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ENGINEERING CONSULTANTS

Austar Coal Mine:

Longwalls B4 to B7

Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan for Longwalls B4 to B7 at the Austar Coal Mine

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MSEC275 (Revision C) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Austar Longwalls A3 to A5 in Support of a SMP Application (February 2007).

MSEC417 (Revision C) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of the Proposed Longwall A5A in Stage 2 at the Austar Coal Mine (July 2010).

MSEC309 (Revision D) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Austar Longwalls A6 to A17 in Support of a Part 3A Application (September 2008).

MSEC484 (Revision A) – Stage 3 – Longwalls A7 to A19 – Subsidence Predictions and Impact Assessments for Natural Features and Surface Infrastructure in Support of a Modification to the Development Consent (May 2011).

MSEC769 (Revision A) – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Environmental Assessment for a Section 75W Modification Application for the Inclusion of the Proposed Longwalls B1 to B3 at the Austar Coal Mine (October 2015).

MSEC833 (Revision A) – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Extraction Plan for Longwalls B1 to B3 at the Austar Coal Mine (April 2016).

MSEC869 (Revision A) – Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the Modification Application for Longwalls B4 to B7 at the Austar Coal Mine (April 2017).

Background reports available at *www.minesubsidence.com*:

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

EXECUTIVE SUMMARY

Austar Coal Mine Pty Limited (Austar, the Mine) is located in the Newcastle Coalfield, approximately 10 km south-west of the township of Cessnock. The Mine has completed the extraction of Longwalls A1 and A2 in Stage 1, Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 using longwall top coal caving mining techniques. Austar has approval to extract the future Longwalls A9 to A19 in Stage 3 at the Mine.

Austar has approval for the extraction of Longwalls B1 to B3 using conventional longwall mining techniques within the Bellbird South mining area. The Mine proposes to extract four additional longwalls in this mining area, referred to as Longwalls B4 to B7. These longwalls are located on the north-western side of Longwalls B1 to B3 and are a continuation of this longwall series.

Mine Subsidence Engineering Consultants (MSEC) previously prepared Report No. MSEC869 (Rev. A) that provided subsidence predictions and impact assessments for Longwalls B4 to B7 in support of the Modification Application for these longwalls.

Austar is now preparing an Extraction Plan for Longwalls B4 to B7. The finishing ends of Longwalls B2 and B3 have been shortened from the extents indicated in Report No. MSEC869 and the Modification Application. The extents of Longwalls B4 to B7 have not changed. Austar also now proposes to extract Longwall B1 after the completion of Longwalls B2 to B7, rather than after the completion of Longwall B3. This subsidence report provides updated subsidence predictions and impact assessments for Longwalls B4 to B7, based on the shortened finishing ends of Longwalls B2 and B3 and the modified mining sequence.

The maximum predicted subsidence parameters for Longwalls B4 to B7 do not change from those presented in Report No. MSEC869 and the Modification Application. The extent of vertical subsidence slightly differs during intermediate stages of mining, due to the modified mining sequence; however, the extent of vertical subsidence at the completion of mining does not significantly change.

The predicted subsidence parameters for each of the natural and built features are similar to the predictions provided in Report No. MSEC869 and the Modification Application. Whilst the predicted subsidence parameters slightly increase for some features and slightly decrease for other features, the overall levels of the predicted movements do not change.

The changes in the predicted subsidence parameters generally occur for the natural and built features located near the shortened finishing ends of Longwalls B2 and B3. The predicted changes in tilt for these features are typically in the order of ±0.5 mm/m, which represents a change in grade of 1 in 2000 or 0.05 %. The predicted changes in curvature are typically in the order of ±0.01 km^{-1}, which represents a minimum radius of curvature of 100 km. These changes are very small and are similar to the order of accuracy of the prediction method. In some cases, the changes in the predicted tilts and curvatures are greater; however, these predicted parameters are similar to or less than the maxima that occur elsewhere above the mining area.

The assessed levels of potential impact for the natural and built features are the same as those assessed in Report No. MSEC869 and in the Modification Application. The recommended management strategies for these features, therefore, do not change.

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Figures are prefixed by the number of the chapter or the letter of the appendix in which they are presented.

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MSEC903-03	Surface level contours	A
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1.1. Background

Austar Coal Mine Pty Limited (Austar, the Mine) is located in the Newcastle Coalfield, approximately 10 km south-west of the township of Cessnock. The Mine has completed the extraction of Longwalls A1 and A2 in Stage 1, Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 using longwall top coal caving mining techniques. Austar has approval to extract the future Longwalls A9 to A19 in Stage 3 at the Mine.

Austar has approval for the extraction of Longwalls B1 to B3 (LWB1 to LWB3) using conventional longwall mining techniques within the Bellbird South mining area. These longwalls are located to the south of the previously extracted longwalls in Stage 2 at the Mine and to the east of the existing Longwalls 1 to 9A at the Ellalong Colliery. At the time of this report, the Mine had completed the extraction of Longwall B2 and is in the process of extracting Longwall B3.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by Austar to prepare subsidence predictions and impact assessments for Longwalls B1 to B3. Reports Nos. MSEC769 (Rev. A) and MSEC833 (Rev. A) were issued in support of the Modification Application and the Extraction Plan Application for these longwalls. The commencing and finishing ends of Longwalls B2 and B3 indicated in the Extraction Plan (i.e. Report MSEC833) are shorter than the ends indicated in the Modification Application (i.e. Report MSEC769) and the Development Consent (DA29/95, MOD6).

Austar is now preparing an Extraction Plan for Longwalls B4 to B7. These longwalls are located on the north-western side of the Longwalls B1 to B3 and are a continuation of this longwall series. The locations of the existing, approved and proposed longwalls at the Mine are shown in Drawing No. MSEC903-01.

MSEC has now been commissioned by Austar to provide:

- subsidence predictions for Longwalls B4 to B7, including the cumulative movements due to the previously extracted and approved adjacent longwalls;
- subsidence predictions for each of the natural and built features in the mining area;
- impact assessments, in conjunction with other specialist consultants, for each of these natural and built features; and
- recommended management strategies and monitoring for Longwalls B4 to B7.

MSEC previously prepared Report No. MSEC869 (Rev. A) that provided subsidence predictions and impact assessments for Longwalls B4 to B7 in support of the Modification Application for these longwalls. That report was based on the shortened commencing ends of Longwalls B2 and B3 (as indicated in Report No. MSEC833 and the Extraction Plan for Longwalls B1 to B3) and the longer finishing ends of Longwalls B2 and B3 (as indicated in the Project Approval DA29/95, MOD7). The mining sequence adopted in that report was Longwalls B2, B3, B1 and then Longwalls B4 to B7. The layout of Longwalls B1 to B7 indicated in Report No. MSEC869 is referred to as the *Previous Layout* in this report.

Austar extracted Longwall B2 and proposes to extract Longwall B3 to the shortened finishing ends of these longwalls, as indicated in Report No. MSEC833 and the Extraction Plan for Longwalls B1 to B3. The extents of Longwalls B4 to B7 do not change and are the same as indicated in Report No. MSEC869. Austar also now proposes to extract Longwall B1 after the completion of Longwalls B2 to B7.

This subsidence report provides updated subsidence predictions and impact assessments for Longwalls B4 to B7, based on the shortened finishing ends of Longwalls B2 and B3 and the modified mining sequence. The layout of Longwalls B1 to B7 (including the shortened finishing ends of Longwalls B2 and B3) is referred to as the *Current Layout* in this report.

Condition 2A in Schedule 2 of the Development Consent (DA29/95, as modified) states that "*With the approval of the Secretary, longwall panels may be shortened or narrowed, providing that the proposed variations do not result in increased subsidence impacts or environmental consequences*".

The comparison of Longwalls B1 to B7 based on the *Previous Layout* and the *Current Layout* is provided in Fig. 1.1. The finishing ends of Longwalls B2 and B3 have been shortened by 179 m and 165 m, respectively.

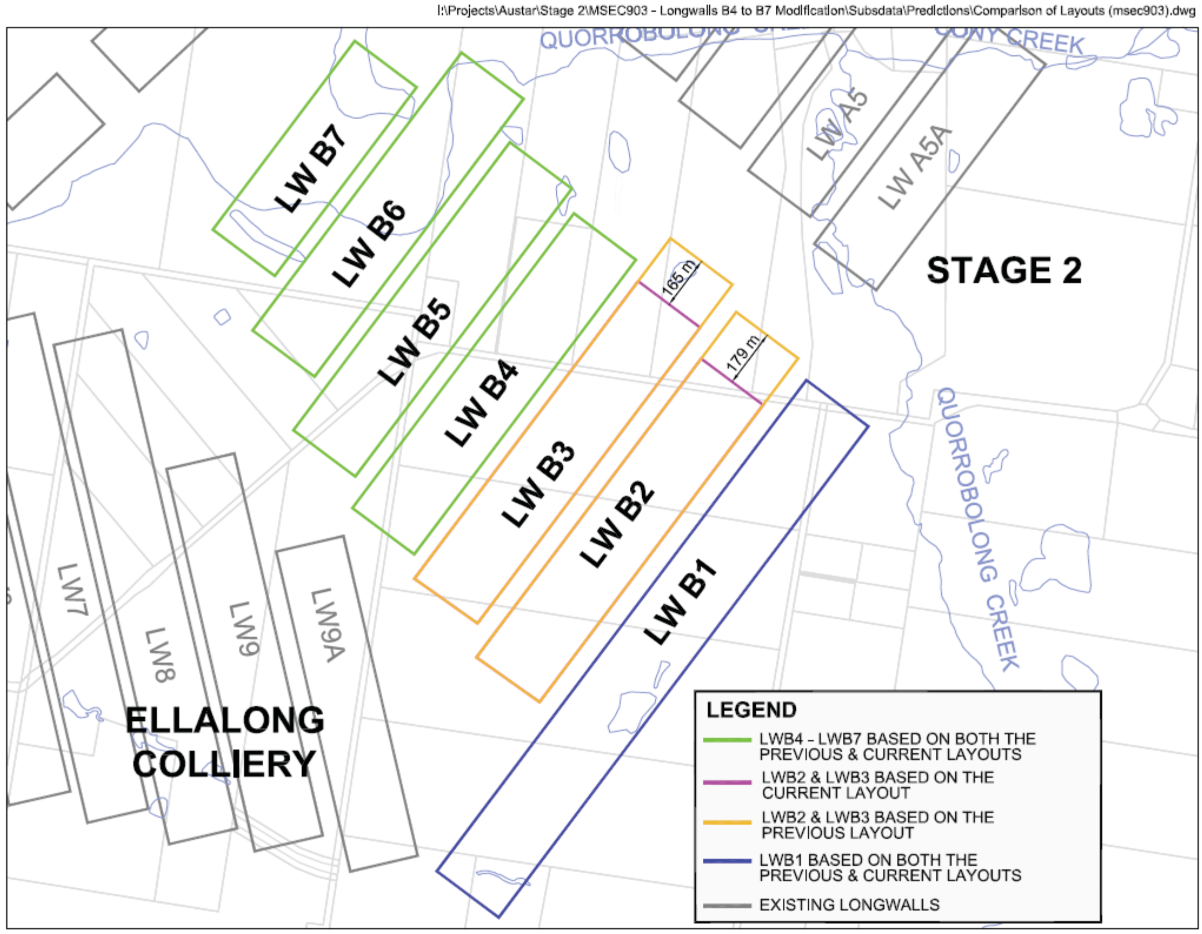


Fig. 1.1 Comparison between the Previous Layout and the Current Layout

This report has been prepared to support the Extraction Plan Application for Longwalls B4 to B7 that will be submitted to the Department of Planning and Environment (DP&E). In some cases, this report will refer to other sources of information on specific natural and built features. This report, therefore, should be read in conjunction with the other relevant documents associated with this application.

Chapter 1 of this report provides a general introduction to the study, which also includes a description of the mining geometry and geological details of the area.

Chapter 2 defines the Study Area and provides a summary of the natural and built features within this area.

Chapter 3 provides an overview of longwall mining, mine subsidence parameters and the methods that have been used to predict the mine subsidence for the longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of Longwall B4 to B7 based on the *Current Layout*. The predicted parameters have been compared with those provided based on the *Previous Layout*.

Chapters 5 and 6 provide the predictions and impact assessments for each of the natural and built features based on the *Current Layout*. The predictions for each of the features have been compared with those based on the *Previous Layout* and, in the cases where they have increased, the impact assessments and recommendations have been reviewed.

1.2. Mining geometry

The layout of existing, approved and proposed longwalls in the Greta Seam is shown in Drawings Nos. MSEC903-01 and MSEC903-02. A summary of the dimensions of the proposed Longwalls B4 to B7 is provided in Table 1.1. The dimensions of these longwalls based on the Current Layout are the same as those based on the Previous Layout.

Table 1.1 Geometry of the proposed Longwalls B4 to B7

Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
LWB4	1125	237	45
LWB5	1105	237	50
LWB6	1065	237	45
LWB7	725	237	45

The widths of the longwall extraction faces (i.e. excluding the first workings) are 226 m providing overall void widths (i.e. including the first workings) of 237 m. The lengths of extraction (i.e. excluding the installation headings) are approximately 9 m less than the overall void lengths provided in the above table. The longwalls will be extracted from the south-west towards the north-east (i.e. towards the main headings).

1.3. Surface and seam levels

The natural surface and the Greta Seam are illustrated along Cross-section 1 in Fig. 1.2, which has been taken transverse to the longwalls near their mid-lengths (looking north-east). The location of this cross-section is shown in Drawings Nos. MSEC903-03 to MSEC903-05, in Appendix E.

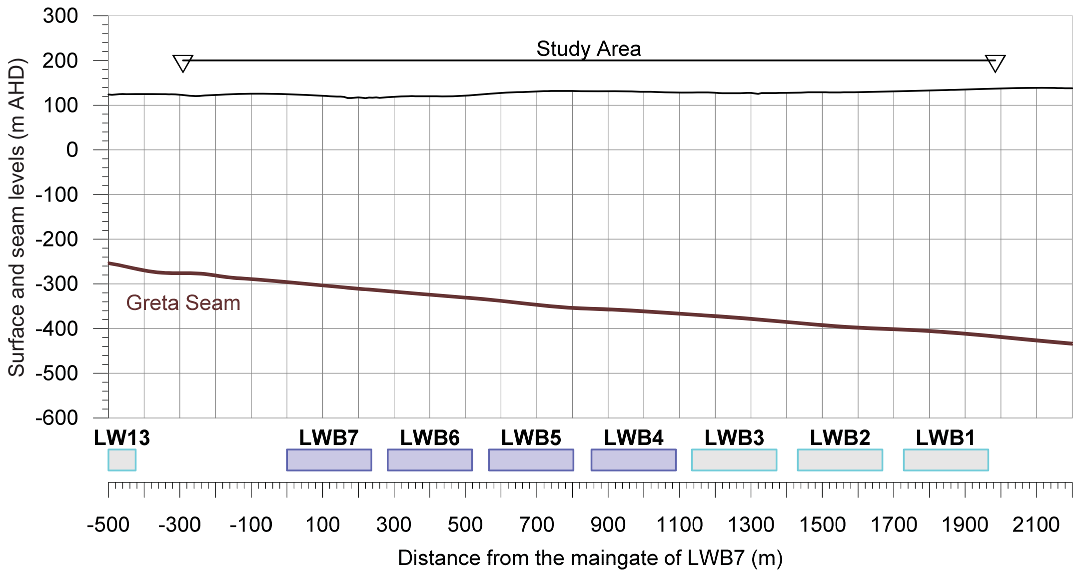


Fig. 1.2 Surface and seam levels along Cross-section 1

The surface level contours are shown in Drawing No. MSEC903-03. There are three small ridgelines located above the western, eastern and northern parts of the mining area. These ridgelines are separated by Quorrobolong Creek in the northern part of the mining area and by an unnamed drainage line in the southern part of the mining area.

The surface levels directly above the proposed longwalls vary from a high point of 160 m above Australian Height Datum (mAHD) above the commencing (i.e. south-western) end of Longwall B4, to a low point of approximately 115 mAHD along Quorrobolong Creek.

The seam floor contours, seam thickness contours and depth of cover contours for the Greta Seam are shown in Drawings Nos. MSEC903-04, MSEC903-05 and MSEC903-06, respectively. The contours are based on the latest information provided by the Mine.

The depth of cover to the Greta Seam directly above the proposed longwalls varies between a minimum of 400 m above the commencing (i.e. south-western) end of Longwall B7 and a maximum of 505 m above the finishing (i.e. north-eastern) end of Longwall B4. The seam floor within the proposed mining area dips from the west to the east, having an average gradient of around 8 %, or 1 in 12.

The thickness of the Greta Seam within the mining area varies between 3.7 and 4.8 m. It is proposed that a constant thickness of 3.4 m will be extracted using conventional longwall mining techniques.

1.4. Geological details

The Austar Coal Mine lies in the Newcastle Coalfield, within the Northern Sydney Basin. A typical stratigraphic section of the Newcastle Coalfield (after Ives et al, 1999, Moelle and Dean-Jones, 1995, Lohe and Dean-Jones, 1995, Sloan and Allman, 1995) is shown in Table 1.2. The strata shown in this table were laid down between the Early Permian and the Middle Triassic Periods.

Table 1.2 Stratigraphy of the Newcastle Coalfield
(after Ives et al, 1999, Moelle & Dean-Jones, 1995, Lohe & Dean-Jones, 1995, Sloan & Allan, 1995)

Stratigraphy			Lithology
Group	**Formation**	**Coal Seams**	
Narrabeen Group	Clifton		Sandstone, siltstone, mudstone, claystone
Newcastle Coal Measures	Moon Island Beach	Vales Point Wallarah Great Northern	Sandstone, shale, conglomerate, claystone, coal
	Awaba Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert
	Boolaroo	Fassifern Upper Pilot Lower Pilot Hartley Hill	Conglomerate, sandstone, shale, claystone, coal
	Warners Bay Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert
	Adamstown	Australasian Montrose Wave Hill Fern Valley Victoria Tunnel	Conglomerate, sandstone, shale, claystone, coal
	Nobbys Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone chert
	Lambton	Nobbys Dudley Yard Borehole	Sandstone, shale, minor conglomerate, claystone, coal
	Waratah Sandstone		Sandstone
Tomago Coal Measures	Dempsey		Shale, siltstone, fine sandstone, coal, and minor tuffaceous claystone
	Four Mile Creek		
	Wallis Creek		
Maitland Group	Mulbring Siltstone		Siltstone
	Muree Sandstone		Sandstone
	Branxton		Sandstone, and siltstone
Greta Coal Measures	Paxton	Pelton	Sandstone, conglomerate, and coal
	Kitchener	**Greta**	
	Kurri Kurri	Homeville	
	Neath Sandstone		Sandstone
Dalwood Group	Farley		Shale, siltstone, lithic sandstone, conglomerate, minor marl and coal, and interbedded basalts, volcanic breccia, and tuffs
	Rutherford		
	Allandale		
	Lochinvar		
Seaham Formation			

Longwalls B4 to B7 will be extracted within the Greta Seam, which is located within the Kitchener Formation of the Greta Coal Measures. The overlying strata comprise the Paxton Formation, which consists of interbedded sandstone and siltstone layers up to 20 m thick. The uppermost layer in the Greta Coal Measures is the Pelton Seam, which is less than 0.5 m thick. The underlying strata comprise the Kurri Kurri Conglomerate and the Neath Sandstone. Strong and thick strata consisting of conglomerate and sandstone are typically observed within these formations.

The main sequence overlying the Greta Coal Measures is the Branxton Formation, which is part of the Maitland Group sediments from the mid Permian period. The Maitland Group comprises, in order of deposition, the Branxton Formation, Muree Sandstone and Mulbring Siltstone. The Branxton Formation immediately overlies the Greta Coal Measures and is made up of a substantial thickness of sedimentary rocks. The lithology of the Branxton Formation generally consists of the coarser sandstone and conglomerate rocks at the base of the formation, grading to finer deposits of silty sandstone and siltstone at the top of the formation. The upper part of the formation contains a unit known as *Fenestella Shale* that contains numerous fossils of marine invertebrate fauna.

