	-	-	-
A12t09	T	295892	6413125	1.800	2.500	6	6	6	6	6	0.1	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	-	-	-	-	-
A12t10	T	295675	6413194	2.500	2.500	1436	1436	1436	1436	1436	24.9	0.0	0.0	0.0	0.0	5.8	5.8	5.8	5.8	5.8	-	-	-	-	-
A12t11	T	295681	6413202	2.800	2.500	1450	1450	1450	1450	1450	24.9	0.0	0.0	0.0	0.0	4.4	4.4	4.4	4.4	4.4	-	-	-	-	-
A12t12	T	295682	6413199	2.800	2.500	1442	1442	1442	1442	1442	24.8	0.0	0.0	0.0	0.0	5.3	5.3	5.3	5.3	5.3	-	-	-	-	-
A12t13	T	295752	6413183	2.000	2.500	1088	1088	1088	1088	1088	17.8	0.0	0.0	0.0	0.0	22.2	22.2	22.2	22.2	22.2	-	-	-	-	-
A12t14	T	295734	6412980	11.692	2.500	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-
A12t15	T	295883	6413227	11.200	2.500	931	931	931	931	931	14.0	0.0	0.0	0.0	0.0	19.6	19.6	19.6	19.6	19.6	-	-	-	-	-
A13t01	T	293148	6414679	5.000	2.500	0	0	0	0	1588	0.0	0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	17.3	-	-	-	-	-

Table F.04 - Mount Arthur Underground Project - Predictions and Impact Assessments for Building Structures

Structure Name	Structure Type	Structure Centroid MGA Easting (m)	Structure Centroid MGA Northing (m)	Maximum Structure Plan Dimension (m)	Structure Height (m)	Impact Assessment Strain due to the Extraction of WH (mm/m)	Strain Impact Assessment due to the Extraction of WH	Impact Assessment Strain due to the Extraction of WH+GM (mm/m)	Strain Impact Assessment due to the Extraction of WH+GM	Impact Assessment Strain due to the Extraction of WH+GM+AF (mm/m)	Strain Impact Assessment due to the Extraction of WH+GM+AF	Impact Assessment Strain due to the Extraction of WH+GM+AF+ BF (mm/m)	Strain Impact Assessment due to the Extraction of WH+GM+AF+ BF	Impact Assessment Strain due to the Extraction of WH+GM+AF+ BF+PF (mm/m)	Strain Impact Assessment due to the Extraction of WH+GM+AF+ BF+PF	Tilt Impact Assessment at the Completion of All Longwalls within All Seams with an Increased Prediction x1.25	Tilt Impact Assessment at the Completion of All Longwalls within All Seams with an Increased Prediction x1.5	Tilt Impact Assessment at the Completion of All Longwalls within All Seams with an Increased Prediction x1.75	Tilt Impact Assessment at the Completion of All Longwalls within All Seams with an Increased Prediction x2.0	Tilt Impact Assessment at the Completion of All Longwalls within All Seams with an Increased Prediction x5.0	Strain Impact Assessment due to the Extraction of All Longwalls within All Seams with an Increased Prediction x1.25	Strain Impact Assessment due to the Extraction of All Longwalls within All Seams with an Increased Prediction x1.5	Strain Impact Assessment due to the Extraction of All Longwalls within All Seams with an Increased Prediction x1.75	Strain Impact Assessment due to the Extraction of All Longwalls within All Seams with an Increased Prediction x2.0	Strain Impact Assessment due to the Extraction of All Longwalls within All Seams with an Increased Prediction x5.0
A05a	H1	294575	6418024	14.489	3.750	0.1	Category 0	0.1	Category 0	4.9	Category 3	4.9	Category 3	-14.0	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A05b	R	294571	6418036	5.253	3.750	0.1	Category 0	0.1	Category 0	2.7	Category 1	2.7	Category 1	18.1	Category 3	Category D	Category D	Category D	Category D	Category D	Category 3	Category 4	Category 4	Category 5	Category 5
A05t01	T	294589	6418043	5.900	3.000	0.1	-	0.1	-	2.5	-	2.5	-	17.3	-	-	-	-	-	-	-	-	-	-	-
A05t02	T	294572	6418012	4.800	2.500	0.1	-	0.1	-	7.0	-	7.0	-	7.0	-	-	-	-	-	-	-	-	-	-	-
A06a	H1	294534	6417816	9.138	3.750	0.1	Category 0	0.1	Category 0	3.5	Category 2	3.5	Category 2	3.5	Category 2	Category D	Category D	Category D	Category D	Category D	Category 2	Category 2	Category 2	Category 3	Category 4
A06b	R	294564	6417812	20.294	3.000	0.1	Category 0	0.1	Category 0	-6.0	Category 4	-6.0	Category 4	-6.0	Category 4	Category D	Category D	Category D	Category D	Category D	Category 4	Category 5	Category 5	Category 5	Category 5
A06c	R	294562	6417799	4.549	2.500	0.1	Category 0	0.1	Category 0	-7.2	Category 2	-7.2	Category 2	-7.2	Category 2	Category D	Category D	Category D	Category D	Category D	Category 2	Category 2	Category 2	Category 3	Category 4
A06d	R	294528	6417871	6.233	2.500	0.1	Category 0	0.1	Category 0	3.3	Category 1	3.3	Category 1	3.3	Category 1	Category C	Category D	Category D	Category D	Category D	Category 1	Category 2	Category 2	Category 2	Category 3
A06t01	T	294533	6417622	1.500	2.500	0.1	-	0.1	-	3.2	-	3.2	-	3.2	-	-	-	-	-	-	-	-	-	-	-
A06t02	T	294536	6417622	1.500	2.500	0.1	-	0.1	-	3.2	-	3.2	-	3.2	-	-	-	-	-	-	-	-	-	-	-
A06t03	T	294529	6417811	1.800	2.500	0.1	-	0.1	-	3.1	-	3.1	-	3.1	-	-	-	-	-	-	-	-	-	-	-
A07a	H1	292916	6419059	21.310	3.750	0.1	Category 0	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A07b	R	292960	6419040	18.578	5.000	0.1	Category 0	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A07c	R	293024	6419017	13.660	2.500	0.1	Category 0	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A07d	R	292971	6419306	16.306	5.000	0.1	Category 0	0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A07e	O	293208	6419649	0.000	0.000	0.1	-	0.1	-	0.1	-	0.9	-	0.9	-	-	-	-	-	-	-	-	-	-	-
A07t01	T	292947	6419037	5.000	2.500	0.1	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A07t02	T	293017	6419016	2.700	2.500	0.1	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A07t03	T	293017	6419012	3.400	2.500	0.1	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A07t04	T	292990	6419055	5.134	2.500	0.1	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A08a	H1	293948	6417521	14.558	3.750	0.1	Category 0	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category C	Category C	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A08b	R	293924	6417524	8.759	2.500	0.1	Category 0	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category A	Category B	Category B	Category C	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A08c	R	293904	6417523	10.004	4.000	0.1	Category 0	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category C	Category C	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A08d	R	293886	6417524	10.459	2.500	0.1	Category 0	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category C	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A08t01	T	293764	6417306	7.400	2.500	0.1	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A08t02	T	293936	6417539	4.300	2.500	0.1	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A08t03	T	293801	6417326	2.000	2.500	0.1	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A09a	R	294416	6416101	13.582	3.000	0.1	Category 0	0.1	Category 0	0.1	Category 0	1.8	Category 1	22.4	Category 5	Category C	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A09b	R	294408	6416103	6.626	3.000	0.1	Category 0	0.1	Category 0	0.1	Category 0	1.6	Category 2	4.9	Category 2	Category D	Category D	Category D	Category D	Category D	Category 2	Category 2	Category 2	Category 4	Category 4
A09c	R	294443	6416053	10.623	2.500	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	8.1	Category 3	9.2	Category 3	Category D	Category D	Category D	Category D	Category D	Category 4	Category 4	Category 4	Category 5	Category 5
A09t01	T	294421	6416096	2.900	2.500	0.1	-	0.1	-	0.1	-	1.8	-	23.2	-	-	-	-	-	-	-	-	-	-	-
A09t02	T	294422	6416106	3.400	2.500	0.1	-	0.1	-	0.1	-	1.5	-	4.0	-	-	-	-	-	-	-	-	-	-	-
A09t03	T	294403	6416109	3.400	2.500	0.1	-	0.1	-	0.1	-	1.4	-	2.6	-	-	-	-	-	-	-	-	-	-	-
A09t04	T	294402	6416114	3.400	2.500	0.1	-	0.1	-	0.1	-	1.3	-	2.2	-	-	-	-	-	-	-	-	-	-	-
A09t05	T	294442	6416045	2.900	2.500	-0.1	-	-0.1	-	-0.1	-	2.1	-	3.3	-	-	-	-	-	-	-	-	-	-	-
A10a	R	296331	6415183	10.021	3.750	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A10b	H1	296322	6415174	9.652	3.750	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A10c	R	296318	6415201	7.950	3.750	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A10d	R	296344	6415222	8.886	3.750	15.2	Category 4	15.2	Category 4	15.2	Category 4	15.2	Category 4	15.2	Category 4	Category D	Category D	Category D	Category D	Category D	Category 4	Category 5	Category 5	Category 5	Category 5
A10e	R	296572	6415142	25.842	6.000	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category A	Category A	Category B	Category B	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A10f	R	296518	6415120	23.787	3.750	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category A	Category A	Category B	Category B	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A10g	R	296524	6415168	5.613	1.000	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	> 25	Category 5	Category A	Category A	Category A	Category A	Category B	Category 5	Category 5	Category 5	Category 5	Category 5
A10h	-	296327	6415187	3.721	3.750	24.4	-	24.4	-	24.4	-	24.4	-	24.4	-	-	-	-	-	-	-	-	-	-	-
A10t01	T	296312	6415184	5.167	2.500	21.6	-	21.6	-	21.6	-	21.6	-	21.6	-	-	-	-	-	-	-	-	-	-	-
A10t02	T	296325	6415188	2.100	2.500	20.8	-	20.8	-	20.8	-	20.8	-	20.8	-	-	-	-	-	-	-	-	-	-	-
A10t03	T	296544	6415301	8.700	2.500	4.8	-	4.8	-	4.8	-	4.8	-	4.8	-	-	-	-	-	-	-	-	-	-	-
A10t04	T	296582	6415163	8.700	2.500	> 25	-	> 25	-	> 25	-	> 25	-	> 25	-	-	-	-	-	-	-	-	-	-	-
A12a	H2	295693	6413017	34.580	3.750	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 1
A12b	H1	295683	6413192	12.498	4.750	15.8	Category 5	15.8	Category 5	15.8	Category 5	15.8	Category 5	15.8	Category 5	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A12c	H1	295755	6413191	13.193	3.750	11.7	Category 4	11.7	Category 4	11.7	Category 4	11.7	Category 4	11.7	Category 4	Category D	Category D	Category D	Category D	Category D	Category 5	Category 5	Category 5	Category 5	Category 5
A12d	H1	295882	6413122	9.637	3.750	0.8	Category 0	0.8	Category 0	0.8	Category 0	0.8	Category 0	0.8	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 1	Category 1	Category 2
A12e	R	295708	6413085	23.002	3.750	1.7	Category 2	1.7	Category 2	1.7	Category 2	1.7	Category 2	1.7	Category 2	Category A	Category A	Category B	Category B	Category D	Category 2	Category 2	Category 3	Category 3	Category 5
A12f	R	295796	6413081	13.681	3.750	0.9	Category 0	0.9	Category 0	0.9	Category 0	0.9	Category 0	0.9	Category 0	Category A	Category A	Category A	Category A	Category A	Category 1	Category 1	Category 1	Category 1	Category 3
A12g	R	295789	6413081	13.671	3.750	0.6	Category 0	0.6	Category 0	0.6	Category 0	0.6	Category 0	0.6	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 1	Category 1	Category 2
A12h	R	295763	6413054	6.076	3.750	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12i	R	295834	6413060	10.633	5.000	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12j	R	295849	6413045	11.243	3.750	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12k	-	295859	6413091	5.220	1.500	-0.1	-	-0.1	-	-0.1	-	-0.1	-	-0.1	-	-	-	-	-	-	-	-	-	-	-
A12l	R	295887	6413144	3.672	3.750	1.3	Category 0	1.3	Category 0	1.3	Category 0	1.3	Category 0	1.3	Category 0	Category A	Category A	Category A	Category A	Category C	Category 0	Category 0	Category 0	Category 0	Category 1
A12m	R	295754	6413118	8.507	3.000	1.8	Category 1	1.8	Category 1	1.8	Category 1	1.8	Category 1	1.8	Category 1	Category B	Category B	Category C	Category C	Category D	Category 1	Category 1	Category 1	Category 2	Category 3
A12n	R	295713	6413199	7.584	3.750	13.7	Category 3	13.7	Category 3	13.7	Category 3	13.7	Category 3	13.7	Category 3	Category D	Category D	Category D	Category D	Category D	Category 4	Category 4	Category 5	Category 5	Category 5
A12o	-	295681	6412953	15.993	3.000	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
A12p	H1	295734	6412996	9.735	3.750	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12q	R	295659	6413130	4.400	5.000	1.4	Category 0	1.4	Category 0	1.4	Category 0	1.4	Category 0	1.4	Category 0	Category A	Category A	Category A	Category A	Category C	Category 0	Category 0	Category 0	Category 0	Category 2
A12r	R	295689	6413035	7.101	3.000	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	-0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12s	R	295695	6413219	5.184	2.000	12.5	Category 3	12.5	Category 3	12.5	Category 3	12.5	Category 3	12.5	Category 3	Category A	Category A	Category A	Category A	Category D	Category 3	Category 3	Category 3	Category 4	Category 5
A12t	R	295770	6413017	5.008	3.000	14.3	Category 3	14.3	Category 3	14.3	Category 3	14.3	Category 3	14.3	Category 3	Category D	Category D	Category D	Category D	Category D	Category 3	Category 3	Category 4	Category 4	Category 5
A12u	R	295734	6413001	9.832	3.750	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12v	R	295739	6412997	2.911	2.500	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12w	R	295798	6412995	9.354	2.500	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12x	R	295792	6413002	3.189	2.500	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12y	R	295803	6413002	3.464	2.500	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	0.1	Category 0	Category A	Category A	Category A	Category A	Category A	Category 0	Category 0	Category 0	Category 0	Category 0
A12z	R	295816	6413010	6.080	2.500	14.4	Category 3	14.4	Category 3	14.4	Category 3	14.4	Category 3	14.4	Category 3	Category D	Category D	Category D	Category D	Category D	Category 3	Category 3	Category 4	Category 4	Category 5
A12aa	R	295825	6413007	6.080	3.750	16.0	Category 3	16.0	Category 3	16.0	Category 3	16.0	Category 3	16.0	Category 3	Category D	Category D	Category D	Category D	Category D	Category 4	Category 4	Category 5	Category 5	Category 5
A12t01	T	295689	6413040	2.400	3.000	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
A12t02	T	295710	6412981	5.523	2.500	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
A12t03	T	295727	6412899	3.500	2.500	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
A12t04	T	295732	6412899	3.500	2.500	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
A12t05	T	295737	6412896	3.500	2.500	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
A12t06	T	295759	6413079	4.100	3.000	0.6	-	0.6	-	0.6	-	0.6	-	0.6	-	-	-	-	-	-	-	-	-	-	-
A12t07	T	295768	6413052	2.700	2.500	-0.1	-	-0.1	-	-0.1	-	-0.1	-	-0.1	-	-	-	-	-	-	-	-	-	-	-
A12t08	T	295676	6413124	1.800	2.500	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-	-	-	-	-	-	-	-	-	-	-
A12t09	T	295892	6413125	1.800	2.500	0.6	-	0.6	-	0.6	-	0.6	-	0.6	-	-	-	-	-	-	-	-	-	-	-
A12t10	T	295675	6413194	2.500	2.500	13.6	-	13.6	-	13.6	-	13.6	-	13.6	-	-	-	-	-	-	-	-	-	-	-
A12t11	T	295681	6413202	2.800	2.500	13.5	-	13.5	-	13.5	-	13.5	-	13.5	-	-	-	-	-	-	-	-	-	-	-
A12t12	T	295682	6413199	2.800	2.500	13.5	-	13.5	-	13.5	-	13.5	-	13.5	-	-	-	-	-	-	-	-	-	-	-
A12t13	T	295752	6413183	2.000	2.500	9.2	-	9.2	-	9.2	-	9.2	-	9.2	-	-	-	-	-	-	-	-	-	-	-
A12t14	T	295734	6412980	11.692	2.500	0.1	-	0.1	-	0.1	-	0.1	-	0.1	-	-	-	-	-	-	-	-	-	-	-
A12t15	T	295883	6413227	11.200	2.500	6.8	-	6.8	-	6.8	-	6.8	-	6.8	-	-	-	-	-	-	-	-	-	-	-
A13t01	T	293148	6414679	5.000	2.500	0.1	-	0.1	-	0.1	-	0.1	-	-2.1	-	-	-	-	-	-	-	-	-	-	-

Table F.05 - Mount Arthur Underground Project - Details and Predictions for Farm Dams

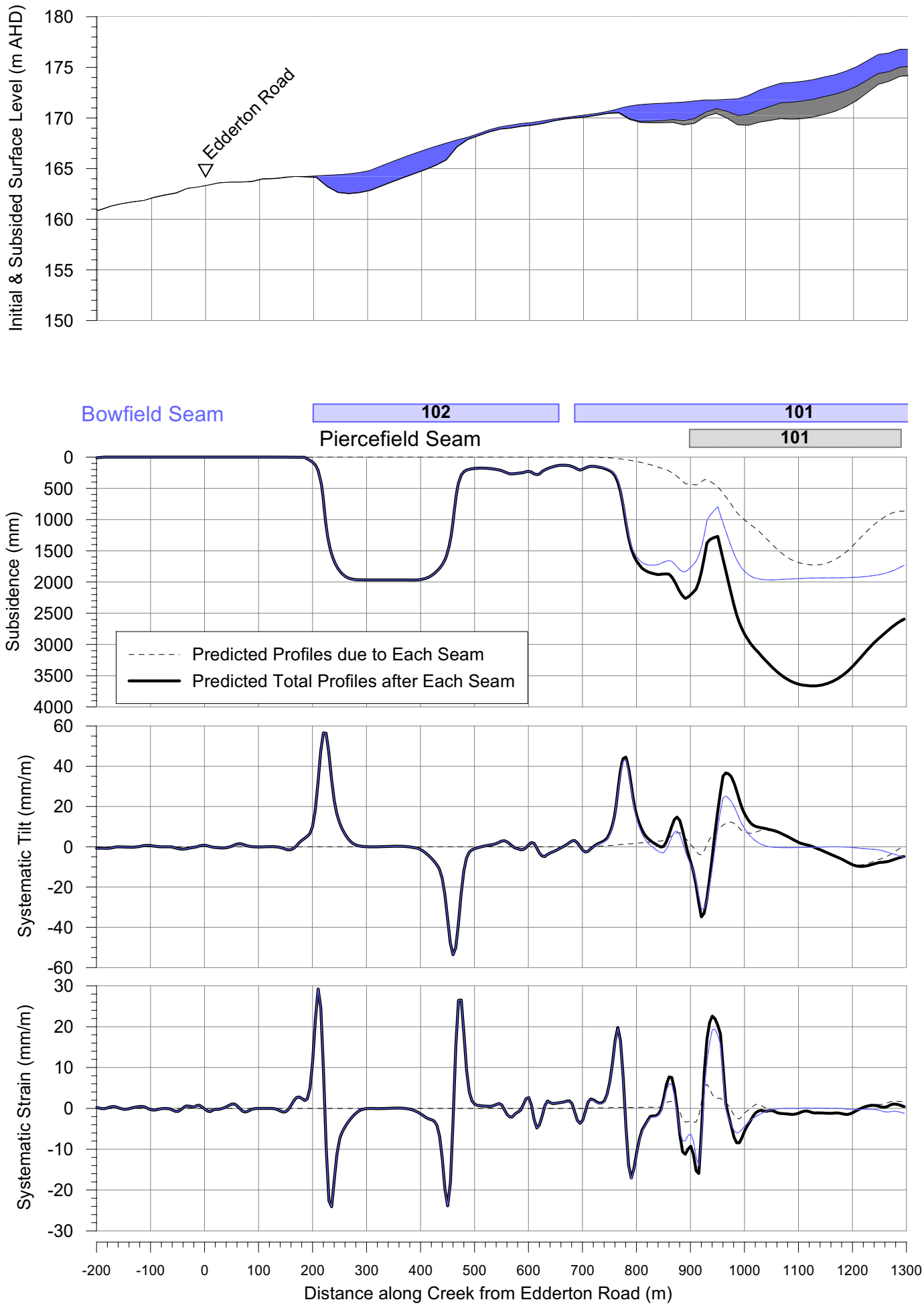
Name	Type	Centroid MGA Easting (m)	Centroid MGA Northing (m)	Maximum Plan Dimension (m)	Height of Dam Wall (m)	Plan Area (m^2)	Maximum Predicted Subsidence due to WH (mm)	Maximum Predicted Subsidence due to WH+GM (mm)	Maximum Predicted Subsidence due to WH+GM+AF (mm)	Maximum Predicted Subsidence due to WH+GM+AF +BF (mm)	Maximum Predicted Subsidence due to WH+GM+AF +BF+PF (mm)	Maximum Predicted Travel Tilt during the Extraction of WH Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of GM Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of AF Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of BF Longwalls (mm/m)	Maximum Predicted Travel Tilt during the Extraction of PF Longwalls (mm/m)	Maximum Predicted Total Tilt due to WH (mm/m)	Maximum Predicted Total Tilt due to WH+GM (mm/m)	Maximum Predicted Total Tilt due to WH+GM+AF (mm/m)	Maximum Predicted Total Tilt due to WH+GM+AF+BF (mm/m)	Maximum Predicted Total Tilt due to WH+GM+AF+BF +PF (mm/m)	Impact Assessment Strain due to the Extraction of WH (mm/m)	Impact Assessment Strain due to the Extraction of WH+GM (mm/m)	Impact Assessment Strain due to the Extraction of WH+GM+AF (mm/m)	Impact Assessment Strain due to the Extraction of WH+GM+AF+BF (mm/m)	Impact Assessment Strain due to the Extraction of WH+GM+AF+BF+PF (mm/m)	Maximum Change in Freeboard at Any Time during or after the Proposed Longwalls (mm)	Maximum Change in Freeboard at the Completion of all Proposed Longwalls (mm)
A05d01	D	294465	6418347	14.000	3.0	2059	0	0	286	286	1793	0.0	0.0	2.9	0.0	6.2	0.0	0.0	10.9	10.9	31.2	0.1	0.1	10.1	10.1	24.0	218	218
A05d02	D	294717	6417963	11.000	3.0	944	0	0	1461	1461	2901	0.0	0.0	11.7	0.0	5.4	0.0	0.0	5.0	5.0	7.3	0.1	0.1	3.2	3.2	3.2	65	41
A05d03	D	294821	6417855	12.000	3.0	1285	0	0	1132	1132	2009	0.0	0.0	8.4	0.0	3.2	0.0	0.0	28.1	28.1	25.5	0.1	0.1	15.7	15.7	15.7	169	169
A06d01	D	294598	6417360	10.000	3.0	664	0	1493	1568	1568	2960	0.0	> 50	0.5	0.0	4.9	0.0	> 50	> 50	> 50	> 50	0.1	> 25	> 25	> 25	> 25	255	255
A06d02	D	296561	6417261	16.000	3.0	1145	0	2554	2554	2554	2554	0.0	> 50	0.0	0.0	0.0	0.0	42.7	42.7	42.7	42.7	0.1	> 25	> 25	> 25	> 25	408	342
A07d01	D	292955	6419174	11.000	3.0	711	0	0	1632	1632	1632	0.0	0.0	13.9	0.0	0.0	0.0	0.0	40.5	40.5	40.5	0.1	0.1	17.5	17.5	17.5	223	223
A07d02	D	292902	6418311	12.000	3.0	1173	0	0	0	0	51	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.4	0.1	0.1	0.1	0.1	0.6	9	9
A07d03	D	294368	6419337	15.000	3.0	1926	0	0	0	1950	1950	0.0	0.0	0.0	25.3	0.0	0.0	0.0	0.0	> 50	> 50	0.1	0.1	0.1	> 25	> 25	383	383
A08d01	D	294395	6417543	14.000	3.0	2685	0	426	2150	2150	3552	0.0	28.8	13.0	0.0	5.1	0.0	18.8	37.4	37.4	37.0	0.1	> 25	> 25	> 25	> 25	262	262
A08d02	D	293768	6417231	17.000	3.0	1758	0	1278	2853	2853	3689	0.0	> 50	9.8	0.0	2.8	0.0	40.4	36.0	36.0	33.0	0.1	> 25	> 25	> 25	> 25	434	343
A08d03	D	293829	6417124	9.000	3.0	317	0	1481	2356	2356	3472	0.0	> 50	4.9	0.0	3.5	0.0	0.8	4.3	4.3	6.8	0.1	> 25	> 25	> 25	> 25	230	30
A08d04	D	293795	6417291	13.000	3.0	1245	0	368	2228	2228	3533	0.0	23.7	11.9	0.0	4.4	0.0	12.7	19.2	19.2	25.3	0.1	> 25	> 25	> 25	> 25	165	165
A08d05	D	293214	6417968	23.000	3.0	4958	0	2203	3316	3316	4562	0.0	> 50	5.4	0.0	3.7	0.0	47.8	38.9	38.9	40.8	0.1	> 25	> 25	> 25	> 25	687	549
A09d01	D	294367	6416109	12.000	3.0	993	0	0	0	71	1159	0.0	0.0	0.0	0.5	3.9	0.0	0.0	0.0	2.8	10.9	0.1	0.1	0.1	1.5	3.4	95	68
A09d02	D	294383	6416049	14.000	3.0	856	0	0	0	795	1534	0.0	0.0	0.0	5.2	2.6	0.0	0.0	0.0	22.0	20.7	0.1	0.1	0.1	8.2	8.2	154	154
A10d01	D	296549	6415265	6.000	3.0	118	1578	1578	1578	1578	1578	36.7	0.0	0.0	0.0	0.0	42.5	42.5	42.5	42.5	42.5	> 25	> 25	> 25	> 25	> 25	127	127
A10d02	D	296306	6414869	11.000	3.0	743	1334	1334	1334	1334	1334	38.3	0.0	0.0	0.0	0.0	46.5	46.5	46.5	46.5	46.5	> 25	> 25	> 25	> 25	> 25	256	256
A10d03	D	296904	6414199	21.000	3.0	1786	1937	1937	1937	1937	1937	47.3	0.0	0.0	0.0	0.0	44.3	44.3	44.3	44.3	44.3	> 25	> 25	> 25	> 25	> 25	466	466
A11d01	D	297321	6415744	16.000	3.0	4005	2200	2200	2200	2200	2200	> 50	0.0	0.0	0.0	0.0	3.3	3.3	3.3	3.3	3.3	> 25	> 25	> 25	> 25	> 25	408	26
A12d01	D	295410	6413094	14.000	3.0	1338	1472	1472	1472	1472	1472	33.2	0.0	0.0	0.0	0.0	17.6	17.6	17.6	17.6	17.6	24.2	24.2	24.2	24.2	24.2	233	124
A12d02	D	295294	6413984	16.000	3.0	1475	1584	1584	1584	1584	1584	49.3	0.0	0.0	0.0	0.0	23.2	23.2	23.2	23.2	23.2	> 25	> 25	> 25	> 25	> 25	394	185
A12d03	D	295581	6413805	27.000	3.0	7125	1604	1604	1604	1604	1604	40.4	0.0	0.0	0.0	0.0	15.7	15.7	15.7	15.7	15.7	> 25	> 25	> 25	> 25	> 25	546	212
A12d04	D	295840	6413719	15.000	3.0	1552	678	678	678	678	678	14.6	0.0	0.0	0.0	0.0	21.8	21.8	21.8	21.8	21.8	12.3	12.3	12.3	12.3	12.3	164	164
A13d01	D	297048	6415950	36.000	3.0	11113	2211	2211	2211	2211	2235	> 50	0.0	0.0	0.0	0.1	> 50	> 50	> 50	> 50	> 50	> 25	> 25	> 25	> 25	> 25	918	918
A13d02	D	296651	6416662	8.000	3.0	204	346	346	346	377	436	5.1	0.0	0.0	0.1	0.2	8.3	8.3	8.3	8.4	9.5	3.1	3.1	3.1	3.1	4.0	38	38
A15d01	D	294195	6416742	12.000	3.0	1239	0	8	8	8	9	0.0	0.2	0.0	0.0	0.0	0.0	0.4	0.4	0.4	0.4	0.1	0.6	0.6	0.6	0.7	3	3
A15d02	D	294265	6416771	12.000	3.0	1345	0	10	10	10	14	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.6	0.1	0.7	0.7	0.7	0.7	3	3
A15d03	D	293294	6416729	15.000	3.0	992	0	1334	2499	2499	2734	0.0	24.6	5.1	0.0	0.6	0.0	25.9	12.4	12.4	8.1	0.1	14.8	14.8	14.8	14.8	194	194
A15d04	D	293397	6416884	8.000	3.0	217	0	1319	2823	2823	3898	0.0	31.0	7.3	0.0	3.1	0.0	38.4	28.8	28.8	30.6	0.1	23.5	23.5	23.5	23.5	154	154
A15d06	D	294170	6416274	10.000	3.0	52	0	0	0	0	161	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	3.2	0.1	0.1	0.1	0.1	0.9	16	16
A17d01	D	293421	6419970	15.000	3.0	987	0	0	0	1802	1802	0.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0	42.7	0.1	0.1	0.1	> 25	> 25	320	320
A18d01	D	292829	6414599	19.000	3.0	2923	0	0	0	0	1494	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.0	0.0	16.6	0.1	0.1	0.1	0.1	3.2	158	158
A18d02	D	293122	6414774	8.000	3.0	429	0	0	0	340	340	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	4.2	0.1	0.1	0.1	0.1	1.0	17	17
A19d01	D	290757	6418557	53.000	3.0	1278	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	1	1
B05d01	D	292704	6419112	10.000	3.0	439	0	0	1214	1214	1214	0.0	0.0	10.9	0.0	0.0	0.0	0.0	42.9	42.9	42.9	0.1	0.1	24.9	24.9	24.9	215	215
B05d02	D	292573	6419205	16.000	3.0	3658	0	0	5	5	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.1	0.4	0.4	0.4	2	2
B05d04	D	292308	6419061	17.000	3.0	2583	0	0	12	12	12	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.1	0.1	0.8	0.8	0.8	5	5
B05d05	D	292241	6419067	62.000	3.0	2343	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0	0
B08d01	D	294350	6418228	13.000	3.0	1673	0	0	1429	1429	2877	0.0	0.0	13.6	0.0	5.9	0.0	0.0	35.6	35.6	37.1	0.1	0.1	20.8	20.8	20.8	241	241
B08d02	D	294210	6418159	14.000	3.0	3356	0	0	1553	1553	2899	0.0	0.0	14.0	0.0	5.4	0.0	0.0	23.8	23.8	24.9	0.1	0.1	-11.4	-11.4	-11.6	174	174
B09d01	D	293789	6418109	19.000	3.0	3617	0	2109	3567	3567	4979	0.0	> 50	11.3	0.0	5.2	0.0	2.1	16.5	16.5	20.0	0.1	> 25	> 25	> 25	> 25	485	190
B10d01	D	292427	6417184	18.000	3.0	3885	0	1423	3373	3373	3375	0.0	> 50	10.8	0.0	0.0	0.0	43.5	41.6	41.6	41.6	0.1	> 25	> 25	> 25	> 25	459	391
B10d02	D	291810	6417288	18.000	3.0	1335	0	1183	1183	1183	1183	0.0	> 50	0.0	0.0	0.0	0.0	> 50	> 50	> 50	> 50	0.1	> 25	> 25	> 25	> 25	459	459
B10d03	D	291941	6417494	14.000	3.0	1255	0	1641	1730	1730	1732	0.0	> 50	0.5	0.0	0.0	0.0	1.1	1.8	1.8	1.8	0.1	> 25	> 25	> 25	> 25	357	13
B13d01	D	292533	6415070	16.000	3.0	2079	0	0	0	0	721	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	0.0	12.3	0.1	0.1	0.1	-0.1	2.4	99	99
B13d02	D	292574	6415266	15.000	3.0	1679	0	0	0	1981	3027	0.0	0.0	14.6	4.1	0.0	0.0	0.0	0.0	38.9	32.0	0.1	0.1	0.1	-10.1	-11.9	292	292
B14d01	D	293334	6415924	9.000	3.0	602	0	0	0	0	616	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	9.1	0.1	0.1	0.1	0.1	1.5	41	41
B14d02	D	293357	6415649	13.000	3.0	1069	0	0	0	2198	3031	0.0	0.0	0.0	13.5	2.9	0.0	0.0	0.0	29.8	28.5	0.1	0.1	0.1	-9.8	-9.8	194	194
B14d03	D	293449	6415467	13.000	3.0	1028	1434	1434	1434	1954	3589	> 50	0.0	0.0	3.4	5.9	19.6	19.6	19.6	7.8	8.2	> 25	> 25	> 25	> 25	> 25	332	127
B14d04	D	294104	6415535	12.000	3.0	1148	1496	1496	1496	1504	2488	44.2	0.0	0.0	0.0	3.3	34.9	34.9	34.9	34.9	33.7	> 25	> 25	> 25	> 25	> 25	265	209
B14d05	D	293803	6416007	12.000	3.0	2413	0	0	0	0	1242	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0	11.0	0.1	0.1	0.1	-0.1	-2.8	66	66
B15d01	D	293899	6414363	13.000	3.0	979	974	974	974	974	974	40.4	0.0	0.0	0.0	0.0	37.5	37.5	37.5	37.5	37.5	> 25	> 25	> 25	> 25	> 25	263	244
B15d02	D	293521	6414550	13.000	3.0	2146	52	52	52	52	228	2.7	0.0	0.0	0.0	0.7	2.1	2.1	2.1	2.1	6.3	4.5	4.5	4.5	4.5	4.5	41	4
B15d03	D	293683	6414926	18.000	3.0	2574	1416	1416	1416	1416	2973	> 50	0.0	0.0	0.0	5.7	38.8	38.8	38.8	38.8	45.2	> 25	> 25	> 25	> 25	> 25	459	407
B15d04	D	293461	6415047	11.000	3.0	411	1434	1434	1434	1434	3264	> 50	0.0	0.0	0.0	7.0	0.3	0.3	0.3	0.3	10.4	> 25	> 25	> 25	> 25	> 25	281	57
B16d01	D	292438	6414596	21.000	3.0	1600	0	0	0	0	192	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	1.8	0.1	0.1	0.1	0.1	1.0	19	19
B18d01	D	293996	6414281	12.000	3.0	883	1444	1444	1444	1444	1444	> 50	0.0	0.0	0.0	0.0	1.2	1.2	1.2	1.2	1.2	> 25	> 25	> 25	> 25	> 25	306	7
B18d02	D	293554	6414289	13.000	3.0	995	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0	0
B18d03	D	293454	6414024	8.000	3.0	202	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0	0
B18d04	D	293499	6413816	16.000	3.0	1692	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0	0
B21d02	D	295063	6413053	9.000	3.0	773	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0	0
B21d03	D	295328	6413114	8.000	3.0	909	1477	1477	1477	1477	1477	36.2	0.0	0.0	0.0	0.0	8.6	8.6	8.6	8.6	8.6	> 25	> 25	> 25	> 25	> 25	145	34
B21d04	D	295168	6413646	23.000	3.0	12588	1605	1605	1605	1605	1605	47.9	0.0	0.0	0.0	0.0	36.9	36.9	36.9	36.9	36.9	> 25	> 25	> 25	> 25	> 25	551	424
B21d05	D	294095	6414009	17.000	3.0	4765	1422	1422	1422	1422	1422	> 50	0.0	0.0	0.0	0.0	28.3	28.3	28.3	28.3	28.3	> 25	> 25	> 25	> 25	> 25	434	241
B24d02	D	298051	6414729	9.000	3.0	1853	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0	0
B25d01	D	297293	6414931	13.000	3.0	620	230	230	230	230	230	6.9	0.0	0.0	0.0	0.0	3.7	3.7	3.7	3.7	3.7	6.6	6.6	6.6	6.6	6.6	45	24
B26d01	D	297168	6415269	15.000	3.0	1482	1930	1930	1930	1930	1930	> 50	0.0	0.0	0.0	0.0	> 50	> 50	> 50	> 50	> 50	> 25	> 25	> 25	> 25	> 25	383	383
B27d01	D	295935	6414496	12.000	3.0	2026	1547	1547	1547	1547	1547	48.8	0.0	0.0	0.0	0.0	44.9	44.9	44.9	44.9	44.9	> 25	> 25	> 25	> 25	> 25	293	269
B27d02	D	295673	6414673	9.000	3.0	342	203	203	203	203	203	7.9	0.0	0.0	0.0	0.0	3.5	3.5	3.5	3.5	3.5	9.7	9.7	9.7	9.7	9.7	36	18
B28d01	D	295288	6414792	12.000	3.0	493	1496	1496	1496	1496	1496	47.2	0.0	0.0	0.0	0.0	16.7	16.7	16.7	16.7	16.7	> 25	> 25	> 25	> 25	> 25	283	200
B28d02	D	294552	6414827	17.000	3.0	3735	1563	1563	1563	1563	1607	> 50	0.0	0.0	0.0	0.1	8.6	8.6	8.6	8.6	6.7	> 25	> 25	> 25	> 25	> 25	434	73
B29d01	D	295538	6414976	20.000	3.0	8499	1514	1514	1514	1514	1521	> 50	0.0	0.0	0.0	0.0	42.3	42.3	42.3	42.3	42.3	> 25	> 25	> 25	> 25	> 25	510	423
B30d01	D	294730	6415466	14.000	3.0	1596	1498	1498	1498	1499	2909	> 50	0.0	0.0	0.0	4.9	4.9	4.9	4.9	5.0	12.3	> 25	> 25	> 25	> 25	> 25	357	86
B31d01	D	295466	6415635	19.000	3.0	2773	1720	1720	1720	3561	4464	> 50	0.0	0.0	10.9	3.1	> 50	> 50	> 50	> 50	> 50	> 25	> 25	> 25	> 25	> 25	485	485
B32d01	D	295662	6415585	13.000	3.0	1539	2051	2051	2051	2890	3738	> 50	0.0	0.0	4.9	2.9	45.8	45.8	45.8	29.5	32.8	> 25	> 25	> 25	> 25	> 25	332	288
B32d02	D	295875	6415582	11.000	3.0	510	2174	2174	2174	2548	3654	> 50	0.0	0.0	2.1	3.5	0.9	0.9	0.9	6.5	3.7	> 25	> 25	> 25	> 25	> 25	281	36
B33d01	D	295357	6415758	18.000	3.0	3595	2011	2011	2011	3096	4535	> 50	0.0	0.0	7.7	4.2	4.7	4.7	4.7	11.8	10.1	> 25	> 25	> 25	> 25	> 25	459	196
B33d02	D	295196	6416083	9.000	3.0	329	1810	1810	1810	2852	4113	> 50	0.0	0.0	5.8	4.1	26.0	26.0	26.0	12.7	14.8	> 25	> 25	> 25	> 25	> 25	230	117
B33d03	D	294961	6416159	9.000	3.0	366	7	7	7	1984	2705	0.3	0.0	0.0	12.3	2.5	0.2	0.2	0.2	7.5	8.8	0.4	0.4	0.4	2.6	2.6	95	40
B34d01	D	295683	6415813	15.000	3.0	788	2204	2204	2204	3882	4990	> 50	0.0	0.0	9.7	3.7	4.5	4.5	4.5	12.1	10.3	> 25	> 25	> 25	> 25	> 25	383	91
B34d02	D	295837	6415752	14.000	3.0	1794	780	780	780	2760	3610	24.1	0.0	0.0	11.5	2.8	26.1	26.1	26.1	26.0	30.5	24.2	24.2	24.2	24.2	24.2	213	213
B34d03	D	295981	6415763	12.000	3.0	806	498	498	498	2199	2958	12.6	0.0	0.0	9.3	2.4	13.6	13.6	13.6	4.2	6.2	14.3	14.3	14.3	14.3	14.3	81	81
B35d01	D	294758	6416632	66.000	3.0	34724	0	0	0	0	16	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.6	0.1	0.1	0.1	0.1	0.3	20	20
B35d02	D	294961	6416368	9.000	3.0	244	0	0	0	0	1094	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	3.5	0.1	0.1	0.1	-0.1	-2.7	17	16
B36d01	D	296469	6416535	10.000	3.0	429	1648	1648	1648	2496	3139	29.5	0.0	0.0	4.0	1.9	31.7	31.7	31.7	26.9	29.9	17.3	17.3	17.3	17.3	17.3	158	158
B40d01	D	294257	6417708	18.000	3.0	172	0	2055	3594	3594	4360	0.0	> 50	11.9	0.0	2.9	0.0	27.2	26.8	26.8	26.8	0.1	> 25	> 25	> 25	> 25	459	245
B41d01	D	294850	6418533	103.000	3.0	3325	0	0	0	361	1216	0.0	0.0	0.0	3.3	3.6	0.0	0.0	0.0	13.2	> 50	0.1	0.1	0.1	13.6	> 25	> 1000	> 1000
B41d02	D	294911	6418876	67.000	3.0	1937	0	0	0	444	1647	0.0	0.0	0.0	4.9	5.5	0.0	0.0	0.0	12.7	26.6	0.1	0.1	0.1	19.2	19.2	890	890
B41d03	D	295253	6418472	45.000	3.0	955	0	0	0	1878	3479	0.0	0.0	0.0	17.0	6.8	0.0	0.0	0.0	0.7	8.8	0.1	0.1	0.1	5.1	5.1	382	199
B41d04	D	295724	6418808	94.000	3.0	58238	0	0	0	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	1	1