The Newcastle region is characterised by a complex geological setting, with a great variety of rock types occurring over short lateral and vertical distances (Moelle and Dean-Jones, 1995). Folds, normal faults and dykes dominate the region and generally trend north-west to north-north-west (Lohe and Dean-Jones, 1995).

The surface lithology within the Study Area is shown in Fig. 1.3, which shows the proposed longwalls overlaid on Geological Series Sheet Cessnock 9132, which is published by Department of Mineral Resources (DMR, 1995), now known as the Department of Industry – Division of Resources and Energy. It can be seen from this figure, that the surface lithology within the mining area comprises predominately of areas derived from the Branxton Formation (Pmb and Pmbf) and Quaternary alluvium (Qa).

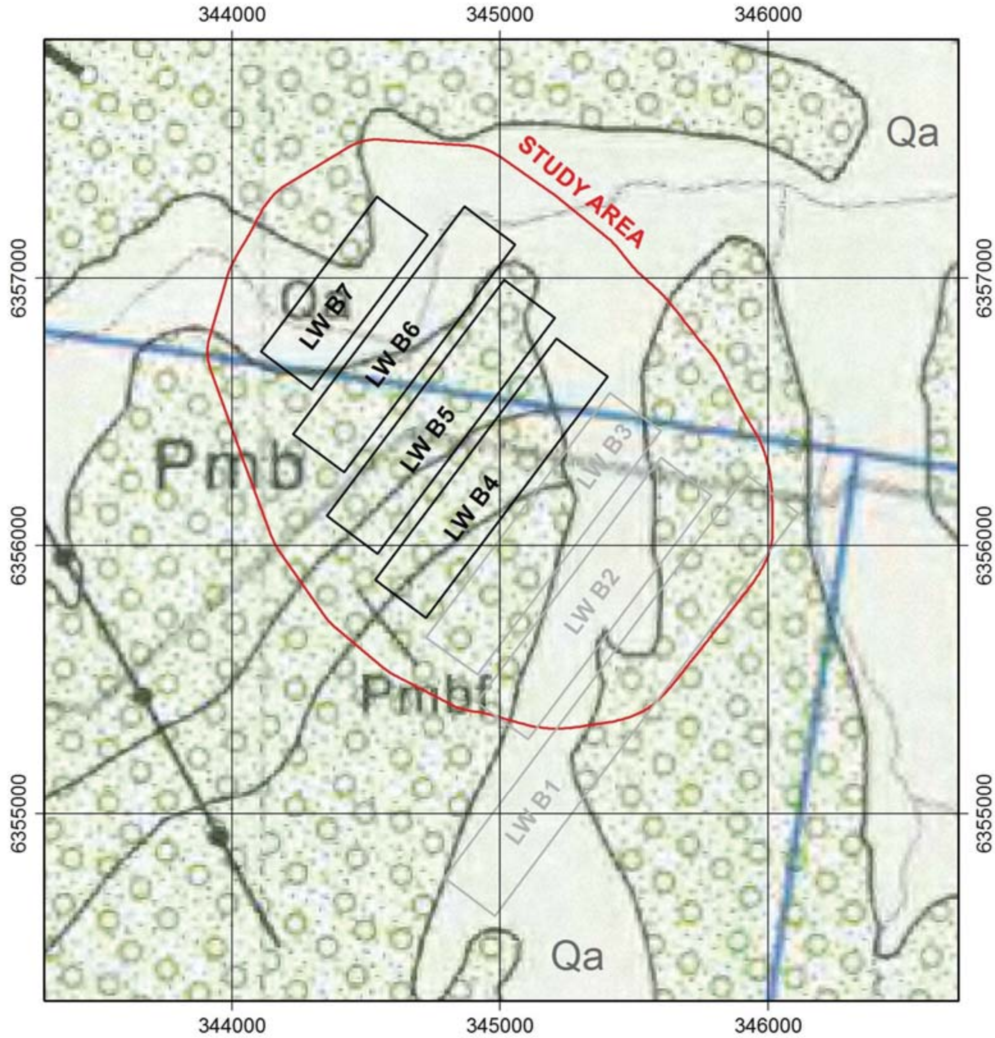


Fig. 1.3 Surface lithology within the Study Area
Geological Series Sheet Cessnock 9132 (DMR, 1995)

The major geological zones identified at seam level are shown in Drawings Nos. MSEC903-04 and MSEC903-05. The *Swamp Fault Zone* has been identified near the finishing (i.e. north-eastern) ends of the proposed longwalls. The *Barraba Fault Zone* has also been identified adjacent to the commencing (i.e. south-western) ends of the longwalls. The nature and extents of these faulting zones will be better defined as further geological data is gathered during the development of the first workings and, if necessary, the extents of mining will be reviewed based on this information.

2.1. Definition of the Study Area

This report provides updated subsidence predictions and impact assessments for Longwalls B4 to B7, based on the shortened finishing ends of Longwalls B2 and B3. This report also considers the modified mining sequence, with Longwall B1 now proposed to be extracted after the completion of Longwall B7, rather than after the completion of Longwall B3.

The modified mining sequence affects the extents of vertical subsidence during the intermediate stages of mining as only two, rather than three longwalls, have been extracted prior to the commencement of Longwalls B4 to B7. However, magnitude of vertical subsidence at the completion of mining does not significantly change due to the modified mining sequence.

The *Study Area* therefore has been defined as the surface area that is likely to be affected by the mining of Longwalls B4 to B7 in the Greta Seam at the Mine. That is, the Study Area does not just consider the changes to the finishing ends of Longwalls B2 and B3.

The extent of the Study Area has been calculated by combining the areas bounded by the following limits:

- The 26.5° angle of draw line from the extents of Longwalls B4 to B7, based on both the Previous and Current Layouts; and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of Longwalls B4 to B7, based on both the Previous and Current Layouts.

The depth of cover contours are shown in Drawing No. MSEC903-06. The depth of cover varies between 400 and 505 m directly above the proposed Longwalls B4 to B7. The 26.5° angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 200 and 253 m around the extents of the longwall voids.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method, which is described in further detail in Section 3.5. The angle of draw to the predicted total 20 mm subsidence contour has been calibrated to 30° adjacent to the longitudinal edges of the mining area (i.e. the maingate of the last longwall and tailgate of the first longwall in the series), in order to match those observed over the previously extracted longwalls at the Mine.

The predicted total 20 mm subsidence contour, therefore, is generally located outside the 26.5° angle of draw line adjacent to the longitudinal edges of the longwalls, and is generally located inside the 26.5° angle of draw line adjacent to the commencing and finishing ends of the longwalls. A line has therefore been drawn defining the Study Area, based upon the 26.5° angle of draw line and the predicted total 20 mm subsidence contour, whichever is furthest from the longwalls, and is shown in Drawings Nos. MSEC903-01 and MSEC903-02.

There are areas that lie outside the Study Area that are expected to experience either far-field movements, or valley related upsidence and closure movements. The surface features which are sensitive to such movements have been identified in this report and have been included in the assessments provided in this report.

2.2. Natural and built features within the Study Area

The major natural features and items of surface infrastructure within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered QUORROBOLONG 9132-2-S. The longwalls and the Study Area have been overlaid on an extract of this CMA Map and are shown in Fig. 2.1.

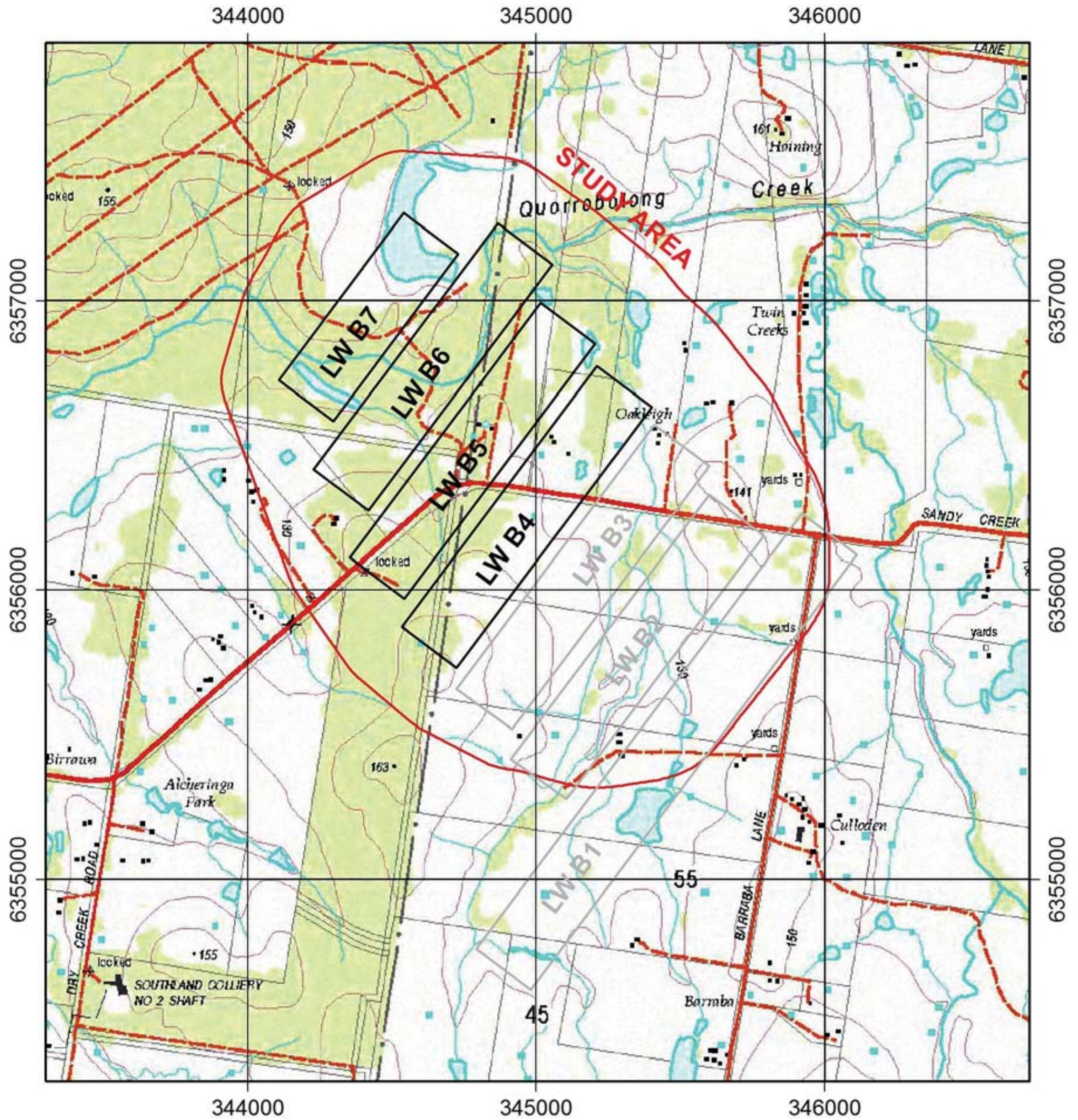


Fig. 2.1 The proposed Longwalls B4 to B7 and the Study Area overlaid on CMA Map No. Quorrobolong 9132-2-S

A summary of the natural and built features within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC903-07 to MSEC903-09. The descriptions of these features are provided in Chapters 5 and 6, as indicated by the Section number in Table 2.1.

Table 2.1 Natural and built features

Item	Within Study Area	Section number reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	×	
Rivers or Creeks	✓	5.2
Aquifers or Known Groundwater Resources	✓	5.3
Springs	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Pagodas	×	
Steep Slopes	✓	5.4
Escarpments	×	
Land Prone to Flooding or Inundation	✓	5.5
Swamps, Wetlands or Water Related Ecosystems	✓	5.6
Threatened or Protected Species	✓	5.7
National Parks	×	
State Forests	×	
State Conservation Areas	×	
Natural Vegetation	✓	5.7
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES	×	
Railways	×	
Roads (All Types)	✓	6.1
Bridges	✓	6.2
Tunnels	×	
Culverts	✓	6.3
Water, Gas or Sewerage Infrastructure	×	
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.4
Telecommunication Lines or Associated Plants	✓	6.5
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 or Agricultural Suitability of Farm Land	✓	6.6
Farm Buildings or Sheds	✓	6.7
Tanks	✓	6.7
Gas or Fuel Storages	✓	6.8
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.9
Farm Dams	✓	6.10
Wells or Bores	✓	6.11
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 or Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Infrastructure Including Tailings Dams or Emplacement Areas	×	
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	6.12
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.13
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	6.14
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	✓	6.15 & 6.16
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

3.0 OVERVIEW OF MINE SUBSIDENCE AND THE METHOD USED TO PREDICT THE MINE SUBSIDENCE PARAMETERS FOR THE LONGWALLS

3.1. Introduction

This chapter provides an overview of the mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the longwalls. Further details on methods of mine subsidence prediction are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2. Overview of conventional subsidence parameters

The normal ground movements resulting from the extraction of pillars or longwalls are referred to as conventional or 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 beyond the longwall goaf edges, 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 %, or 1 in 1,000.
- **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* (km^{-1}), but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.
- **Strain** is the relative differential horizontal movements of the ground. **Normal 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 when 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.

  Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.
- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using traditional 2D or 3D monitoring techniques.

  High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations). Conversely, high deformations across monitoring lines are also generally measured where high normal strains have been measured along the monitoring line.

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each longwall. The **cumulative** subsidence, tilts, curvatures and strains are the accumulated parameters which result from the extraction of a series of longwalls. The **total** subsidence, tilts, curvatures and strains are the final parameters at the completion of a series of longwalls. The **travelling** tilts, curvatures and strains are the transient movements as the longwall extraction face mines directly beneath a given point.

3.3. Far-field movements

The measured horizontal movements at survey marks which are located beyond the longwall goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as *far-field movements*.

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 impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt, curvature and strain.

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.5.

3.4. Overview of non-conventional subsidence movements

Conventional subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata spanning the extracted void. Normal conventional subsidence movements due to longwall extraction are easy to identify where longwalls are regular in shape, the extracted coal seams are relatively uniform in thickness, the geological conditions are consistent and surface topography is relatively flat.

As a general rule, the smoothness of the profile is governed by the depth of cover and lithology of the overburden, particularly the near surface strata layers. Where the depth of cover is greater than 400 m, such as is the case within the Study Area, the observed subsidence profiles along monitoring survey lines are generally smooth. Where the depth of cover is less than 100 m, the observed subsidence profiles along monitoring lines are generally irregular. Very irregular subsidence movements are observed with much higher tilts and strains at very shallow depths of cover where the collapsed zone above the extracted longwalls extends up to or near the surface.

Irregular subsidence movements are occasionally observed at the greater depths of cover along an otherwise smooth subsidence profile. The cause of these irregular subsidence movements can be associated with:

- issues related to the timing and the method of the installation of monitoring lines;
- sudden or abrupt changes in geological conditions;
- steep topography; and
- valley related mechanisms.

Non-conventional movements due to geological conditions and valley related movements are discussed in the following sections.

3.4.1. Non-conventional subsidence movements due to changes in geological conditions

It is believed that most non-conventional ground movements are a result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts, curvatures and strains.

Even though it may be possible to attribute a reason behind most observed non-conventional ground movements, there remain some observed irregular ground movements that still cannot be explained with the available geological information. The term "*anomaly*" is therefore reserved for those non-conventional ground movement cases that were not expected to occur and cannot be explained by any of the above possible causes.

It is not possible to predict the locations and magnitudes of non-conventional anomalous movements. In some cases, approximate predictions for the non-conventional ground movements can be made where the underlying geological or topographic conditions are known in advance. It is expected that these methods will improve as further knowledge is gained through ongoing research and investigation.

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural features and items of surface infrastructure, which are provided in Chapters 5 through to 9, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

3.4.2. Non-conventional subsidence movements due to steep topography

Non-conventional movements can also result from downslope movements where longwalls are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops of the steep slopes and elevated compressive strains develop near the bases of the steep slopes. The potential impacts resulting from down slope movements include the development of tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes.

Further discussions on the potential for down slope movements for the steep slopes within the Study Area are provided in Section 5.3.

3.4.3. Valley related movements

The watercourses within the Study Area may also 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 Newcastle Coalfield. The reason why valley related movements are less commonly observed in the Newcastle Coalfield could be that the conventional subsidence movements are typically much larger than those observed in the Southern Coalfield and tend to mask any smaller valley related movements which may occur.

Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.1. The potential for these natural movements are influenced by the geomorphology of the valley.

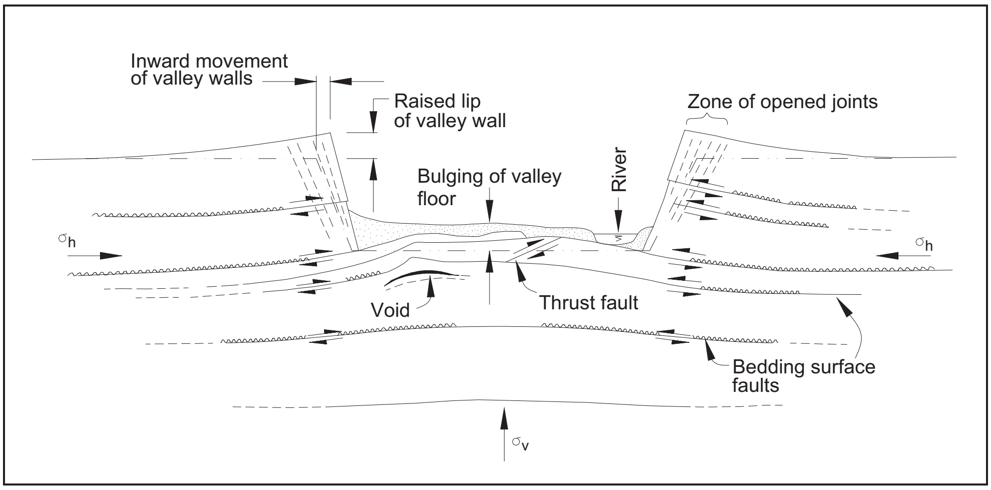


Fig. 3.1 Valley formation in flat-lying sedimentary rocks (after Patton and Hendren 1972)

Valley related movements can be caused by or accelerated by mine subsidence as the result of a number of factors, including the redistribution of horizontal in-situ stresses and down slope movements. Valley related movements are normally described by the following parameters:

- **Upsidence** is the reduced subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides.
- **Compressive strains** occur within the bases of valleys as a result of valley closure and upsidence movements. **Tensile strains** also occur in the sides and near the tops of the valleys as a result of valley closure movements. The magnitudes of these strains, which are typically expressed in the units of *millimetres per metre (mm/m)*, are calculated as the changes in horizontal distance over a standard bay length, divided by the original bay length.

The predicted valley related movements resulting from the extraction of the longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*. There are other methods available to predict valley related movements, however, the ACARP method was adopted for this project as it is the most thoroughly used and tested method

3.5. The Incremental Profile Method

The Incremental Profile Method (IPM) was initially developed by Waddington Kay and Associates, now known as MSEC, as part of a study, in 1994 to assess the impacts of subsidence on particular surface infrastructure over a proposed series of longwall panels at Appin Colliery. The method evolved following detailed analyses of subsidence monitoring data from the Southern Coalfield, which was then extended to include detailed subsidence monitoring data from the Newcastle, Hunter and Western Coalfields.

The review of the detailed ground monitoring data from the New South Wales (NSW) Coalfields showed that whilst the final subsidence profiles measured over a series of longwalls were irregular, the observed incremental subsidence profiles due to the extraction of individual longwalls were consistent in both magnitude and shape and varied according to local geology, depth of cover, panel width, seam thickness, the extent of adjacent previous mining, the pillar width and stability of the chain pillar and a time-related subsidence component.

MSEC developed a series of subsidence prediction curves for the Newcastle and Hunter Coalfields, in 1996 to 1998, after receiving extensive subsidence monitoring data from Centennial Coal for the Cooranbong Life Extension Project (Waddington and Kay, 1998). The subsidence monitoring data from many collieries in the Newcastle and Hunter Coalfields were reviewed and, it was found, that the incremental subsidence profiles resulting from the extraction of individual longwalls were consistent in shape and magnitude where the mining geometries and overburden geologies were similar.

Since this time, extensive monitoring data has been gathered from the Southern, Newcastle, Hunter and Western Coalfields of NSW and from the Bowen Basin in Queensland, including: Angus Place, Appin, Awaba, Baal Bone, Bellambi, Beltana, Blakefield South, Bulga, Bulli, Burwood, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Donaldson, Eastern Main, Ellalong, Elouera, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Moranbah North, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, NRE Wongawilli, Oaky Creek, Ravensworth, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

Based on the extensive empirical data, MSEC has developed standard subsidence prediction curves for the Southern, Newcastle, Hunter and Western Coalfields. The prediction curves can then be further refined, for the local geology and local conditions, based on the available monitoring data from the area. Discussions on the calibration and review of the IPM at the Mine are provided in Section 3.6.

The prediction of subsidence is a three stage process where, first, the magnitude of each increment is calculated, then, the shape of each incremental profile is determined and, finally, the total subsidence profile is derived by adding the incremental profiles from each longwall in the series. In this way, subsidence predictions can be made anywhere above or outside the extracted longwalls, based on the local surface and seam information.

For longwalls in the Newcastle and Hunter Coalfields, the maximum predicted incremental subsidence is initially determined, using the IPM subsidence prediction curves for a single isolated panel, based on the longwall void width (W) and the depth of cover (H). The incremental subsidence is then increased, using the IPM subsidence prediction curves for multiple panels, based on the longwall series, panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H). In this way, the influence of the panel width (W), depth of cover (H), as well as panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H) are each taken into account.

The shapes of the incremental subsidence profiles are then determined using the large empirical database of observed incremental subsidence profiles from the Newcastle and Hunter Coalfields. The profile shapes are derived from the normalised subsidence profiles for monitoring lines where the mining geometry and overburden geology are similar to that for the longwalls. The profile shapes can be further refined, based on local monitoring data, which is discussed further in Section 3.6.

Finally, the total subsidence profiles resulting from the series of longwalls are derived by adding the predicted incremental profiles from each of the longwalls. Comparisons of the predicted total subsidence profiles, obtained using the Incremental Profile Method, with observed profiles indicates that the method provides reasonable, if not, slightly conservative predictions where the mining geometry and overburden geology are within the range of the empirical database. The method can also be further tailored to local conditions where observed monitoring data is available close to the mining area.

3.6. Calibration and review of the Incremental Profile Method at Austar Coal Mine

The IPM was originally calibrated for the local conditions at the Mine during the preparation of the Subsidence Management Plan Application for Longwalls A3 to A5 in Stage 2, which was discussed in Section 3.4.1 of Report No. MSEC275.

The calibration was based on the available ground monitoring data at that time, which included: eight monitoring lines above Longwalls SL1 to SL4 and Longwalls 1 to 13A at Ellalong Colliery; and three monitoring lines above Longwalls A1 and A2 in Stage 1 of the Mine.

Initially, the magnitudes and shapes of the observed incremental subsidence profiles along each monitoring line were compared with the back-predicted subsidence profiles obtained using the standard Incremental Profile Method, which is based on the typical Newcastle Coalfield subsidence profiles. The standard IPM was not modified for the presence of any thick massive strata units, which can reduce the sag subsidence directly above the extracted longwalls.

It was found that the values of maximum observed incremental subsidence for the previously extracted longwalls along each of the monitoring lines were less than the values of maximum back-predicted incremental subsidence obtained using the standard Incremental Profile Method. It was also found that the observed incremental subsidence profiles along the monitoring lines were slightly wider, and that the points of maximum observed subsidence were located closer to the longwall tailgates, than for the back-predicted incremental subsidence profiles obtained using the standard Incremental Profile Method.

The reason that the observed subsidence profiles were wider than the predicted profiles and that the maximum observed subsidence was less than the maximum predicted subsidence was the result of the geology of the overburden. The massive sandstones in the overlying Branxton Formation were capable of spanning the extracted voids with minimal sag subsidence and, hence, the observed subsidence profiles and the magnitudes of the observed subsidence were governed, to a large extent, by pillar compression.

The shapes of the back-predicted incremental subsidence profiles along each monitoring line were adjusted to more closely match those observed. No adjustments were made to the magnitudes of the maximum back-predicted incremental subsidence for each longwall. The angle of draw to the predicted total 20 mm subsidence contour, obtained using the Incremental Profile Method, was also calibrated to 30° adjacent to the longitudinal edges of the mining area, to match those observed over the previously extracted longwalls at the colliery.

Subsequent to the calibration undertaken as part of Report No. MSEC275, Austar has extracted Longwalls A3 to A5A in Stage 2, Longwalls A7 and A8 in Stage 3 and Longwall B2 in the Bellbird South mining area. The mine subsidence movements have been monitored along four monitoring lines in above Longwalls A3 to A5A, four monitoring lines above Longwalls A7 and A8 and three monitoring lines above Longwall B2. The comparisons between the observed and predicted movements have been provided in the End of Panel subsidence review reports for each of these longwalls.

The comparisons between the observed and predicted subsidence, tilt and strain have been provided for: Line 1B above Longwalls A1 and A2 in Fig. 3.2; Line A3X above Longwalls A3 to A5A in Fig. 3.3; the XL3 Line above Longwalls A7 and A8 in Fig. 3.4; the BSX Line above Longwall B2 in Fig. 3.5; and the B2 Line above Longwall B2 in Fig. 3.6.

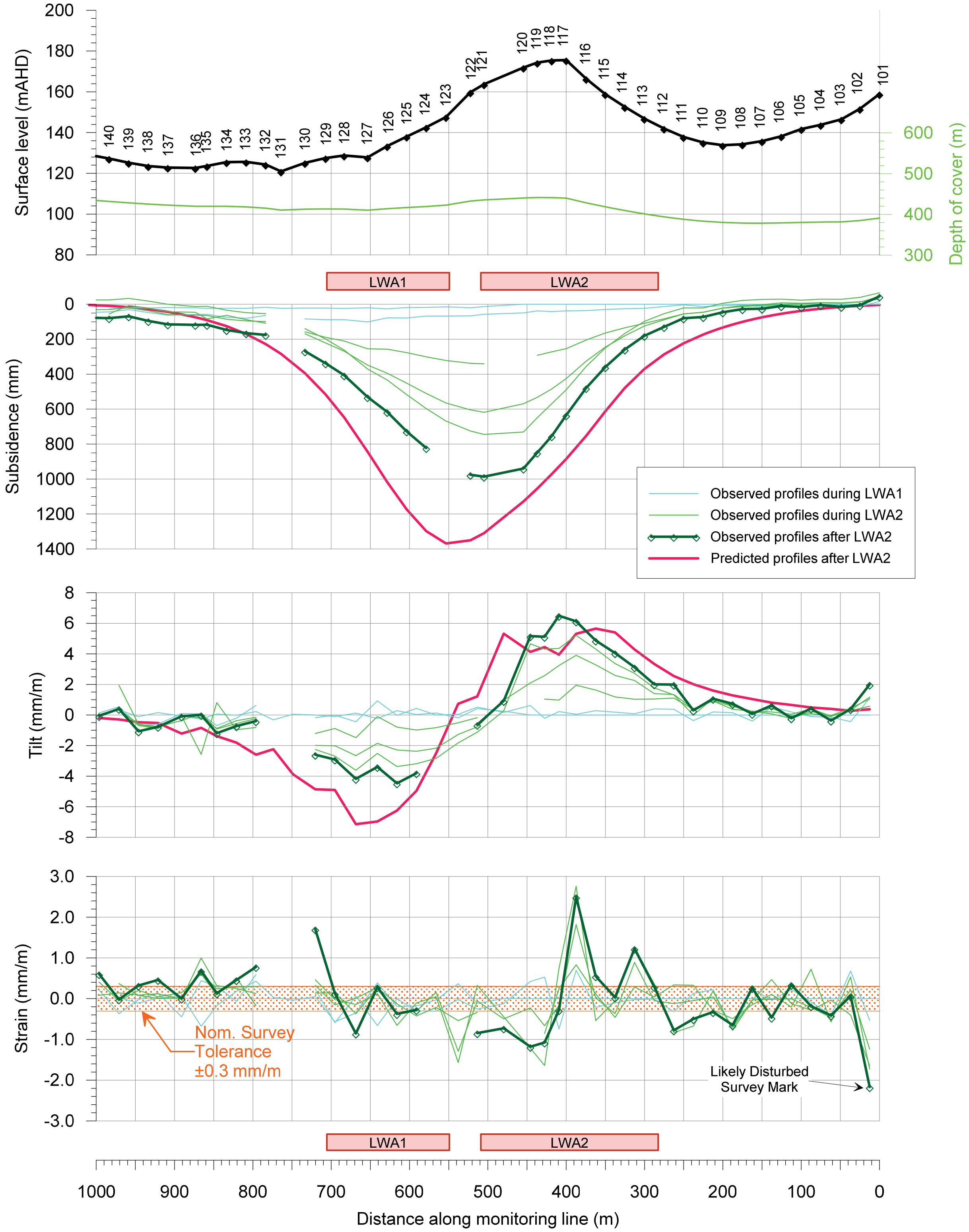


Fig. 3.2 Observed and predicted profiles of subsidence, tilt and strain along Line 1B above Longwalls A1 and A2 in Stage 1

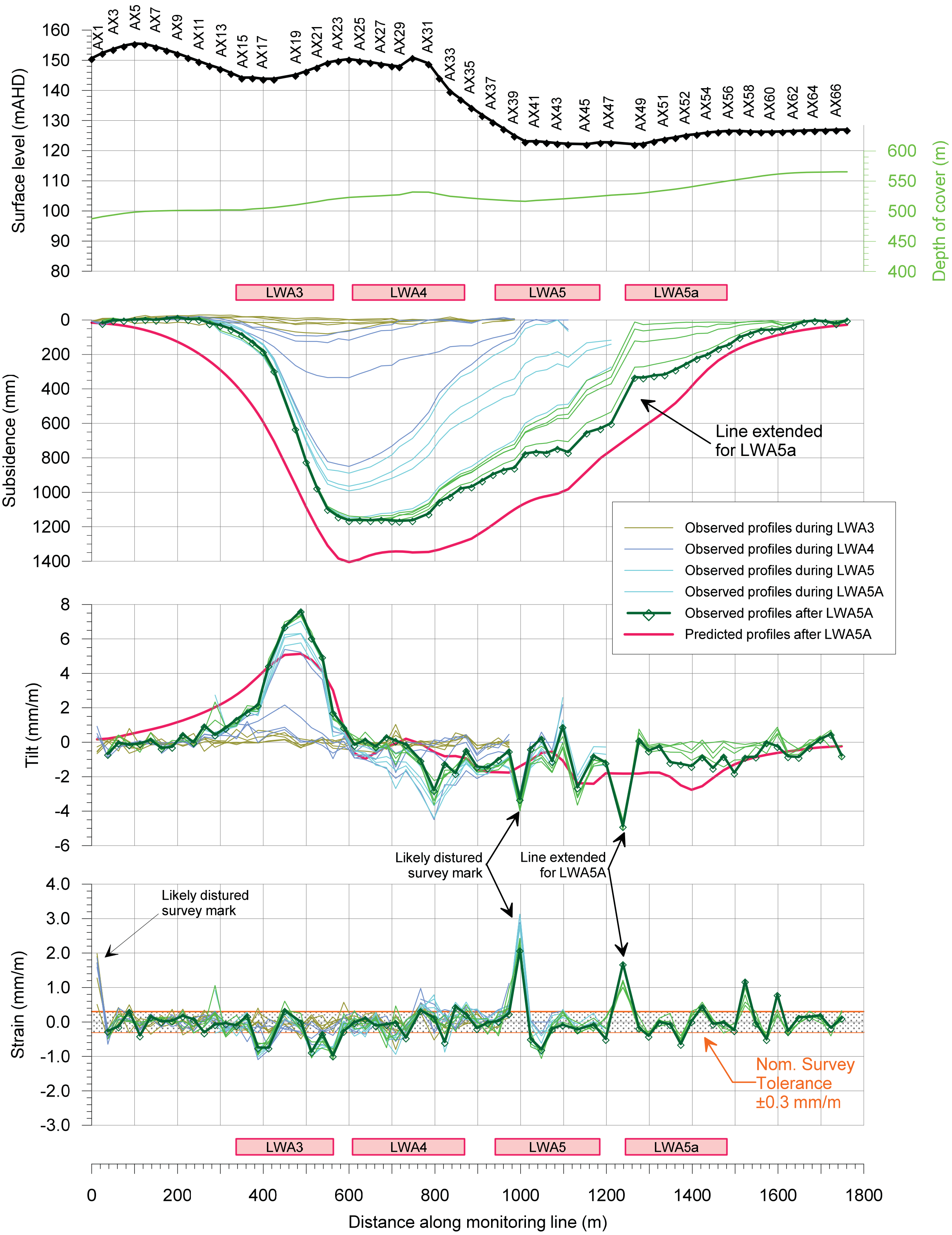


Fig. 3.3 Observed and predicted profiles of subsidence, tilt and strain along Line A3X above Longwalls A3 to A5A in Stage 2

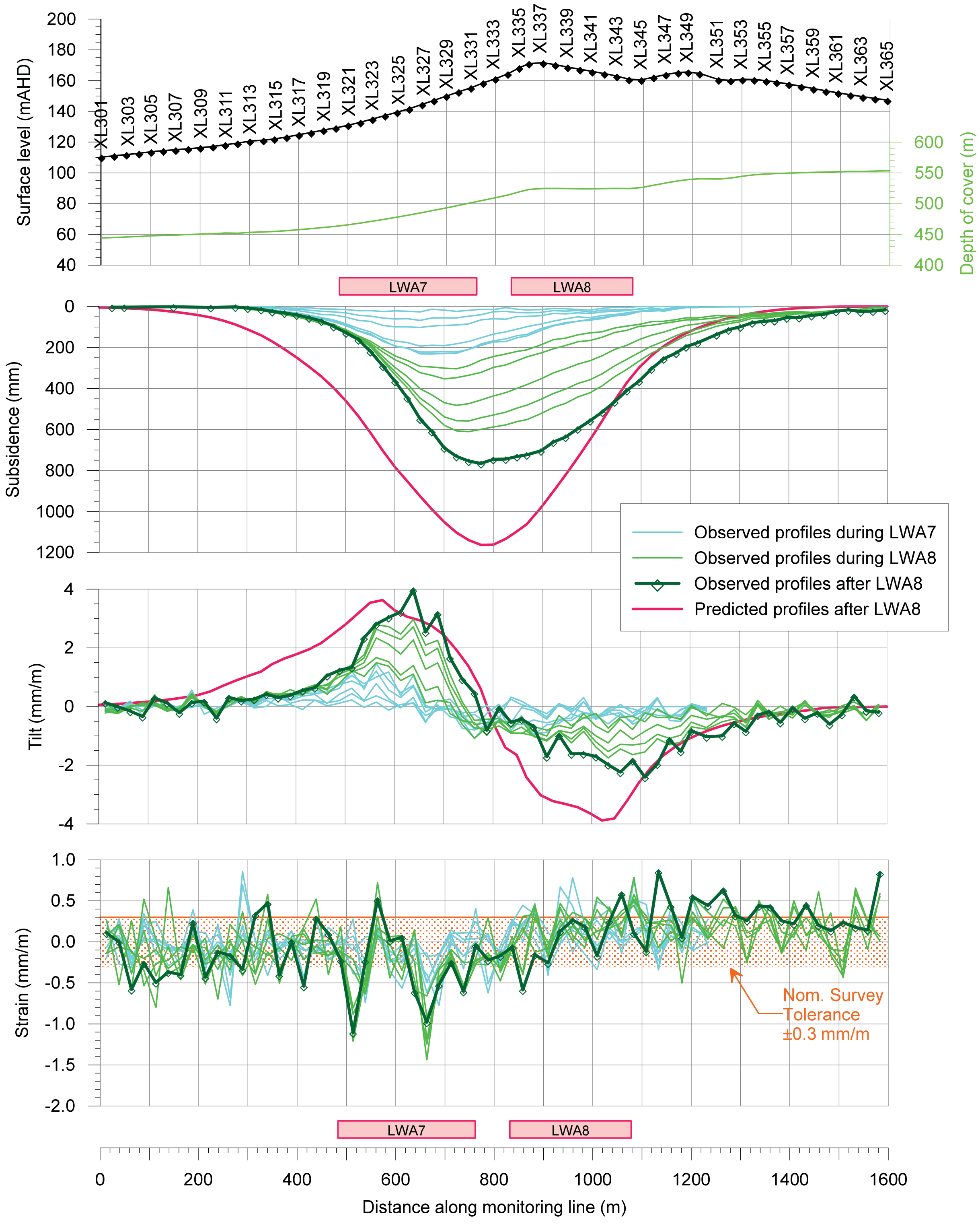


Fig. 3.4 Observed and predicted profiles of subsidence, tilt and strain along the XL3 Line above Longwalls A7 and A8 in Stage 3

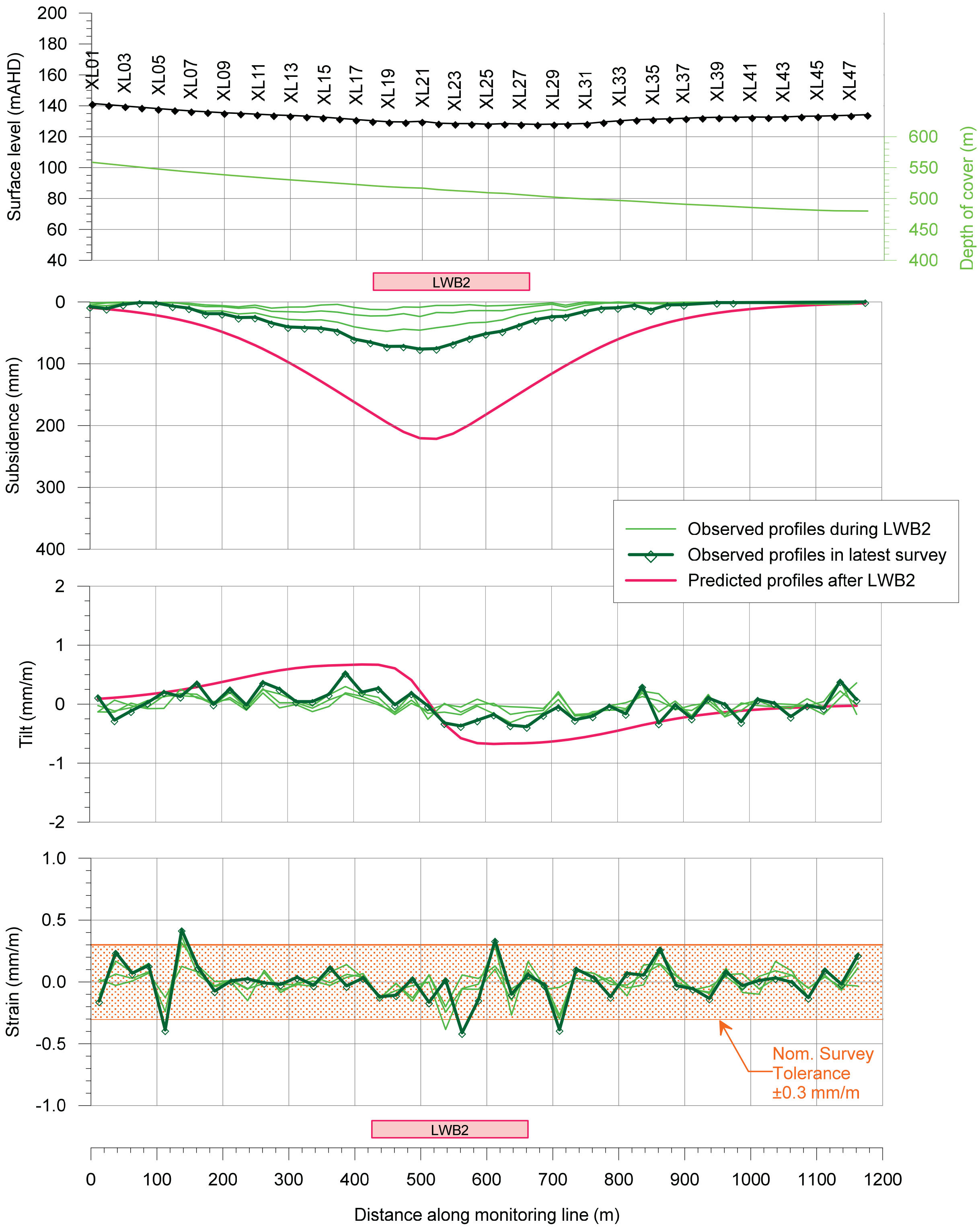


Fig. 3.5 Observed and predicted profiles of subsidence, tilt and strain along the BSX Line above Longwall B2 in the Bellbird South Mining Area