Table F.06 - Mount Arthur Underground Project - Details and Predictions for Water Bores

Location	Owner	MGA Easting (m)	MGA Northing (m)	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Tensile Strain (mm/m)	Maximum Predicted Comp Strain (mm/m)	Maximum Predicted Travel Tilt (mm/m)	Maximum Predicted Travel Tensile Strain (mm/m)	Maximum Predicted Travel Comp Strain (mm/m)
GW018298	MAC	294395	6423509	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW024700	MAC	295585	6423269	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW027311	MAC	292056	6422787	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW029646	Private	292830	6414889	1637	4.9	< 0.1	3.7	6.6	0.6	0.6
GW029647	MAC	291015	6413909	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW029648	MAC	290880	6413869	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW029649	MAC	291315	6413799	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW029661	Private	293060	6414699	714	12.9	3.2	< 0.1	2.9	0.3	0.3
GW030745	MAC	296045	6422839	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW031622	MAC	294450	6415944	2562	2.7	< 0.1	1.3	9.8	1.4	1.4
GW031623	MAC	294120	6417459	4980	5.8	< 0.1	7.4	> 50	> 25	> 25
GW031859	MAC	294645	6415464	2996	3.9	< 0.1	1.4	> 50	> 25	> 25
GW032077	MAC	294255	6416787	< 20	0.5	0.5	< 0.1	0.3	0.2	0.2
GW032512	MAC	294380	6418639	1121	14.1	< 0.1	1.1	4.7	0.5	0.5
GW033193	MAC	293695	6417034	3818	8.1	0.2	1.6	47.5	> 25	> 25
GW033547	MAC	296175	6415469	983	22.0	13.7	< 0.1	14.5	6.8	7.2
GW033915	MAC	294185	6419509	1934	0.4	< 0.1	0.5	24.8	7.8	7.5
GW038607	MAC	290215	6420909	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW045469	MAC	295545	6420539	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW049223	MAC	298120	6413669	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW053572	MAC	291651	6423266	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW060282	MAC	292590	6422609	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
GW078026	MAC	294351	6419981	< 20	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

APPENDIX G. FIGURES

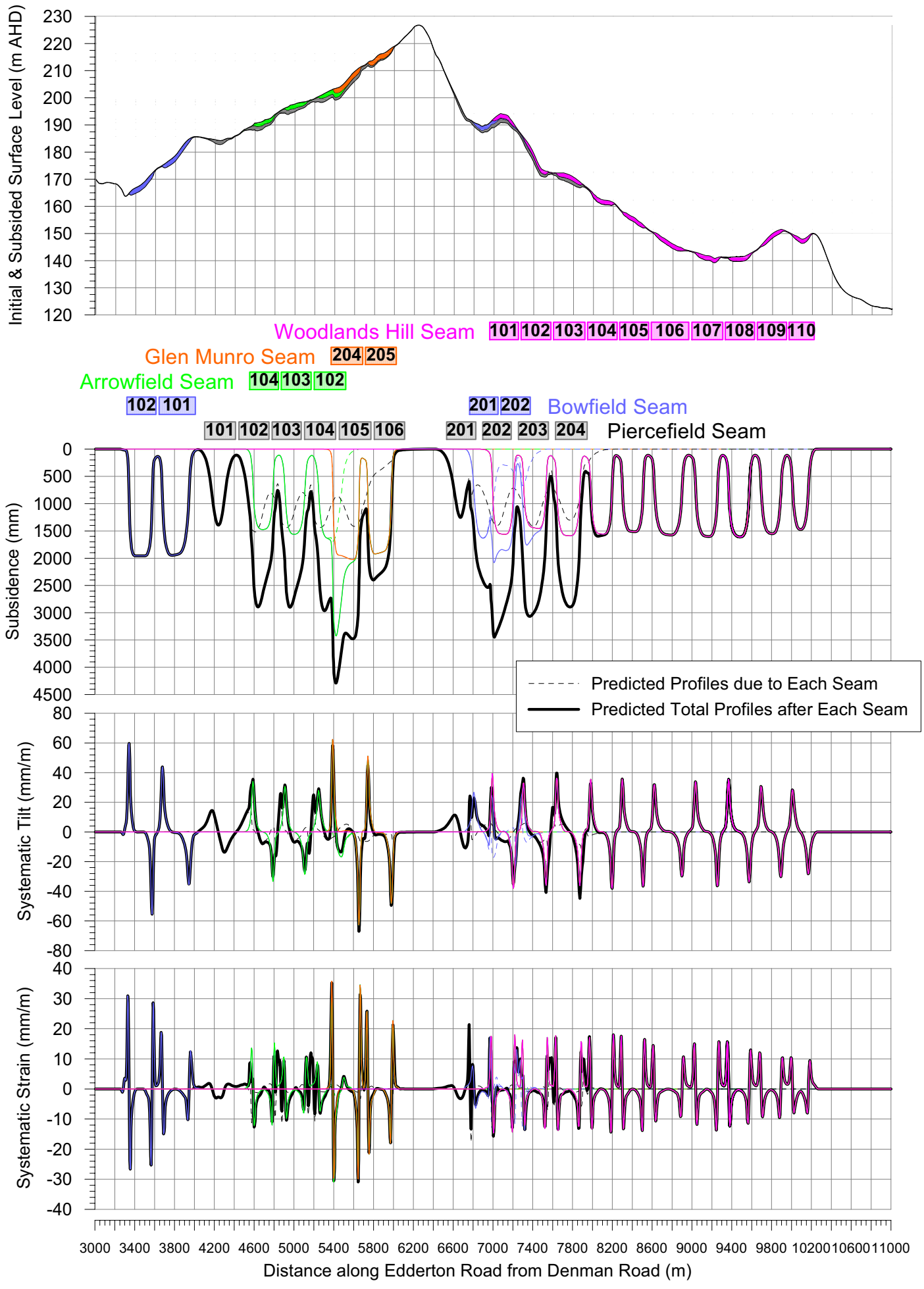
Predicted Subsidence, Tilt and Strain Profiles along Quarry Creek due to the Extraction of the Woodlands Hill, Glen Munro, Arrowfield, Bowfield and Piercefield Seams (21 years)



Mine Subsidence Engineering Consultants

Fig. G.01

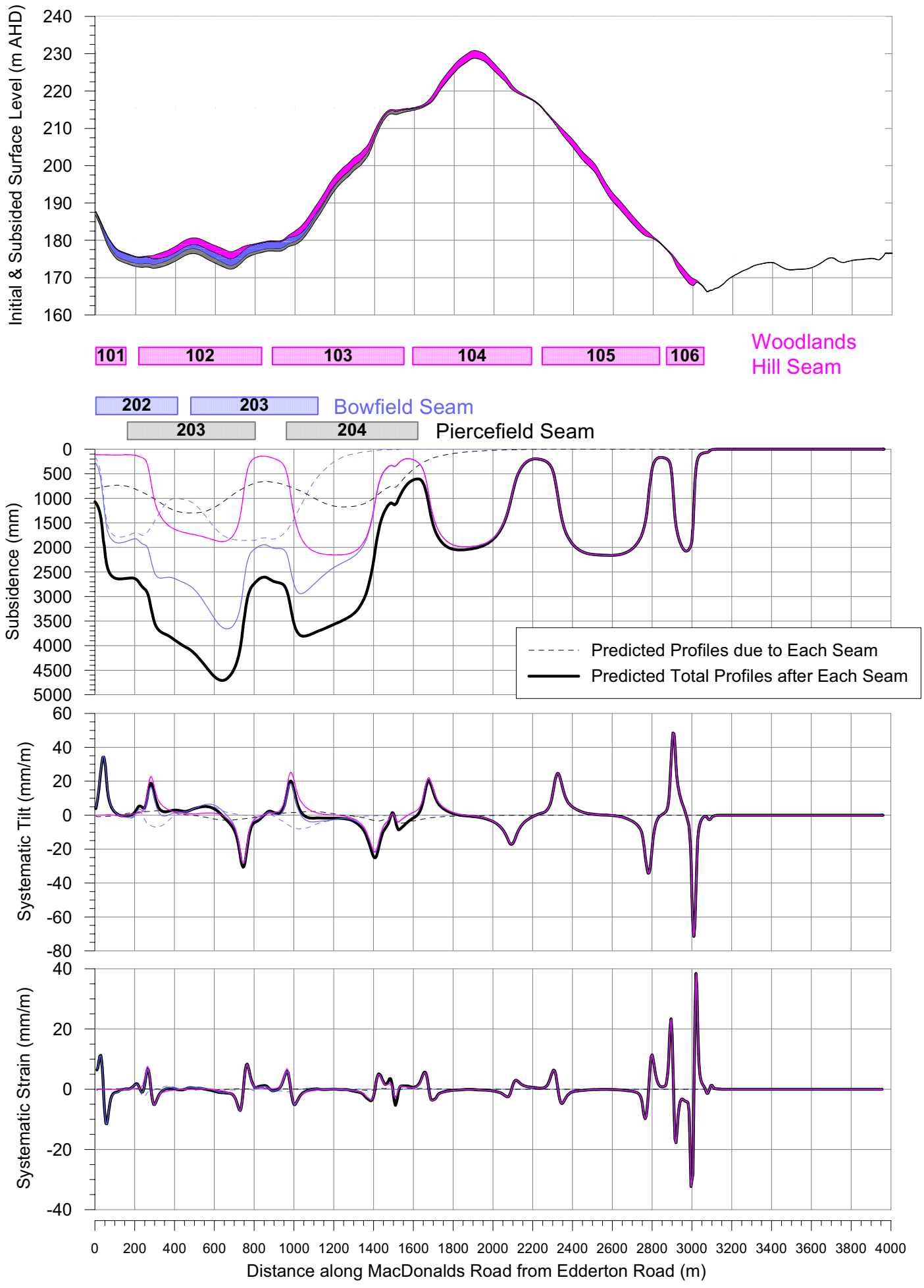
Predicted Subsidence, Tilt and Strain Profiles along Edderton Road due to the Extraction of the Woodlands Hill, Glen Munro, Arrowfield, Bowfield and Piercefield Seams (21 years)



Mine Subsidence Engineering Consultants

Fig. G.02

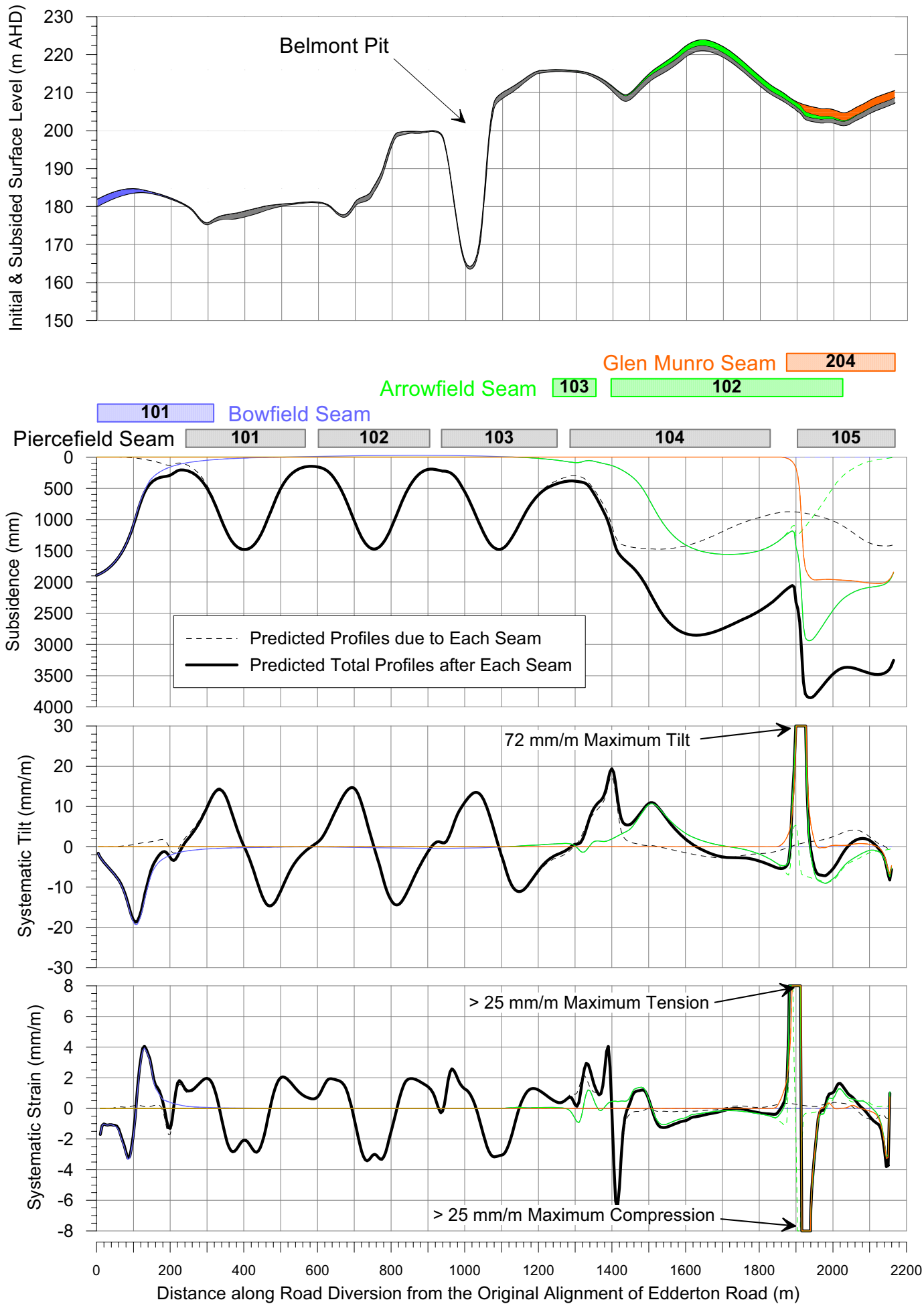
Predicted Subsidence, Tilt and Strain Profiles along MacDonalds Road due to the Extraction of the Woodlands Hill, Glen Munro, Arrowfield, Bowfield and Piercefield Seams (21 years)



Mine Subsidence Engineering Consultants

Fig. G.03

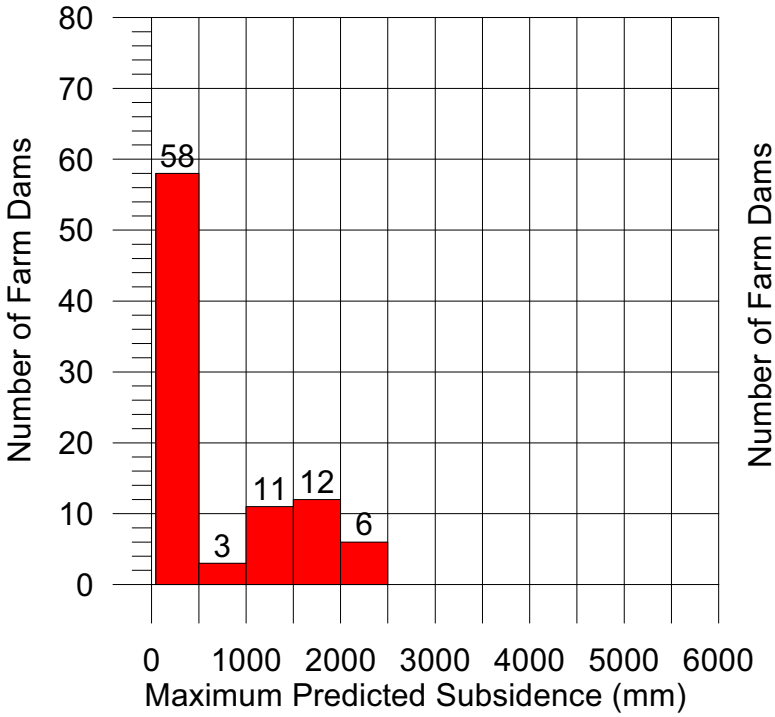
Predicted Subsidence, Tilt and Strain Profiles along the Diversion of Edderton Road due to the Extraction of the Woodlands Hill, Glen Munro, Arrowfield, Bowfield and Piercefield Seams

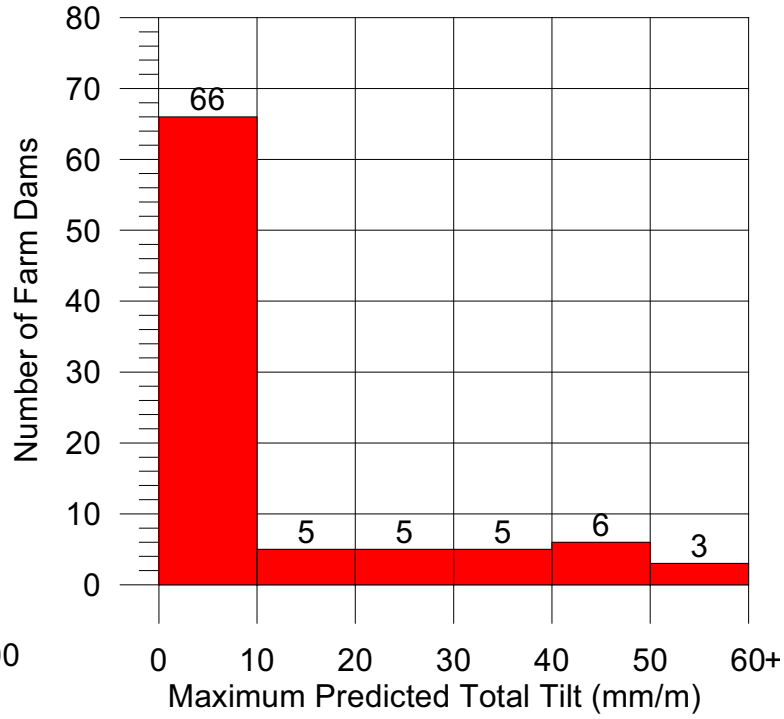


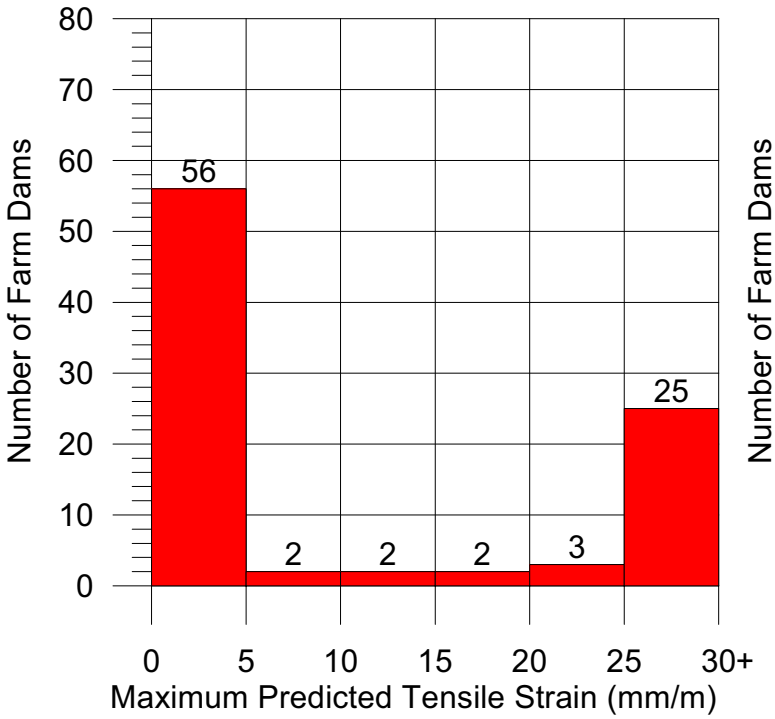
Mine Subsidence Engineering Consultants

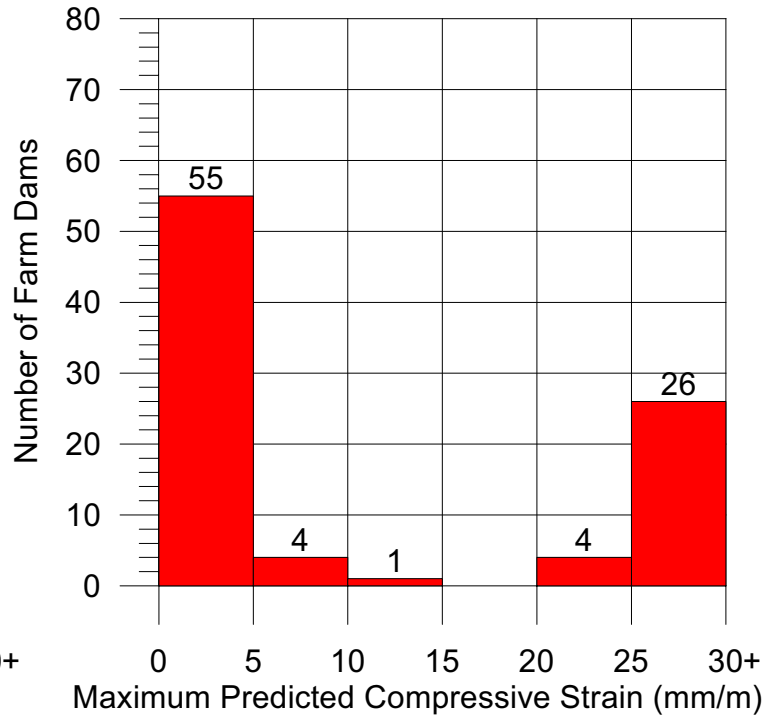
Fig. G.04

Predicted Subsidence, Tilt and Strain at the Farm Dams at the Completion of the Woodlands Hill Seam