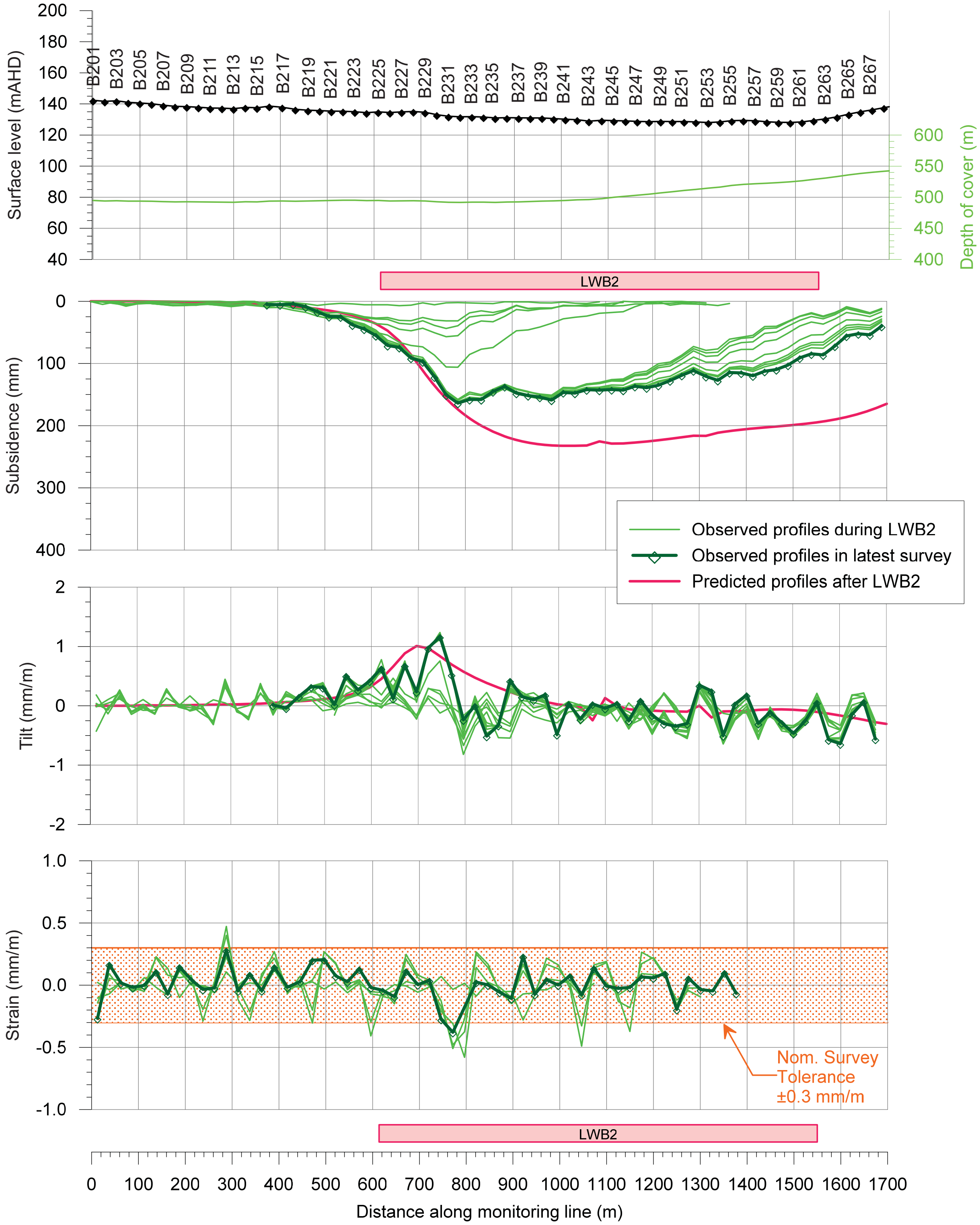


Fig. 3.6 Observed and predicted profiles of subsidence, tilt and strain along the B2 Line above Longwall B2 in the Bellbird South Mining Area

It can be seen from Fig. 3.2 to Fig. 3.6, that the maximum observed vertical subsidence movements along these monitoring lines are less than the maxima predicted using the calibrated IPM. The percentages of the maximum observed to maximum predicted vertical subsidence movements are 75 % for Line 1B, 83 % for Line A3X, 66 % for the XL3 Line, 34 % for the BSX Line and 70 % for the B2 Line. The IPM has provided conservative predictions of vertical subsidence as no subsidence reduction factor has been applied due to the presence of the massive Branxton Formation within the overburden.

The observed vertical subsidence slightly exceeds the predicted vertical subsidence outside the extents of the extracted longwalls adjacent to the tailgate of Longwall A1 (see Fig. 3.2), adjacent to the maingate of Longwall A8 (see Fig. 3.4) and adjacent to the commencing end of Longwall B2 (see Fig. 3.6). This low level vertical subsidence, however, is not associated with any significant observed tilts, curvatures or strains and impacts are not anticipated outside the extents of the extracted longwalls.

The shapes of the observed vertical subsidence profiles reasonably match the predicted profiles. The maximum observed tilts are generally less than the maxima predicted. However, the maximum observed tilt along the A3X Line (see Fig. 3.3) of 7.6 mm/m is greater than the maximum predicted of 5.1 mm/m. It has been considered that the higher observed tilt is associated with the reduced subsidence above solid coal which may be the result of stronger strata cantilevering and reducing the subsidence over the tailgate of Longwall A3.

The maximum observed tilt along the B2 Line (see Fig. 3.6) of 1.2 mm/m is slightly greater than the maximum predicted of 1.0 mm/m. This exceedance is very small and is within the order of accuracy of the prediction method and the survey tolerance. Localised and elevated tilts have also been observed in other locations along the monitoring lines, which exceeded the predictions, however, it is likely that many of these have occurred as the result of disturbed survey marks, as they occurred outside of the extents of the longwalls.

The observed strains are typically less than those expected based on conventional ground movements, which are 1 mm/m tensile and 2 mm/m compressive. A localised tensile strain of 3.1 mm/m has occurred along Line 1B (see Fig. 3.2) which is considered to have been influenced by top of hill effects. Localised tensile strains between 1 mm/m and 2 mm/m have also occurred along the A3X Line (see Fig. 3.3), which are likely the result of disturbed survey marks.

It is considered that the calibrated IPM has provided reasonable, if not, conservative predictions for the monitoring lines above the longwalls extracted in Stages 1 to 3 and in the Bellbird South mining area. It has not been considered necessary to undertake any further refinement of the subsidence prediction model based on the available results. It is expected that the calibrated IPM would provide reasonable, if not, slightly conservative predictions for the Longwalls B4 to B7.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of Longwalls B4 to B7 based on the Current Layout. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted subsidence, tilt and curvature have been obtained using the IPM, which has been calibrated and reviewed based on the local mining conditions, as described in Section 3.5. The predicted strains have been determined by analysing the strains measured at the Mine.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include the valley related upsidence and closure movements, nor the effects of faults and other geological structures. Such effects have been addressed separately in the impact assessments for each feature provided in Chapters 5 and 6.

4.2. Maximum predicted conventional subsidence, tilt and curvature

The predicted additional conventional subsidence contours due to the extraction of the proposed Longwalls B4 to B7 only, based on the Current Layout, are shown in Drawing No. MSEC903-10. The predicted additional 20 mm subsidence contour based on the Previous Layout is also shown in this drawing for comparison. These contours represent the additional movements after the completion of Longwall B3, but include the influence of the previously extracted Longwalls B1 to B3.

The predicted total conventional subsidence contours due to the extraction of Longwalls B1 to B7, based on the Current Layout, are shown in Drawings Nos. MSEC903-11 to MSEC903-15. The predicted total 20 mm subsidence contour based on the Previous Layout is also shown in this drawing for comparison. The predicted total subsidence contours including the adjacent existing and approved longwalls at Ellalong and Austar Mines are shown in Drawing No. MSEC903-16.

A summary of the maximum predicted values of incremental conventional vertical subsidence, tilt and curvature due to the extraction of each of the proposed longwalls is provided in Table 4.1. The incremental values are the additional movements due to each proposed longwall.

Table 4.1 Maximum predicted incremental conventional vertical subsidence, tilt and curvature due to the extraction of each of the longwalls

Due to longwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
LWB4	675	3.5	0.03	0.06
LWB5	625	3.5	0.03	0.05
LWB6	700	3.5	0.04	0.05
LWB7	725	4.0	0.05	0.06

A summary of the maximum predicted values of total conventional vertical subsidence, tilt and curvature after the extraction of each of the proposed longwalls is provided in Table 4.2. The total values are the maximum accumulated movements within the Study Area including the predicted movements due to the approved Longwalls B1 to B3.

Table 4.2 Maximum predicted total conventional vertical subsidence, tilt and curvature after the extraction of each of the proposed longwalls

After longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
LWB4	1200	5.0	0.03	0.06
LWB5	1250	5.5	0.04	0.06
LWB6	1350	5.5	0.04	0.06
LWB7	1350	5.5	0.05	0.06

The maximum predicted total vertical subsidence within Study Area is 1350 mm, which represents 40 % of the proposed extraction height of 3.4 m. The maximum predicted subsidence occurs directly above the approved Longwall B3.

The maximum predicted total conventional tilt is 5.5 mm/m (i.e. 0.55 % or 1 in 180), which occurs adjacent to the maingate of Longwall B7. The maximum predicted total conventional curvatures are 0.05 km^{-1} hogging and 0.06 km^{-1} sagging, which represent minimum radii of curvatures of 20 km and 17 km, respectively.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, seam thickness and overburden geology. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1, the location of which is shown in Drawings Nos. MSEC903-10 to MSEC903-16.

The predicted profiles of conventional vertical subsidence, tilt and curvature along Prediction Line 1, resulting from the extraction of Longwalls B1 to B7, are shown in Fig. C.01, in Appendix C. The predicted total profiles along the prediction line, after the extraction of Longwalls B2, B3 and the previously extracted longwalls at the Mine, are shown as the cyan lines. The predicted total profiles after the extraction of each of the proposed Longwalls B4 to B7 are shown as blue lines. The predicted final profiles after the completion of Longwall B1 are shown as the red lines.

4.3. Comparisons of the maximum predicted subsidence parameters

The comparison of the maximum predicted subsidence parameters for the Longwalls B1 to B7, based on the Previous Layout and Current Layout, is provided in Table 4.3. The total values are the maximum accumulated movements within the mining area.

Table 4.3 Comparison of the maximum predicted total conventional subsidence parameters within the Bellbird South mining area based on the Previous Layout and Current Layout

Layout	After longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	LWB4	1200	5.0	0.03	0.06
	LWB5	1250	5.5	0.04	0.06
	LWB6	1350	5.5	0.04	0.06
	LWB7	1350	5.5	0.05	0.06
Current Layout (MSEC903)	LWB4	1200	5.0	0.03	0.06
	LWB5	1250	5.5	0.04	0.06
	LWB6	1350	5.5	0.04	0.06
	LWB7	1350	5.5	0.05	0.06

The maximum predicted total subsidence parameters after the extraction of each of the Longwalls B4 to B7, based on the Current Layout, are the same as the maxima predicted based on the Previous Layout. That is, the shortened finishing ends of Longwalls B2 and B3 do not affect the maximum predicted subsidence parameters for Longwalls B4 to B7.

Whilst the maximum predicted subsidence parameters are the same, the extent of vertical subsidence due to the extraction of Longwalls B4 to B7, above the previously extracted longwalls, changes due to the modified mining sequence. Austar now proposes to extract Longwall B1 after the completion of Longwalls B4 to B7, rather than after the completion of Longwall B3 and prior to the commencement of Longwalls B4 to B7.

In the Current Layout, there are two longwalls (i.e. Longwalls B2 and B3) that are extracted prior to the commencement of Longwalls B4 to B7. Whereas in the Previous Layout, there are three longwalls (i.e. Longwalls B1 to B3) that are extracted prior to the commencement of Longwalls B4 to B7. As a result, the additional subsidence due to the extraction of Longwalls B4 to B7, based on Current Layout, does not extend as far above the earlier extracted longwalls when compared to that based on the Previous Layout. This is due to the one less longwall being completed prior to the extraction of Longwalls B4 to B7.

However, the additional vertical subsidence due to the extraction of Longwall B1, based on the Current Layout, extends further above the earlier extracted longwalls when compared to that based on the Previous Layout. This is due to Longwalls B4 to B7 being completed prior to the extraction of Longwall B1.

At the completion of all longwalls in the series, the extent of vertical subsidence does not significantly change due to the modified mining sequence. However, the extent of subsidence decreases at the finishing ends of Longwalls B2 and B3 due to their shortened ends. Whist the extent of subsidence decreases during transient stages of mining and at the finishing ends of Longwalls B2 and B3, the maximum predicted subsidence parameters do not change.

4.4. Predicted strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

For this reason, the range of potential strains for the longwalls has been determined using monitoring data from the previously extracted longwalls at the Mine. The discussions on the available ground monitoring data and strain analysis are provided in Section 4.4 of Report No. MSEC869.

4.4.1. Analysis of strains measured in survey bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

The histogram of the maximum observed tensile and compressive strains measured in survey bays located above goaf (i.e. longwalls and chain pillars) is provided in Fig. 4.1. The probability distribution functions, based on the fitted Generalised Pareto Distributions (GPDs), have also been shown in this figure.

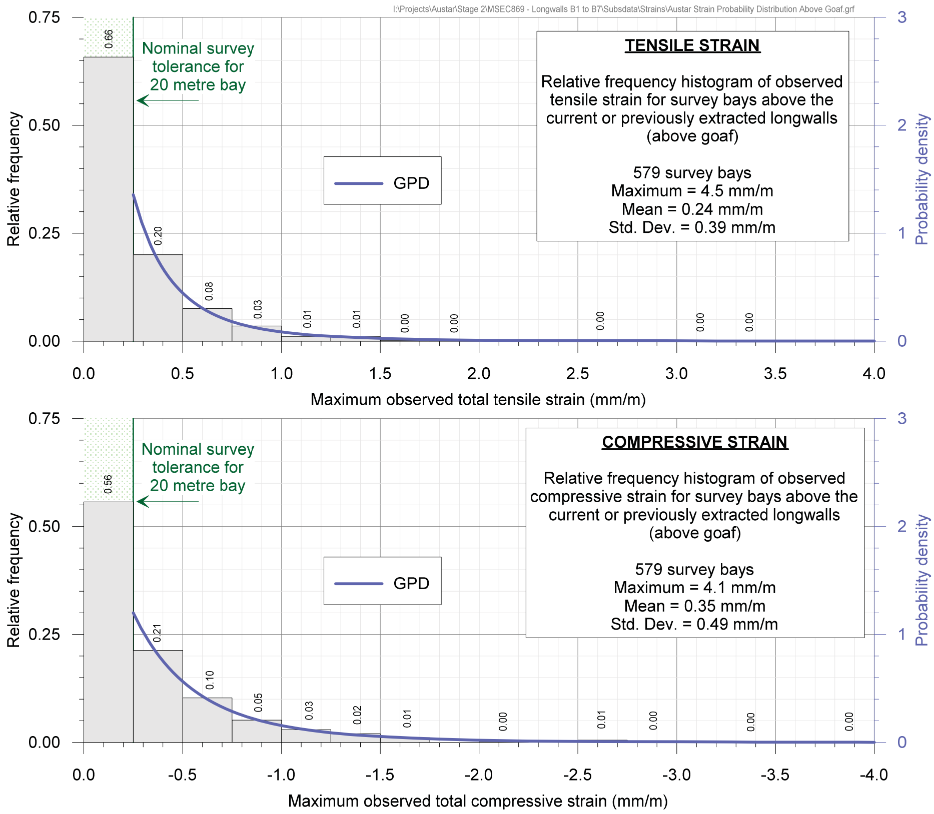


Fig. 4.1 Distributions of the measured maximum tensile and compressive strains during the extraction of previous longwalls for survey bays located above goaf

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during the longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay). A summary of the predicted strains directly above Longwalls B4 to B7 (i.e. above goaf) is provided in Table 4.4.

Table 4.4 Predicted strains directly above Longwalls B4 to B7 (i.e. above goaf)

Location	Confidence level	Predicted tensile strain (mm/m)	Predicted compressive strain (mm/m)
Above goaf	95 %	0.9	1.2
	99 %	1.7	2.2

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal (i.e. outside but within 250 m of the nearest longwall) is provided in Fig. 4.2. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

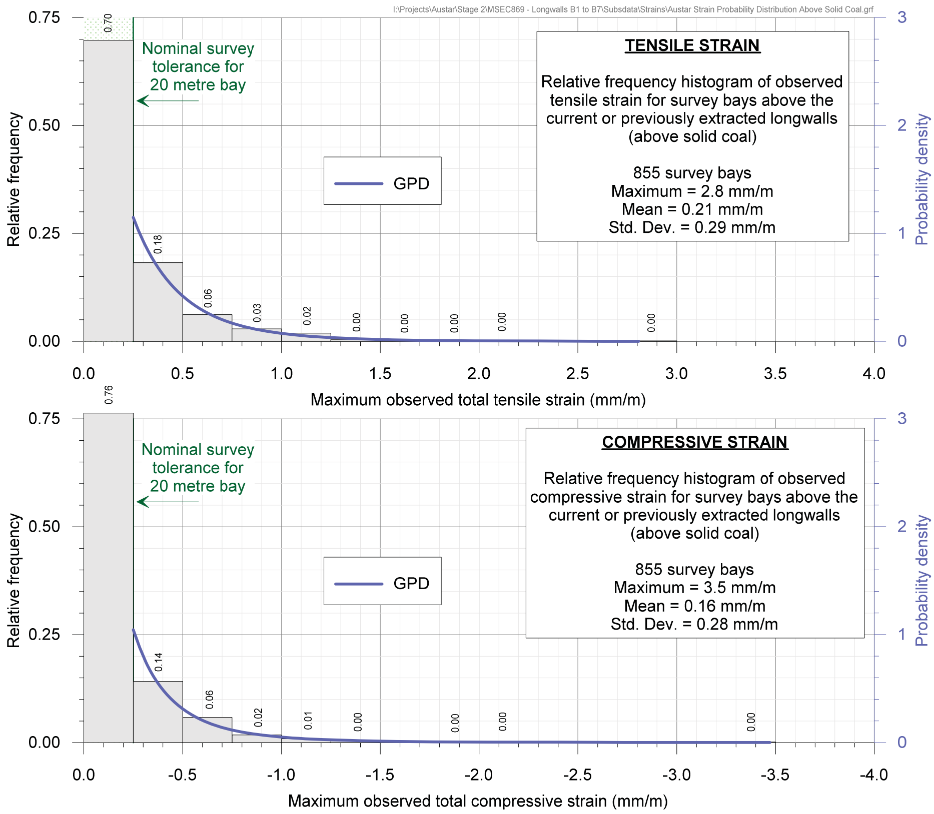


Fig. 4.2 Distributions of the measured maximum tensile and compressive strains during the extraction of previous longwalls for survey bays located above solid coal

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during the longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay). A summary of the predicted strains outside but within 250 m of Longwalls B4 to B7 (i.e. above solid coal) is provided in Table 4.5.