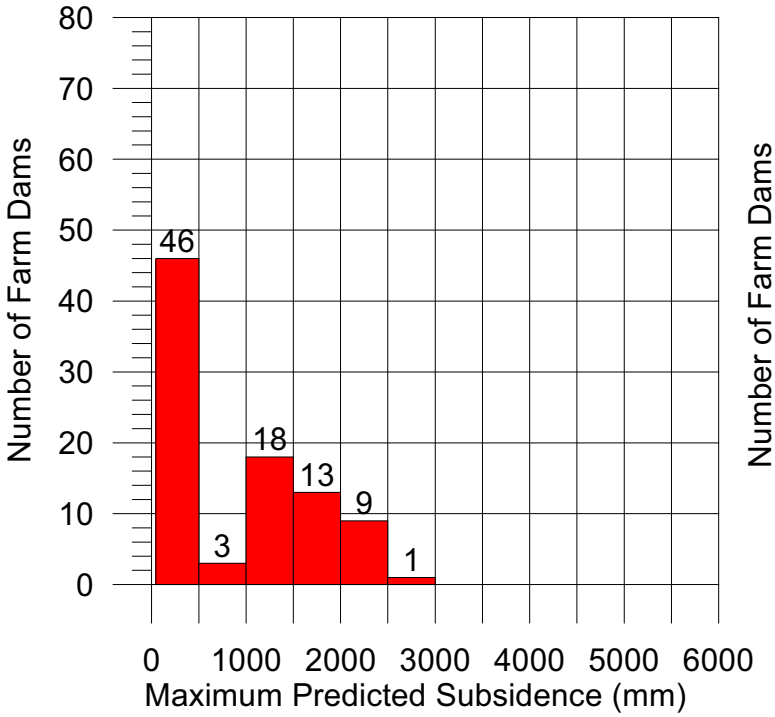


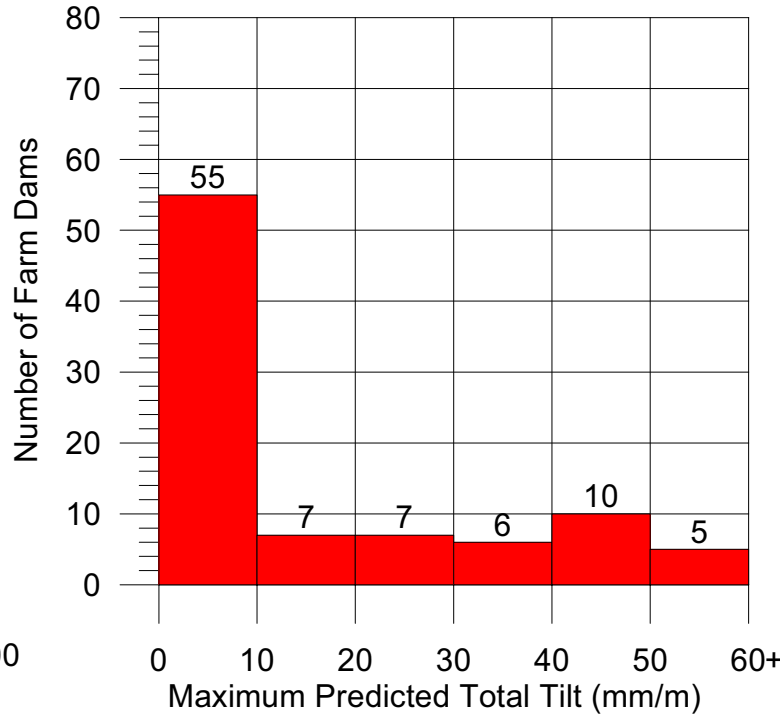


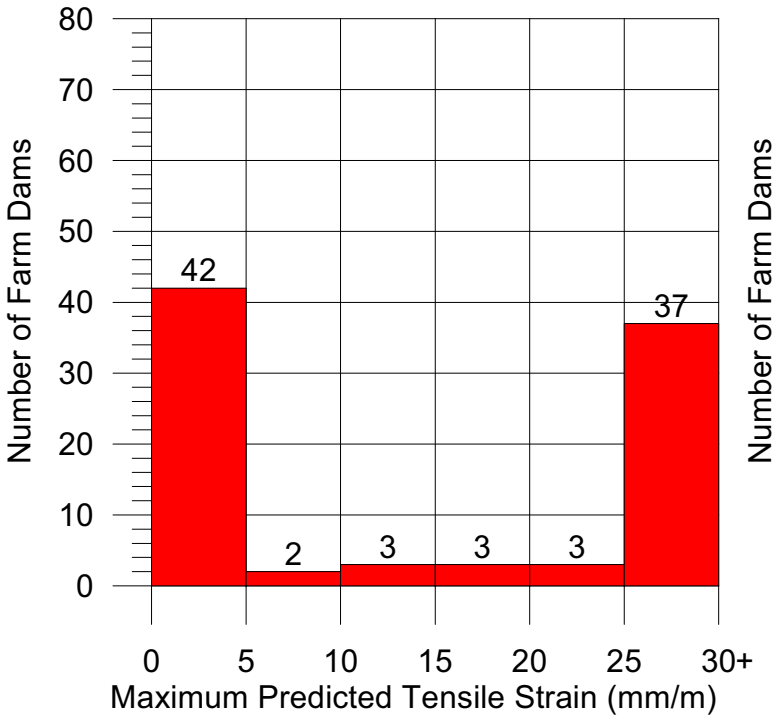


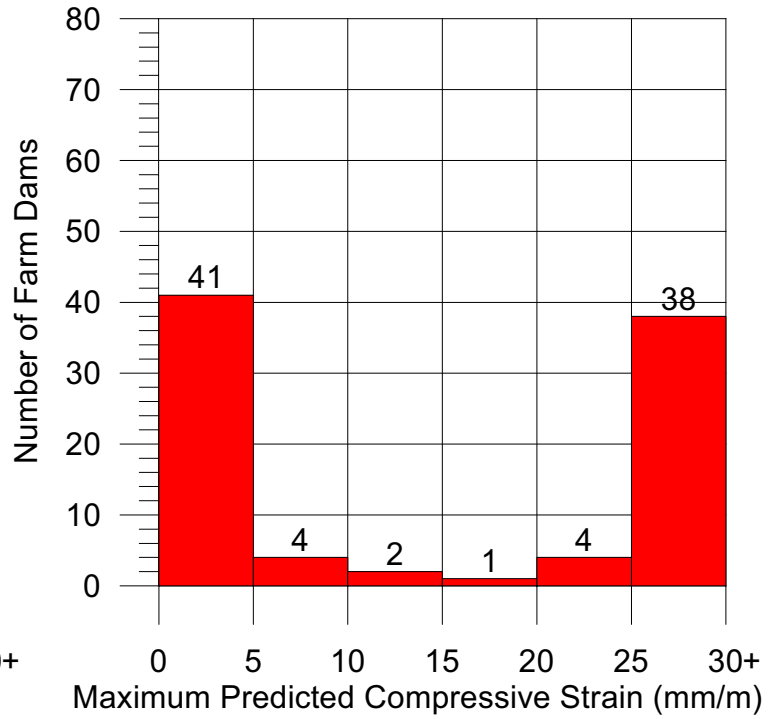


Predicted Subsidence, Tilt and Strain at the Farm Dams at the Completion of the Glen Munro Seam

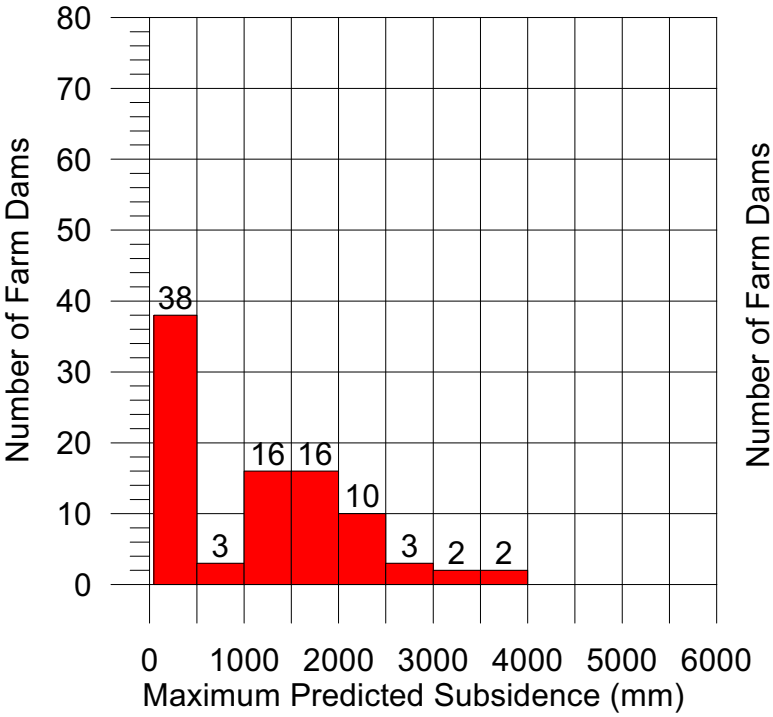


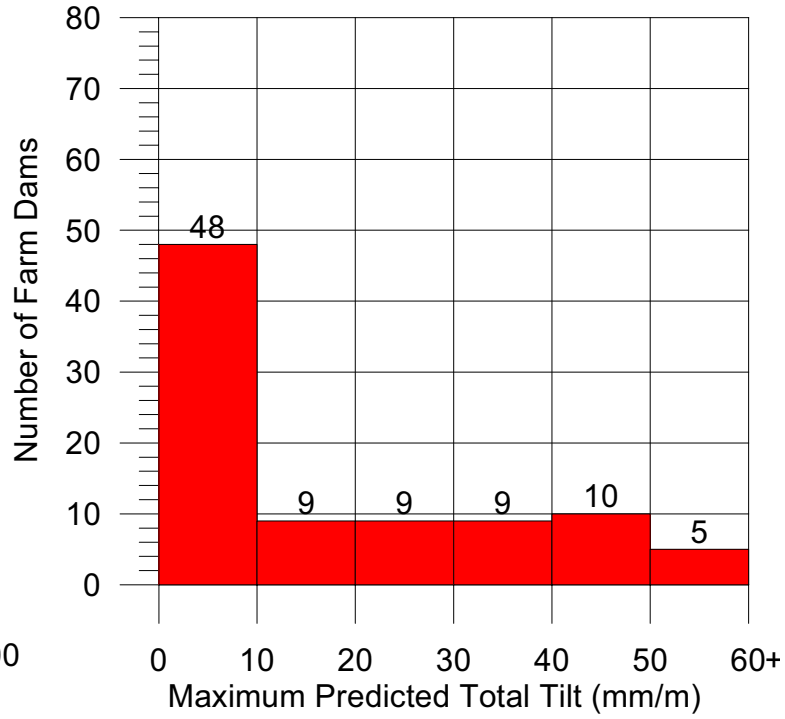


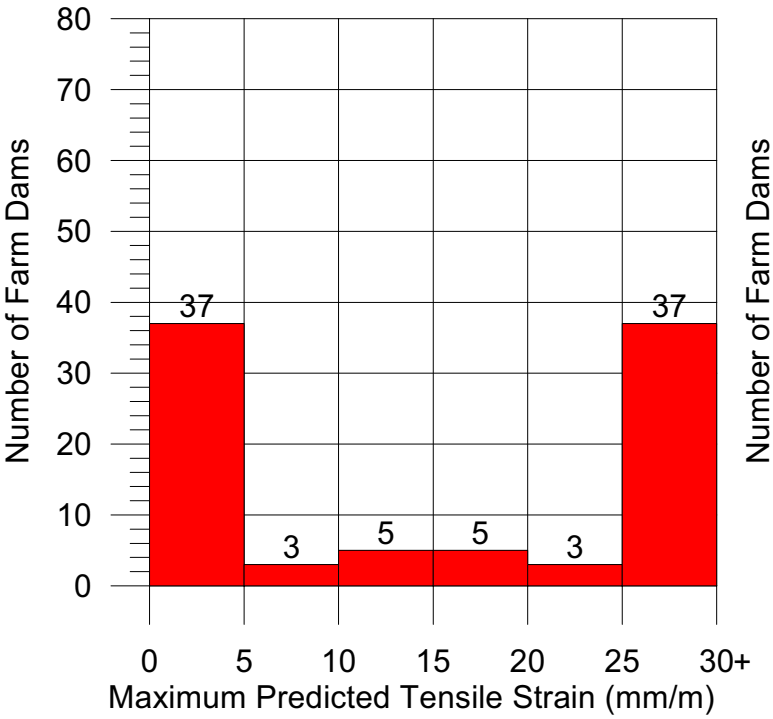


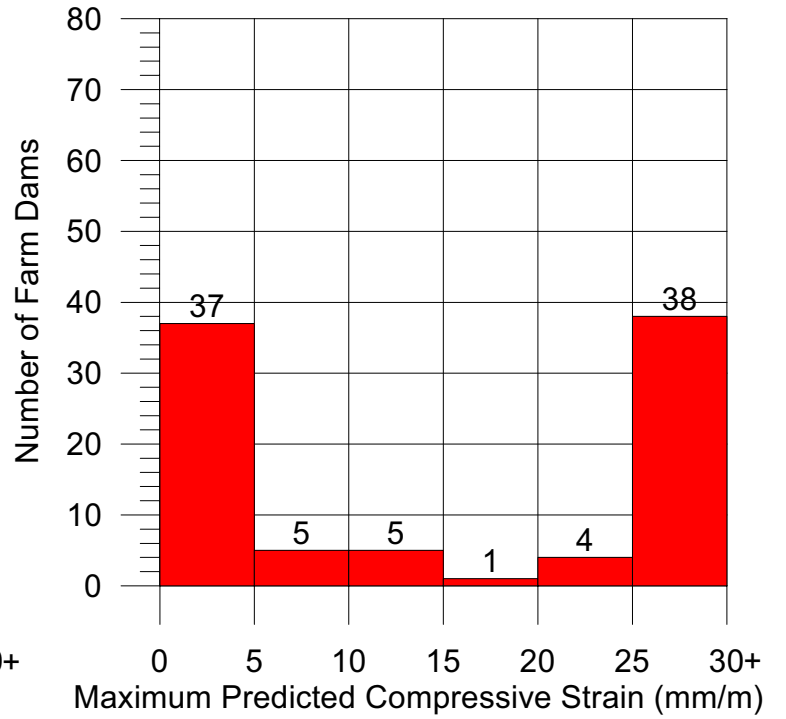


Predicted Subsidence, Tilt and Strain at the Farm Dams at the Completion of the Arrowfield Seam

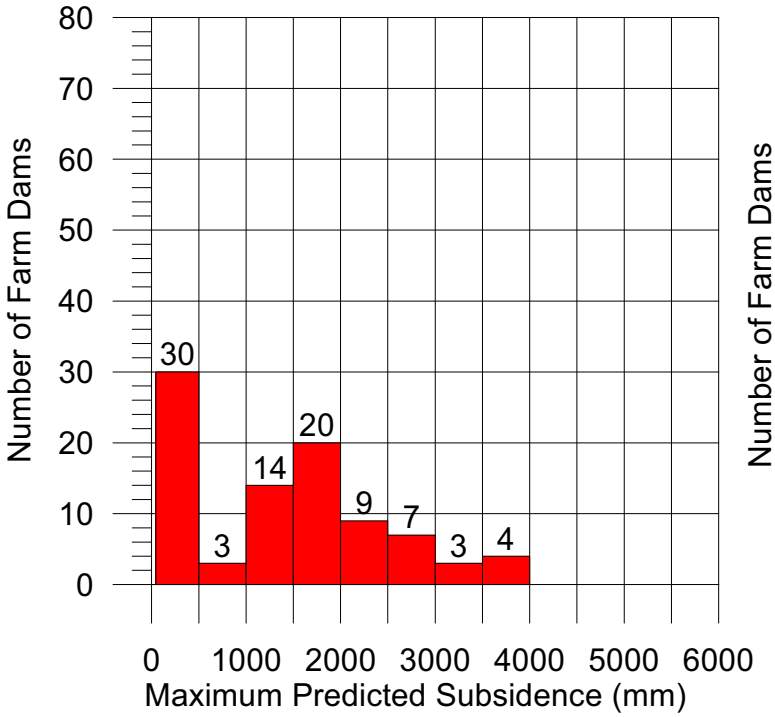


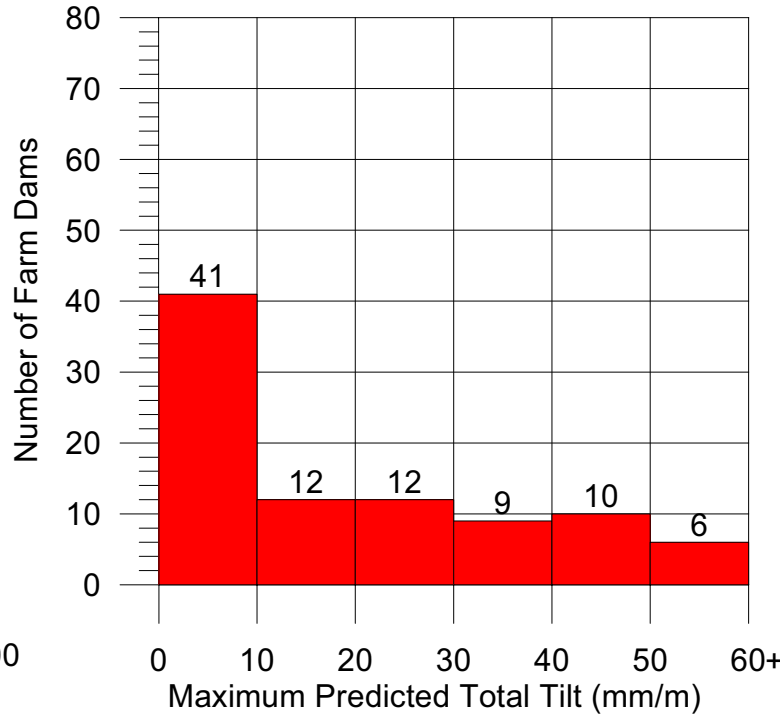


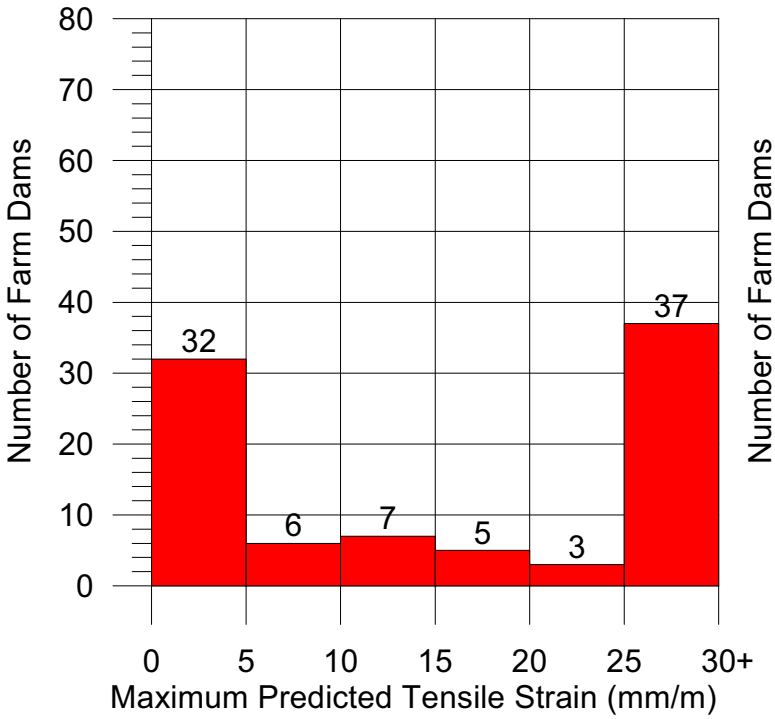




Predicted Subsidence, Tilt and Strain at the Farm Dams at the Completion of the Bowfield Seam







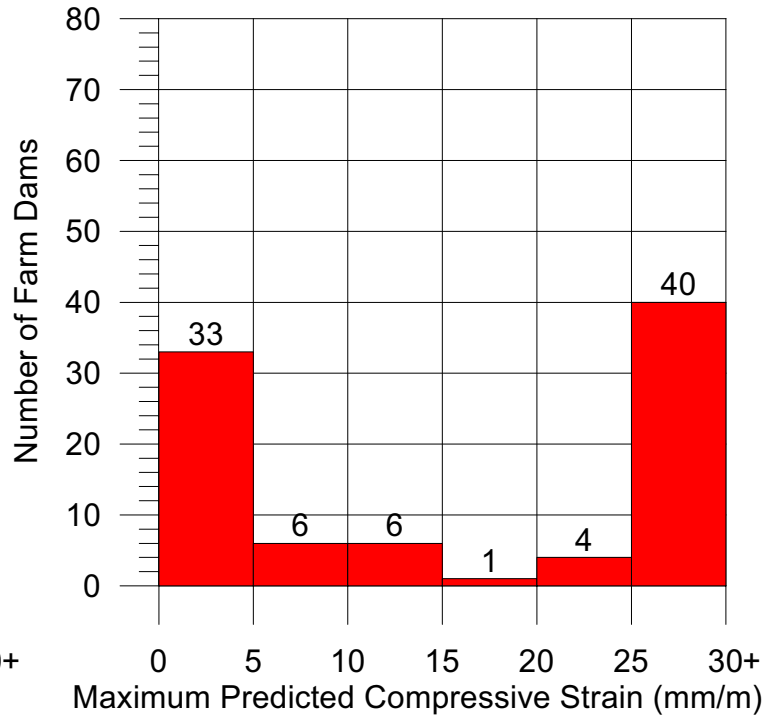
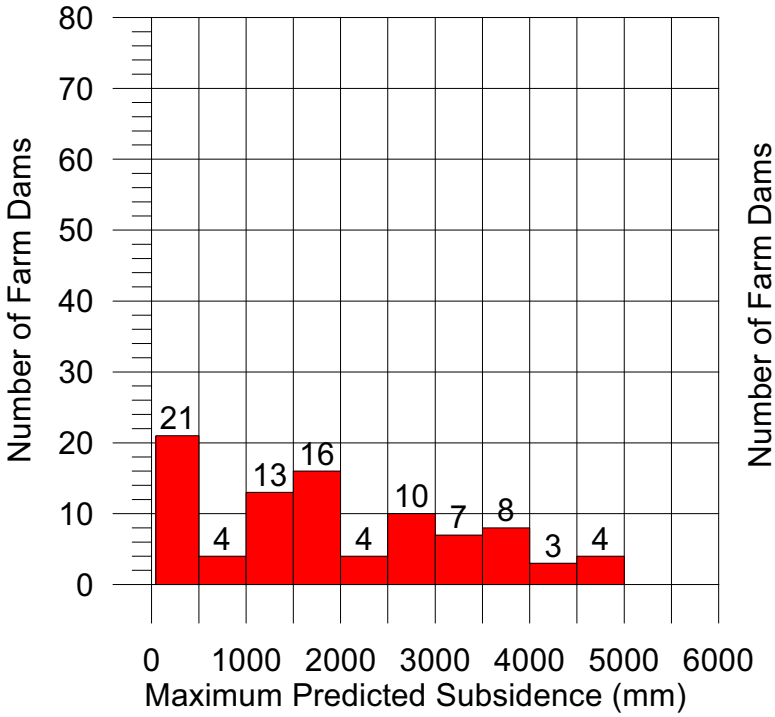
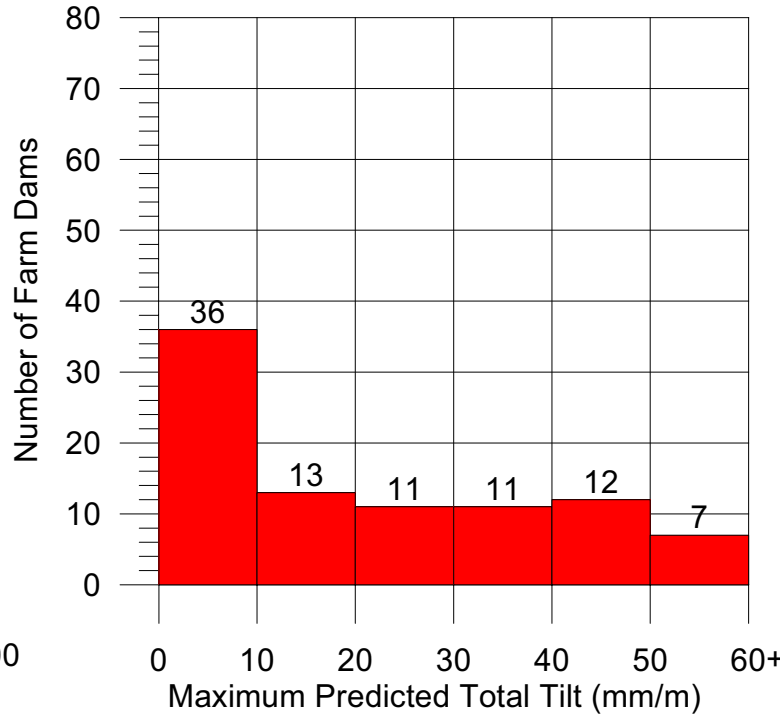
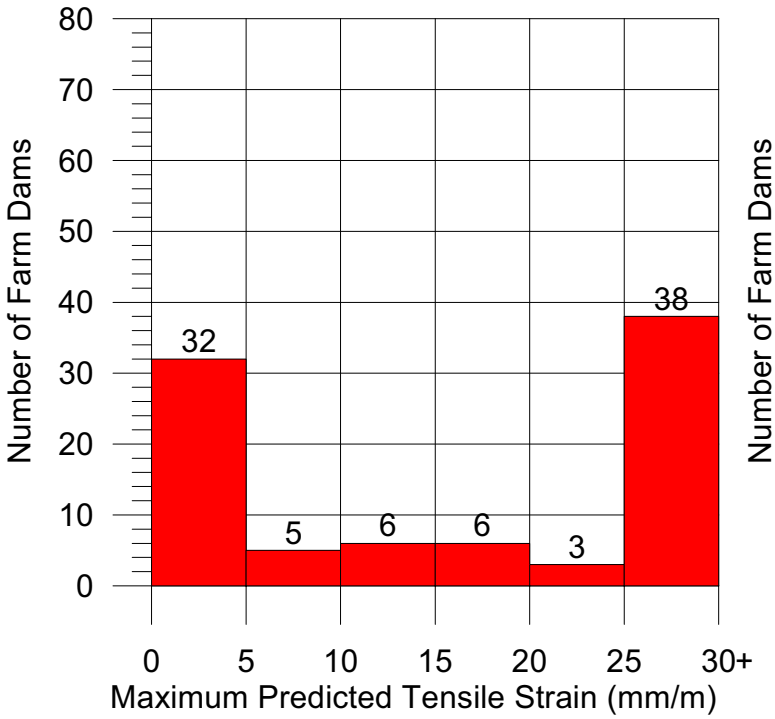


Fig. G.08

Predicted Subsidence, Tilt and Strain at the Farm Dams at the Completion of the Piercefield Seam







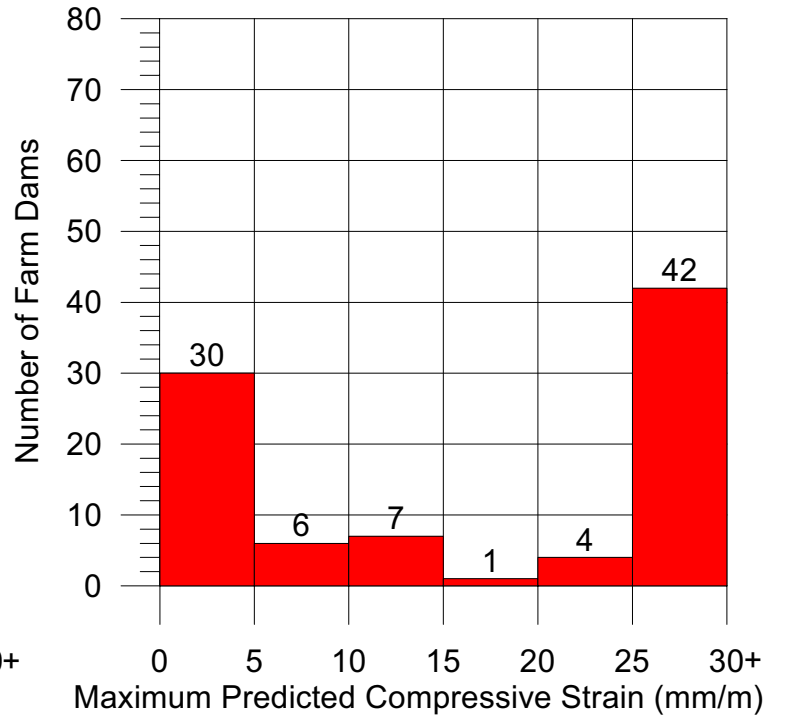


Fig. G.09

APPENDIX H. DRAWINGS

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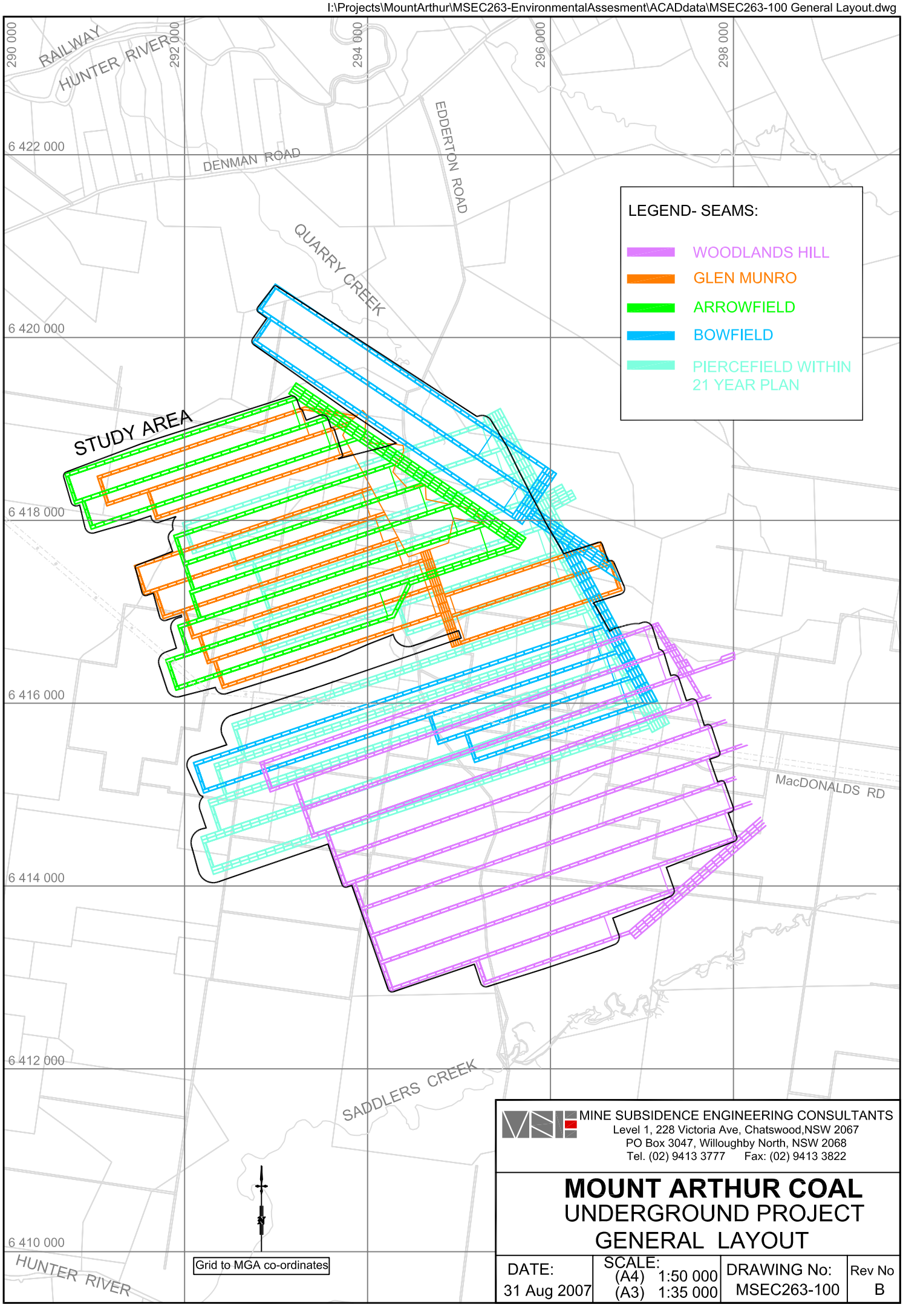

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
GENERAL LAYOUT

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31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-100	B