Table 4.5 Predicted strains outside Longwalls B4 to B7 (i.e. above solid coal)

Location	Confidence level	Predicted tensile strain (mm/m)	Predicted compressive strain (mm/m)
Above solid coal	95 %	0.8	0.7
	99 %	1.3	1.3

4.4.2. Analysis of strains measured along whole monitoring lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of observed maximum strains along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains anywhere along the monitoring lines, regardless of where the strain actually occurs.

The histogram of maximum observed tensile and compressive strains measured anywhere along the monitoring lines is provided in Fig. 4.3.

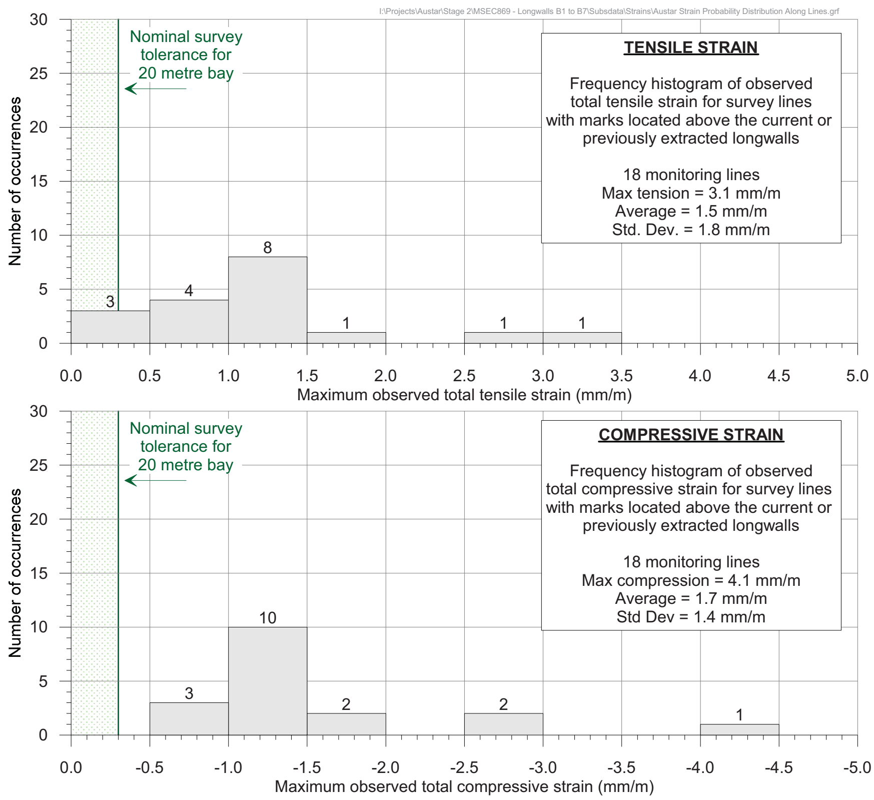


Fig. 4.3 Distributions of measured maximum tensile and compressive strains along the monitoring lines during the extraction of previous longwalls

It can be seen from Fig. 4.3, that 16 of the 18 monitoring lines (i.e. 89 % of the total) have recorded maximum total tensile strains of 2 mm/m or less. It can also be seen, that 15 of the 18 monitoring lines (i.e. 83 % of the total) also have recorded maximum compressive strains of 2 mm/m or less. The maximum observed strains along the monitoring lines, excluding the survey bays which appear to have been disturbed, were 3.1 mm/m tensile and 4.1 mm/m compressive.

4.5. Predicted conventional and far-field horizontal movements

The predicted conventional and far-field horizontal movements for Longwalls B4 to B7 are discussed in Sections 4.5 and 4.6 of Report No. MSEC869. The predicted horizontal movements, based on the Current Layout, are the same as those predicted based on the Previous Layout (i.e. as described in Report No. MSEC869).

The maximum predicted conventional horizontal movement above Longwalls B4 to B7 is approximately 85 mm. The far-field horizontal movements in the order of 30 mm are predicted at distances of 1 km from the longwalls.

Conventional and far-field horizontal movements do not directly impact on natural and built features, rather impacts occur as the result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural and built features are addressed in the impact assessments provided in Chapters 5 and 6.

4.6. Mining induced ground deformations

Longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The discussion on the potential for mining-induced ground deformations for Longwalls B4 to B7 is provided in Section 4.7 of Report No. MSEC869.

The potential for surface deformations, based on the Current Layout, is similar to that based on the Previous Layout (i.e. as described in Report No. MSEC869). However, the surface area affected by mine subsidence slightly reduces due to the shortened finishing ends of Longwalls B2 and B3.

The surface area located directly above Longwalls B1 to B7, including the chain pillars, is 235 hectares (ha) based on the Previous Layout and 225 ha based on the Current Layout. That is, the surface area above the longwalls reduces by 10 ha due to the proposed shortened finishing ends of Longwalls B2 and B3. The overall level of impact due to the mining-induced surface deformations therefore slightly reduces due to these proposed modifications.

There has been no significant or visible surface cracking above the previously extracted Longwalls A3 to A8 in Stages 2 and 3 and Longwall B2 in the Bellbird South mining area. The surface cracking, if any, resulting from the extraction of Longwalls B4 to B7 is expected to be of a minor nature, having widths generally less than 10 to 25 mm. It is expected that the surface cracking could be remedied by infilling with soil or other suitable materials, or by locally regrading and recompacting the surface.

4.7. Estimated height of the fractured zone

The estimated height of the fractured zone, based on the Current Layout, is the same as that based on the Previous Layout. The discussion on the height of fracturing for Longwalls B4 to B7 is provided in Section 4.8 of Report No. MSEC869.

Further discussions on the effects of mining on the overburden and groundwater are provided by the specialist groundwater consultant in the report by Dundon Consulting (2017). Further details on sub-surface strata movements are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES

The following sections provide the descriptions, predictions and impact assessments for the natural features within the Study Area, as identified in Chapter 2. The impact assessments are based on the predicted movements due to the extraction of the proposed Longwalls B4 to B7, as well as the predicted movements due to the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements due to the existing and proposed longwalls).

All significant natural features located outside the Study Area, which may be subjected to valley related or far-field horizontal movements due to the proposed Longwalls B4 to B7 and may be sensitive to these movements, have also been included as part of these assessments.

5.1. Natural Features

As listed in Table 2.1, the following natural features were not identified within the Study Area nor in the immediate surrounds:

- drinking water catchment areas or declared special areas;
- known springs or groundwater seeps;
- seas or lakes;
- shorelines;
- natural dams;
- cliffs or pagodas;
- escarpments;
- lands declared as critical habitat under the *Threatened Species Conservation Act 1995*;
- National Parks or State Forests;
- State Recreation Areas or State Conservation Areas;
- areas of significant geological interest; and
- other significant natural features.

The following sections provide the descriptions, predictions and impact assessments for the natural features which have been identified within or in the vicinity of the Study Area.

5.2. Streams

The locations of the streams within the Study Area are shown in Drawing No. MSEC903-07. The descriptions, predictions and impact assessments for these streams are provided in the following sections.

5.2.1. Descriptions of the streams

Quorrobolong Creek crosses directly above the proposed Longwalls B6 and B7. The total length of the creek located above these longwalls is approximately 1.3 km. Quorrobolong Creek has been previously directly mined beneath by Longwalls SL1 and 1 to 5 at Ellalong Colliery and by Longwalls A3 to A5A at the Austar Coal Mine, with a total length of approximately 4 km located directly above these previously extracted longwalls.

Quorrobolong Creek flows in a westerly direction to where it drains to Ellalong Lagoon, which is located more than 5 km from the proposed longwalls. The creek is ephemeral, but localised areas of natural ponding occur along its alignment. The natural grade of the section of creek within the Study Area varies between approximately 1 mm/m and 3 mm/m, with an average grade of approximately 2 mm/m.

The creek is incised into the natural surface soils, with the heights of the banks ranging between 3 and 5 m. The bed of the creek comprises Quaternary alluvium. There are debris accumulations along some sections of the creek, including tree branches, other vegetation and loose rocks.

Photographs of Quorrobolong Creek within the Study Area are provided in Fig. 5.1.

Fig. 5.1 Quorrobolong Creek

There are also ephemeral drainage lines within the Study Area that have formed on and between the small ridgelines. The locations of these drainage lines are shown in Drawing No. MSEC903-07. The largest ephemeral drainage line within the Study Area has been referred to as Drainage Line 1, in this report, as shown in Drawing No. MSEC903-07.

The drainage lines within the Study Area all drain to Quorrobolong Creek. The upper reaches of the drainage lines have formed in the Branxton Formation and have steep natural gradients, but with localised areas of ponding and stepping in some locations. The lower reaches of the drainage lines have shallow incisions into the natural surface soils that are comprised of Quaternary alluvium.

Photographs of the typical drainage lines within the Study Area are provided in Fig. 5.2.

Fig. 5.2 Typical drainage lines within the Study Area

5.2.2. Predictions for the streams

The predicted profiles of conventional subsidence, tilt and curvature along the alignment of Quorrobolong Creek are shown in Fig. C.02, in Appendix C. The predicted total profiles along the creek, after the extraction of Longwalls B2, B3 and the previously extracted longwalls at the Mine, are shown as the cyan lines. The predicted total profiles after the extraction of each of the proposed Longwalls B4 to B7 are shown as blue lines. The predicted final profiles after the completion of Longwall B1 are shown as the red lines.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for Quorrobolong Creek is provided in Table 5.1. The predictions are the maxima within the Study Area, i.e. do not include the sections of creek located above the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine, but include the predicted movements resulting from these previous longwalls.

Table 5.1 Maximum predicted total vertical subsidence, tilt and curvature for Quorrobolong Creek

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Quorrobolong Creek	After LWB3	60	0.5	0.01	< 0.01
	After LWB4	60	0.5	0.01	< 0.01
	After LWB5	90	0.5	0.01	< 0.01
	After LWB6	650	3.0	0.02	0.02
	After LWB7	1100	5.0	0.04	0.04
	After LWB1	1100	5.0	0.04	0.04

The tilts provided in the above table are the maxima predicted along the alignment of Quorrobolong Creek after the completion of each of the longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the longwalls.

The predicted profiles of conventional subsidence, tilt and curvature along the alignment of Drainage Line 1 are shown in Fig. C.03, in Appendix C. The predicted total profiles along the drainage line, after the extraction of Longwalls B2, B3 and the previously extracted longwalls at the Mine, are shown as the cyan lines. The predicted total profiles after the extraction of each of the proposed Longwalls B4 to B7 are shown as blue lines.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for Drainage Line 1 is provided in Table 5.2. The predictions are the maxima within the Study Area, but also include the predicted movements resulting from the adjacent previously extracted longwalls.

Table 5.2 Maximum predicted total vertical subsidence, tilt and curvature for Drainage Line 1

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Drainage Line 1	After LWB3	700	2.0	0.02	0.05
	After LWB4	900	3.0	0.02	0.06
	After LWB5	1050	3.5	0.04	0.06
	After LWB6	1100	3.5	0.05	0.06
	After LWB7	1150	3.5	0.05	0.06
	After LWB1	1250	4.0	0.05	0.06

The streams are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The remaining drainage lines are located across the Study Area and, therefore, they could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence parameters within the Study Area is provided in Chapter 4.

Quorrobolong Creek and the drainage lines located within the Study Area have shallow incisions into the natural surface soils. It is unlikely, therefore, that these streams would experience any significant valley related movements resulting from the extraction of the proposed longwalls.

5.2.3. Comparisons of the predictions for the streams

The comparisons of the maximum predicted subsidence parameters for the streams, based on the Previous Layout and Current Layout, is provided in Table 5.3 for Quorrobolong Creek and Table 5.4 for Drainage Line 1. The values are the maximum predicted movements for the extents of the streams located within the Study Area due to the extraction of Longwalls B1 to B7.

Table 5.3 Comparison of the maximum predicted total conventional subsidence parameters for Quorrobolong Creek based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	1100	5.0	0.04	0.04
Current Layout (MSEC903)	1100	5.0	0.04	0.04

Table 5.4 Comparison of the maximum predicted total conventional subsidence parameters for Drainage Line 1 based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	1350	3.5	0.04	0.06
Current Layout (MSEC903)	1250	4.0	0.05	0.06

The maximum predicted subsidence parameters for Quorrobolong Creek, based on the Current Layout, are the same as the maxima predicted based on the Previous Layout. The predicted mine subsidence movements for this creek do not change as it is not located near the finishing ends of Longwalls B2 and B3.

The maximum predicted vertical subsidence for Drainage Line 1, based on the Current Layout, is slightly less than the maximum predicted based on the Previous Layout. The maximum predicted tilt and hogging curvature for this drainage line slightly increase as it is located close to the shortened finishing ends of Longwalls B2 and B3. The maximum predicted parameters for Drainage Line 1 are similar to or less than the maxima predicted for other drainage lines located elsewhere above the longwalls.

The predicted increase in the maximum tilt for Drainage Line 1 of 0.5 mm/m represents a change in grade of 1 in 2000 or 0.05 %. The increase in the maximum predicted hogging curvature for this drainage line of 0.01 km^{-1} represents a minimum radius of curvature of 100 km. These changes are very small and are similar to the order of accuracy of the prediction method.

5.2.4. Impact assessments for the streams

The maximum predicted subsidence parameters for Quorrobolong Creek and the drainage lines, based on the Current Layout, are similar to the maxima predicted based on the Previous Layout. The predicted tilts and curvatures for the drainage lines located near the shortened finishing ends of Longwalls B2 and B3 slightly increase; however, these changes are very small and are similar to the order of accuracy of the prediction method. The predicted tilts and curvatures at the shortened finishing ends of Longwalls B2 and B3 are less than the maxima elsewhere above the mining area.

The assessed levels of potential impact for Quorrobolong Creek and the drainage lines, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for the streams, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Further discussions on the potential impacts on the surface water flows are also provided in the reports by Umwelt (2017a and 2017b).

5.3. Aquifers and known groundwater resources

The groundwater resources within the Study Area occur in the shallow alluvial aquifers associated with Quorrobolong Creek, the upper parts of the Branxton Formation and within the deeper Newcastle Coal Measures. Further descriptions of the aquifers within the Study Area are provided in the report by Dundon Consulting (2017).

5.4. Steep slopes

The definition of a steep slope provided in the NSW Department of Planning and Environment Standard and Model Conditions for Underground Mining (DP&E, 2012) is: *"An area of land having a gradient between 1 in 3 (33% or 18.3º) and 2 in 1 (200% or 63.4º)"*. The locations of any steep slopes were identified from the 1 m surface level contours, which were generated from the Light Detection and Ranging (LiDAR) survey of the area.

There are no broad areas that have been identified within the Study Area comprising steep slopes. That is, the natural grades within the Study Area are typically less than 1 in 3. The surface grades are locally greater than 1 in 3, in some isolated locations, such as along the banks of Quorrobolong Creek and the drainage lines. These areas could experience mining inducing cracking, as a result of the proposed longwalls, which is discussed in Section 5.2.

5.5. Land prone to flooding and inundation

The natural gradients along the alignments of Quorrobolong Creek and the lower reaches of the drainage lines are relatively flat and could be prone to flooding and inundation. A detailed flood study of the area has been undertaken and is described in the report by Umwelt (2017b).

5.6. Swamps, wetlands and water related ecosystems

There are no swamps or wetlands identified within the Study Area. There are water related ecosystems associated with the streams which are described in the report by Umwelt (2017c).

5.7. Natural vegetation

The land in the south-eastern part of the Study Area has been predominately cleared for agricultural and light residential uses. The land directly above the proposed longwalls contains large areas of native bushland, as shown in Fig. 5.3, predominately on the Crown and Austar-owned land. Threatened species and ecological communities have been identified within the Study Area and are described by the specialist ecology consultant (Umwelt, 2017c).

The potential for impacts on the natural vegetation is dependent on the surface cracking, changes in surface water and changes in groundwater. It is unlikely that significant surface cracking would occur as a result of the proposed longwalls, as none has been observed at Austar Coal Mine to date. Also, as described in Section 5.2, the streams within the Study Area are ephemeral and it is unlikely that the mining induced tilts would have a significant impact on the surface water flows. Further discussions on the potential impacts on the surface water are provided by Umwelt (2017b).

Fig. 5.3 Aerial photograph overlaid with the proposed Longwalls B4 to B7 and the Study Area

The following sections provide the descriptions, predictions and impact assessments for the built features which have been identified within or in the vicinity of the Study Area, as identified in Chapter 2. The impact assessments are based on the predicted movements due to the extraction of Longwalls B1 to B7, as well as the predicted movements due to the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements due to the existing and proposed longwalls).

6.1. Public roads

The locations of public roads within the Study Area are shown in Drawing No. MSEC903-08. The descriptions, predictions and impact assessments for the roads within the Study Area are provided in the following sections.

6.1.1. Descriptions of the roads

Sandy Creek Road crosses directly above the proposed Longwalls B4 and B5 as well as above the approved Longwalls B1 to B3. The total length of this road located directly above the Bellbird South mining area is approximately 1.8 km, of which approximately 0.9 km is located directly above the proposed longwalls. Sandy Creek Road has also been previously directly mined beneath by Longwalls 1 to 9 at Ellalong Colliery, to the west of the Study Area, with a total length of approximately 2 km located directly above these previously extracted longwalls.

Sandy Creek Road provides access between the township of Ellalong, which is located to the west of the Study Area, and Freemans Drive and Lake Road, which are located east of the Study Area. The section of road within the Study Area has a single carriageway with a bitumen seal and grass verges (i.e. no kerb and guttering), however, there are concrete v-channels adjacent to the road on the hill to the west of Barraba Lane. There is a small cutting above the south-western end of the proposed Longwall B5, which is less than 3 m in height. Drainage culverts are located where the road crosses the drainage lines and these are discussed in Section 6.3.

Barraba Lane is located in the south-eastern corner of the Study Area. The lane is located at a distance of 0.7 km east of Longwall B4, at its closest point to the proposed longwalls. Barraba Lane is an unsealed road that provides access to private properties located to the south of Sandy Creek Road.

Photographs of Sandy Creek Road (left side) and Barraba Lane (right side) are provided in Fig. 6.1.

Fig. 6.1 Sandy Creek Road (left side) and Barraba Lane (right side)

The roads are owned and maintained by the Cessnock City Council.

6.1.2. Predictions for the roads

The predicted profiles of conventional subsidence, tilt and curvature along the alignment of Sandy Creek Road are shown in Fig. C.04, in Appendix C. The predicted total profiles along the road, after the extraction of Longwalls B2, B3 and the previously extracted longwalls at the Mine, are shown as the cyan lines. The predicted total profiles after the extraction of each of the proposed Longwalls B4 to B7 are shown as blue lines. The predicted final profiles after the completion of Longwall B1 are shown as the red lines.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for Sandy Creek Road is provided in Table 6.1. The predictions are the maxima within the Study Area, i.e. do not include the sections of road located above the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine, but include the predicted movements resulting from these previous longwalls.