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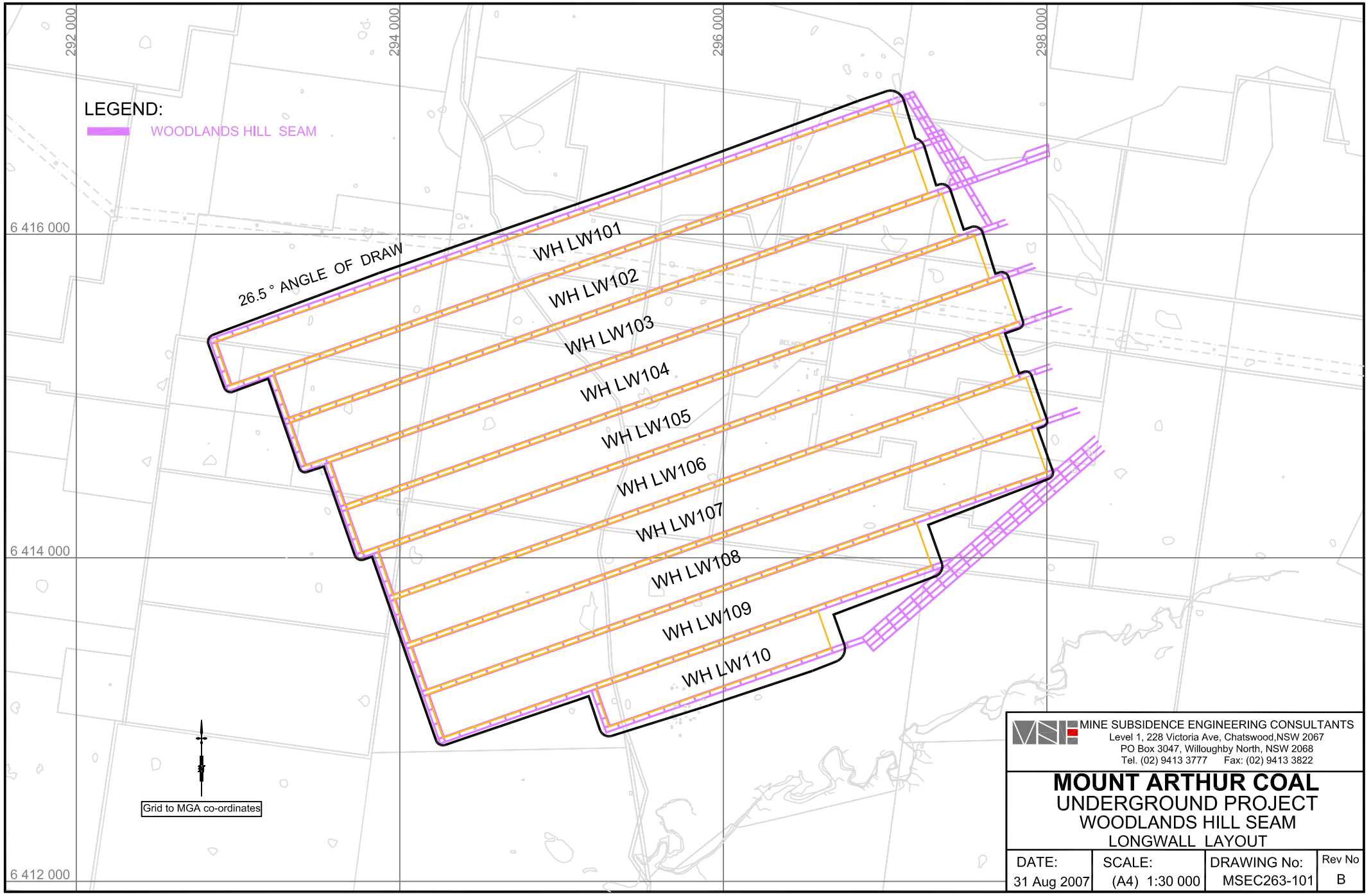

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
WOODLANDS HILL SEAM
LONGWALL LAYOUT

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31 Aug 2007	(A4) 1:30 000	MSEC263-101	B

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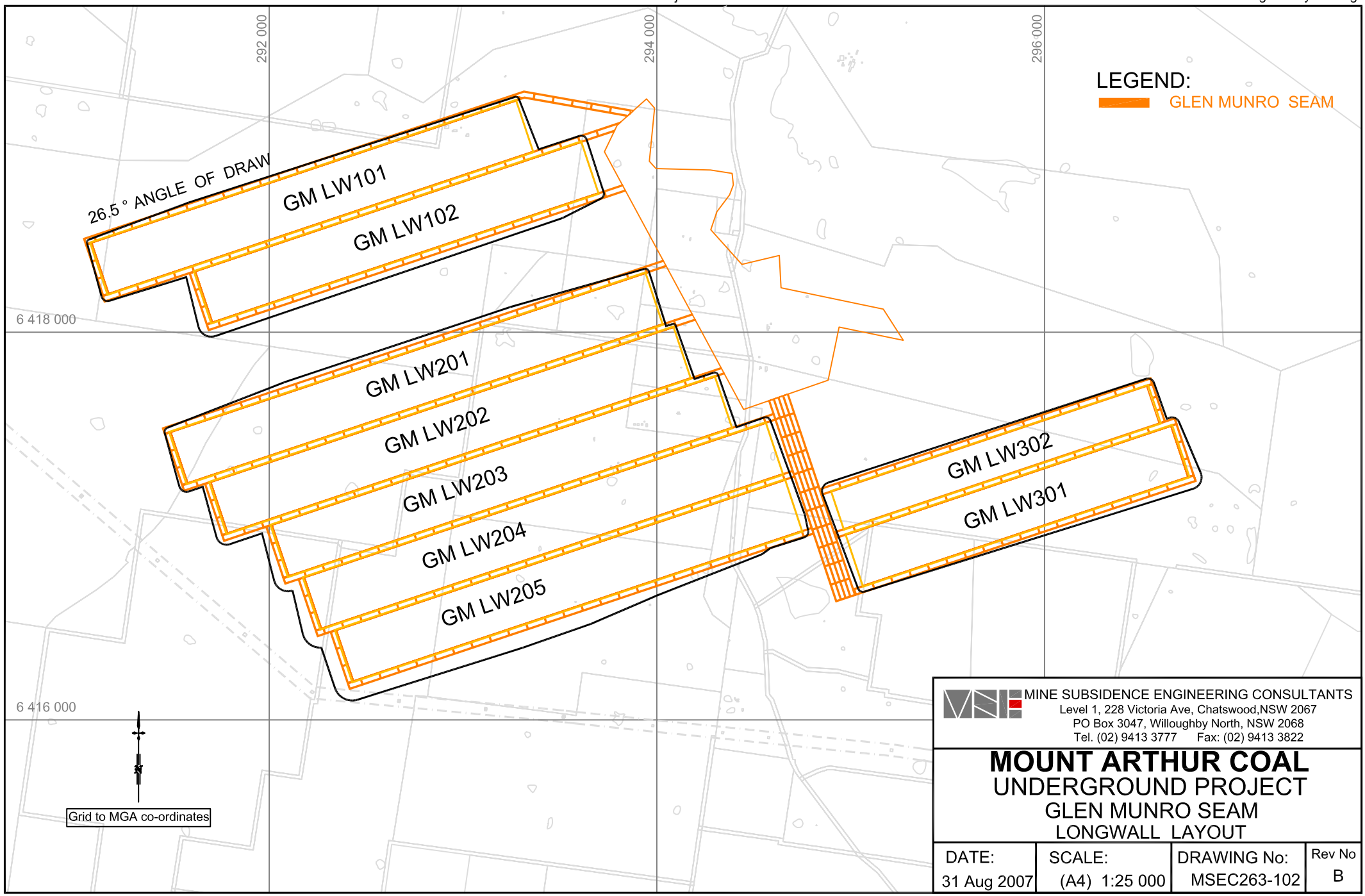

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MOUNT ARTHUR COAL
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GLEN MUNRO SEAM
LONGWALL LAYOUT

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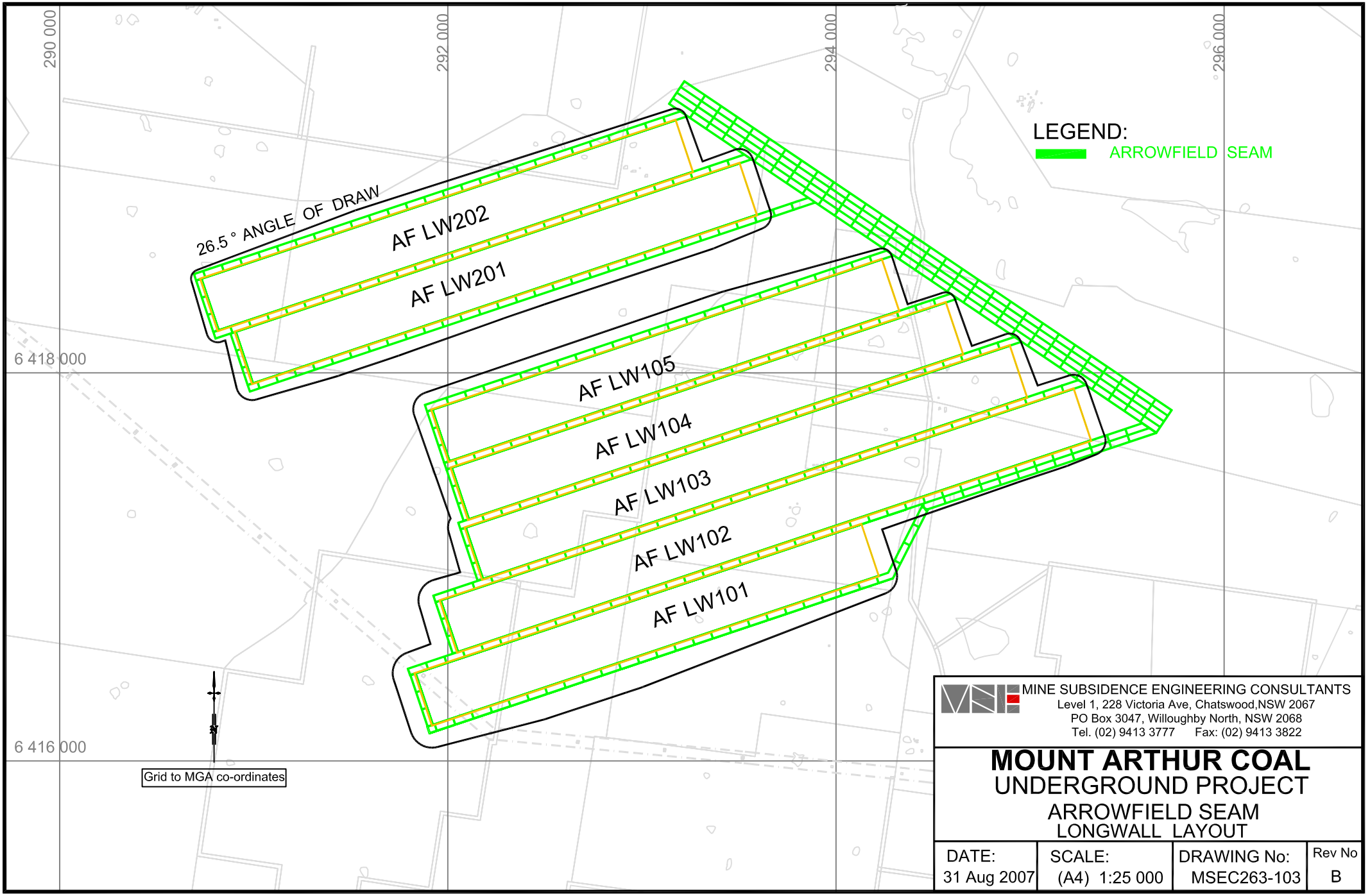

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
ARROWFIELD SEAM
LONGWALL LAYOUT

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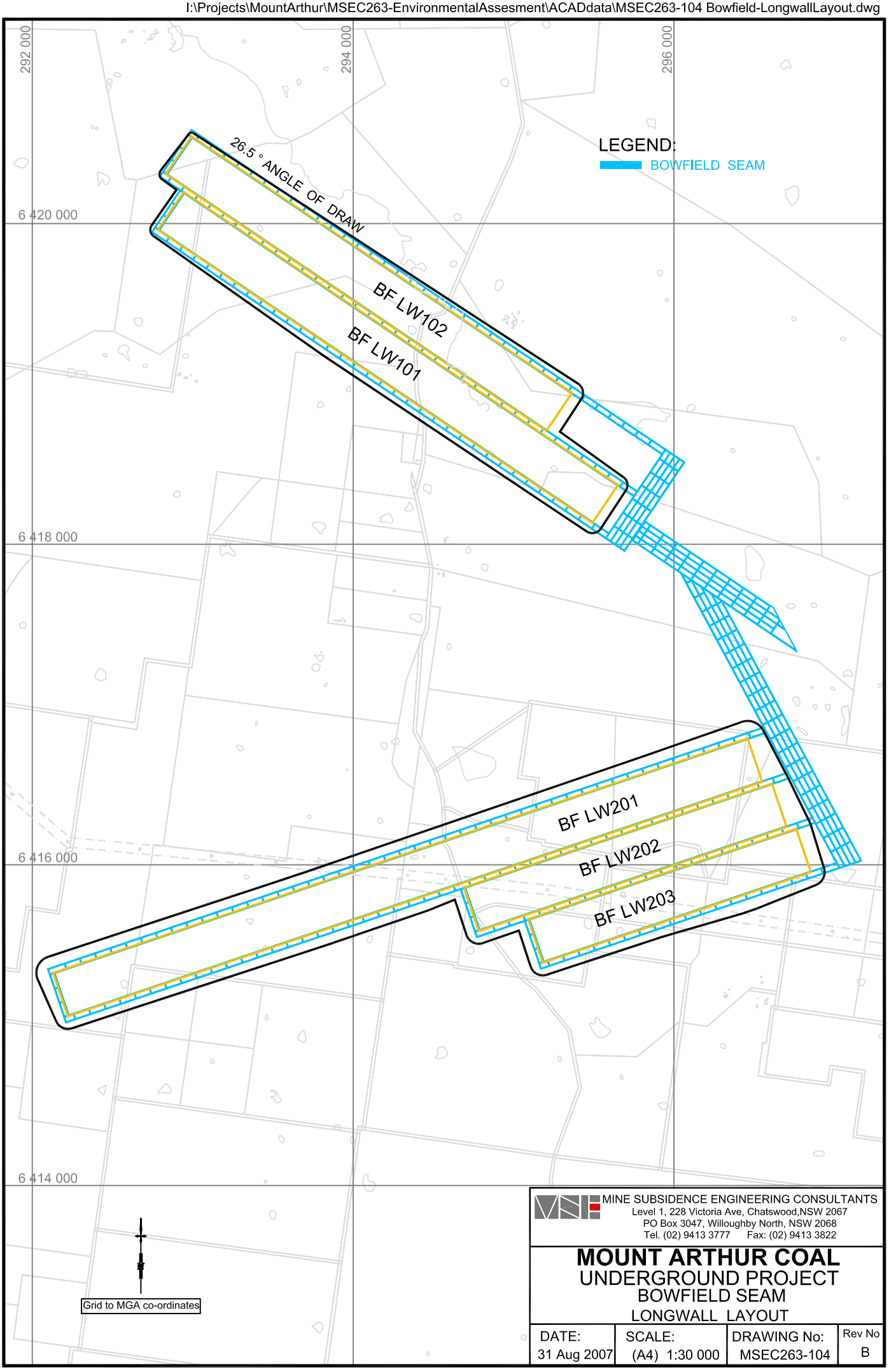

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BOWFIELD SEAM
LONGWALL LAYOUT

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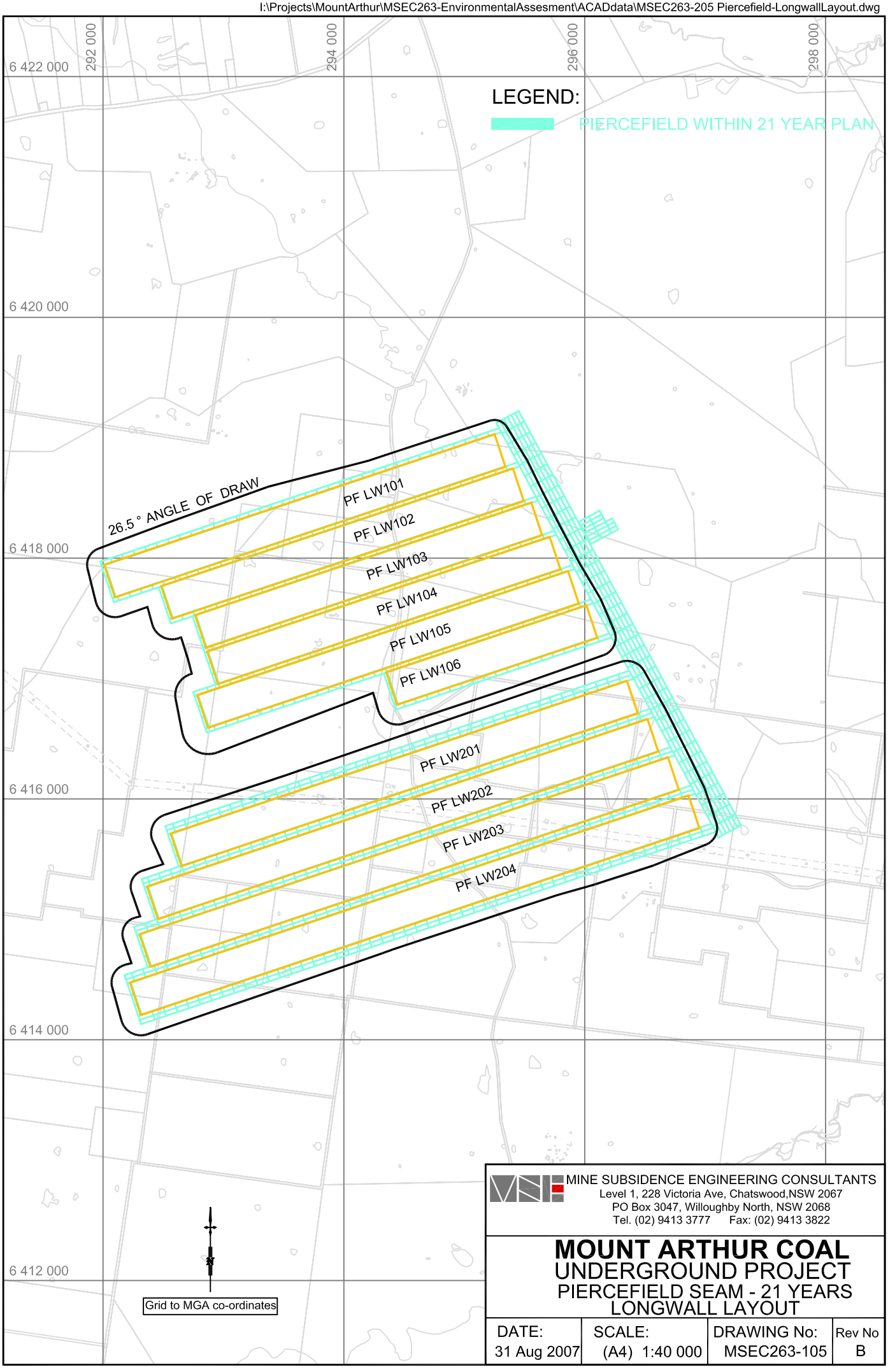

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PIERCEFIELD SEAM - 21 YEARS LONGWALL LAYOUT

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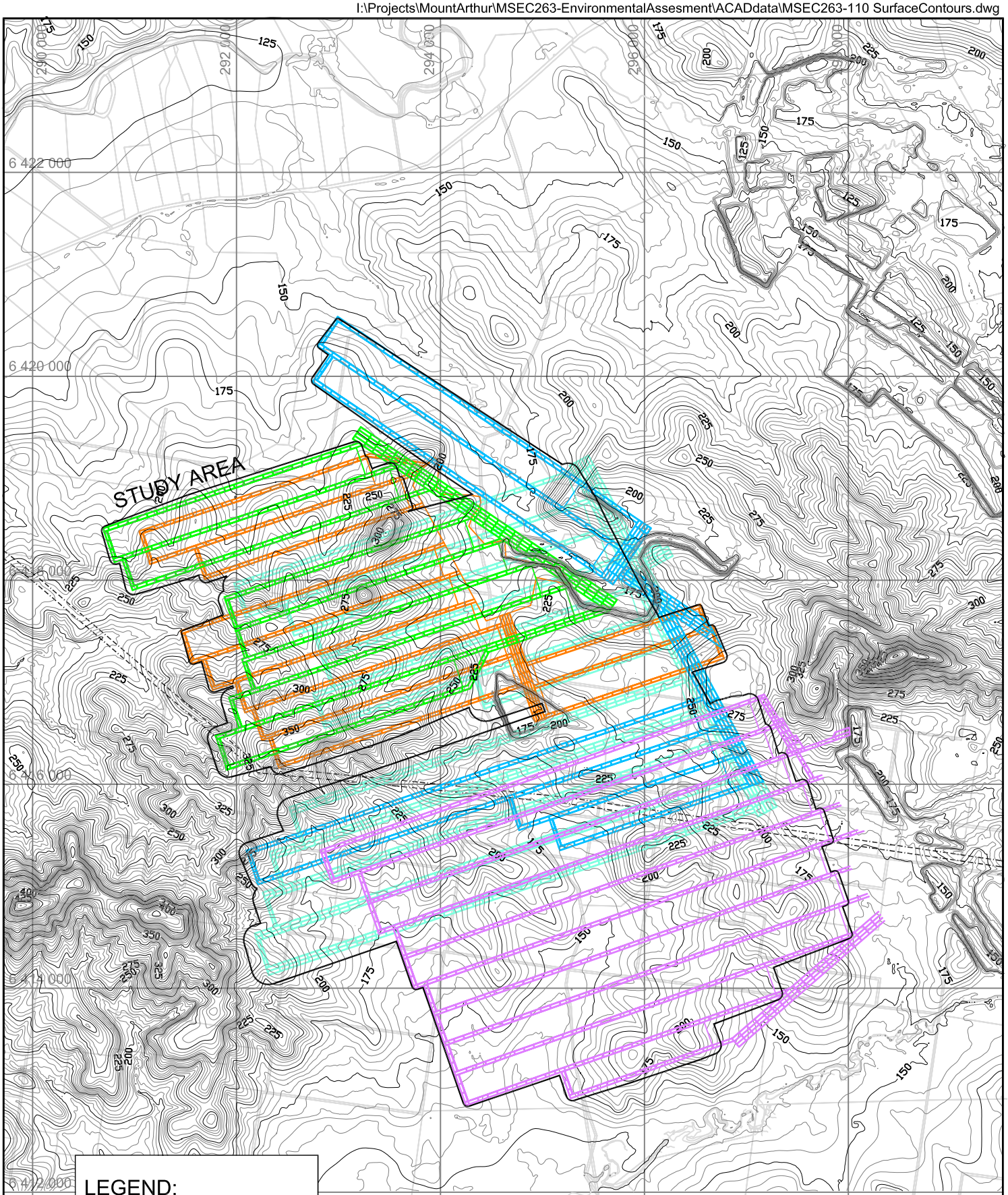

LEGEND:

- WOODLANDS HILL
- GLEN MUNRO
- ARROWFIELD
- BOWFIELD
- PIERCEFIELD WITHIN 21 YEAR PLAN

Grid to MGA co-ordinates

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
SURFACE CONTOURS

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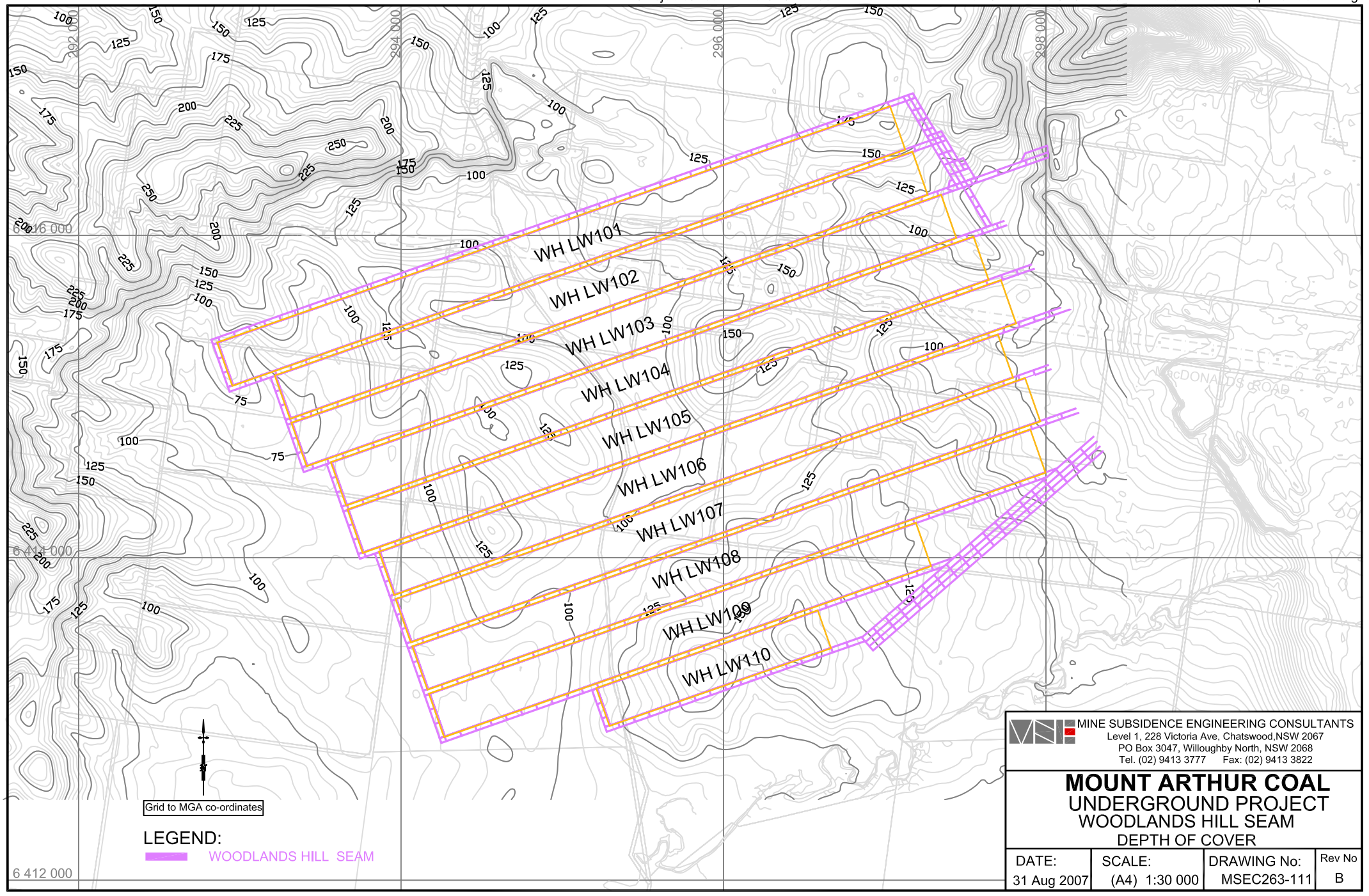

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
WOODLANDS HILL SEAM
DEPTH OF COVER

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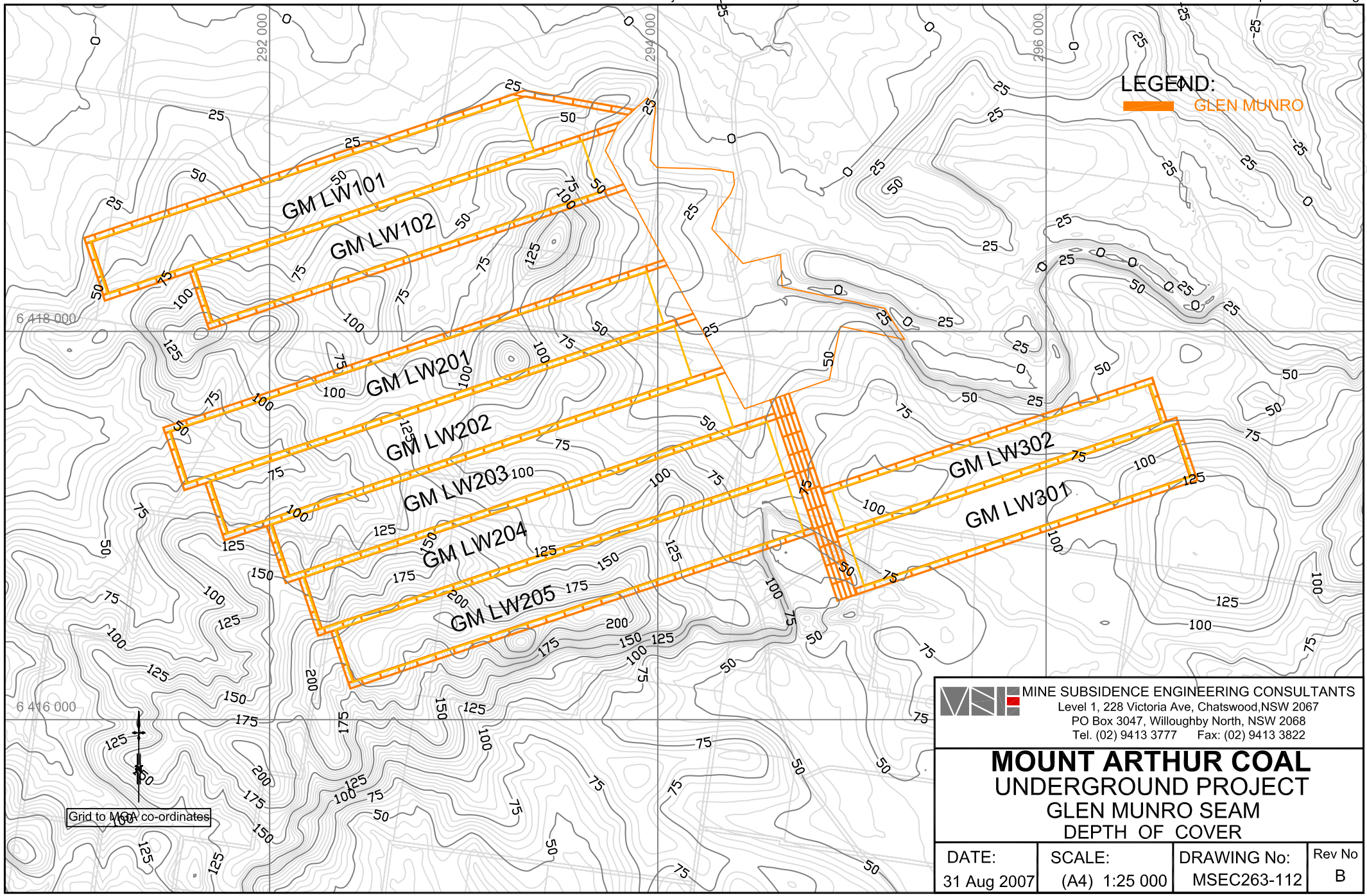

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
GLEN MUNRO SEAM
DEPTH OF COVER