Table 6.1 Maximum predicted total vertical subsidence, tilt and curvature for Sandy Creek Road

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Sandy Creek Road	After LWB3	500	2.5	0.02	0.04
	After LWB4	875	3.0	0.03	0.05
	After LWB5	1150	3.5	0.03	0.06
	After LWB6	1250	4.0	0.03	0.06
	After LWB7	1300	4.0	0.03	0.06
	After LWB1	1300	4.0	0.03	0.06

The tilts provided in the above table are the maxima predicted along the alignment of Sandy Creek Road after the completion of each of the longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the longwalls.

The roads are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The predicted additional vertical subsidence along Barraba Lane due to the extraction of the proposed Longwalls B4 to B7 is less than 20 mm. Whilst the lane could experience very low levels of additional vertical subsidence due to the proposed longwalls, it is not expected to experience measurable tilts, curvatures or strains.

6.1.3. Comparisons of the predictions for the roads

The comparisons of the maximum predicted subsidence parameters for Sandy Creek Road, based on the Previous Layout and Current Layout, is provided in Table 6.2. The values are the maximum predicted movements for the extent of the road located within the Study Area due to the extraction of Longwalls B1 to B7.

Table 6.2 Comparison of the maximum predicted total conventional subsidence parameters for Sandy Creek Road based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	1350	4.0	0.03	0.06
Current Layout (MSEC903)	1300	4.0	0.03	0.06

The maximum predicted vertical subsidence for Sandy Creek Road, based on the Current Layout, is slightly less than the maximum predicted based on the Previous Layout. The predicted vertical subsidence slightly decreases as the road is located close to the shortened finishing ends of Longwalls B2 and B3. The maximum predicted tilt, hogging curvature and sagging curvature do not change.

The maximum predicted additional vertical subsidence along Barraba Lane, due to the extraction of Longwalls B4 to B7, is 30 mm based on the Previous Layout and less than 20 mm based on the Current Layout. However, the maximum predicted total subsidence for the road after the completion of Longwall B1 does not change.

6.1.4. Impact Assessments for the roads

The maximum predicted subsidence parameters for Sandy Creek Road and Barraba Lane, based on the Current Layout, are the same or slightly less than the maxima predicted based on the Previous Layout. The assessed levels of potential impact for these roads, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for the roads, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Management strategies have previously been developed for the public roads in the Bellbird South mining area for the approved Longwalls B1 to B3. It is recommended that the existing management strategies for the roads be reviewed in consultation with Cessnock City Council and, where required, are revised to include the effects of the proposed longwalls.

6.2. Road bridges

There are no road bridges within the Study Area. The *Quorrobolong Creek Forbes Bridge* (Ref. SCR-B1) is located outside the Study Area at a distance of approximately 0.9 km east of the proposed Longwall B4. The bridge is predicted to experience less than 20 mm vertical subsidence resulting from the extraction of Longwalls B4 to B7. Whilst the bridge could experience very low levels of vertical subsidence, it is not expected to experience measurable tilts, curvatures or strains. It is not anticipated that adverse impacts would occur to the bridge due to the extraction of Longwalls B4 to B7.

6.3. Road drainage culverts

The locations of the road drainage culverts within the Study Area are shown in Drawing No. MSEC903-08. The descriptions, predictions and impact assessments for the culverts within the Study Area are provided in the following sections.

6.3.1. Descriptions of the road drainage culverts

There are three concrete box culverts (Refs. SCR-C1 to SCR-C3) that are located directly above the approved Longwall B3. These double box culverts have overall widths of 5 m and heights between 0.6 and 1.2 m. There is also a double 600 mm diameter concrete culvert (Ref. SCR-C4) located above the maingate of the approved Longwall B3 and a single 1.5 m diameter concrete culvert (Ref. SCR-C5) located above the proposed Longwall B5. Photographs of these culverts are provided in Fig. 6.2 and Fig. 6.3.

Fig. 6.2 Box culverts SCR-C1 (left side) and SCR-C2 (right side)

Fig. 6.3 Box culvert SCR-C3 (left side) and concrete culvert SCR-C4 (right side)

Dual 300 mm diameter circular concrete culverts are also located on Barraba Lane (Ref. BL-C1), near the intersection with Sandy Creek Road, which are directly above the approved Longwall B1. There are also other concrete drainage culverts within the Study Area beneath the driveways to the properties along Sandy Creek Road and Barraba Lane.

6.3.2. Predictions for the road drainage culverts

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for the drainage culverts SCR-C1 to SCR-C5, after the completion of the approved and proposed longwalls, is provided in Table 6.3. The predictions are the maximum values within 20 m of the mapped locations of the culverts.

Table 6.3 Maximum predicted total vertical subsidence, tilt and curvature for the drainage culverts

Layout	Location	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	SCR-C1	1350	1.5	0.02	0.04
	SCR-C2	1350	1.5	0.02	0.06
	SCR-C3	1300	1.5	0.02	0.02
	SCR-C4	1200	1.0	0.03	0.02
	SCR-C5	900	2.5	0.02	0.03
Current Layout (MSEC903)	SCR-C1	1100	2.0	0.01	0.02
	SCR-C2	1150	2.0	0.01	0.04
	SCR-C3	1200	1.0	0.02	0.02
	SCR-C4	1200	1.0	0.02	0.02
	SCR-C5	900	2.5	0.02	0.03

The maximum predicted subsidence parameters for the dual circular culverts BL-C1 are: 150 mm vertical subsidence, 2.0 mm/m tilt, 0.02 km^{-1} hogging curvature and less than 0.01 km^{-1} sagging curvature. The other culverts located outside the extents of the longwalls could also experience vertical subsidence up to around 100 mm.

The culverts are point features and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain measured in individual survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.3.3. Comparisons of the predictions for the drainage culverts

The comparisons of the maximum predicted subsidence parameters for the drainage culverts, based on the Previous Layout and Current Layout, is provided in Table 6.4. The values are the maximum predicted movements within 20 m of their mapped locations due to the extraction of Longwalls B1 to B7.

Table 6.4 Comparison of the maximum predicted total conventional subsidence parameters for the drainage culverts based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	1350	2.5	0.03	0.06
Current Layout (MSEC903)	1200	2.5	0.02	0.04

The maximum predicted subsidence parameters for the drainage culverts, based on the Current Layout, are the same or slightly less than the maximum predicted based on the Previous Layout.

The predicted tilts for Culverts SCR-C2 and SCR-C3 slightly increase as they are located close to the shortened finishing ends of Longwalls B2 and B3. The predicted increase in the tilt for these culverts of 0.5 mm/m represents a change in grade of 1 in 2000 or 0.05 %. These changes are very small and are similar to the order of accuracy of the prediction method.

The remaining predicted subsidence parameters for the individual drainage culverts, based on the Current Layout, are the same or slightly less than those predicted based on the Previous Layout.

6.3.4. Impact assessments for the road drainage culverts

The maximum predicted subsidence parameters for drainage culverts, based on the Current Layout, are similar to the maxima predicted based on the Previous Layout. The predicted tilts for Culverts SCR-C2 and SCR-C3 slightly increase; however, these changes are very small and are similar to the order of accuracy of the prediction method. The predicted tilts for Culverts SCR-C2 and SCR-C3 are also less than the maximum predicted tilt for Culvert SCR-C5.

The assessed levels of potential impact for the drainage culverts, based on the Current Layout, are the same as those based on the Previous Layout. Whilst the predicted subsidence parameters slightly increase for some culverts and slightly decrease for other culverts, the overall levels of predicted movements for these structures do not change. The assessments and recommended management strategies for the culverts, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Management strategies have previously been developed for the public roads, including the drainage culverts, in the Bellbird South mining area for the approved Longwalls B1 to B3. It is recommended that the existing management strategies for the roads and culverts be reviewed in consultation with Cessnock City Council and, where required, are revised to include the effects of the proposed longwalls.

6.4. Electrical infrastructure

The locations of the electrical infrastructure within the Study Area are shown in Drawing No. MSEC903-08. The descriptions, predictions and impact assessments for the electrical infrastructure are provided in the following sections.

6.4.1. Descriptions of the electrical infrastructure

The electrical services comprise above ground 11 kV powerlines supported by timber poles. There are also low voltage powerlines that supply power to the rural properties within the Study Area. The total length of the powerlines located directly above the Bellbird South mining area is approximately 4.3 km, of which 2.4 km is located directly above the proposed longwalls.

Photographs of the 11 kV powerlines within the Study Area are provided in Fig. 6.4.

Fig. 6.4 11 kV powerlines

The powerlines are owned and maintained by Ausgrid.

6.4.2. Predictions for the electrical infrastructure

The powerlines will not be directly affected by the ground strains, as the cables are supported by poles above ground level. The cables, however, may be affected by changes in the bay lengths, i.e. the distances between the poles at the levels of the cables, resulting from differential subsidence, horizontal movements, and tilt at the pole locations. The stabilities of the poles may also be affected by the tilts and by changes in the catenary profiles of the cables.

The predicted profiles of conventional subsidence, tilt along and tilt across the alignments of the 11 kV Powerline Branch 1 (adjacent to Sandy Creek Road) and 11 kV Powerline Branch 2 (north of Sandy Creek Road) are shown in Figs. C.05 and C.06, respectively, in Appendix C. The predicted total profiles along the powerlines, after the extraction of Longwalls B2, B3 and the previously extracted longwalls at the Mine, are shown as the cyan lines. The predicted total profiles after the extraction of each of the proposed Longwalls B4 to B7 are shown as blue lines. The predicted final profiles after the completion of Longwall B1 are shown as the red lines.

A summary of the maximum predicted values of total vertical subsidence and tilt for the powerlines is provided in Table 6.5. The predictions are the maxima within the Study Area, i.e. do not include the sections of the powerlines located above the previously extracted longwalls at Ellalong Colliery and Austar Coal Mine, but include the predicted movements resulting from these adjacent previous longwalls. The values provided in this table are also the maxima anywhere along the powerlines, i.e. not just at the pole locations.

Table 6.5 Maximum predicted total vertical subsidence and tilt for the 11 kV powerlines

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt along the alignment (mm/m)	Maximum predicted total tilt across the alignment (mm/m)
11 kV Powerline Branch 1	After LWB3	550	2.5	1.5
	After LWB4	900	3.0	1.5
	After LWB5	1100	3.5	1.5
	After LWB6	1250	3.5	1.5
	After LWB7	1300	4.0	3.0
	After LWB1	1300	4.0	3.0
11 kV Powerline Branch 2	After LWB3	175	1.5	< 0.5
	After LWB4	175	1.5	< 0.5
	After LWB5	450	1.5	3.0
	After LWB6	1050	4.0	2.0
	After LWB7	1200	4.0	1.5
	After LWB1	1250	4.0	1.5

The maximum predicted tilt in any direction at the powerpole locations is 4.0 mm/m (i.e. 0.4 %, or 1 in 250). The maximum predicted horizontal movement at the tops of the powerpoles, based on a pole height of 15 m, is 120 mm.

6.4.3. Comparisons of the predictions for the electrical infrastructure

The comparisons of the maximum predicted subsidence parameters for the electrical infrastructure, based on the Previous Layout and Current Layout, is provided in Table 6.6 for Powerline 1 and Table 6.7 for Powerline 2. The values are the maximum predicted movements for the extents of the powerlines located within the Study Area due to the extraction of Longwalls B1 to B7.

Table 6.6 Comparison of the maximum predicted total conventional subsidence parameters for Powerline 1 based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt along the alignment (mm/m)	Maximum predicted total tilt across the alignment (mm/m)
Previous Layout (MSEC869)	1350	4.0	3.0
Current Layout (MSEC903)	1300	4.0	3.0

Table 6.7 Comparison of the maximum predicted total conventional subsidence parameters for Powerline 2 based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt along the alignment (mm/m)	Maximum predicted total tilt across the alignment (mm/m)
Previous Layout (MSEC869)	1200	4.0	1.5
Current Layout (MSEC903)	1250	4.0	1.5

The maximum predicted vertical subsidence for Powerline 1, based on the Current Layout, is slightly less than the maximum predicted based on the Previous Layout. The predicted vertical subsidence slightly decreases as it is located close to the shortened finishing ends of Longwalls B2 and B3. The maximum predicted tilts for this powerline do not change.

The maximum predicted vertical subsidence for Powerline 2, based on the Current Layout, is slightly greater than the maximum predicted based on the Previous Layout. The predicted vertical subsidence slightly increases due to the modified mining sequence, with Longwall B1 extracted after the completion of Longwalls B4 to B7, rather than after the completion of Longwall B3. However, the maximum predicted tilts for this powerline do not change.

6.4.4. Impact assessments for the electrical infrastructure

The maximum predicted subsidence parameters for the powerlines, based on the Current Layout, are similar to the maxima predicted based on the Previous Layout. The maximum predicted vertical subsidence at Powerline 1 slightly decreases, whilst the maximum predicted vertical subsidence at Powerline 2 slightly increases.

The potential for impacts on powerlines is affected by tilt and horizontal movement, rather than absolute vertical subsidence. The maximum predicted tilts and horizontal movements for the powerlines, based on the Current Layout, are the same as the maxima predicted based on the Previous Layout.

The assessed levels of potential impact for the powerlines, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for the powerlines, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Management strategies have previously been developed for the 11 kV and consumer powerlines in the Bellbird South mining area for the approved Longwalls B1 to B3. It is recommended that the existing management strategies for the powerlines be reviewed in consultation with Ausgrid and, where required, are revised to include the effects of the proposed longwalls.

6.5. Telecommunications infrastructure

The locations of the telecommunications infrastructure within the Study Area are shown in Drawing No. MSEC903-08. The descriptions, predictions and impact assessments for the telecommunications infrastructure are provided in the following sections.

6.5.1. Description of the telecommunications infrastructure

The telecommunication infrastructure within the Study Area are owned by Telstra and comprise underground copper cables with some aerial connections to the houses. The cables generally follow the alignments of Sandy Creek Road and Barraba Lane and service the rural properties within the Study Area. The total length of the copper telecommunications cables located directly above the Bellbird South mining area is approximately 3.3 km, of which 1.0 km is located directly above the proposed longwalls. There are no optical fibre cables located within the Study Area.

6.5.2. Predictions for the telecommunications infrastructure

The copper telecommunications cables within the Study Area generally follow the alignments of the public roads. The predicted profiles of subsidence, tilt and curvature for these copper cables, therefore, are similar to those predicted along Sandy Creek Road which are shown in Fig. C.03, in Appendix C.

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for the copper telecommunications cable, after the completion of each of the longwalls, is provided in Table 6.8.

Table 6.8 Maximum predicted total vertical subsidence, tilt and curvature for the copper telecommunications cables

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Copper telecommunications cables	After LWB3	500	3.0	0.02	0.04
	After LWB4	875	4.0	0.04	0.05
	After LWB5	1150	5.0	0.04	0.06
	After LWB6	1250	5.0	0.04	0.06
	After LWB7	1300	5.0	0.04	0.06
	After LWB1	1300	5.5	0.04	0.06

The tilts and curvatures provided in the above table are the maxima predicted in any direction at any time during or after the extraction of each of the longwalls.

The cables are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.5.3. Comparisons of the predictions for the telecommunications infrastructure

The comparisons of the maximum predicted subsidence parameters for the copper telecommunications cables, based on the Previous Layout and Current Layout, is provided in Table 6.9. The values are the maximum predicted movements for the extent of the copper cables located within the Study Area due to the extraction of Longwalls B1 to B7.

Table 6.9 Comparison of the maximum predicted total conventional subsidence parameters for the copper telecommunications cables based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	1350	5.0	0.03	0.06
Current Layout (MSEC903)	1300	5.5	0.04	0.06

The maximum predicted vertical subsidence for the copper telecommunications cables, based on the Current Layout, is slightly less than the maximum predicted based on the Previous Layout. The predicted vertical subsidence slightly decreases as the cables are located close to the shortened finishing ends of Longwalls B2 and B3. The maximum predicted sagging curvature does not change.

The maximum predicted tilt and hogging curvature for the copper telecommunications cables slightly increase as they are located close to the shortened finishing ends of Longwalls B2 and B3. The predicted tilts and curvatures away from this location do not change.

The predicted increase in the maximum tilt for the copper telecommunications cables of 0.5 mm/m represents a change in grade of 1 in 2000 or 0.05 %. The increase in the maximum predicted hogging curvature for the cables of 0.01 km^{-1} represents a minimum radius of curvature of 100 km. These changes are very small and are similar to the order of accuracy of the prediction method.

6.5.4. Impact assessments for the telecommunications infrastructure

The maximum predicted subsidence parameters for the copper telecommunications cables, based on the Current Layout, are similar to the maxima predicted based on the Previous Layout. The maximum predicted tilt and hogging curvature for the cables located near the shortened finishing ends of Longwalls B2 and B3 slightly increase; however, these changes are very small and are similar to the order of accuracy of the prediction method. The predicted subsidence parameters for the cables located elsewhere above the mining area do not change.

The assessed levels of potential impact for the copper telecommunications cables, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for these cables, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Management strategies have previously been developed for the copper telecommunications cables in the Bellbird South mining area for the approved Longwalls B1 to B3. It is recommended that the existing management strategies for the cables be reviewed in consultation with Telstra and, where required, are revised to include the effects of the proposed longwalls.

6.6. Agricultural utilisation

The land in the south-eastern part of the Study Area has been predominately cleared for agricultural and light residential uses. The land directly above the proposed longwalls contains large areas of native bushland, as can be seen in Fig. 5.3, but also includes built features associated with agricultural and residential use. The descriptions, predictions and impact assessments for the built features on these rural properties are provided in the following sections.

The potential for impacts on the land use within the Study Area can occur from mining-induced surface cracking, changes in surface water drainage and changes in groundwater. It is unlikely that significant surface cracking would occur as a result of the proposed longwalls, as none has been observed at Austar Coal Mine to date. Also, as described in Section 5.2, the streams within the Study Area are ephemeral and it is unlikely that the mining induced tilts would have a significant impact on the surface water flows. Further discussions on the potential impacts on the surface water drainage are provided by Umwelt (2017b).

6.7. Rural structures

6.7.1. Descriptions of the rural structures

The rural structures (Structure Type R) are shown in Drawing No. MSEC903-09. The locations, sizes and details of the rural structures were determined from the aerial photograph of the area and from kerb side inspections.

There are 48 rural structures that have been identified within the Study Area, of which 20 are located directly above the proposed Longwalls B4 to B7 and 14 are located directly above the approved Longwalls B1 to B3. The rural structures within the Study Area are generally of lightweight construction and include farm sheds, garages, tanks and other non-residential structures.

6.7.2. Predictions for the rural structures

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at the vertices of each rural building structure, as well as at eight equally spaced points placed radially around the centroid and vertices at a distance of 20 m. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure.

The predicted total conventional subsidence, tilts and curvatures for the rural structures within the Study Area are provided in Table D.01, in Appendix D. A summary of the maximum predicted subsidence parameters for the rural structures on each of the properties within the Study Area is provided in Table 6.10. The values include the predicted movements resulting from the previous extraction of the adjacent longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements).

Table 6.10 Maximum predicted total vertical subsidence, tilt and curvature for the rural structures

Property	Number of rural structures	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
A01	2	125	1.0	0.01	< 0.01
A02	9	825	5.5	0.04	0.03
A06	3	175	1.0	0.01	< 0.01
A08	6	825	4.0	0.03	0.02
B03	7	925	2.5	0.01	0.02
C01	4	1200	1.5	0.03	0.02
C02	10	1200	1.0	0.03	0.03
C03	2	30	< 0.5	< 0.01	< 0.01
C05	5	100	1.0	< 0.01	< 0.01

The tilts provided in the above table are the maxima predicted in any directions at the completion of the longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the longwalls.