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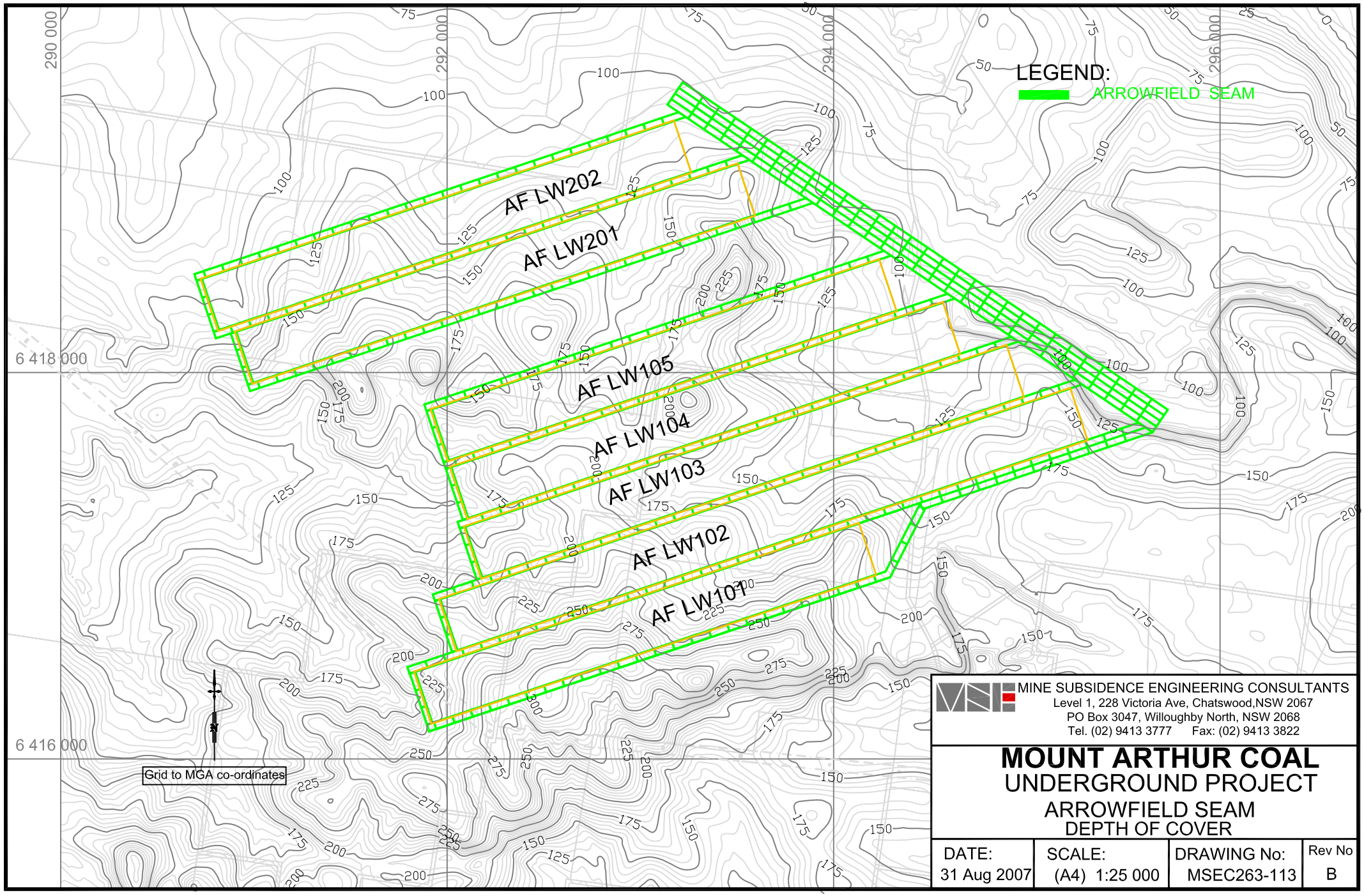

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
ARROWFIELD SEAM
DEPTH OF COVER

DATE:	SCALE:	DRAWING No:	Rev No
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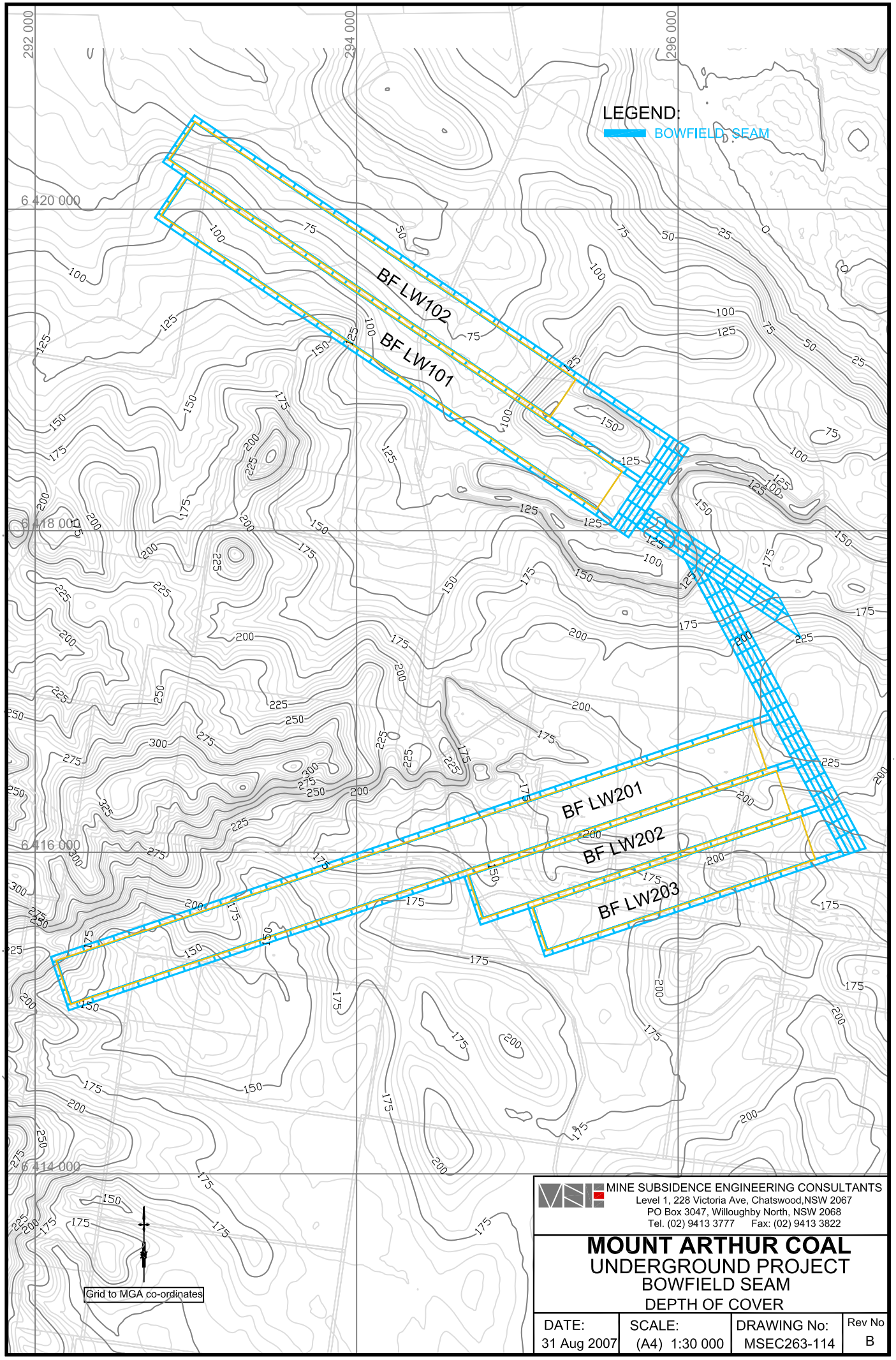

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BOWFIELD SEAM
DEPTH OF COVER

DATE:	SCALE:	DRAWING No:	Rev No
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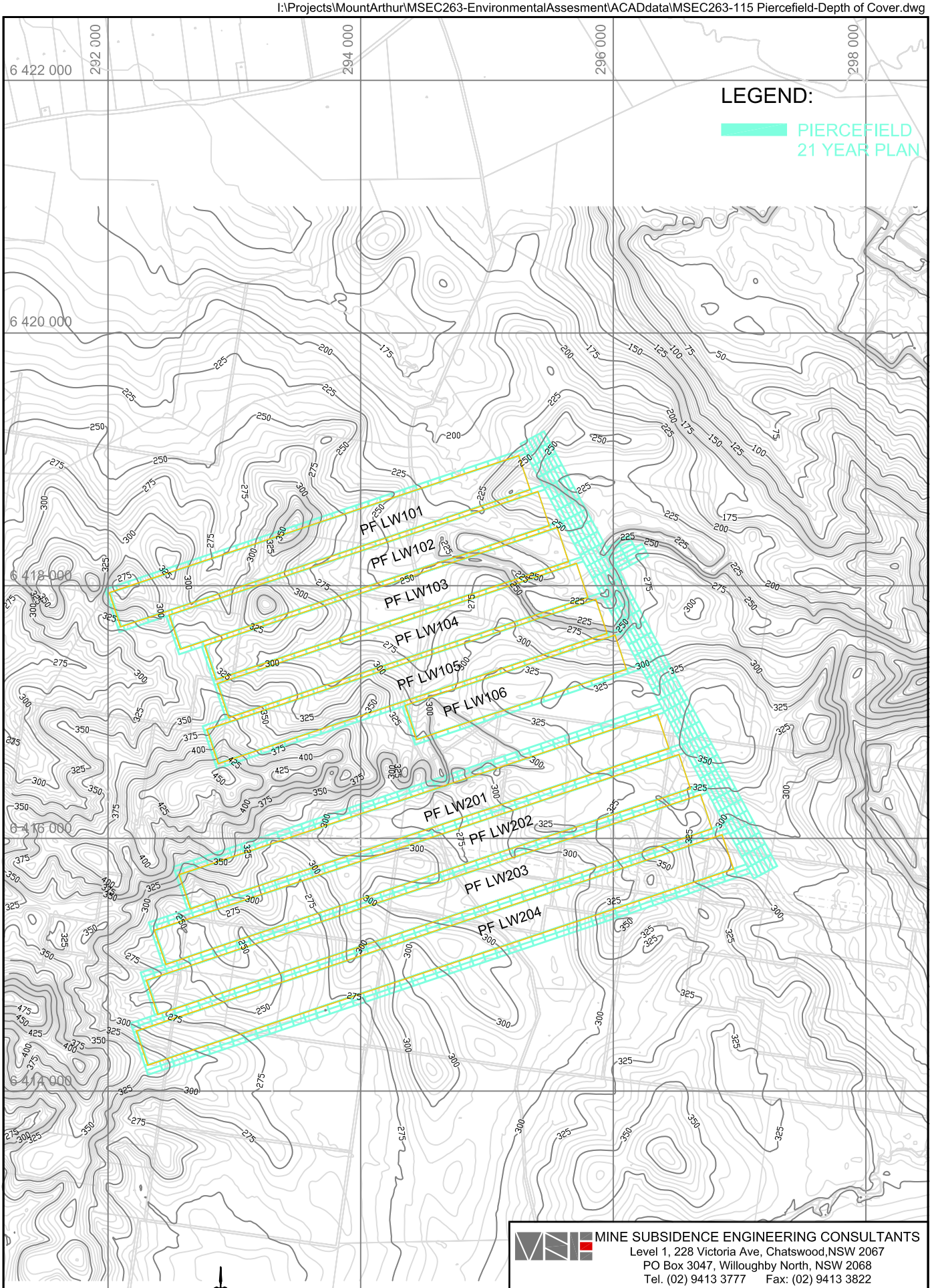

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PIERCEFIELD SEAM - 21 YEARS
DEPTH OF COVER

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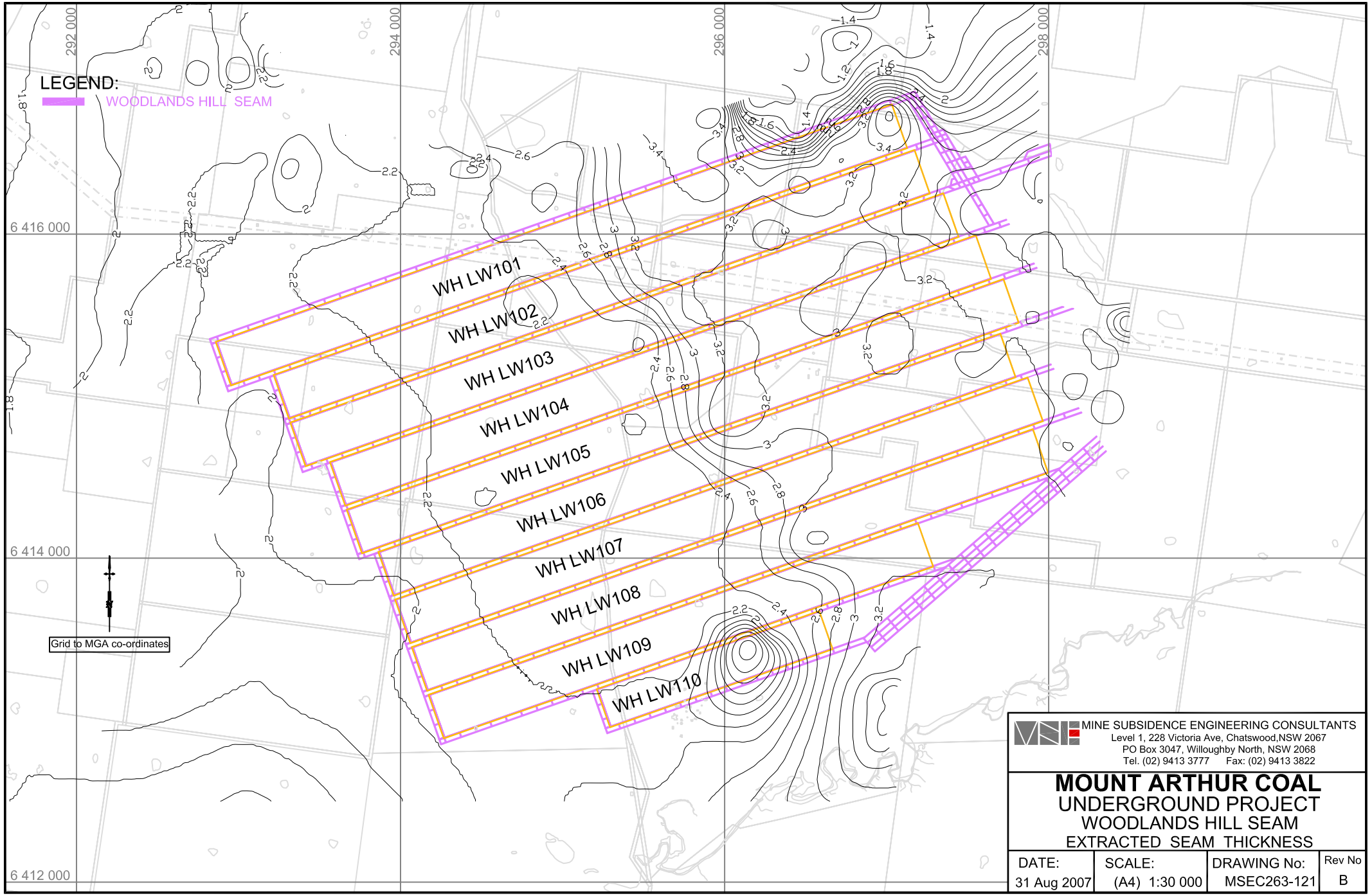

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MOUNT ARTHUR COAL

UNDERGROUND PROJECT

WOODLANDS HILL SEAM

EXTRACTED SEAM THICKNESS

DATE:	SCALE:	DRAWING No:	Rev No
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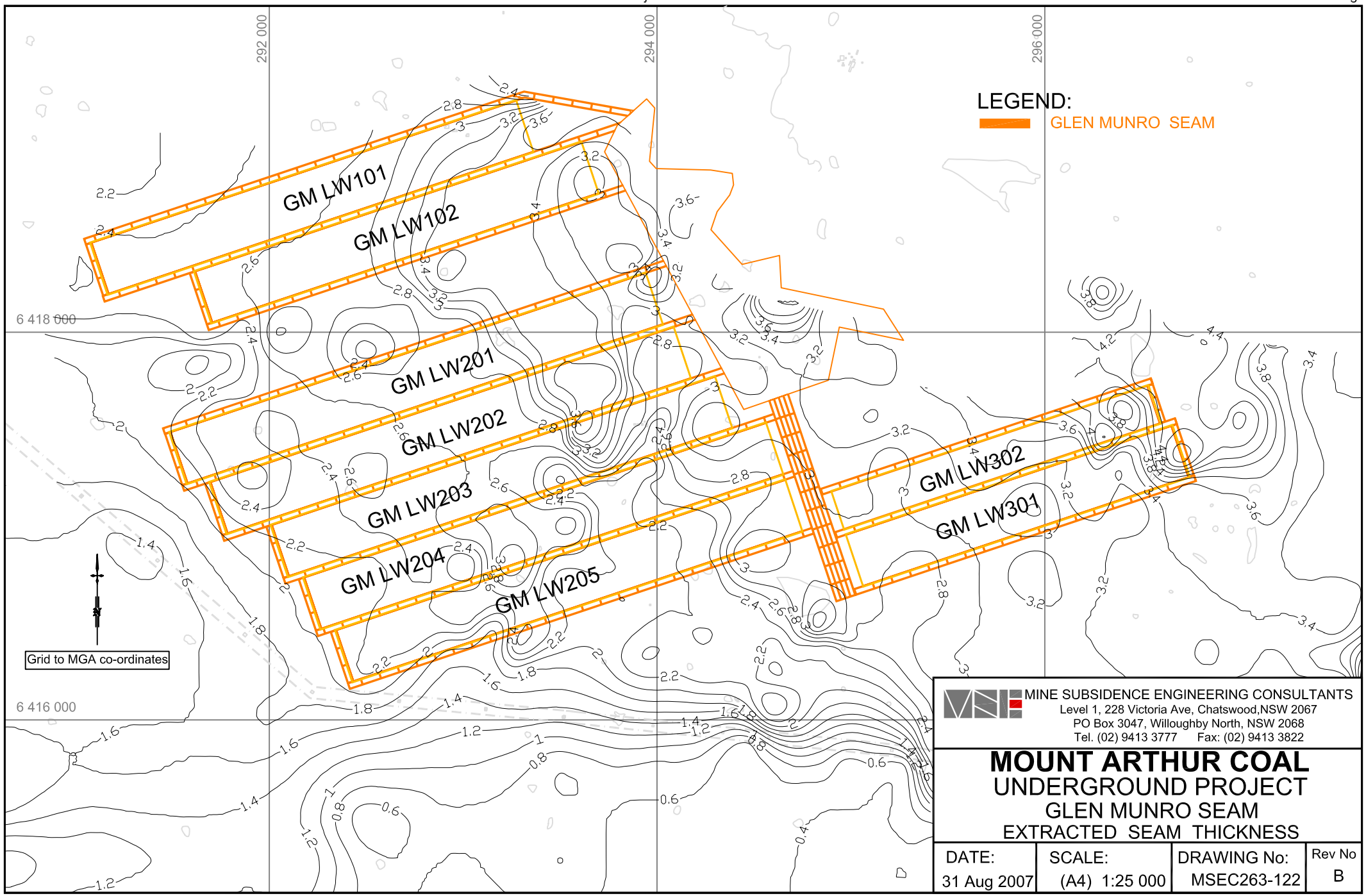

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
GLEN MUNRO SEAM
EXTRACTED SEAM THICKNESS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:25 000	MSEC263-122	B

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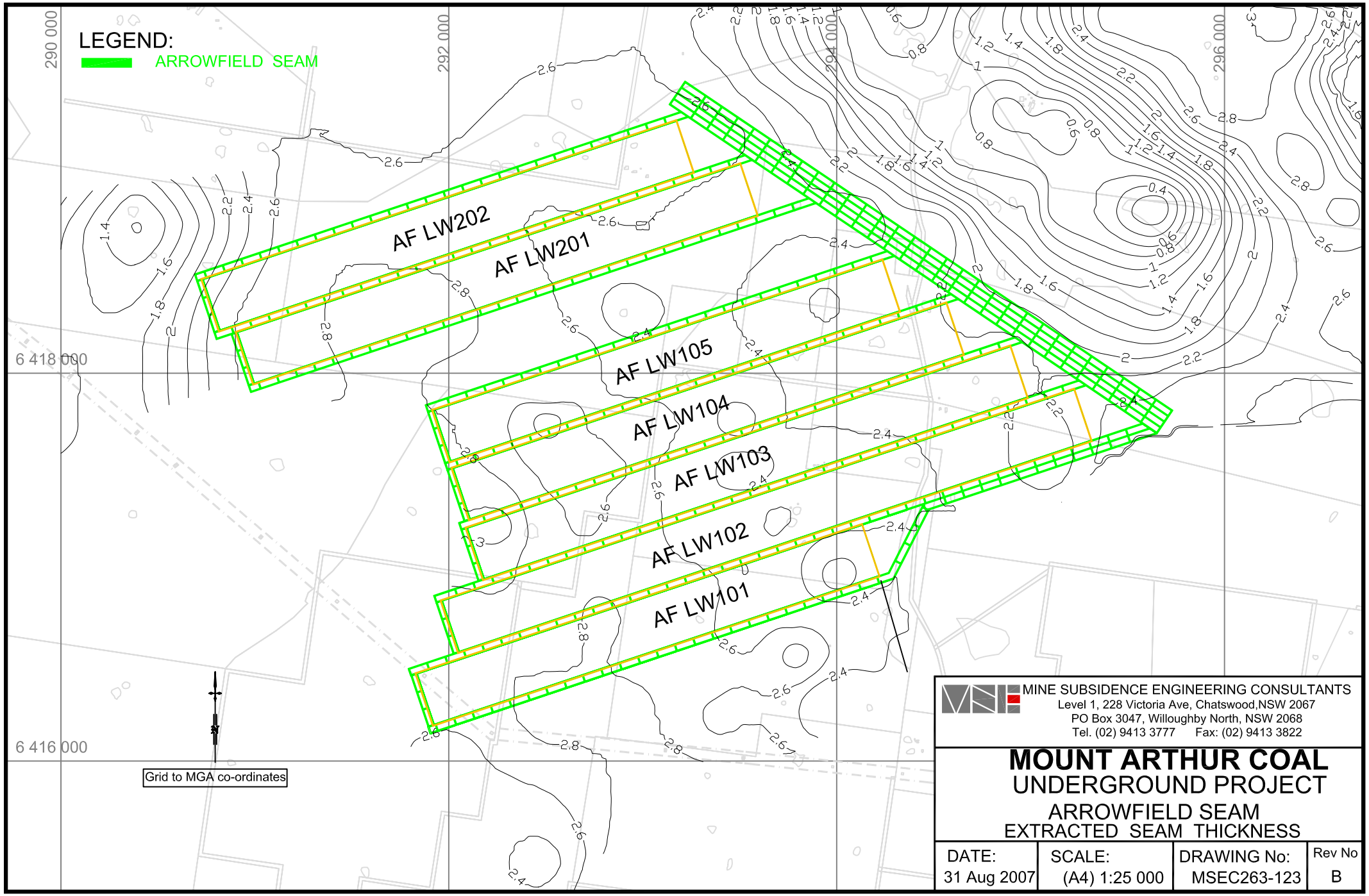

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
ARROWFIELD SEAM
EXTRACTED SEAM THICKNESS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:25 000	MSEC263-123	B

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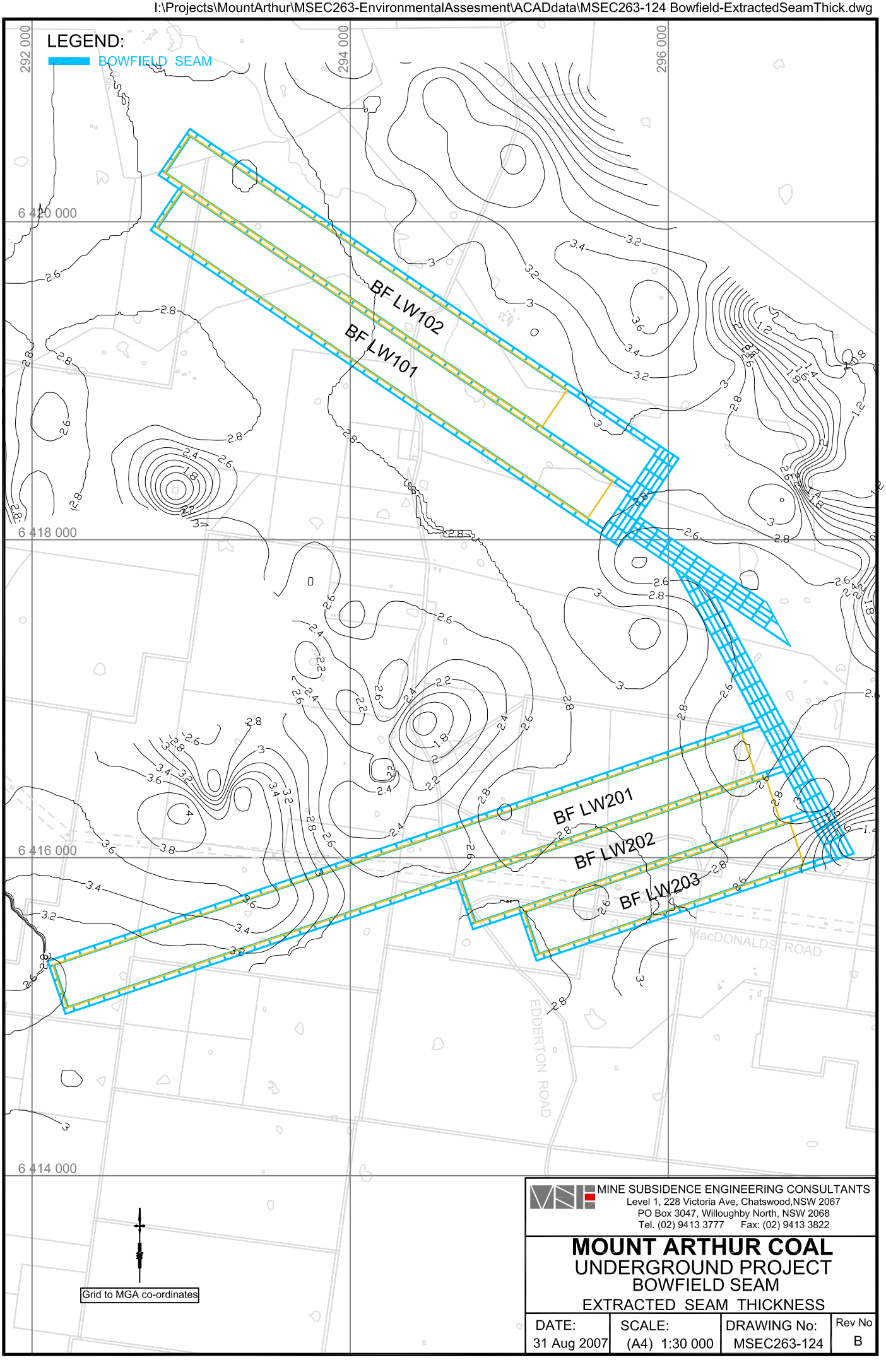

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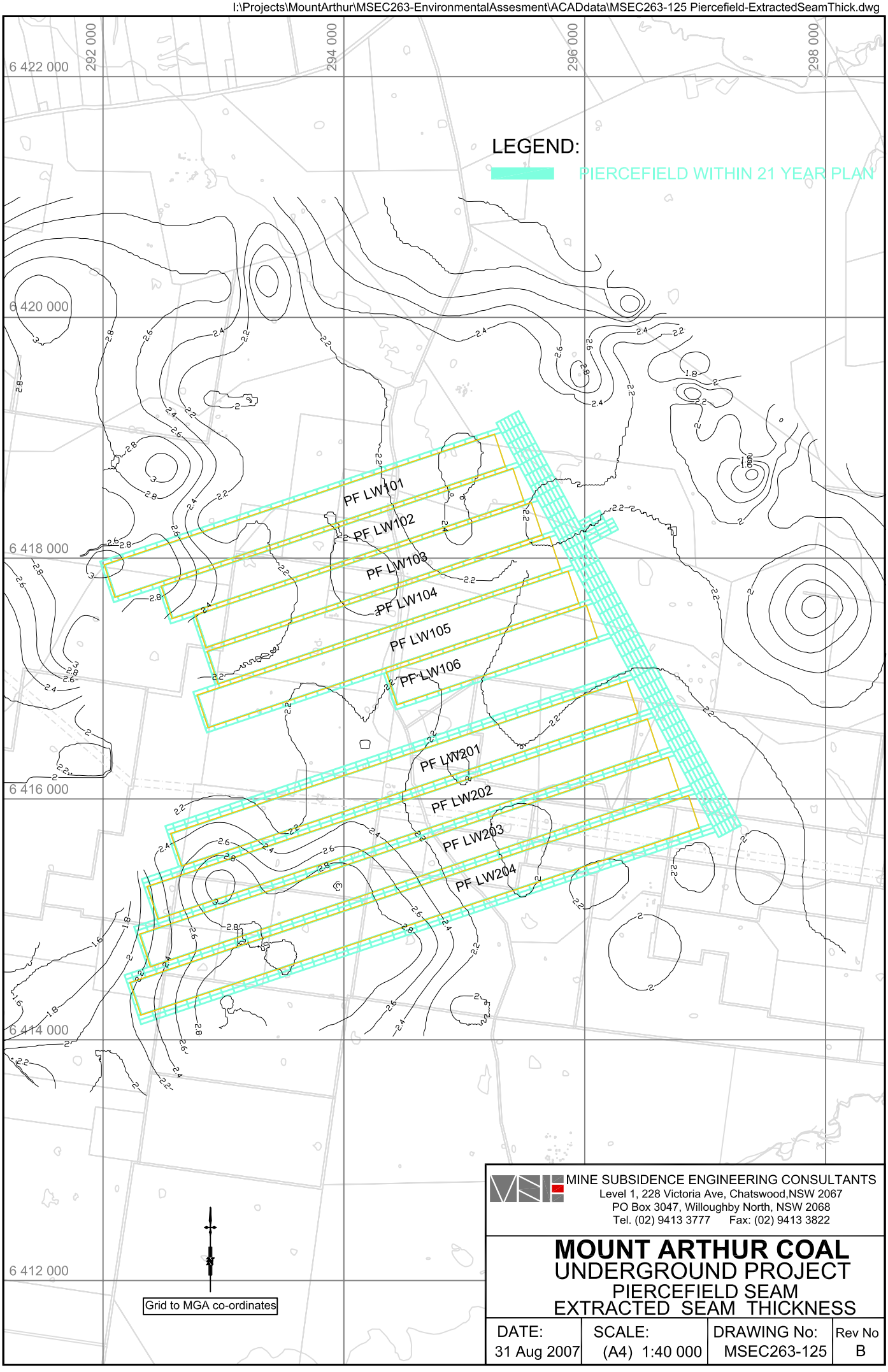
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BOWFIELD SEAM
EXTRACTED SEAM THICKNESS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:30 000	MSEC263-124	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-125 Piercefield-ExtractedSeamThick.dwg



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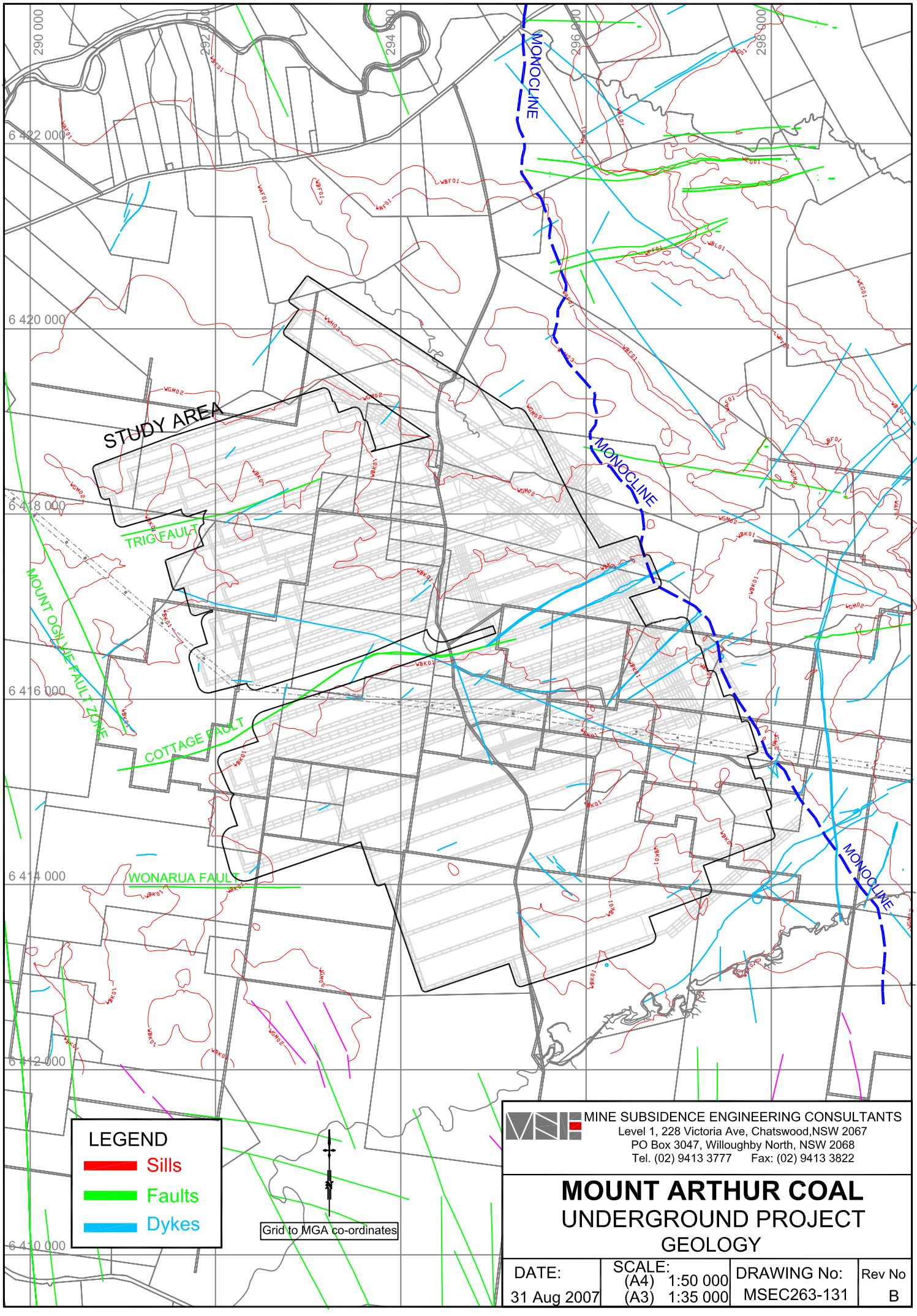
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PIERCEFIELD SEAM
EXTRACTED SEAM THICKNESS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:40 000	MSEC263-125	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-131 Geology.dwg



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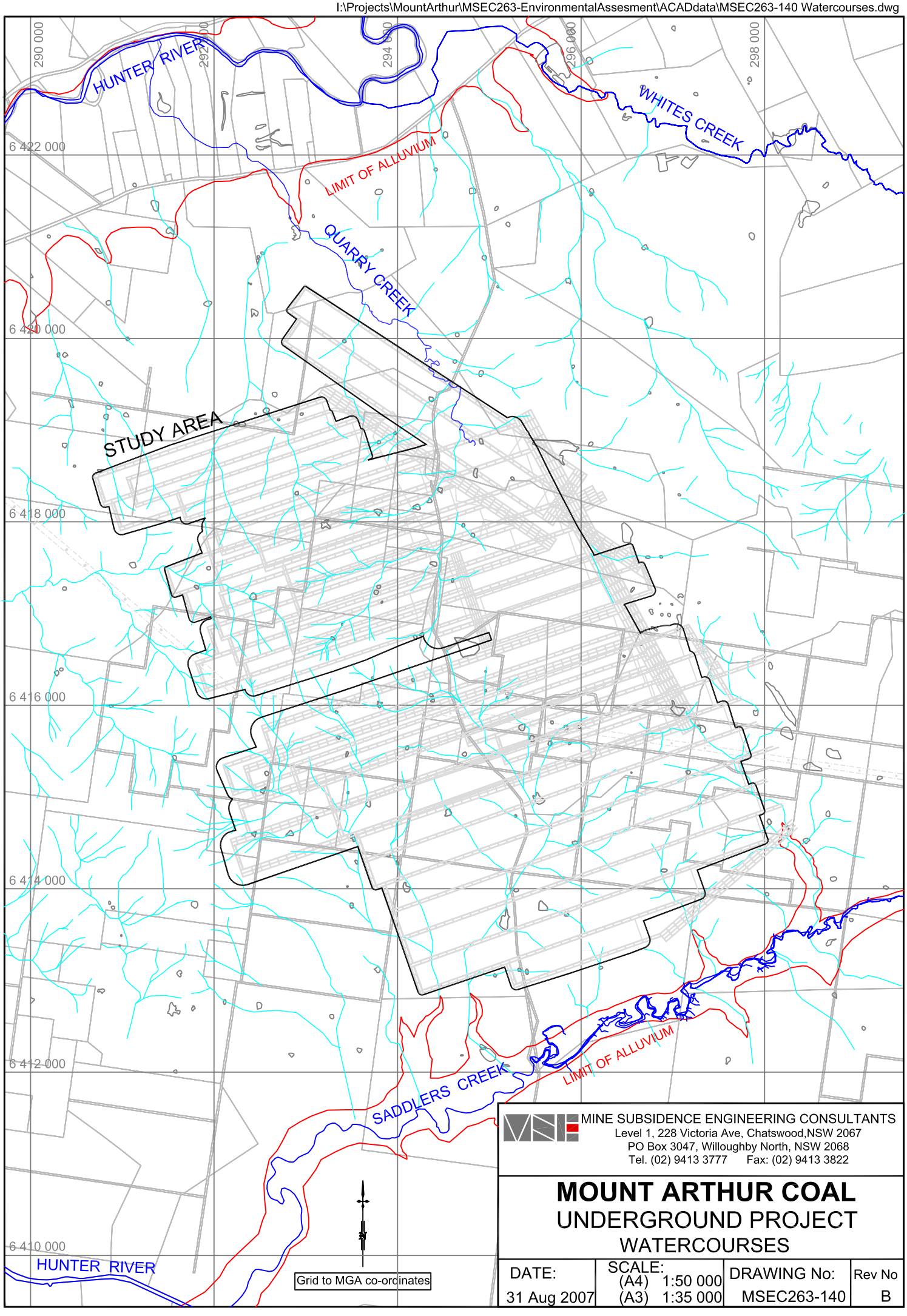
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
GEOLOGY

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-131	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-140 Watercourses.dwg



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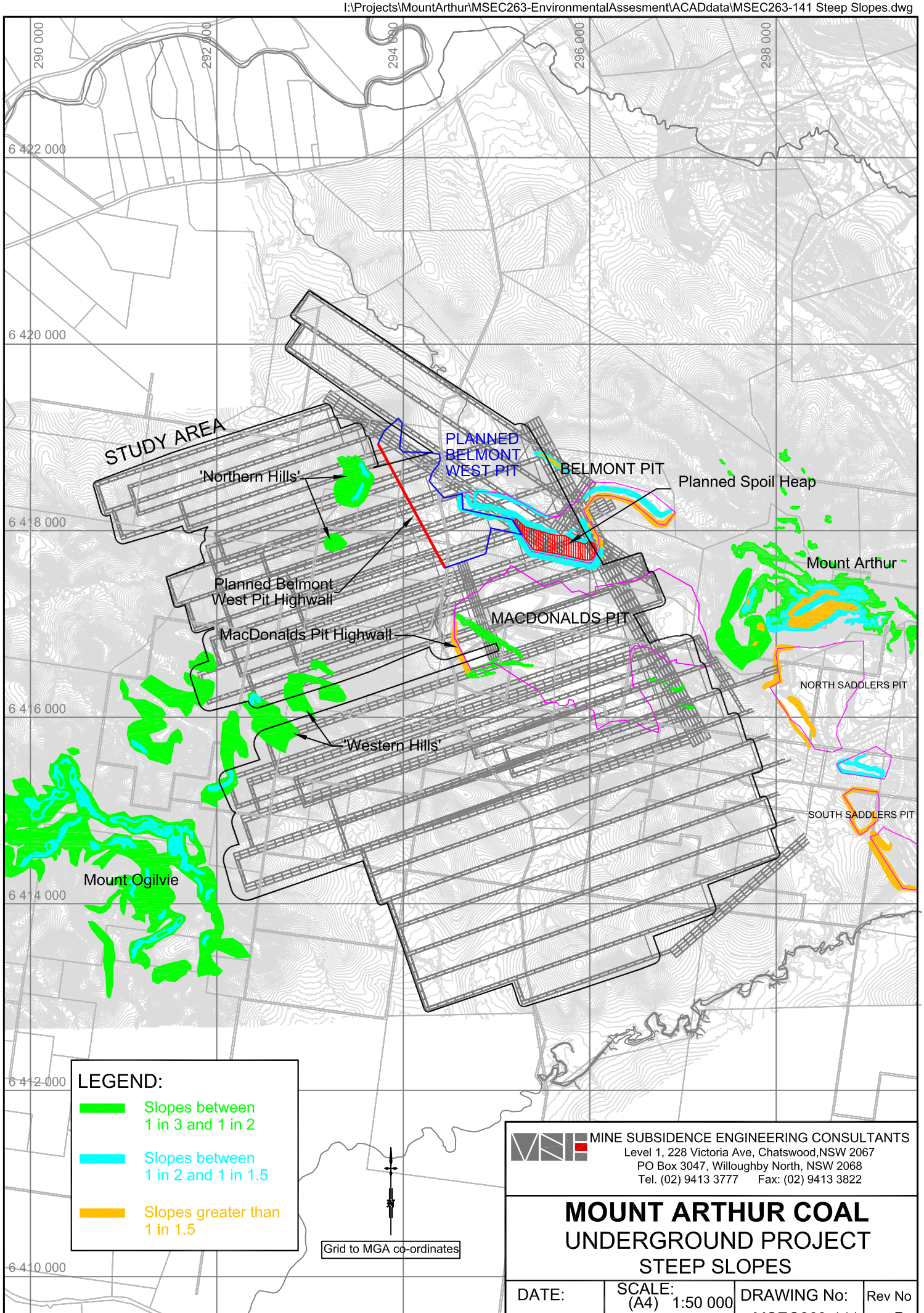
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
WATERCOURSES

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-140	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-141 Steep Slopes.dwg



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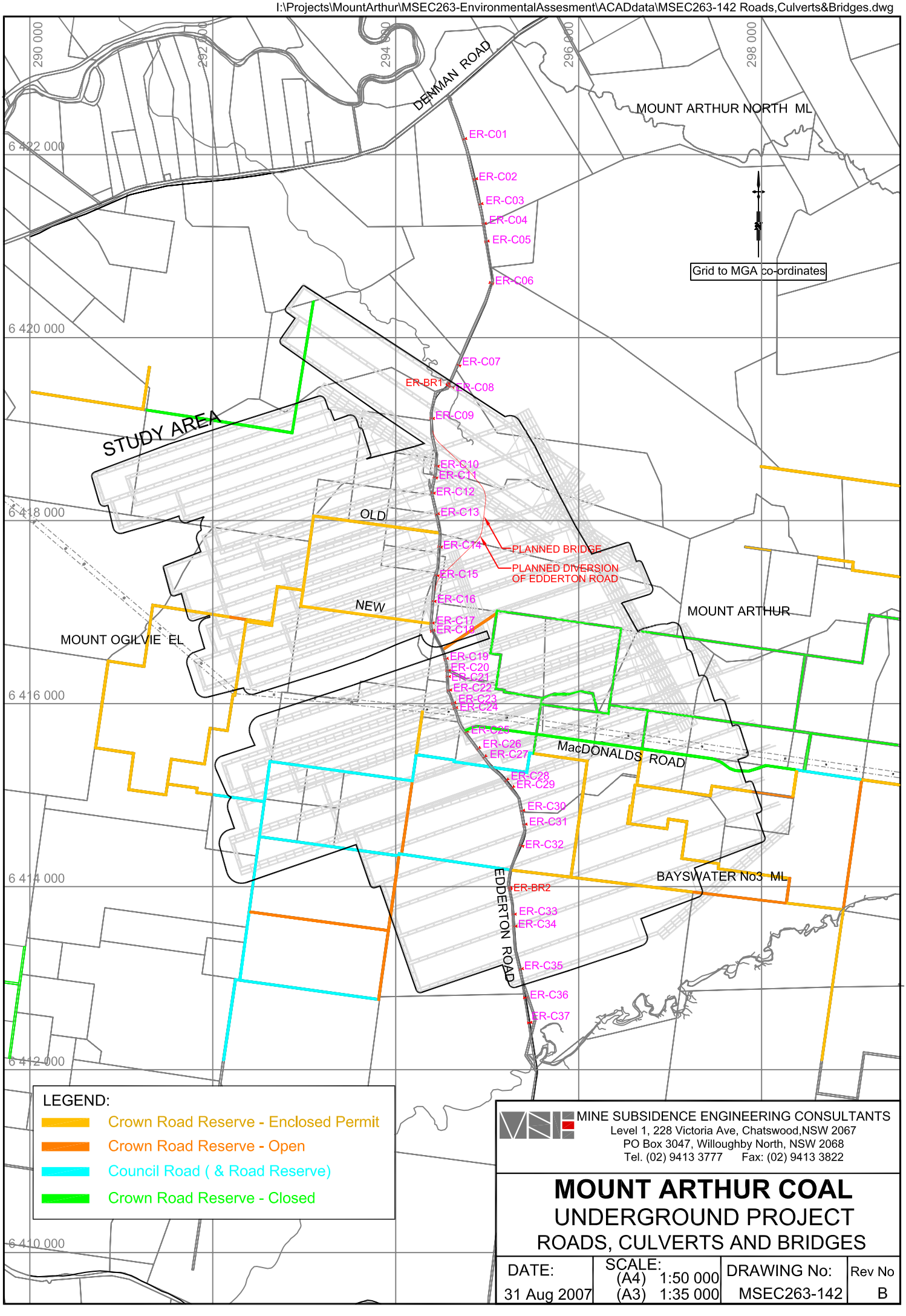
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
STEEP SLOPES

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-141	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-142 Roads,Culverts&Bridges.dwg



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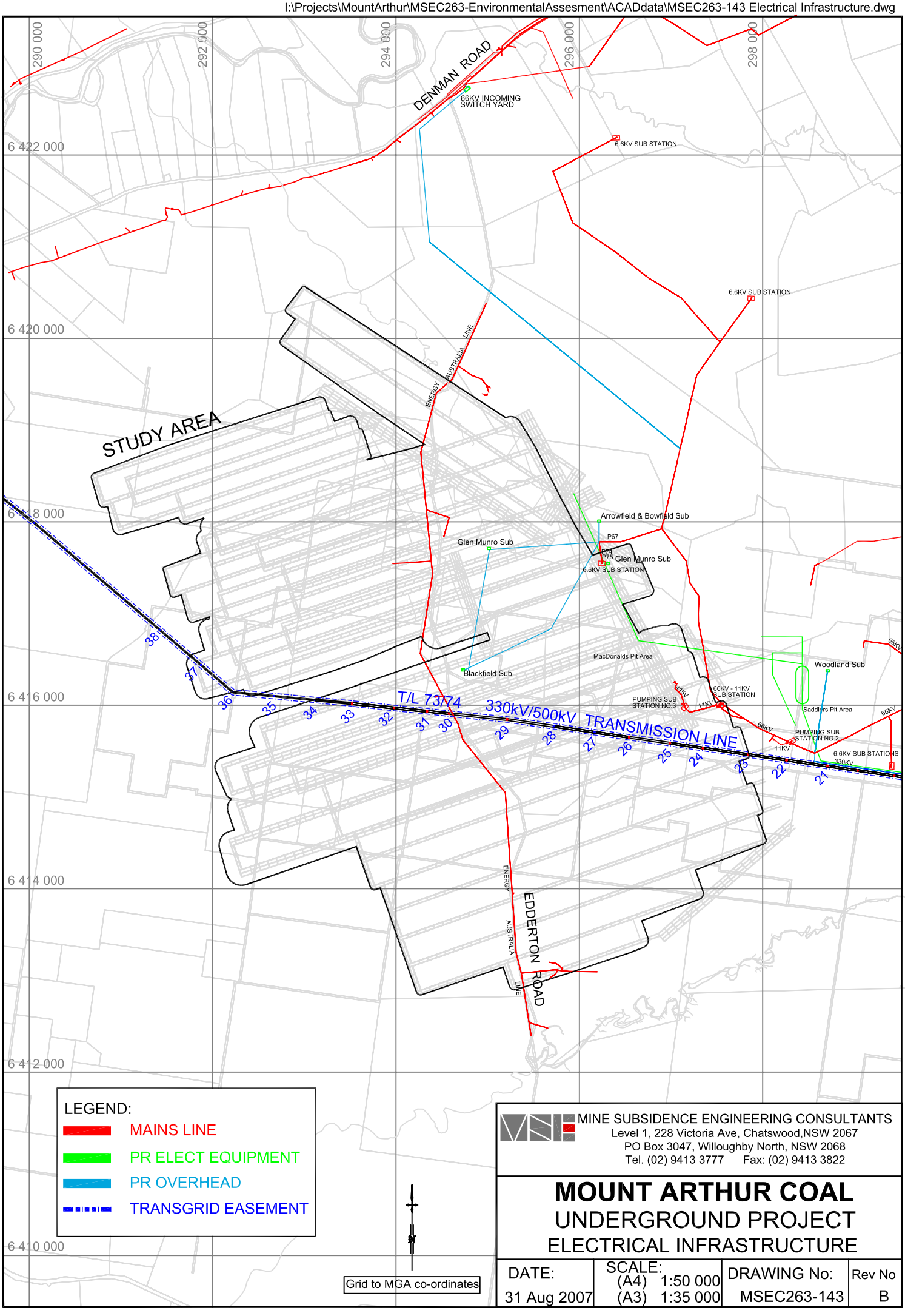
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
ROADS, CULVERTS AND BRIDGES

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-142	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-143 Electrical Infrastructure.dwg



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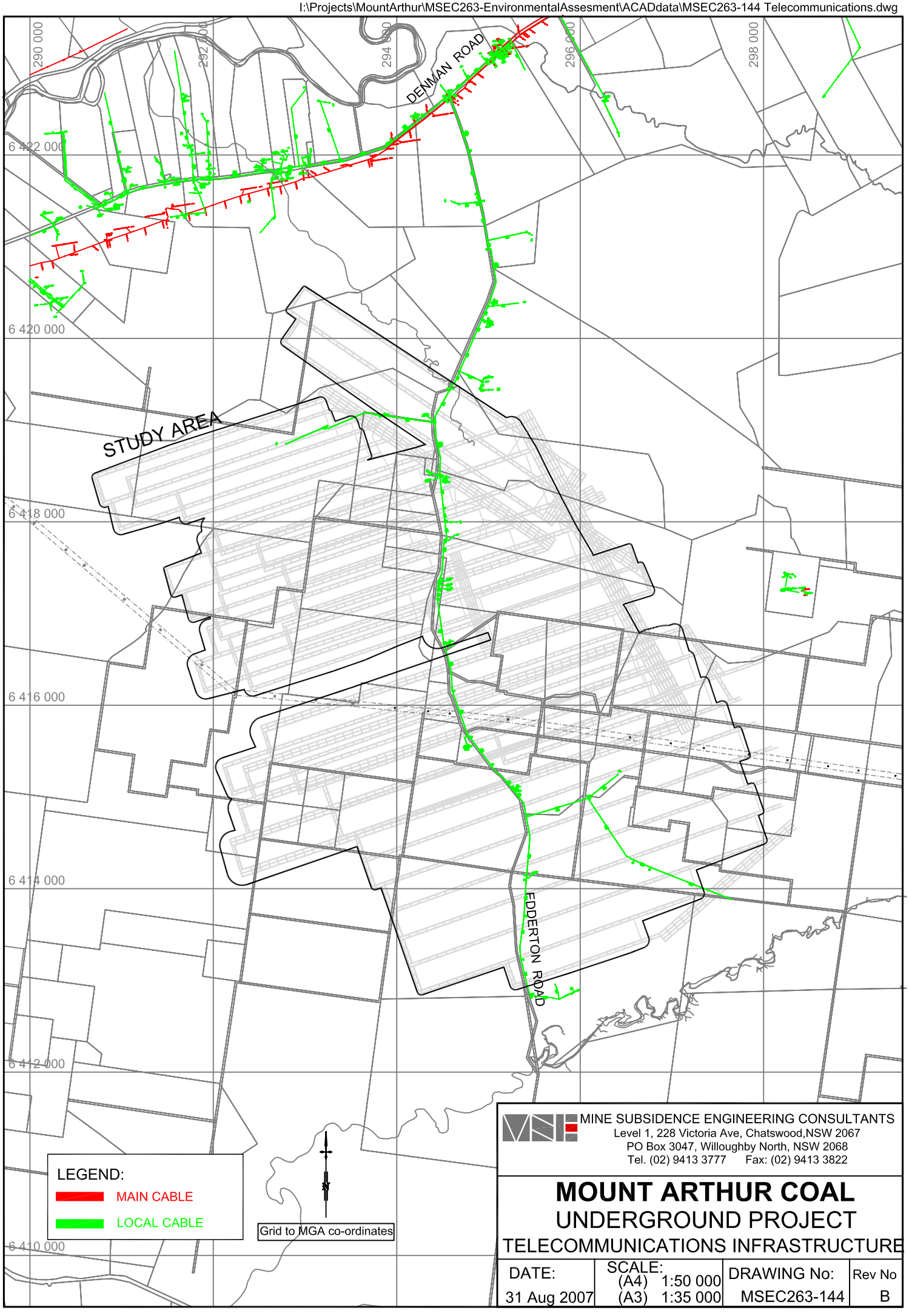
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
ELECTRICAL INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-143	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-144 Telecommunications.dwg



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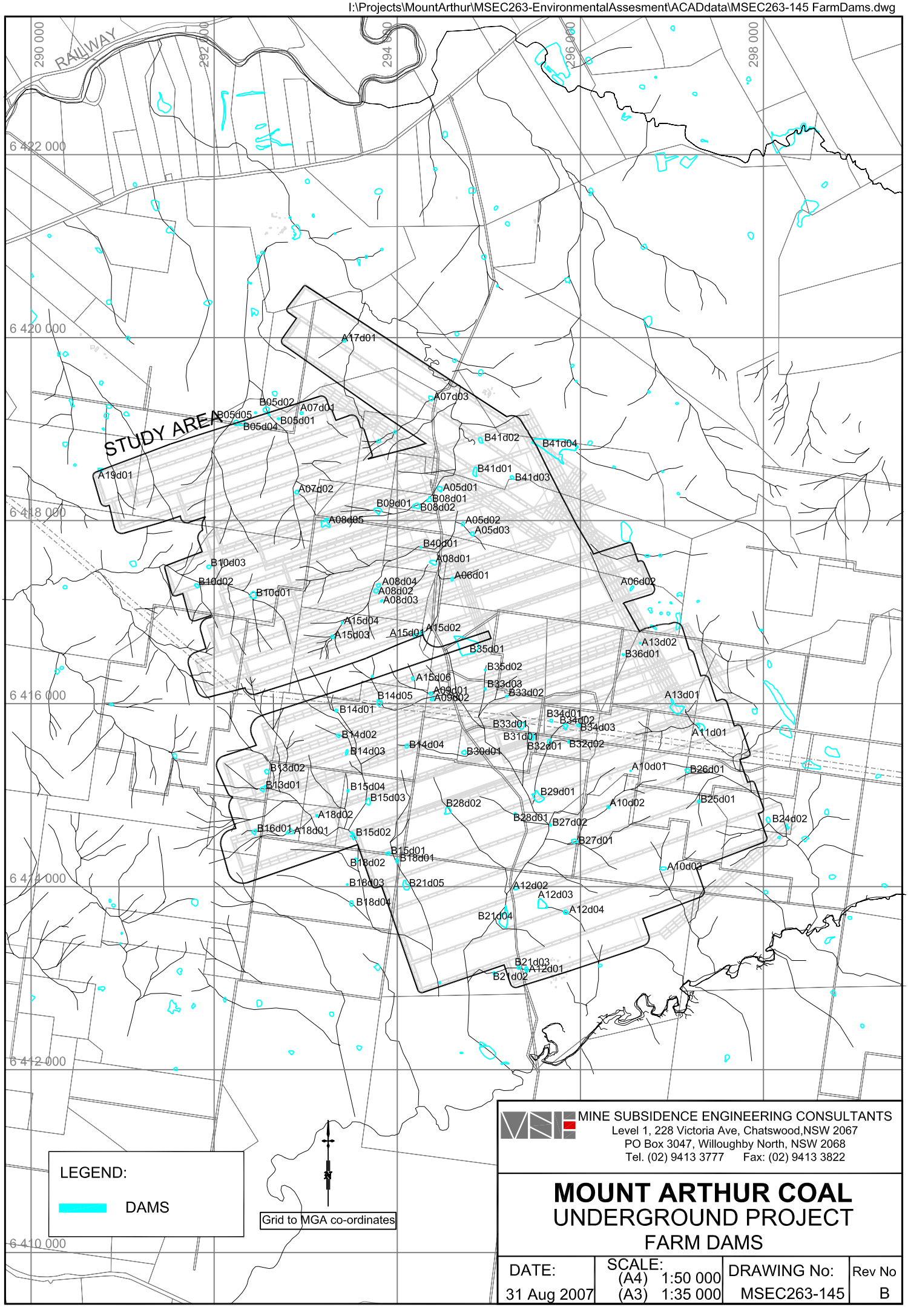
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
TELECOMMUNICATIONS INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-144	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-145 FarmDams.dwg



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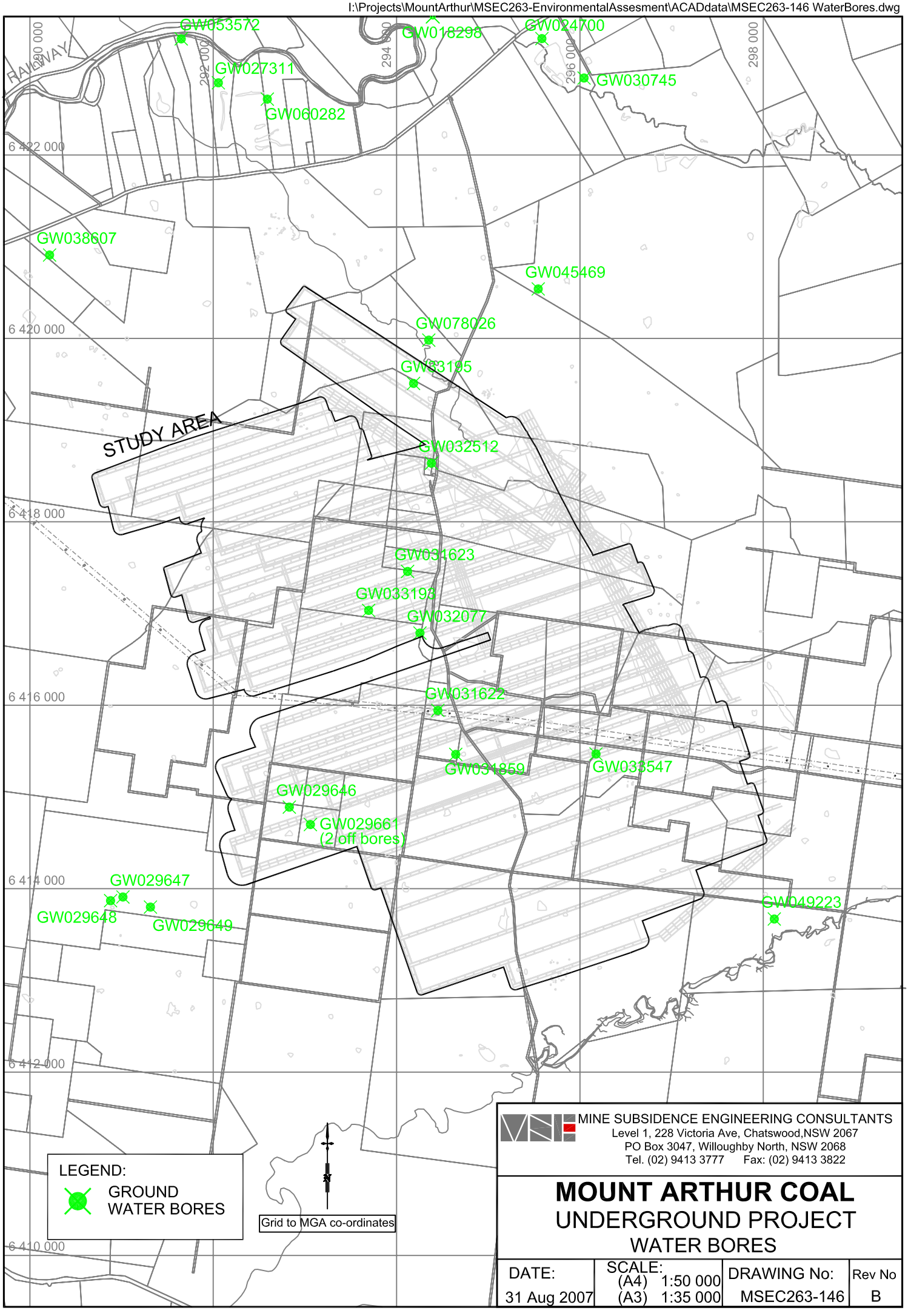
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
FARM DAMS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-145	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-146 WaterBores.dwg



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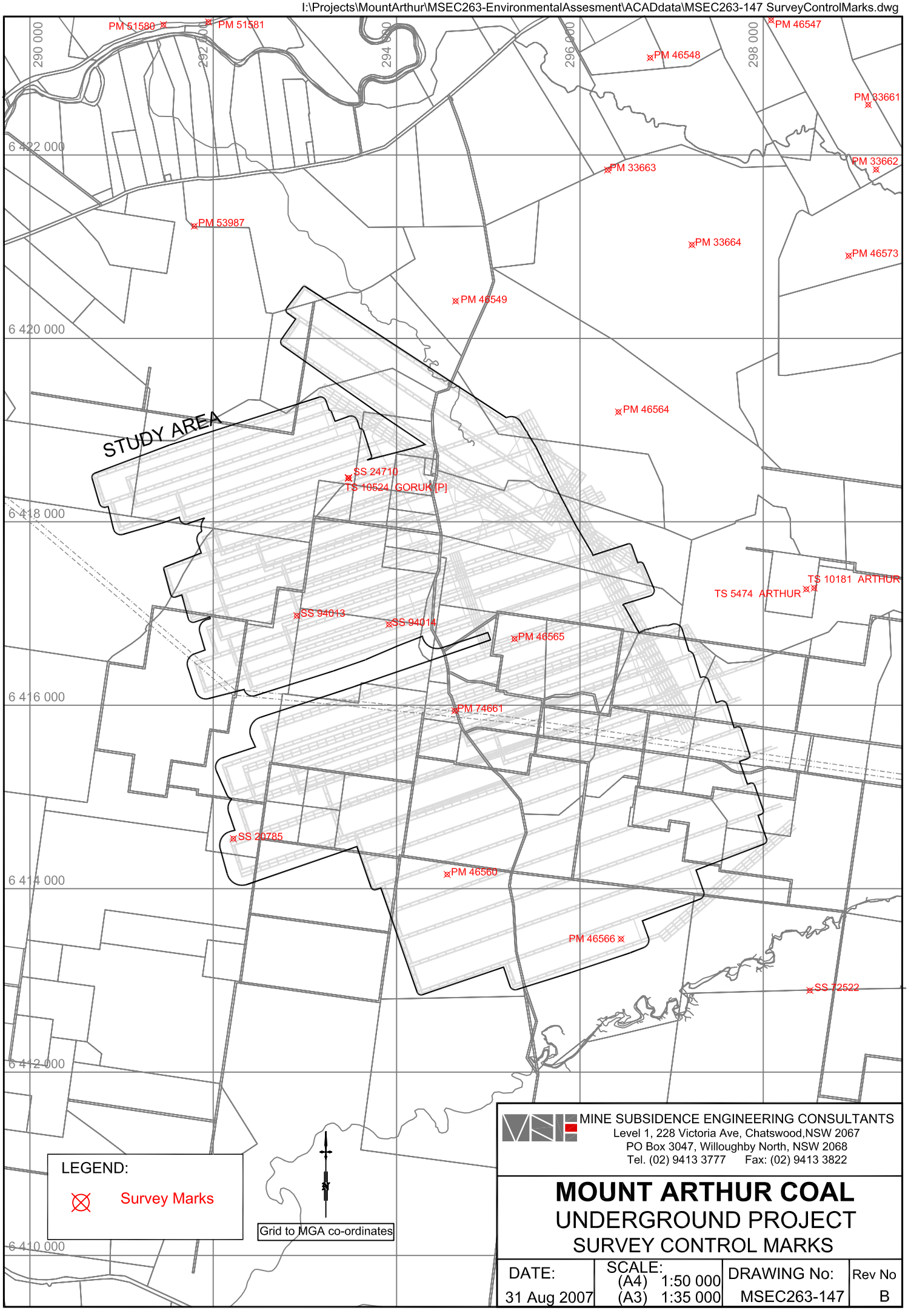
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
WATER BORES

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-146	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-147 SurveyControlMarks.dwg