The rural structures are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.7.3. Comparisons of the predictions for the rural structures

The comparisons of the maximum predicted subsidence parameters for the rural structures on each of the properties, based on the Previous Layout and Current Layout, is provided in Table 6.11. The values are the maximum predicted movements within 20 m of each of the structures within the Study Area due to the extraction of Longwalls B1 to B7.

Table 6.11 Comparison of the maximum predicted total conventional subsidence parameters for the rural structures based on the Previous Layout and Current Layout

Layout	Property	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	A01	200	1.5	0.02	< 0.01
	A02	825	5.0	0.03	0.02
	A06	225	2.0	0.02	< 0.01
	A08	825	4.0	0.03	0.02
	B03	950	2.5	0.01	0.04
	C01	1200	1.0	0.02	0.02
	C02	1200	1.0	0.03	0.03
	C03	30	< 0.5	< 0.01	< 0.01
	C05	100	1.0	< 0.01	< 0.01
Current Layout (MSEC903)	A01	125	1.0	0.01	< 0.01
	A02	825	5.5	0.04	0.03
	A06	175	1.0	0.01	< 0.01
	A08	825	4.0	0.03	0.02
	B03	925	2.5	0.01	0.02
	C01	1200	1.5	0.03	0.02
	C02	1200	1.0	0.03	0.03
	C03	30	< 0.5	< 0.01	< 0.01
	C05	100	1.0	< 0.01	< 0.01

The predicted vertical subsidence for each of the rural structures, based on the Current Layout, are the same or slightly less than those predicted based on the Previous Layout.

The predicted tilts and curvatures for the rural structures on Properties A02 and C01 slightly increase as they are located close to the shortened finishing ends of Longwalls B2 and B3. The predicted increase in tilt for these structures of 0.5 mm/m represents a change in grade of 1 in 2000 or 0.05 %. The predicted increase in curvature for these structures of 0.01 km^{-1} represents a minimum radius of curvature of 100 km. These changes are very small and are similar to the order of accuracy of the prediction method.

The remaining predicted subsidence parameters for the individual rural structures, based on the Current Layout, are the same or slightly less than those predicted based on the Previous Layout.

6.7.4. Impact assessments for the rural structures

The maximum predicted subsidence parameters for the rural structures, based on the Current Layout, are similar to the maxima predicted based on the Previous Layout. The predicted tilts and curvatures for the structures located on Properties A02 and C01 slightly increase; however, these changes are very small and are similar to the order of accuracy of the prediction method.

The maximum predicted tilt for the rural structures of 5.5 mm/m represents a change in grade of 0.55 % or 1 in 180. The maximum predicted curvature for the rural structures 0.04 km^{-1} represents a minimum radius of curvature of 25 km. Whilst the predicted subsidence parameters slightly increase for some rural structures and slightly decrease for other rural structures, the overall levels of predicted movements for these structures do not change.

There is extensive experience of mining directly beneath rural structures in the Southern Coalfield, where the maximum predicted subsidence parameters are similar to or greater than the maxima predicted for the proposed longwalls. This incidence of impacts on these types of structures is very low, with adverse impacts generally reported for the larger industrial type sheds. This is not unexpected, as rural structures are generally small in size and of light-weight construction and they are less susceptible to impact than houses that are typically more rigid. In all cases, the rural structures remained in safe and serviceable conditions.

The assessed levels of potential impact for the rural structures, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for these structures, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Built Features Management Plans have previously been developed for properties located above and adjacent to the approved Longwalls B1 to B3. It is recommended that similar management plans are developed for the additional properties within the Study Area.

6.8. Gas and fuel storages

There are domestic gas and fuel storages on the rural properties within the Study Area and, therefore, they could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The storage tanks are generally elevated above ground level and, therefore, are not susceptible to mine subsidence movements. It is possible, however, that any buried gas pipelines associated with the storage tanks within the Study Area could be impacted by the ground strains, if they are anchored by the storage tanks, or by other structures in the ground. Any impacts would be expected to be of a minor nature, including minor gas leaks, which could be easily repaired. It is unlikely that there would be any significant impacts on the pipelines associated with the gas and fuel storage tanks.

6.9. Farm fences

There are fences within the Study Area that are constructed in a variety of ways, generally using either timber or 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. Wire fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without any significant impact.

The fences are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The fences are linear features and, therefore, the most relevant distributions of strain are the maximum strains measured along whole monitoring lines. The analysis of strain along whole monitoring lines during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

It is possible that some of the wire fences within the Study Area would be impacted as a result of the extraction of the proposed longwalls. Any impacts on the wire fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

Colorbond and timber paling fences are more rigid than wire fences and, therefore, are more susceptible to impacts resulting from mine subsidence movements. It is possible that these types of fences could be impacted as the result of the extraction of the proposed longwalls. Any impacts on Colorbond or timber paling fences are expected to be of a minor nature and relatively easy to remediate or, where necessary, to replace.

6.10. Farm dams

6.10.1. Descriptions of the farm dams

The farm dams (Structure Type D) are shown in Drawing No. MSEC903-09. The locations and sizes of the dams were determined from the aerial photograph of the area. There are 24 farm dams that have been identified within the Study Area, of which six are located directly above the proposed Longwalls B4 to B7 and 11 are located directly above the approved Longwalls B1 to B3.

The farm dams are typically of earthen construction and have been established by localised cut and fill operations along the natural drainage lines. The largest dam is Ref. C03d01, which is located on land owned by the Mine, above the finishing (i.e. north-eastern) end of the proposed Longwall B7. This dam has a surface area of 46,900 m^2 and a maximum dimension of 440 m. The remaining dams within the Study Area have surface areas ranging between 30 and 6,220 m^2 and maximum plan dimensions ranging between 8 and 160 m.

6.10.2. Predictions for the farm dams

The predicted total conventional subsidence, tilts and curvatures for the farm dams within the Study Area are provided in Table D.02, in Appendix D. A summary of the maximum predicted subsidence parameters for the farm dams on each of the properties within the Study Area is provided in Table 6.12. The values include the predicted movements resulting from the previous extraction of the adjacent longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements).

Table 6.12 Maximum predicted total vertical subsidence, tilt and curvature for the farm dams

Property	Number of farm dams	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
A01	1	200	2.0	0.03	< 0.01
A02	1	175	1.5	0.02	< 0.01
A04	1	375	3.5	0.04	< 0.01
A06	4	375	3.5	0.04	< 0.01
A07	1	700	4.5	0.04	< 0.01
A08	2	625	4.0	0.03	0.02
B01	3	1300	2.5	0.02	0.06
B02	2	825	4.0	0.02	0.02
B03	3	750	3.5	0.03	0.01
C01	1	1350	1.5	0.02	0.06
C03	2	625	4.5	0.04	0.03
C05	2	40	< 0.5	< 0.01	< 0.01
C06	1	60	< 0.5	0.01	< 0.01

The tilts provided in the above table are the maxima predicted in any directions at the completion of the longwalls. The curvatures are the maxima predicted in any direction at any time during or after the extraction of each of the longwalls.

The farm dams are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.10.3. Comparison of the predictions for the farm dams

The comparisons of the maximum predicted subsidence parameters for the farm dams on each of the properties, based on the Previous Layout and Current Layout, is provided in Table 6.13. The values are the maximum predicted movements within 20 m of each of the dams within the Study Area due to the extraction of Longwalls B1 to B7.

Table 6.13 Comparison of the maximum predicted total conventional subsidence parameters for the farm based on the Previous Layout and Current Layout

Layout	Property	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	A01	300	3.0	0.02	< 0.01
	A02	175	1.5	0.02	< 0.01
	A04	375	3.5	0.04	< 0.01
	A06	525	4.5	0.03	0.03
	A07	675	4.5	0.04	< 0.01
	A08	625	4.0	0.03	0.02
	B01	1300	2.5	0.02	0.06
	B02	825	4.5	0.02	0.02
	B03	700	4.0	0.02	0.02
	C01	1,250	1.5	0.02	0.04
	C03	625	4.5	0.04	0.03
	C05	40	< 0.5	< 0.01	< 0.01
	C06	60	< 0.5	0.01	< 0.01
Current Layout (MSEC903)	A01	200	2.0	0.03	< 0.01
	A02	175	1.5	0.02	< 0.01
	A04	375	3.5	0.04	< 0.01
	A06	375	3.5	0.04	< 0.01
	A07	700	4.5	0.04	< 0.01
	A08	625	4.0	0.03	0.02
	B01	1300	2.5	0.02	0.06
	B02	825	4.0	0.02	0.02
	B03	750	3.5	0.03	0.01
	C01	1350	1.5	0.02	0.06
	C03	625	4.5	0.04	0.03
	C05	40	< 0.5	< 0.01	< 0.01
	C06	60	< 0.5	0.01	< 0.01

The maximum predicted vertical subsidence for the dams on Properties A01 and A06, based on the Current Layout, are less than the maxima predicted based on the Previous Layout by 100 to 150 mm. The predicted vertical subsidence for these dams decrease as they are located close to the shortened finishing ends of Longwalls B2 and B3.

The maximum predicted vertical subsidence for the dams on Properties A07, B03 and C01, based on the Current Layout, are greater than the maxima predicted based on the Previous Layout by 25 to 100 mm. The predicted vertical subsidence for these dams increase due to the modified mining sequence.

The predicted tilts for the dams within the Study Area, based on the Current Layout, are the same or less than those predicted based on the Previous Layout.

The maximum predicted hogging curvatures for the dams on Properties A01, A06 and B03 and the maximum predicted sagging curvature for the dams on Property C01 slightly increase. The changes in these predicted curvatures are due to the shortened finishing ends of Longwalls B2 and B3 and the modified mining sequence. The predicted increase in the curvatures for these dams of 0.01 km^{-1} hogging and 0.01 km^{-1} sagging represent minimum radii of curvatures of 100 km and 50 km, respectively. These changes are very small and are similar to the order of accuracy of the prediction method.

The remaining predicted subsidence parameters for the individual farm dams, based on the Current Layout, are the same or slightly less than those predicted based on the Previous Layout.

6.10.4. Impact assessments for the farm dams

The maximum predicted subsidence parameters for the farm dams, based on the Current Layout, are similar to the maxima predicted based on the Previous Layout. The predicted vertical subsidence slightly decreases for some dams and slightly increases for other dams within the Study Area. The potential for impacts on farm dams is not affected by absolute vertical subsidence.

The maximum predicted tilts for the farm dams, based on the Current Layout, are the same or less than the maxima predicted based on the Previous Layout. The maximum predicted curvatures for the farm dams on Properties A01, A06, B03 and C01 slightly increase. The maximum predicted curvatures for the farm dams on the other properties are the same or decrease.

Whilst the predicted subsidence parameters slightly increase for some farm dams and slightly decrease for other farm dams, the overall levels of predicted movements for these features do not change.

The maximum predicted curvatures for the dams within the Study Area are similar to the maxima predicted for the farm dams that were located above the previously extracted longwalls at the Mine. There were 14 farm dams located directly above Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 and there were no reported mining related impacts.

There is also extensive experience of mining directly beneath farm dams in the Southern Coalfield, where the maximum predicted subsidence parameters are similar to or greater than the maxima predicted for the proposed longwalls. This incidence of impacts on farm dams is very low, being less than 0.5 %.

The assessed levels of potential impact for the farm dams, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for these dams, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Built Features Management Plans have previously been developed for properties located above and adjacent to the approved Longwalls B1 to B3. It is recommended that similar management plans are developed for the additional properties within the Study Area.

6.11. Groundwater bores

The locations of the groundwater bores near the proposed longwalls are shown in Drawing No. MSEC903-09. The locations and details of the registered groundwater bores were obtained from the *Natural Resource Atlas* website (NRAtlas, 2017).

There are three registered groundwater bores that have been identified within the Study Area, which are shown in Drawing No. MSEC903-09. A summary of these bores is provided in Table 6.14. There are two other bores (Refs. GW080973 and GW054676) that have been decommissioned and, therefore, have not been shown in the drawing nor included in the table.

Table 6.14 Registered groundwater bores within the Study Area

Reference	Location	Authorised use	Owner
GW201408	Above the finishing end of the proposed Longwall B5	Monitoring	Austar Mine (Ref. NER1010)
GW080974	Located outside and adjacent to the finishing end of the proposed Longwall B4	Monitoring	DPI - Water
GW080975	Located outside and adjacent to the finishing end of the proposed Longwall B4	Monitoring	DPI - Water

It is possible that the groundwater bores could experience some impacts as a result of mining the proposed longwalls. Impacts could include temporary lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality.

Such impacts on the groundwater bores can be readily managed, by repairing or replacing the bores at the completion of mining. If required, temporary alternative supplies of water could be provided by the Mine during the mining period.

Further discussions on the potential impacts on the groundwater resources are provided in the report by Dundon Consulting (2017).

6.12. Archaeological sites

6.12.1. Descriptions of the archaeological sites

Archaeological sites have been identified within the Study Area than comprise artefact scatters and isolated finds (Umwelt, 2017d). The boundaries for the larger artefact scatter sites and the isolated finds are shown in Drawing No. MSEC903-09. The archaeological sites are generally located near Quorrobolong Creek and the associated tributaries.

6.12.2. Predictions for the archaeological sites

A summary of the maximum predicted values of total vertical subsidence, tilt and curvature for the archaeological sites within the Study Area, after the completion of each of the longwalls, is provided in Table 6.15.

Table 6.15 Maximum predicted total vertical subsidence, tilt and curvature for the archaeological sites located within the Study Area

Location	Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Archaeological sites	After LWB3	125	1.5	0.03	< 0.01
	After LWB4	125	1.5	0.03	< 0.01
	After LWB5	425	3.0	0.03	0.01
	After LWB6	1050	3.5	0.03	0.03
	After LWB7	1250	5.0	0.04	0.03
	After LWB1	1250	5.0	0.04	0.03

The archaeological sites are predicted to experience mine subsidence movements up to 1250 mm vertical subsidence, 5.0 mm/m tilt (i.e. 0.5 %), 0.04 km^{-1} hogging and sagging curvatures (25 km minimum radius of curvature).

The archaeological sites are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.12.3. Comparisons of the predictions for the archaeological sites

The comparisons of the maximum predicted subsidence parameters for the archaeological sites, based on the Previous Layout and Current Layout, is provided in Table 6.16. The values are the maximum predicted movements within 20 m of their mapped locations due to the extraction of Longwalls B1 to B7.

Table 6.16 Comparison of the maximum predicted total conventional subsidence parameters for the archaeological sites based on the Previous Layout and Current Layout

Layout	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	1225	4.5	0.04	0.04
Current Layout (MSEC903)	1250	5.0	0.04	0.03

The maximum predicted vertical subsidence and tilt for the archaeological sites, based on the Current Layout, are similar to but slightly greater than the maxima predicted based on the Previous Layout. The predicted increase in the maximum tilt of 0.5 mm/m represents a change in grade of 1 in 2000 or 0.05 %. This change is very small and is in the order of accuracy of the prediction method.

The maximum predicted hogging and sagging curvatures for the archaeological sites, based on the Current Layout, are the same or slightly less than the maxima predicted based on the Previous Layout.

6.12.4. Impact assessments for the archaeological sites

The archaeological sites could potentially be affected by cracking of the surface soils as a result of the proposed mining. The potential for surface cracking is affected by curvature and strain, rather than by absolute vertical subsidence and tilt. The maximum predicted curvatures and strains for the archaeological sites, based on the Current Layout, are the same or slightly less than the maxima predicted based on the Previous Layout.

The assessed levels of potential impact for the archaeological sites, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for the archaeological sites, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Archaeological sites are located above the previously extracted Longwalls A3 to A5A in Stage 2 and Longwalls A7 and A8 in Stage 3 at the Mine. There has been minimal visible surface cracking above these previously extracted longwalls. There have also been no reported adverse mining related impacts on the artefact scatters and isolated finds.

Management strategies should be developed to remediate any surface cracking, if required, in the vicinity of the archaeological sites. Further assessments of the potential impacts on the archaeological sites are provided in a report by Umwelt (2017d).

6.13. Survey control marks

The locations of the survey control marks near the proposed longwalls are shown in Drawing No. MSEC903-09. The locations and details of the state survey control marks were obtained from the *Land and Property Management Authority* using the *Six Viewer* (2017).

There are four survey control marks identified within the Study Area, located along the alignment of Sandy Creek Road. These marks are located directly above the approved and proposed longwalls and, therefore, they could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

Additional survey control marks located further afield could be affected by far-field horizontal movements, up to 3 km outside the extents of the proposed longwalls. Far-field horizontal movements and the methods used to predict such movements are described further in Section 4.5.

It will be necessary on the completion of the proposed longwalls, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between Austar and the Department of Lands will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

6.14. Houses

6.14.1. Descriptions of the houses

There are six houses (Structure Type H) that have been identified within the Study Area, of which three are located directly above the proposed Longwalls B4 to B7 and one is located directly above the approved Longwalls B1 to B3. The locations of these houses are shown in Drawing No. MSEC903-09 and details provided in Table 6.17. The sizes of the houses were determined from the aerial photograph of the area. The types of construction of the houses were determined, where possible, from kerb side inspections.

Table 6.17 Descriptions of the houses

Structure ref.	Maximum planar dimension (m)	Number of Storeys	Wall construction	Footing construction	Roof construction
A02d	20	Single	Timber Frame	Piers	Metal
A06a	16	Single	Timber Frame	Slab on Ground	Metal
A08h01	24	Single	Timber Frame	Piers	Metal
C02h01	16	Double	Timber Frame	Piers	Metal
C04h01	23	Single	Steel Frame	Slab on Ground	Metal
C05h01	13	Single	Timber Frame	Piers	Tiles

House Ref. A02d is located above the approved Longwall B3. House Ref. A08h01 is located directly above the maingate of the proposed Longwall B5, near the finishing end of this longwall. House Ref. C02h01 is located above the middle of the proposed Longwall B5. House C04h01 is located above the commencing (i.e. south-western) end of the proposed Longwall B6. The remaining two houses are located outside the extents of the approved and proposed longwalls, at distances between 50 and 100 m.

6.14.2. Predictions for the houses

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at the vertices of each house, as well as at eight equally spaced points placed radially around the centroid and vertices at a distance of 20 m. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure.

The predicted total conventional subsidence, tilts and curvatures for the houses within the Study Area are provided in Table D.03, in Appendix D. A summary of the maximum predicted subsidence parameters for each of the houses within the Study Area is provided in Table 6.18. The values include the predicted movements resulting from the previous extraction of the adjacent longwalls at Ellalong Colliery and Austar Coal Mine (i.e. cumulative movements).

Table 6.18 Maximum predicted total vertical subsidence, tilt and curvature for the houses

Type	Location	Maximum predicted total vertical subsidence (mm)	Maximum predicted final total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Houses	A02d	700	5.5	0.04	0.02
	A06a	125	0.5	< 0.01	< 0.01
	A08h01	700	3.5	0.02	0.02
	C02h01	1200	1	0.03	0.03
	C04h01	450	3.5	0.03	0.02
	C05h01	90	1	< 0.01	< 0.01

The houses are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

6.14.3. Comparison of the predictions for the houses

The comparisons of the maximum predicted subsidence parameters for the houses on each of the properties, based on the Previous Layout and Current Layout, is provided in Table 6.19. The values are the maximum predicted movements within 20 m of each of the structures within the Study Area due to the extraction of Longwalls B1 to B7.

Table 6.19 Comparison of the maximum predicted total conventional subsidence parameters for the houses based on the Previous Layout and Current Layout

Layout	Location	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
Previous Layout (MSEC869)	A02d	725	5.0	0.03	< 0.01
	A06a	175	1.0	0.02	< 0.01
	A08h01	700	3.5	0.02	0.02
	C02h01	1200	1.0	0.03	0.03
	C04h01	450	3.5	0.03	0.02
	C05h01	90	1.0	< 0.01	< 0.01
Current Layout (MSEC903)	A02d	700	5.5	0.04	0.02
	A06a	125	0.5	< 0.01	< 0.01
	A08h01	700	3.5	0.02	0.02
	C02h01	1200	1	0.03	0.03
	C04h01	450	3.5	0.03	0.02
	C05h01	90	1	< 0.01	< 0.01

The predicted vertical subsidence for each of the houses, based on the Current Layout, are the same or slightly less than those predicted based on the Previous Layout.