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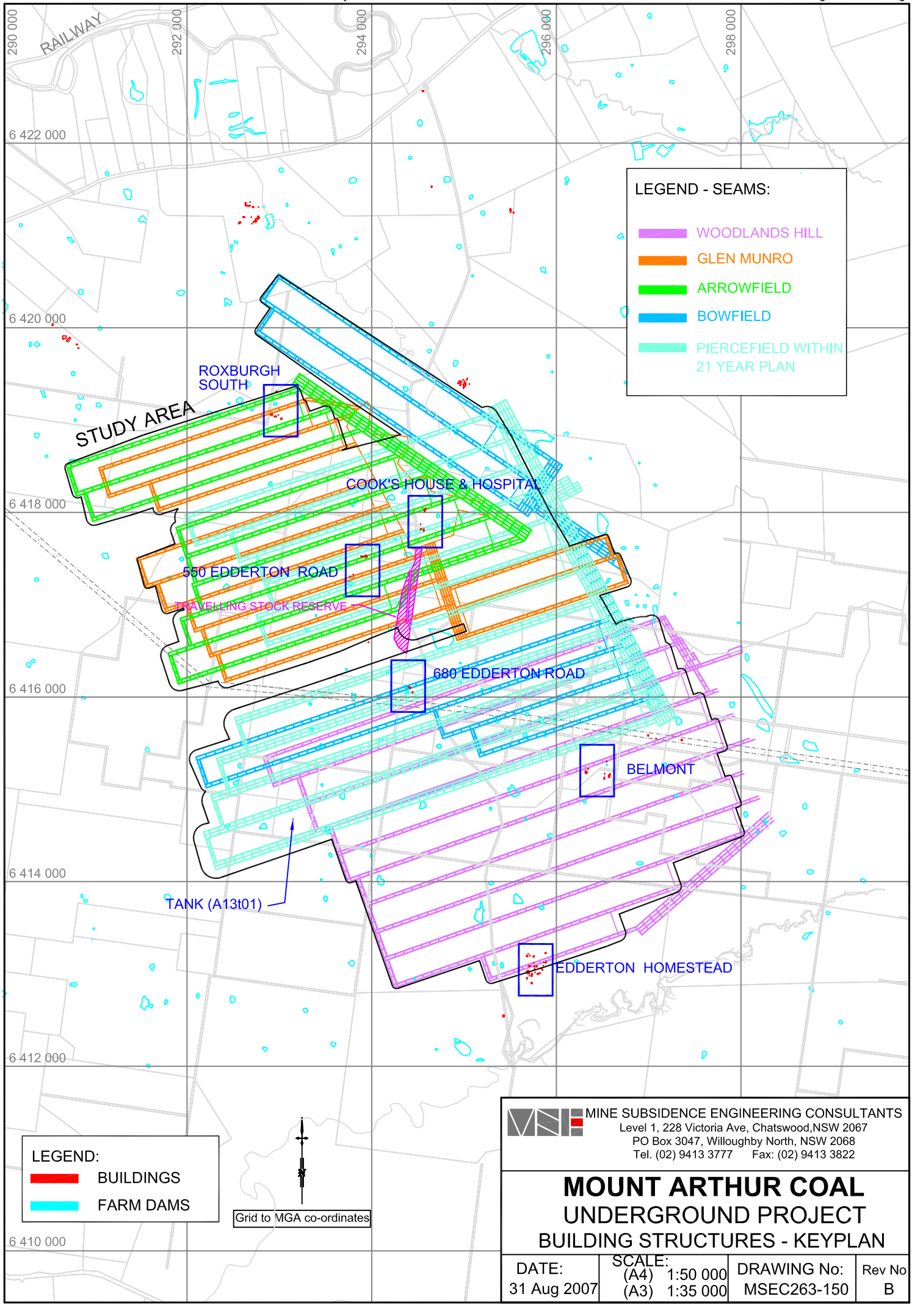
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
SURVEY CONTROL MARKS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-147	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-150 BuildingStructures.dwg



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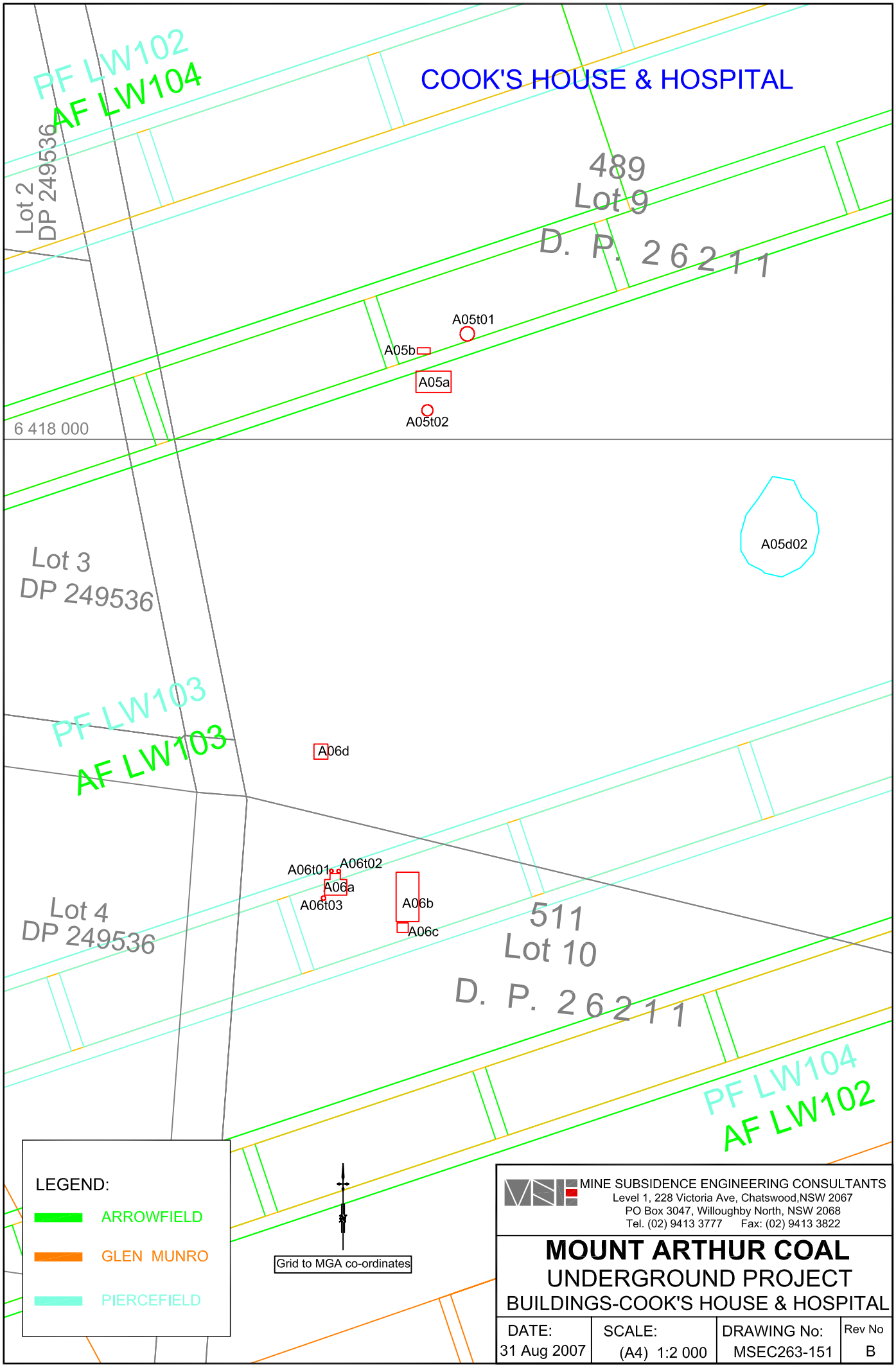
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BUILDING STRUCTURES - KEYPLAN

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-150	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-151 Buildings_CooksHouse&Hospital.dwg



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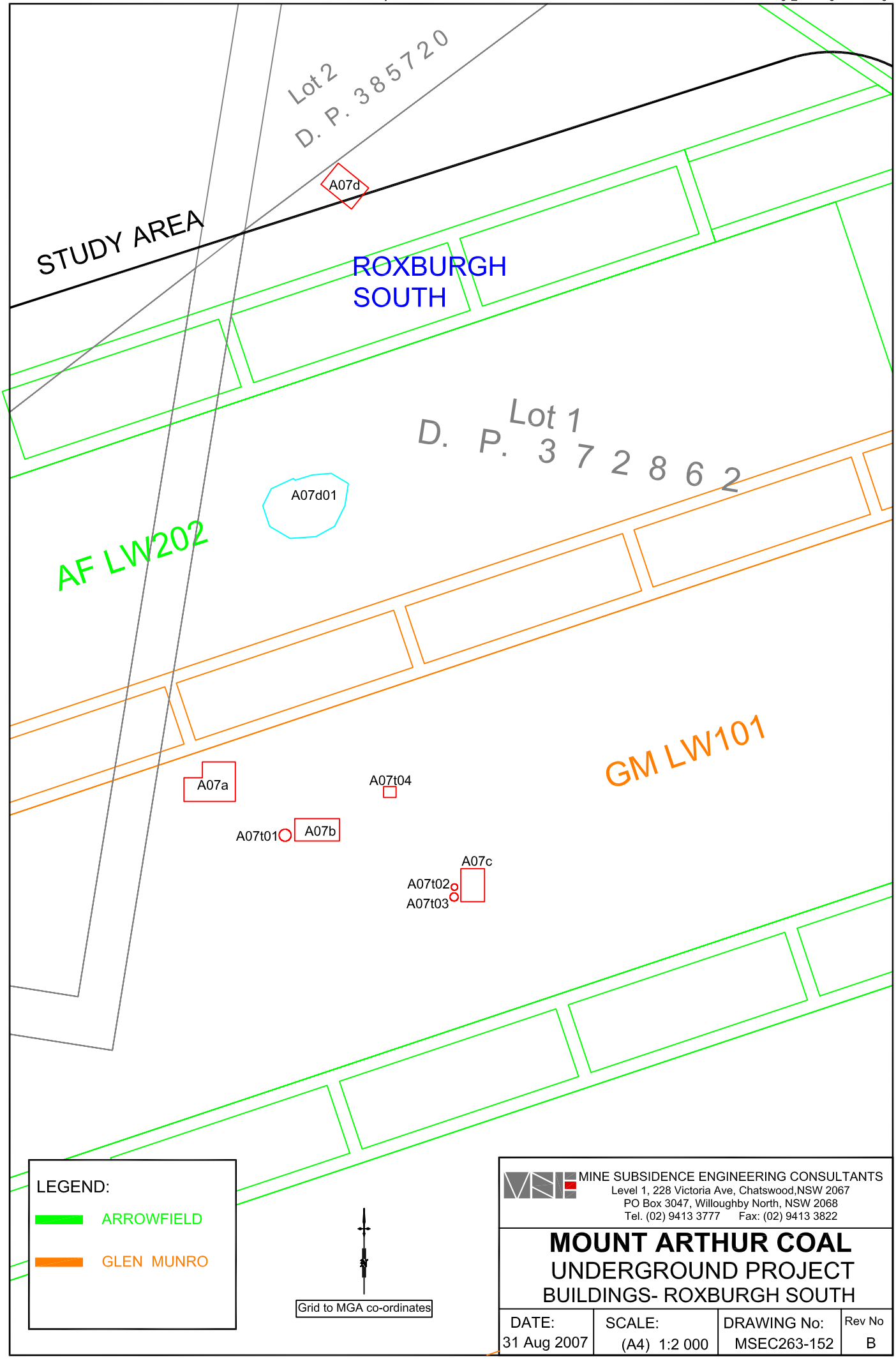
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BUILDINGS-COOK'S HOUSE & HOSPITAL

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:2 000	MSEC263-151	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-152 Buildings_RoxburghSouth.dwg



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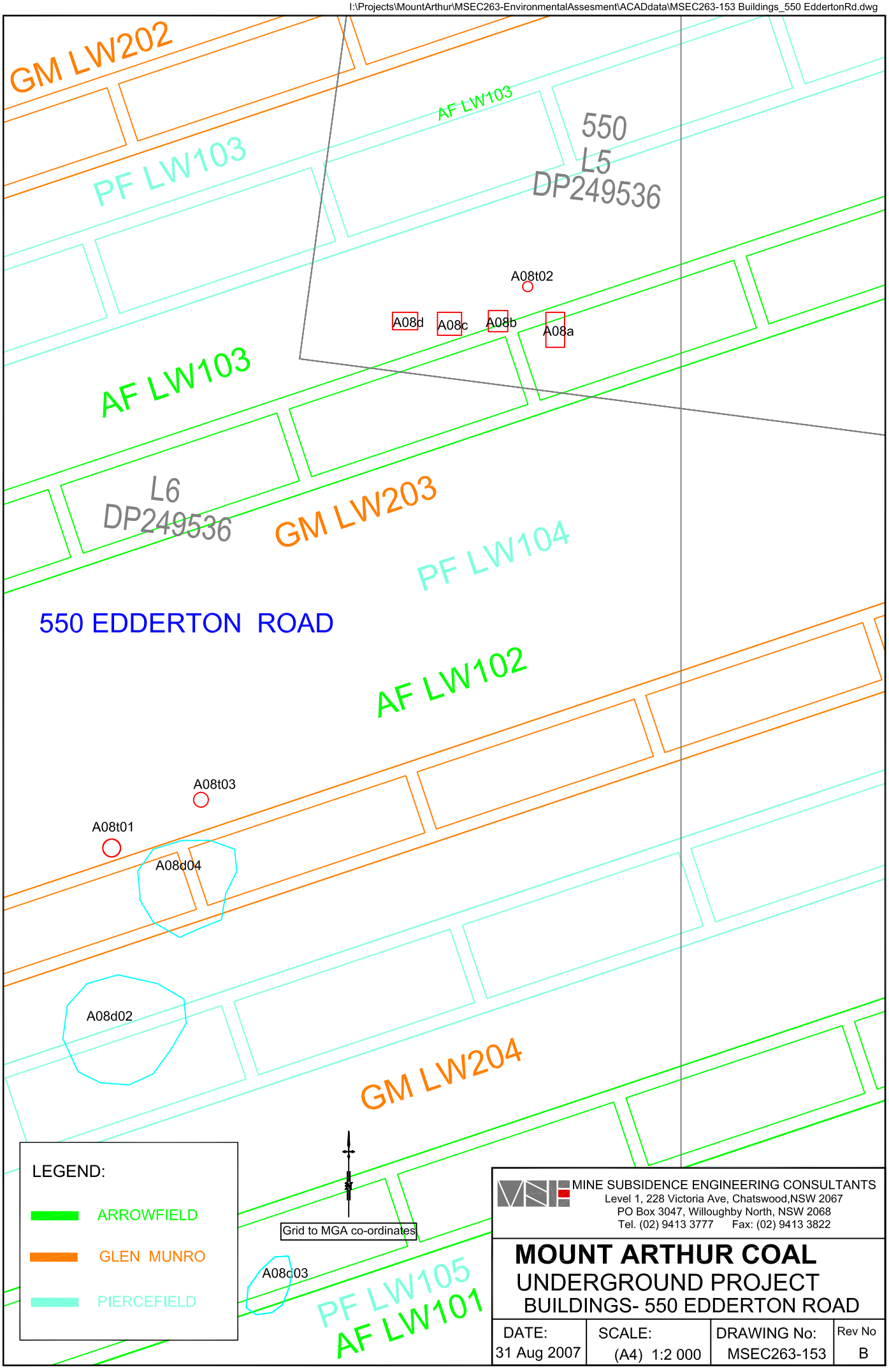
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BUILDINGS- ROXBURGH SOUTH

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:2 000	MSEC263-152	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-153 Buildings_550 EddertonRd.dwg



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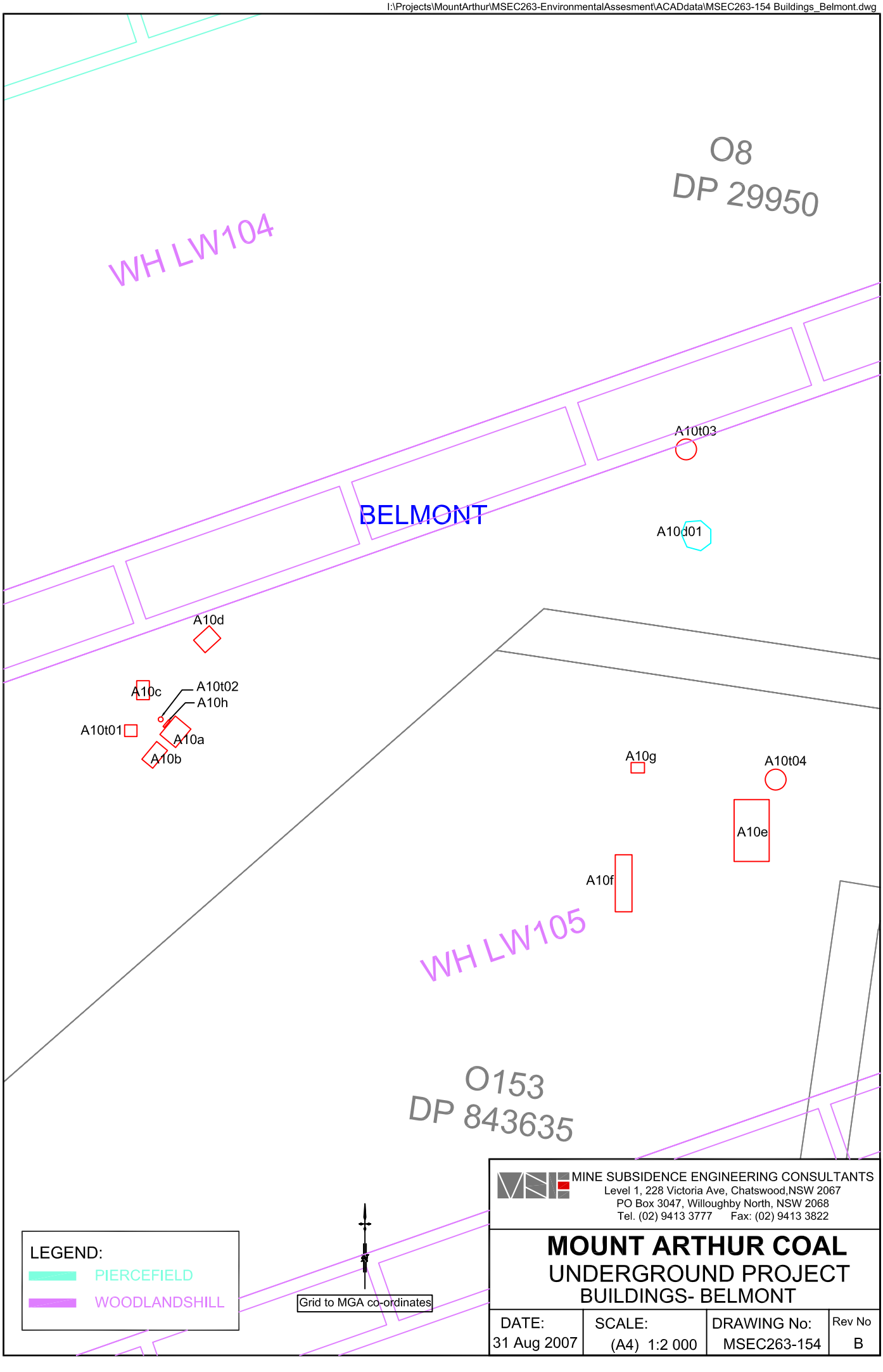
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BUILDINGS- 550 EDDERTON ROAD

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:2 000	MSEC263-153	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-154 Buildings_Belmont.dwg



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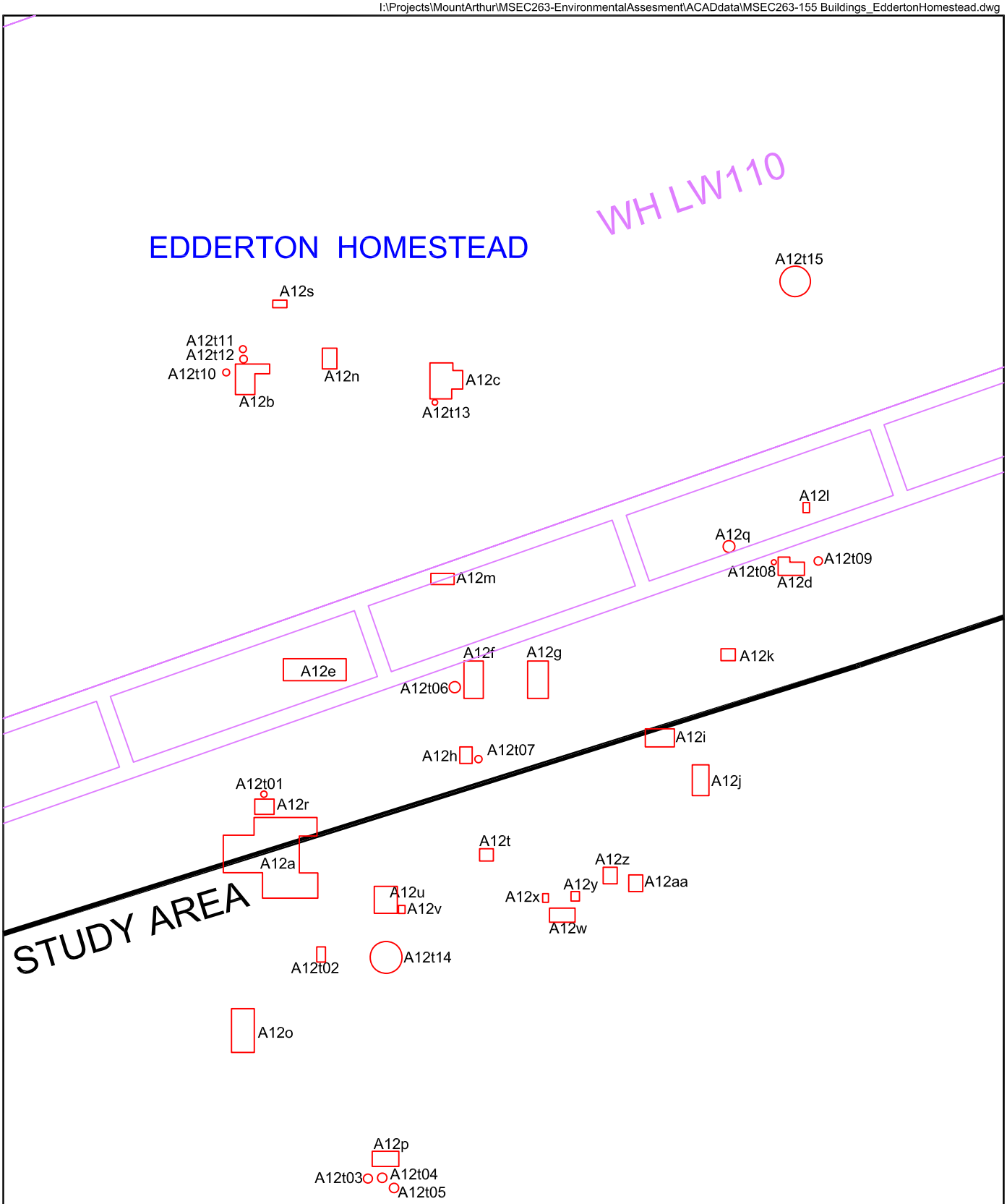
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BUILDINGS- BELMONT

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:2 000	MSEC263-154	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-155 Buildings_EddertonHomestead.dwg



Grid to MGA co-ordinates

LEGEND:

WOODLANDSHILL

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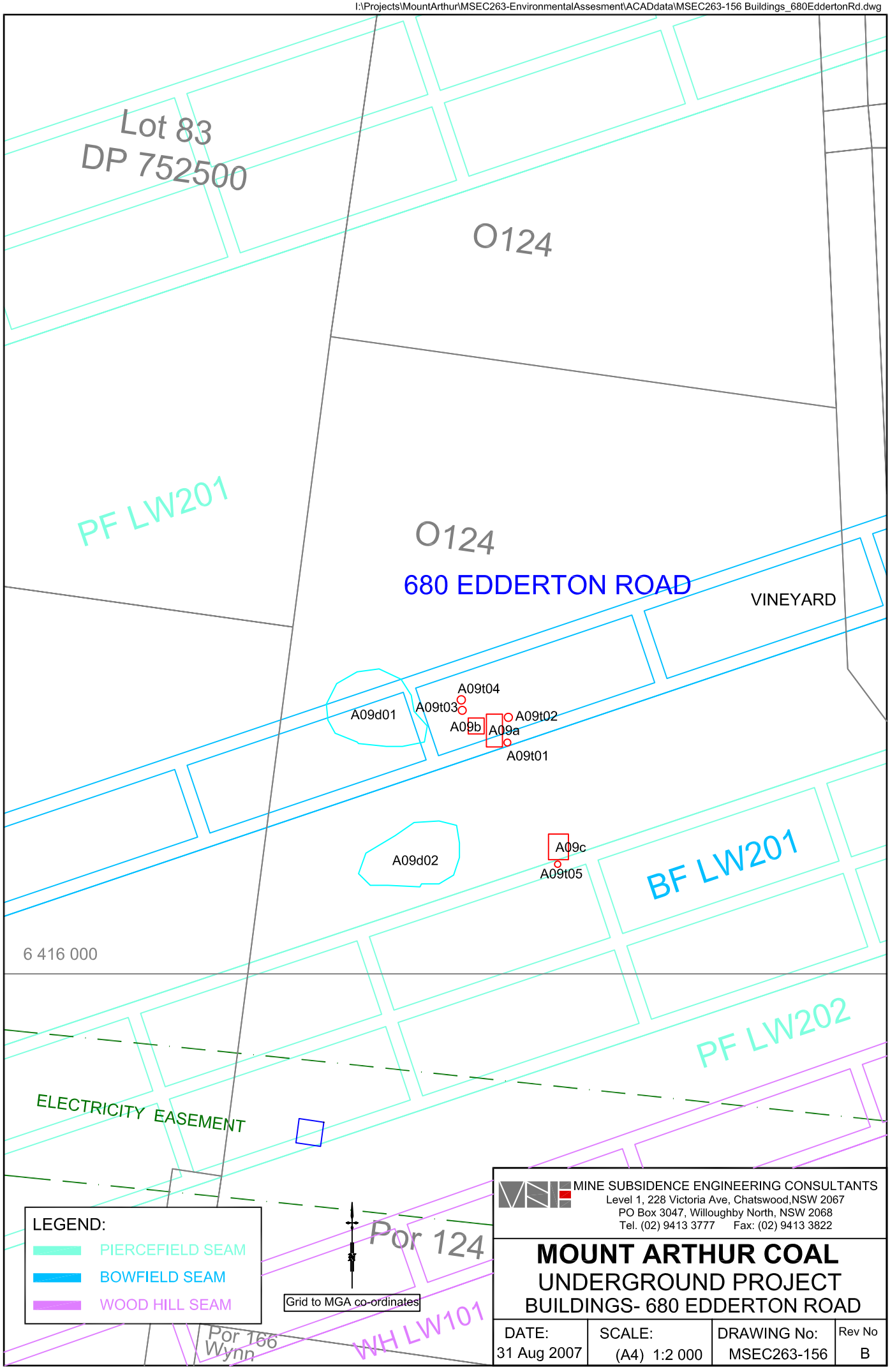
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BUILDINGS- EDDERTON HOMESTEAD

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:2 000	MSEC263-155	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-156 Buildings_680EddertonRd.dwg



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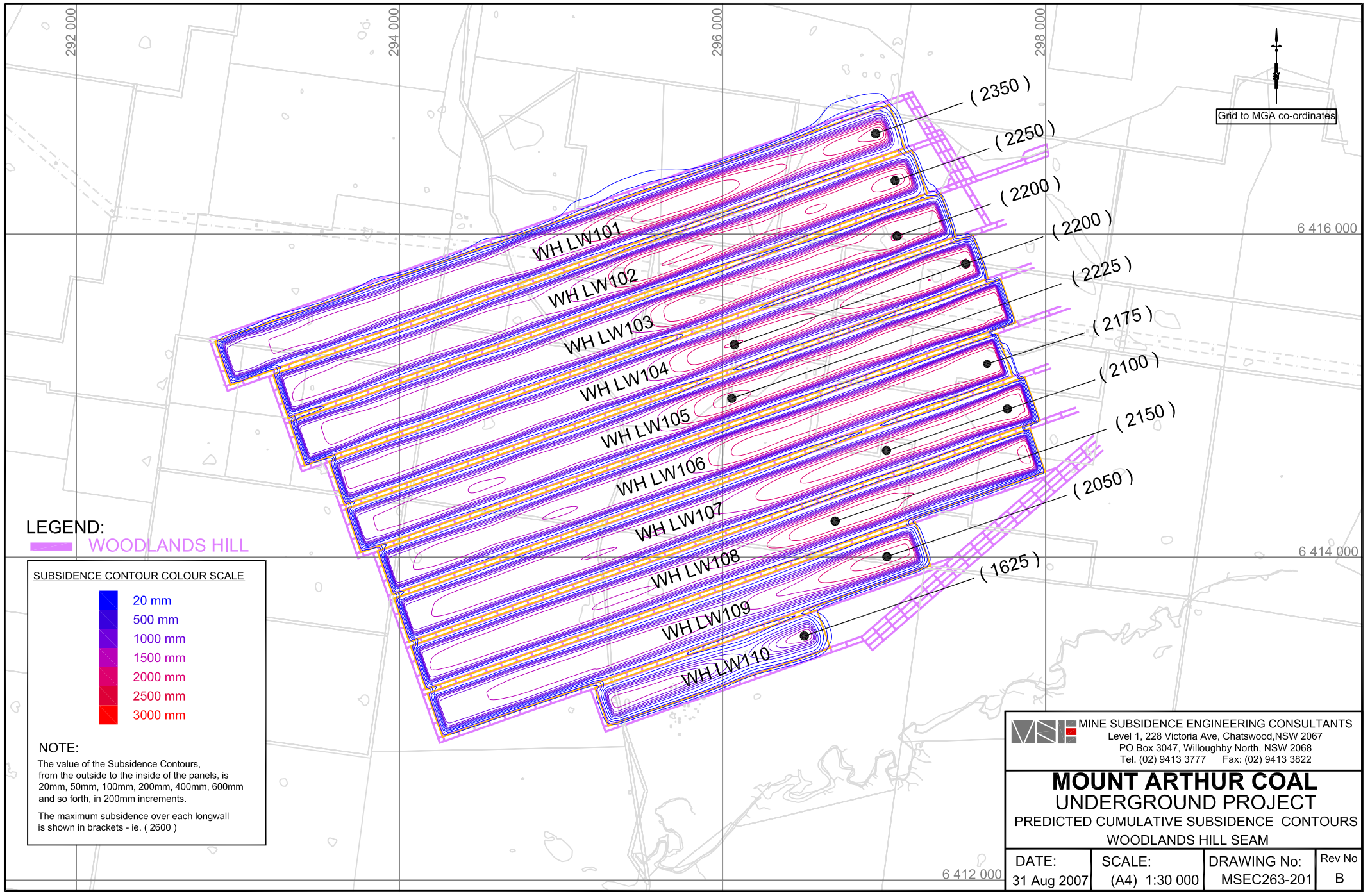
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
BUILDINGS- 680 EDDERTON ROAD

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:2 000	MSEC263-156	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-201 WoodlandsHill-SubsidenceContours.dwg



LEGEND:

WOODLANDS HILL

SUBSIDENCE CONTOUR COLOUR SCALE

- 20 mm
- 500 mm
- 1000 mm
- 1500 mm
- 2000 mm
- 2500 mm
- 3000 mm

NOTE:

The value of the Subsidence Contours, from the outside to the inside of the panels, is 20mm, 50mm, 100mm, 200mm, 400mm, 600mm and so forth, in 200mm increments.

The maximum subsidence over each longwall is shown in brackets - ie. (2600)

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MOUNT ARTHUR COAL

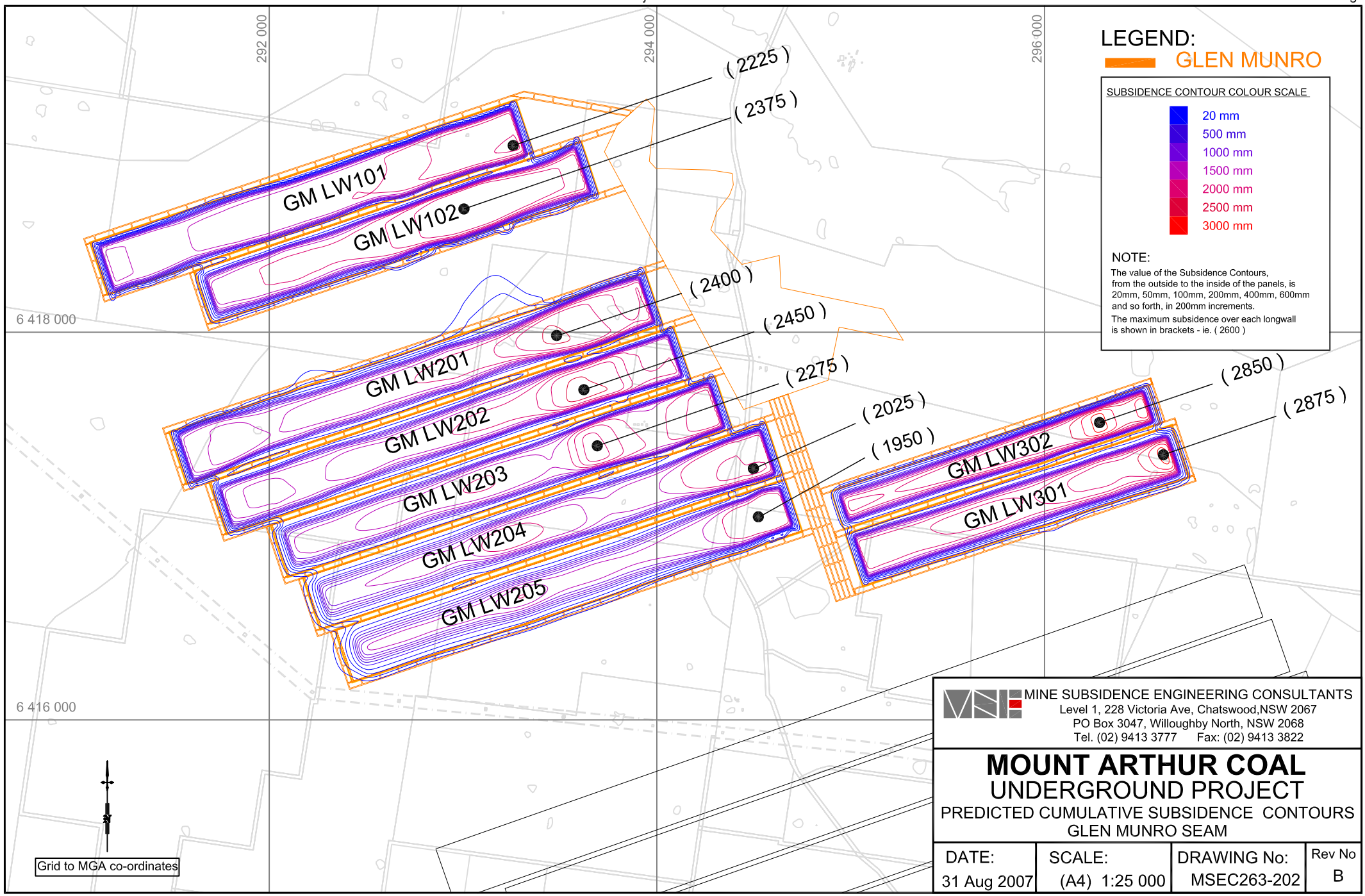
UNDERGROUND PROJECT

PREDICTED CUMULATIVE SUBSIDENCE CONTOURS

WOODLANDS HILL SEAM

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:30 000	MSEC263-201	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-202 GlenMunro-SubsidenceConoturs.dwg



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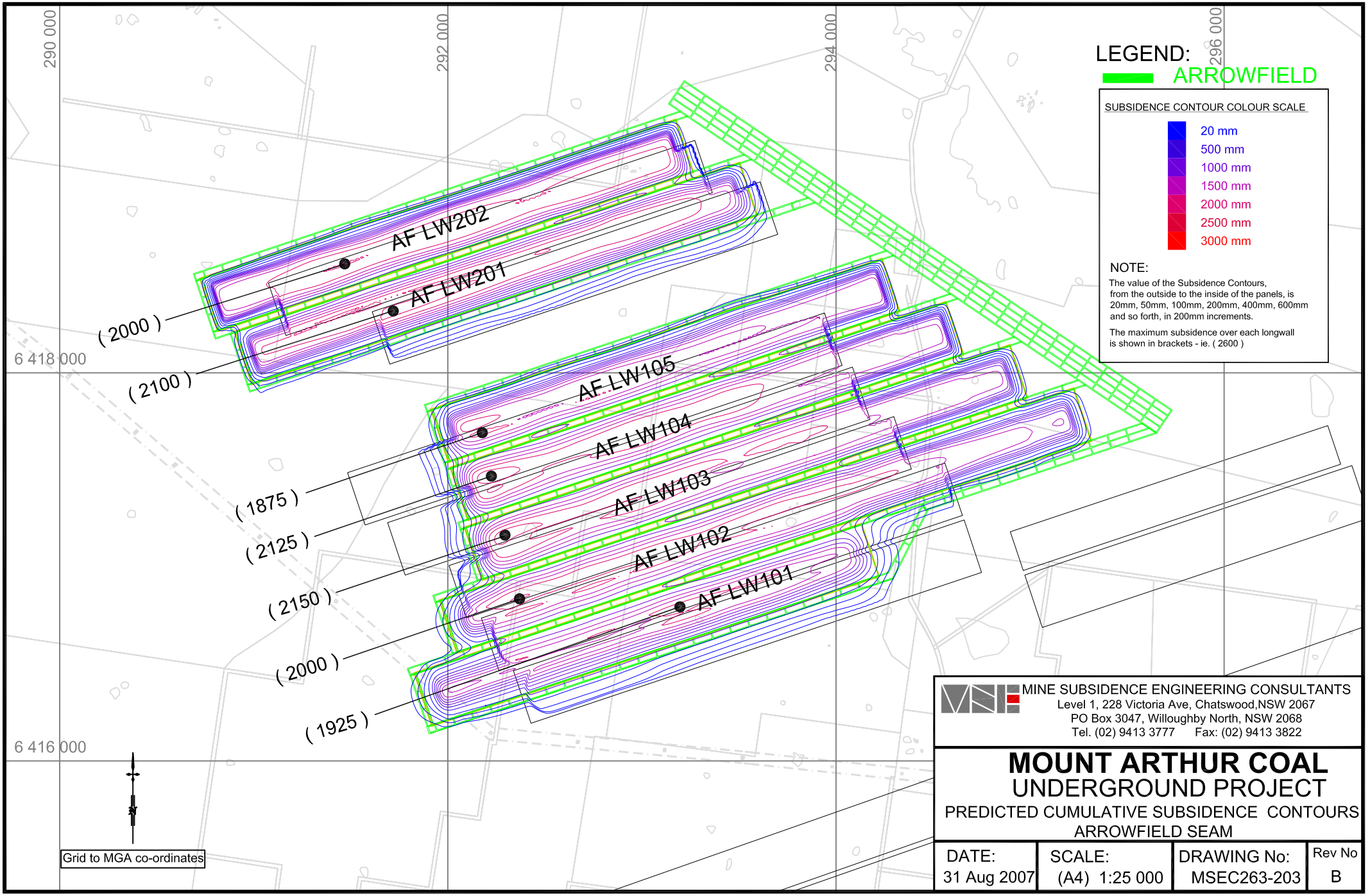
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED CUMULATIVE SUBSIDENCE CONTOURS GLEN MUNRO SEAM

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:25 000	MSEC263-202	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-203 Arrowfield-Subsidence Contours.dwg



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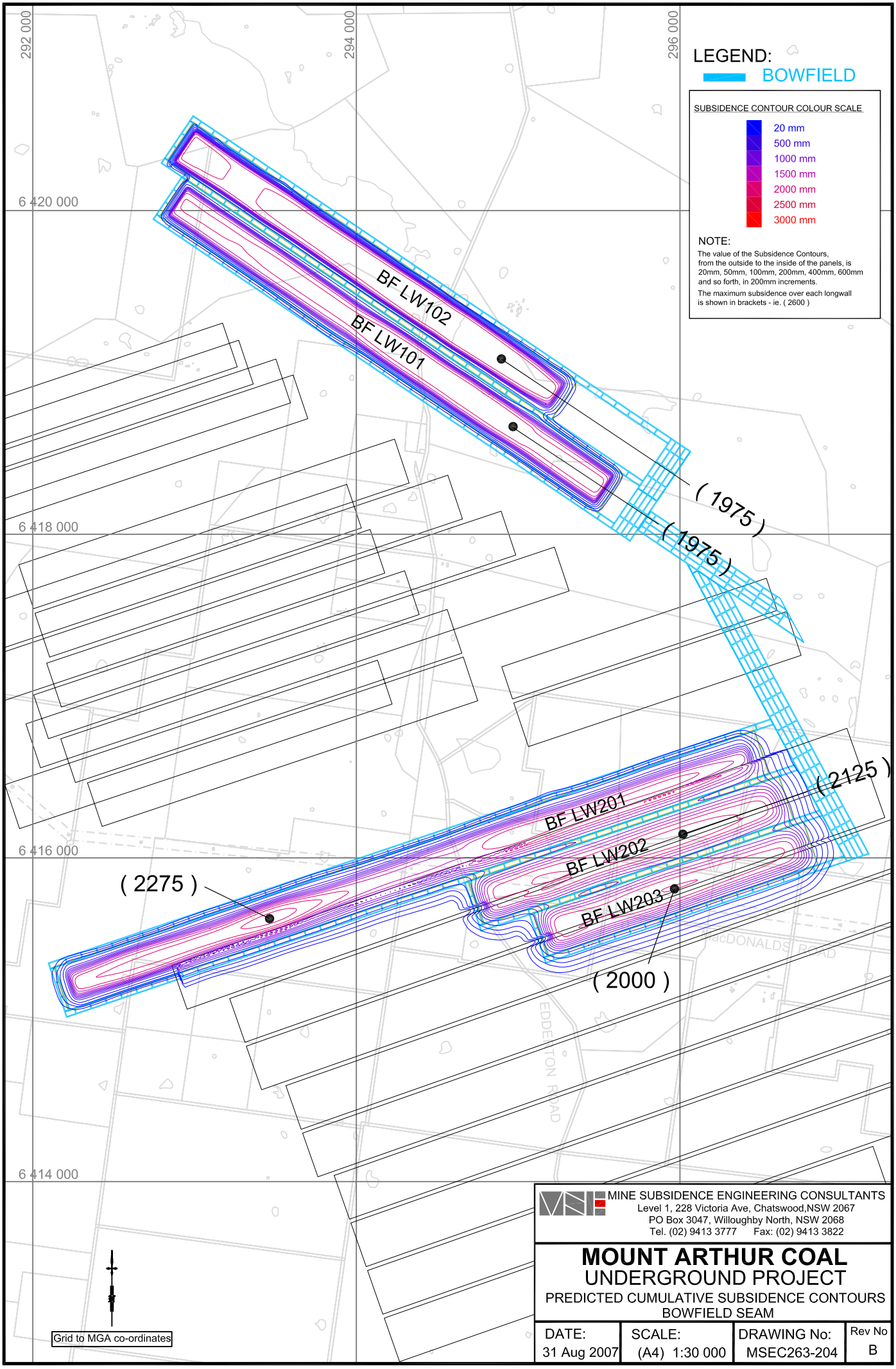
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED CUMULATIVE SUBSIDENCE CONTOURS ARROWFIELD SEAM

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:25 000	MSEC263-203	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-204 Bowfield-SubsidenceContours.dwg



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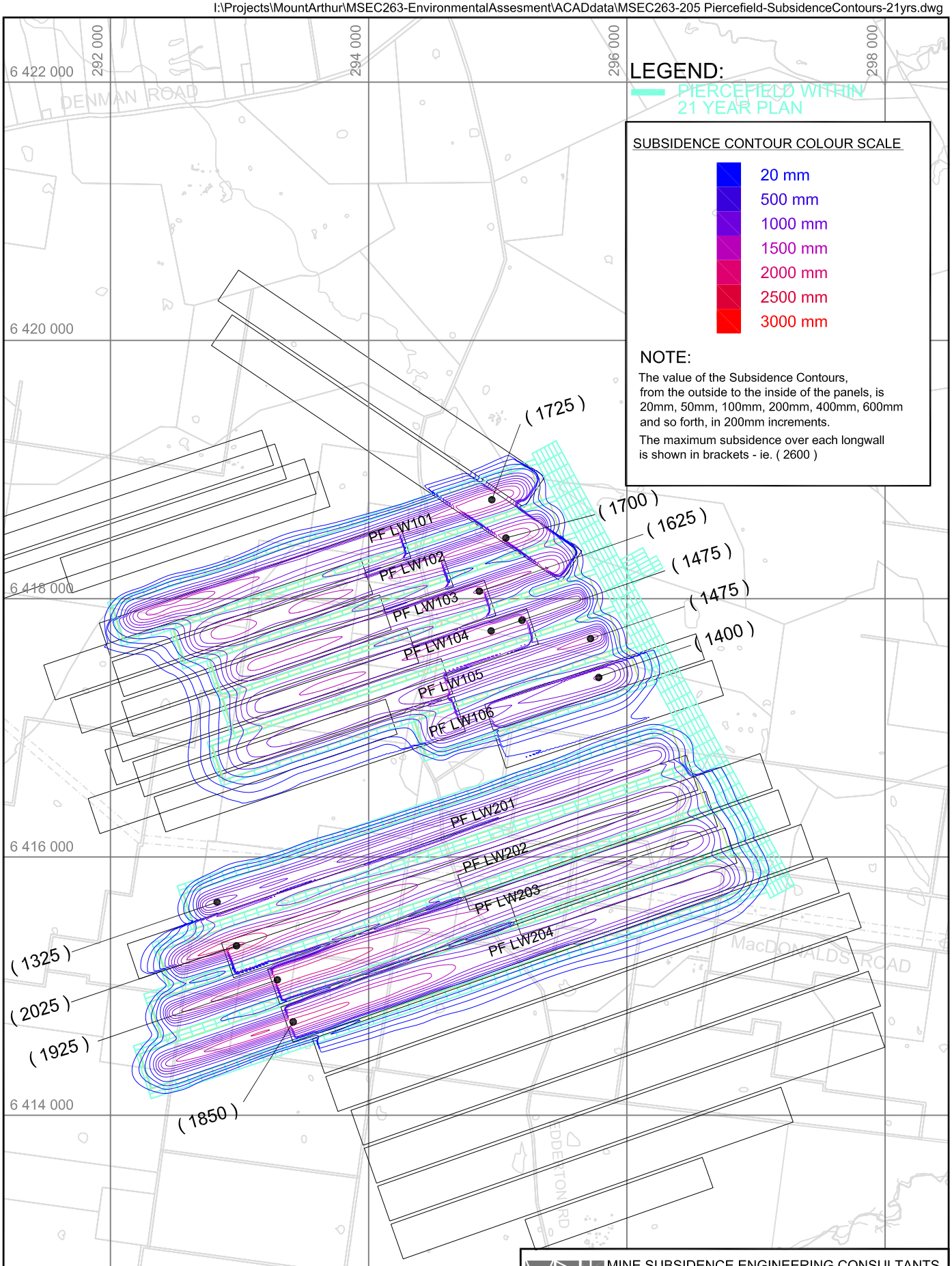
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED CUMULATIVE SUBSIDENCE CONTOURS
BOWFIELD SEAM

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:30 000	MSEC263-204	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-205 Piercefield-SubsidenceContours-21yrs.dwg



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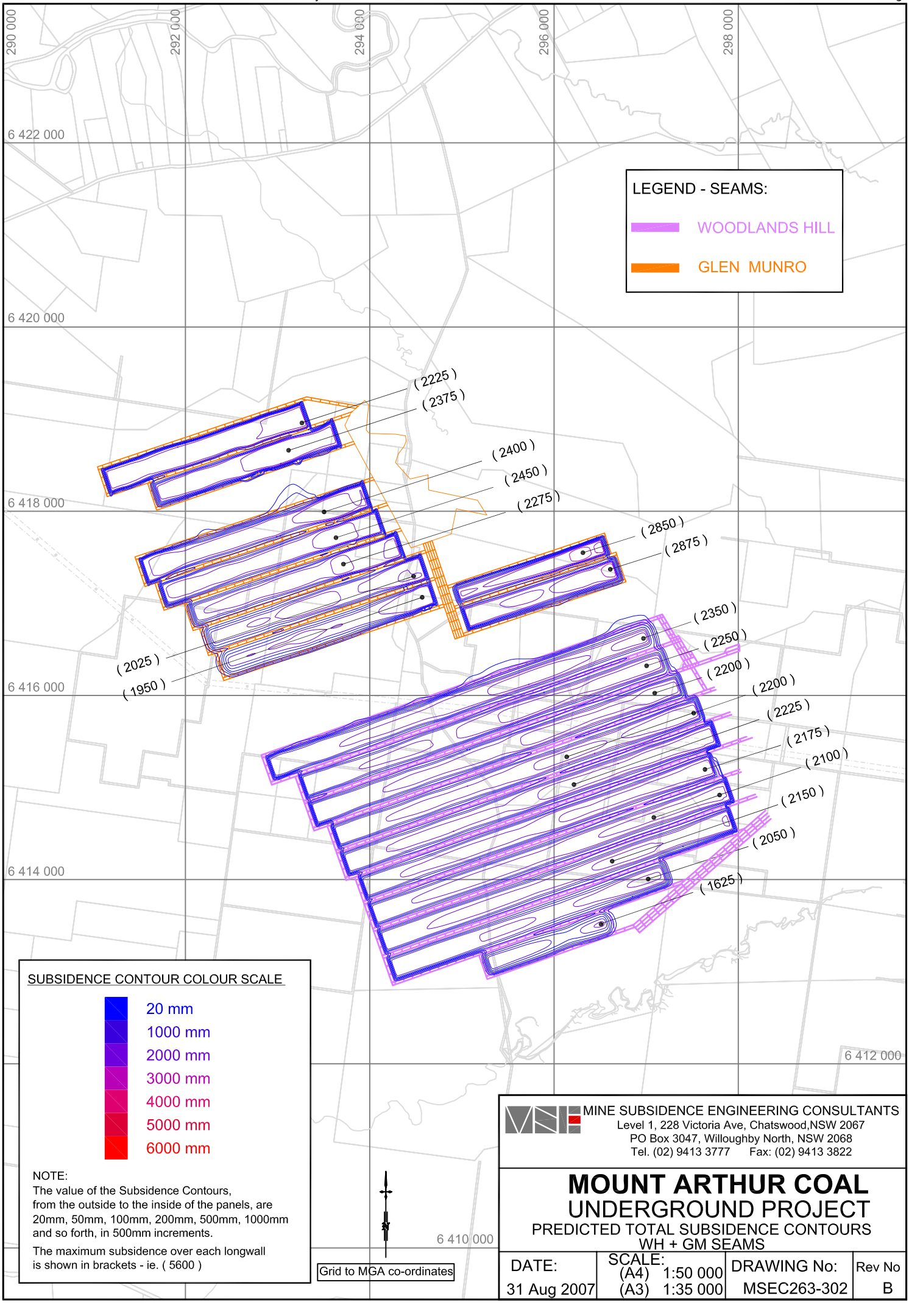
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED CUMULATIVE SUBSIDENCE CONTOURS
PIERCEFIELD SEAM - 21 YEARS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:40 000	MSEC263-205	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-302 PredTotSubs- WH+GM.dwg



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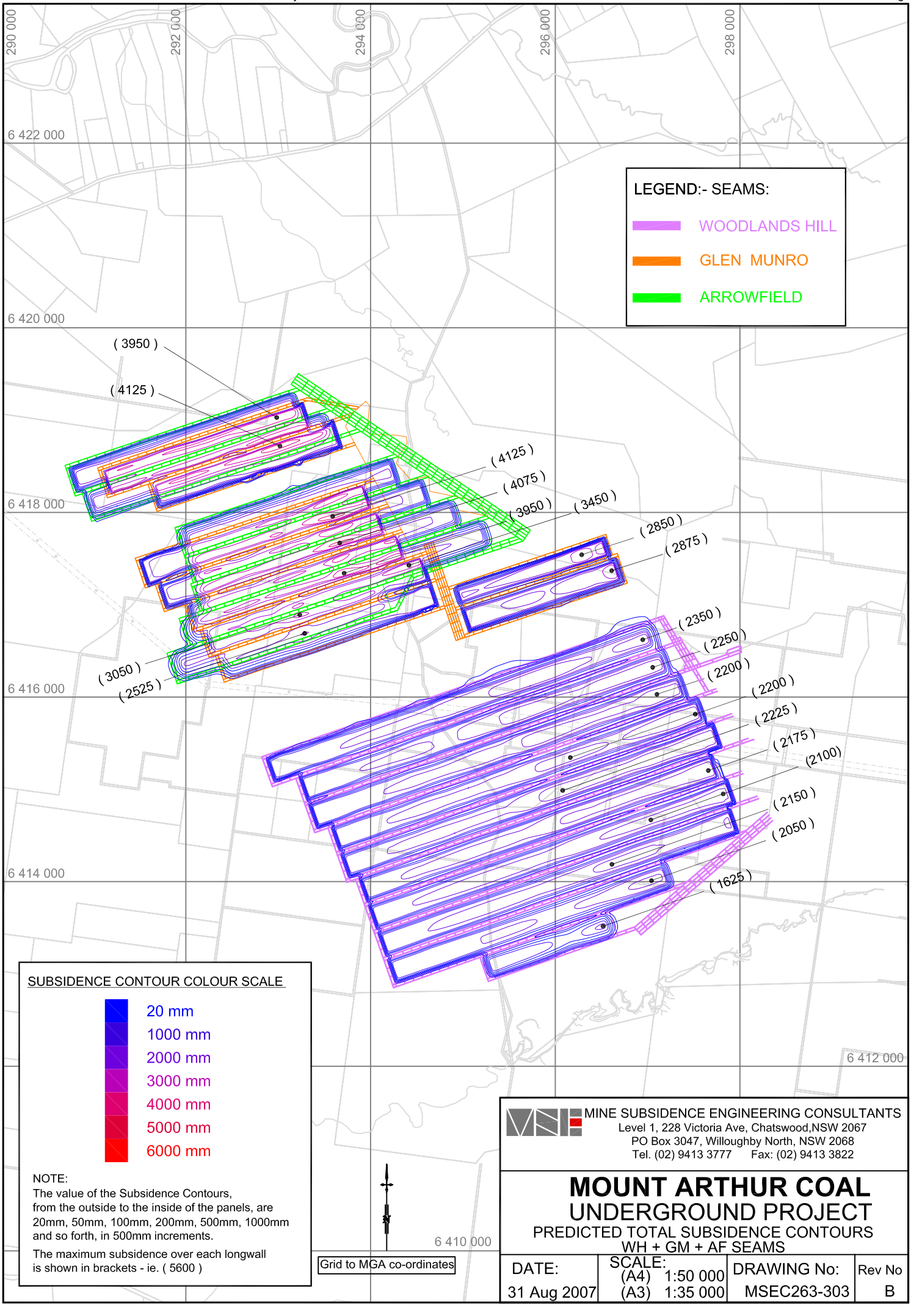
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED TOTAL SUBSIDENCE CONTOURS
WH + GM SEAMS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-302	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-303 PredTotSubs- WH+GM+AF.dwg



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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED TOTAL SUBSIDENCE CONTOURS
WH + GM + AF SEAMS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-303	B

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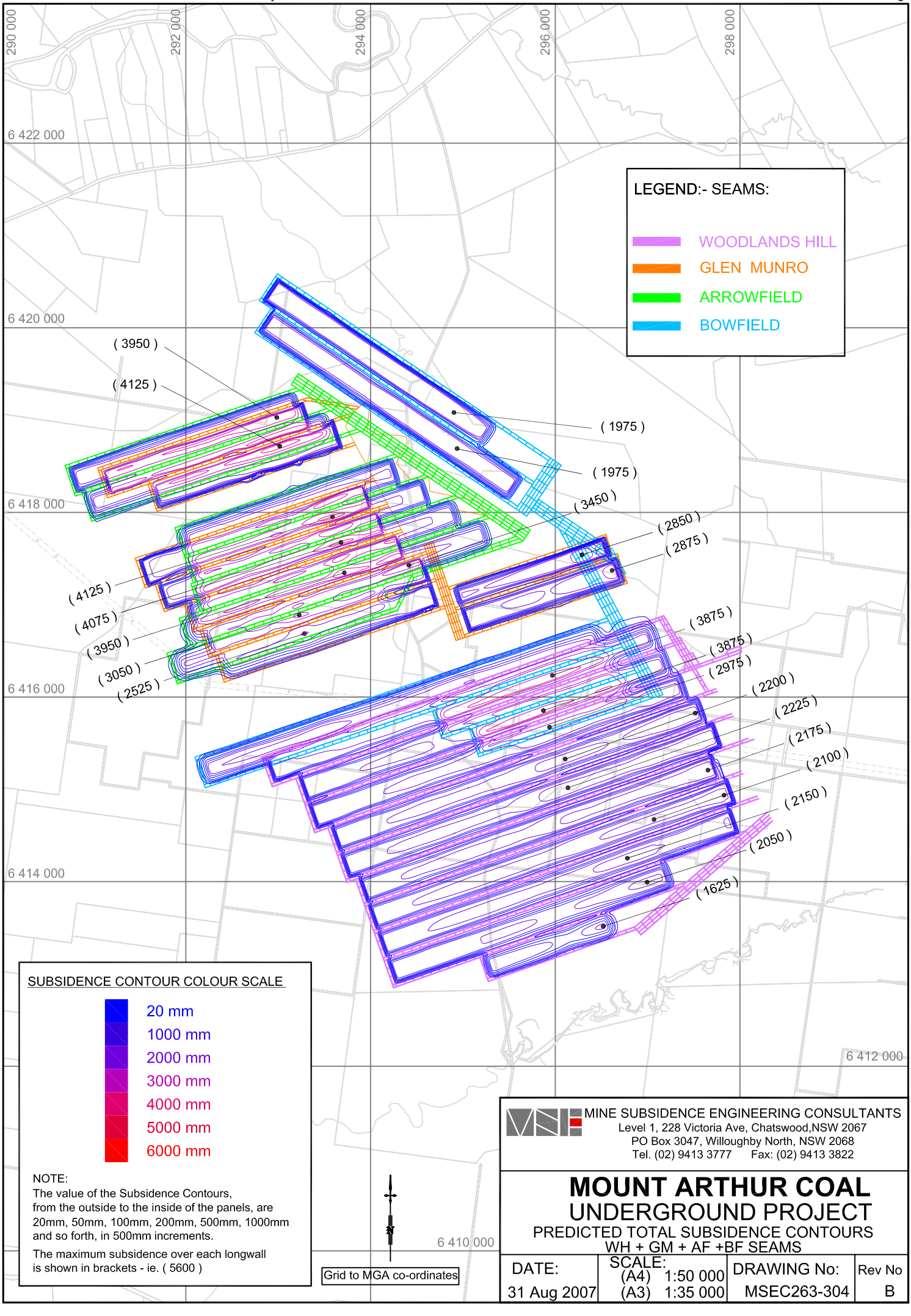

MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
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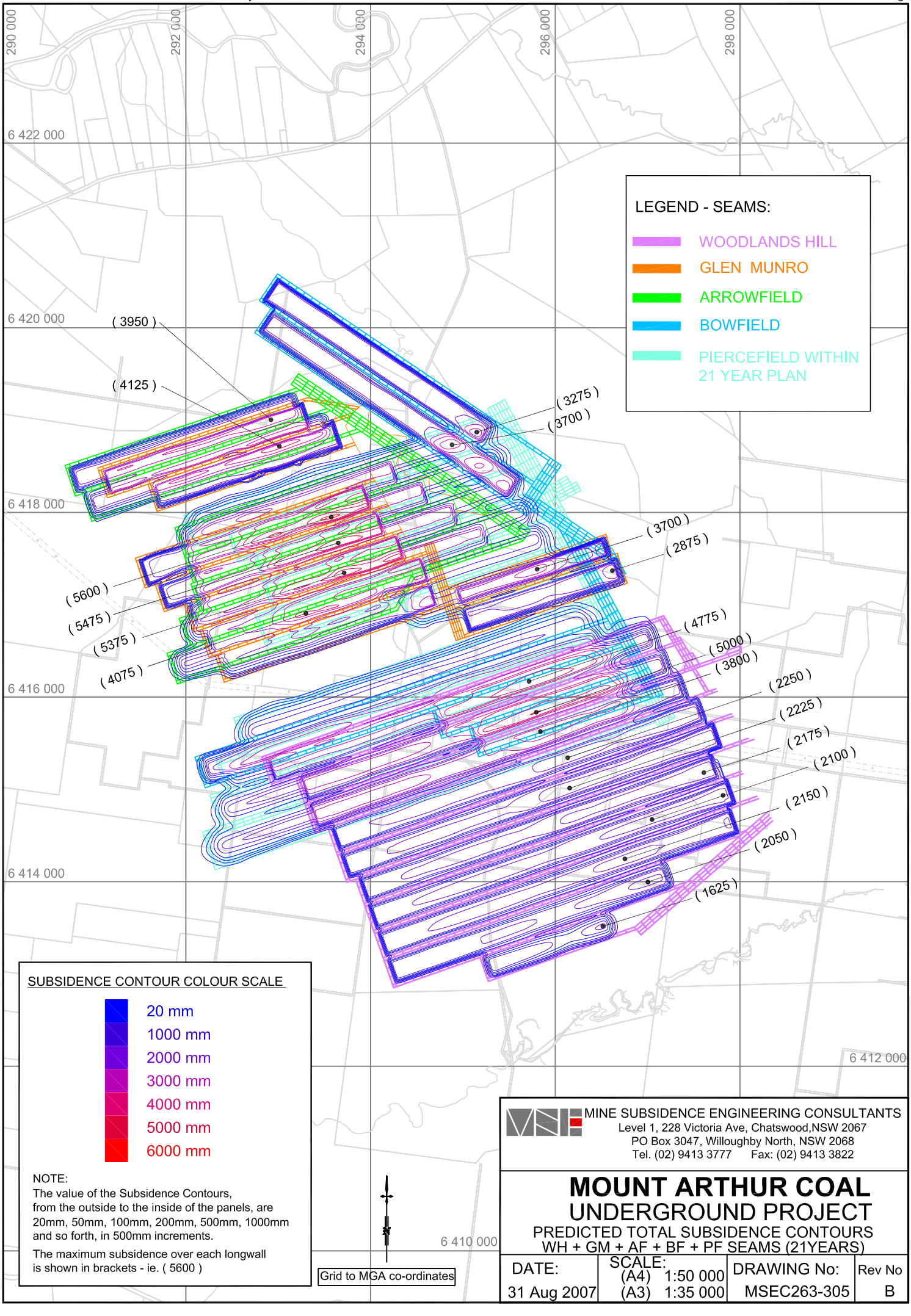
MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED TOTAL SUBSIDENCE CONTOURS
WH + GM + AF +BF SEAMS

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-304	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-305 PredTotSubs- WH+GM+AF+BF+PF.dwg



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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED TOTAL SUBSIDENCE CONTOURS
WH + GM + AF + BF + PF SEAMS (21YEARS)

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-305	B

I:\Projects\MountArthur\MSEC263-EnvironmentalAssesment\ACADdata\MSEC263-315 PredictedSurfaceCrackingZones.dwg

290 000 292 000 294 000 296 000 298 000

6 422 000
6 420 000
6 418 000
6 416 000
6 414 000
6 412 000
6 410 000

LEGEND

Zone	Depth of Cover or Location	Nominal Predicted Crack Width in Final Tensile Zones adjacent to Goaf Edges	Nominal Predicted Surface Crack Width due to Travelling Wave in Middle of Longwalls
	> 200m	< 50mm	< 25mm
	150m - 200m	50mm - 100mm	25mm - 50mm
	100m - 150m	100mm - 150mm	50mm - 75mm
	< 100m	150mm -200mm	75mm -100mm
	Steep Slopes	250mm	250mm
	Final Tensile Zone		

NOTE: The nominal predicted crack widths provided in the above table are the typical crack widths expected for each range of cover.
The maximum predicted crack widths are expected to be greater than those provided in the above table and could be larger than 500mm where the depths of cover are the shallowest.

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Grid to MGA co-ordinates

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MOUNT ARTHUR COAL
UNDERGROUND PROJECT
PREDICTED SURFACE CRACKING ZONES

DATE:	SCALE:	DRAWING No:	Rev No
31 Aug 2007	(A4) 1:50 000 (A3) 1:35 000	MSEC263-315	B