The predicted tilt for House A02d slightly increases and the predicted tilt for House A06a slightly decreases. The predicted changes in tilt for these houses of 0.5 mm/m represents a change in grade of 1 in 2000 or 0.05 %. These changes are very small and are similar to the order of accuracy of the prediction method.

The predicted curvatures for House A02d increase by 0.01 km^{-1} hogging and 0.02 km^{-1} sagging, which represent minimum radii of curvatures of 100 km and 50 km, respectively. The predicted curvatures for this house increase as it is located above the shortened finishing end of Longwall B3.

The remaining predicted subsidence parameters for the individual houses, based on the Current Layout, are the same or slightly less than those predicted based on the Previous Layout.

6.14.4. Impact assessments for the houses

The predicted vertical subsidence and tilt for the houses within the Study Area, based on the Current Layout, are similar to those predicted based on the Previous Layout. The predicted tilt slightly increases for one house and slightly decreases for another house, but the overall levels of predicted movement do not change.

The predicted curvatures for House A02d increase; however, their magnitudes are similar to the predicted curvatures for the other houses within the Study Area. The predicted curvatures for the remaining houses do not change or slightly reduce.

The maximum predicted curvatures and strains for the houses within the Study Area are similar to the maxima predicted for the houses located above the previously extracted longwalls in Stages 2 at the Mine. Longwalls A3 to A5a were extracted directly beneath seven houses and no substantial impacts were reported.

The assessed levels of potential impact for the houses, based on the Current Layout, are the same as those based on the Previous Layout. Whilst the predicted subsidence parameters slightly increase for some houses and slightly decrease for other houses, the overall levels of predicted movements for these structures do not change. The assessments and recommended management strategies for the houses, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

Built Features Management Plans have previously been developed for properties located above and adjacent to the approved Longwalls B1 to B3. It is recommended that similar management plans are developed for the additional properties within the Study Area. It is recommended that the houses are periodically visually monitored during the extraction of the proposed longwalls.

6.15. Pools

There is one privately owned swimming pool (Ref. C02p01) identified within the Study Area, which is located above the proposed Longwall B5. This pool is located near House Ref. C02h01, which is shown in Drawing No. MSEC903-09.

The predicted subsidence parameters for the swimming pool are included in in Table D.01, in Appendix D. The maximum predicted parameters are: 1200 mm vertical subsidence; 1.0 mm/m tilt (i.e. 0.1 %, or 1 in 1000); 0.03 km^{-1} hogging and sagging curvatures (33 km minimum radius).

The predicted subsidence parameters for the private swimming pool, based on the Current Layout, are the same as those predicted based on the Previous Layout.

The assessed levels of potential impact for the private pool, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for the pool, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

It is recommended that the pool is included in the Built Features Management Plan for this property.

6.16. On-site waste water systems

The residences on the rural properties within the Study Area have on-site waste water systems. The systems are located near the houses and, therefore, are expected to experience similar mine subsidence movements as the houses which are provided in Table D.03, in Appendix D.

The on-site waste water systems are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays. The analysis of strain in survey bays during the extraction of the previous longwalls at the Mine is discussed in Section 4.4.1.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

Whilst the predicted subsidence parameters slightly increase for some properties and slightly decrease for other properties, the overall levels of predicted movements for the structures on these properties do not change.

The assessed levels of potential impact for the on-site waste water systems, based on the Current Layout, are the same as those based on the Previous Layout. The assessments and recommended management strategies for these systems, therefore, are the same as those previously provided in Report No. MSEC869 and the Modification Application.

It is recommended that the on-site waste water systems are included in the Built Features Management Plans for the properties.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

Some of the more common 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.
Closure	The reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms.
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, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
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.
Far-field movements	The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain.
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.
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, i.e. from rib to rib.

Shear deformations	The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.
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, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.
Super-critical area	An area of panel greater than the critical area.
Tilt	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 horizontal 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 %, or 1 in 1000.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

APPENDIX B. REFERENCES

References

DMR (1988). *Geological Series Sheet 9132-2-S*. Department of Mineral Resources, 1988.

DP&E (2012). *Standard and Model Conditions for Underground Mining*. NSW Department of Planning and Environment. http://www.planning.nsw.gov.au/Portals/0/Development/SSD_-_Draft_Model_Conditions_-_Underground_Mine.pdf.

Dundon Consulting (2017). *Austar Coal Mine – LWB4-LWB7 Modification – Groundwater Assessment.* Dundon Consulting Pty Limited, April 2017.

Forster (1995). *Impact of Underground Mining in Engineering Geology of the Newcastle-Gosford Region*. Forster, I., R.

Ives, et al (1999). *Revision of the Stratigraphy of the Newcastle Coal Measures*. Ives, M., Brinton, J., Edwards, J., Rigby, R., Tobin, C., Weber, C.R. pp 113-117.

Kratzsch, H., (1983). *Mining Subsidence Engineering*, Published by Springer - Verlag Berlin Heidelberg New York.

Lohe and Dean-Jones, (1995). *Structural Geology of the Newcastle-Gosford Region*. Lohe, E.M., Dean-Jones, G.L. Proceedings of the Australian Geomechanics Society conference on Engineering Geology of the Newcastle-Gosford Region: The University of Newcastle, Newcastle, NSW, Australia, 5-7 Feb, 1995.

McNally, et al (1996). *Geological Factors influencing Longwall-Induced Subsidence*. McNally, G.H., Willey, P.L. and Creech, M. Symposium on Geology in Longwall mining, 12-13 November 1996, Eds G.H. McNally and C.R. Ward, pp 257-267.

Moelle and Dean-Jones, (1995). *The Geological Setting of the Newcastle and Central Coast Region: An Engineering-Geological Overview*. Moelle, K.H.R., Dean-Jones, G.L. Proceedings of the Australian Geomechanics Society conference on Engineering Geology of the Newcastle-Gosford Region: The University of Newcastle, Newcastle, NSW, Australia, 5th to 7th February 1995.

NRAtlas, (2017). *Natural Resource Atlas* website, viewed on the 9th February 2017. The Department of Natural Resources. http://nratlas.nsw.gov.au/

Peng and Chiang (1984). *Longwall Mining*. Wiley, Peng S.S. & Chiang H.S. New York, pg 708.

Singh and Kendorski (1981). *Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments*. Singh, M., M., Kendorski, F., S. Proceedings of the 1st Annual Conference on Ground Control in Mining, Morgantown WV, July 1981.

Six Viewer (2017). Spatial Information Exchange, accessed on the 9th February 2017. Land and Property Information. https://www.six.nsw.gov.au/wps/portal/

Sloan and Allman (1995). *Engineering Geology of the Newcastle-Gosford Region*. Sloan, S.W. and Allman, M.A. The University of Newcastle NSW, 5-7 February 1995, Australian Geomechanics Society, 1995. pp 14-19.

Umwelt (2017a). *LWB4-B7 Modification Environmental Assessment.* Prepared for Austar Coal Mine. Umwelt (Australia) Pty Limited, April 2017.

Umwelt (2017b). *LWB4-B7 Modification Flooding and Drainage Assessment.* Umwelt (Australia) Pty Limited, April 2017.

Umwelt (2017c). *LWB4-B7 Modification Ecological Assessment.* Umwelt (Australia) Pty Limited, April 2017.

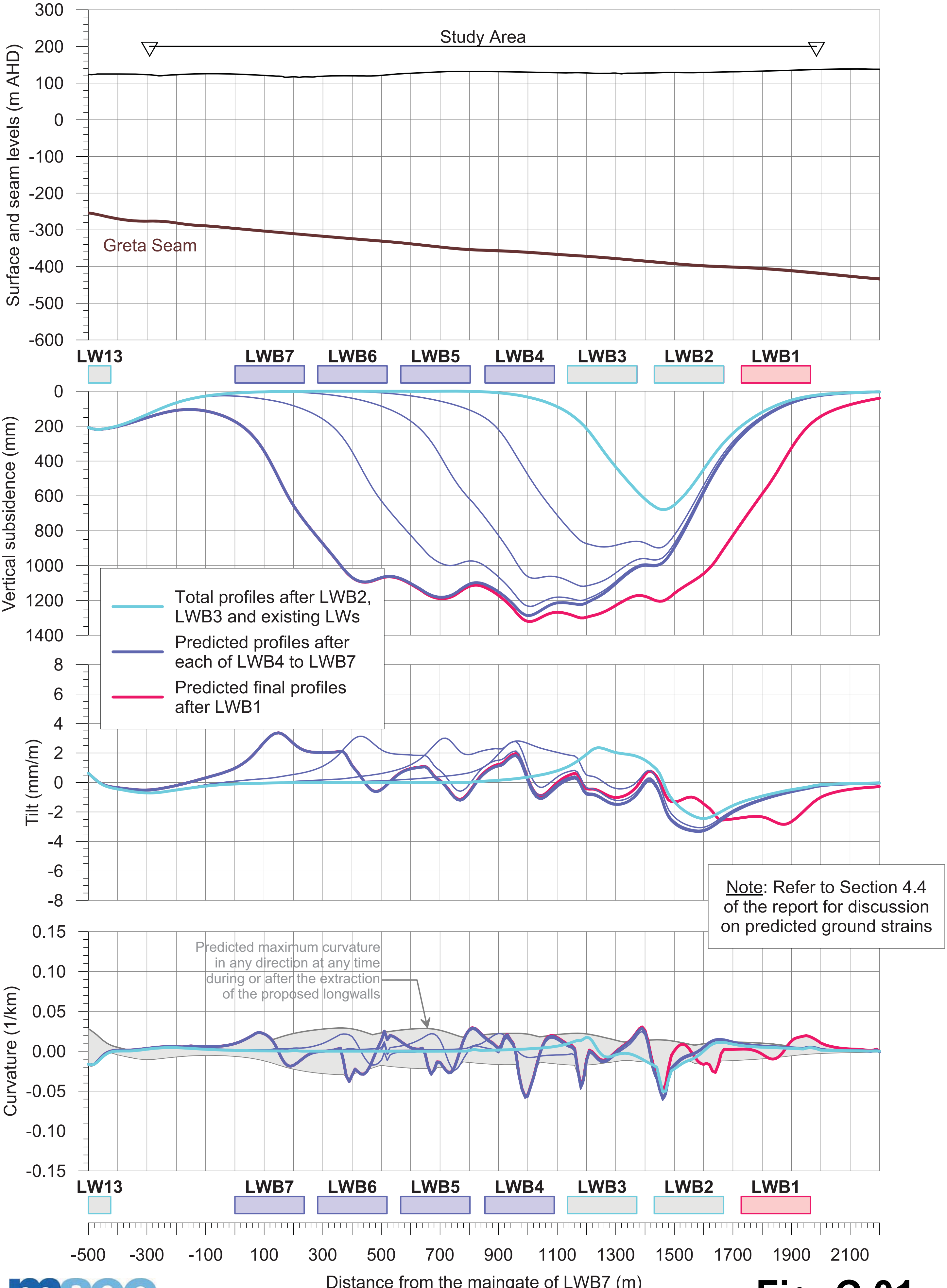
Umwelt (2017d). *LWB4-B7 Modification Aboriginal Cultural Heritage Assessment*. Umwelt (Australia) Pty Limited, April 2017.

Waddington and Kay (1998). *Development of the Incremental Profile Method of Predicting Subsidence and its Application in the Newcastle Coalfield*. Mine Subsidence Technological Society, Fourth Triennial Conference on Buildings and Structures Subject to Ground Movement. Newcastle, July, 1998

Waddington and Kay (2002). *Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems*. Waddington, A.A. and Kay, D.R. ACARP Research Projects Nos. C8005 and C9067, September 2002.

APPENDIX C. FIGURES

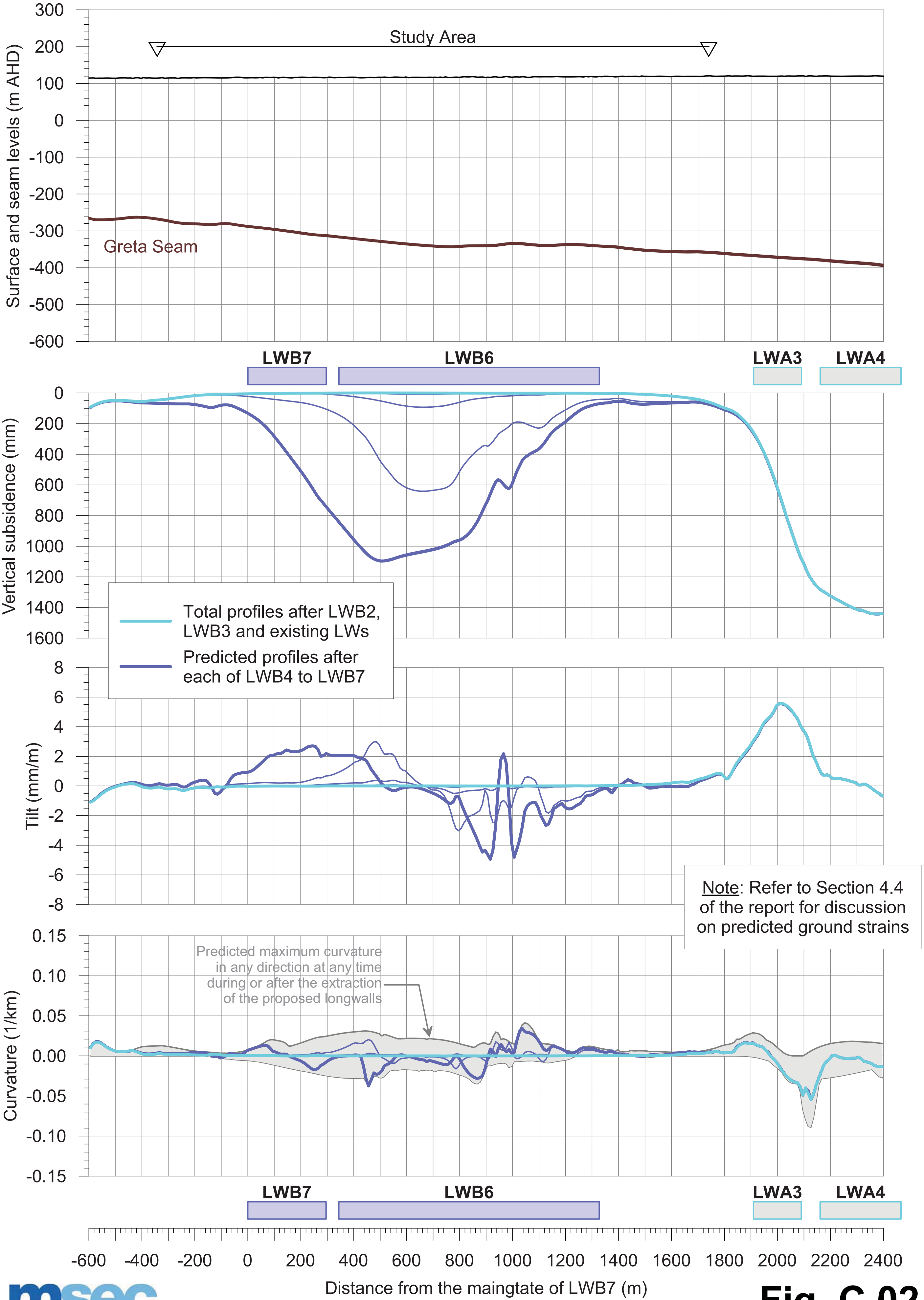
Predicted profiles of conventional subsidence, tilt and curvature along Prediction Line 1 resulting from the extraction of Longwalls B1 to B7



msec

Fig. C.01

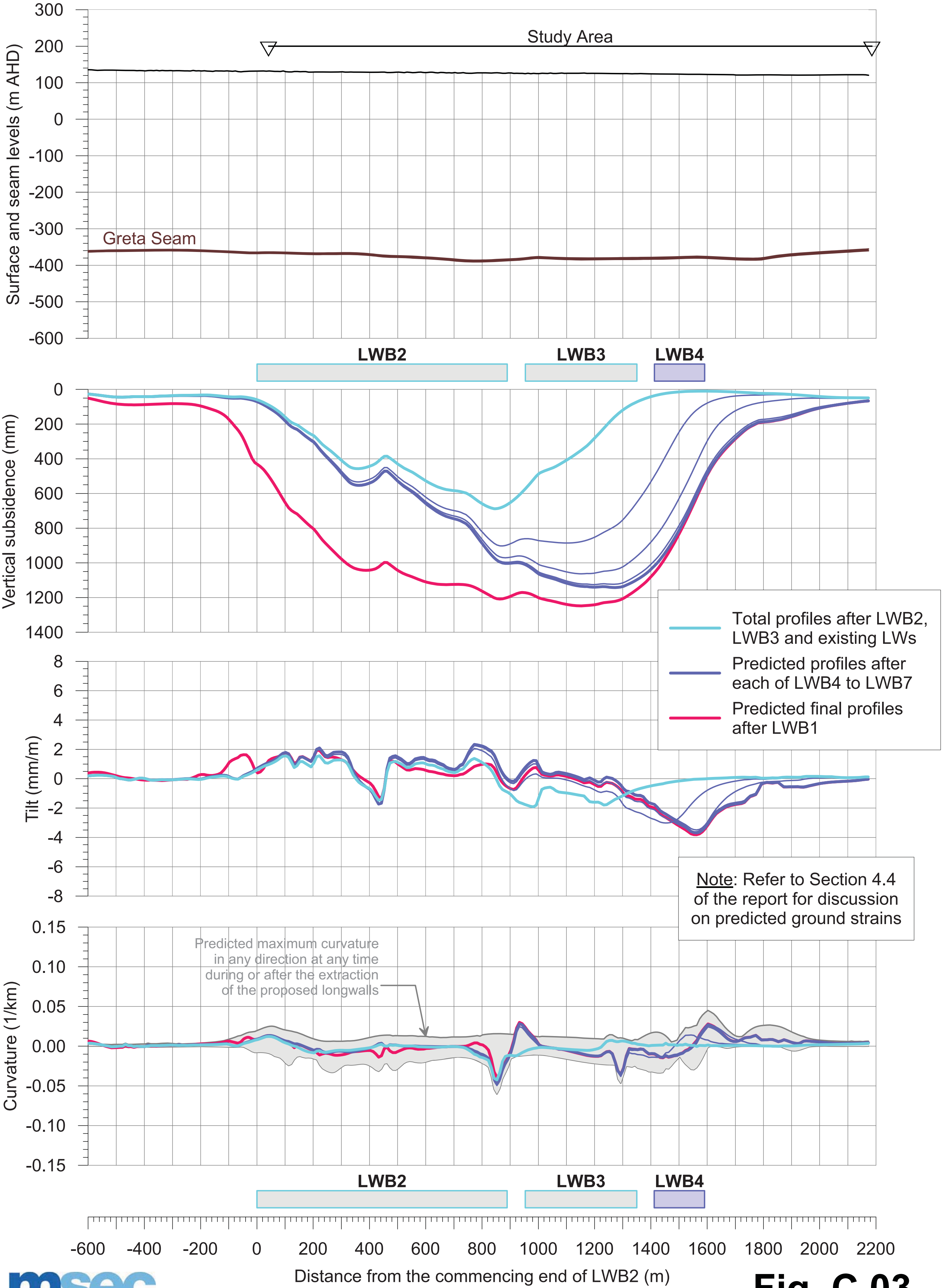
Predicted profiles of conventional subsidence, tilt and curvature along Quorrobolong Creek resulting from the extraction of Longwalls B1 to B7



msec

Fig. C.02

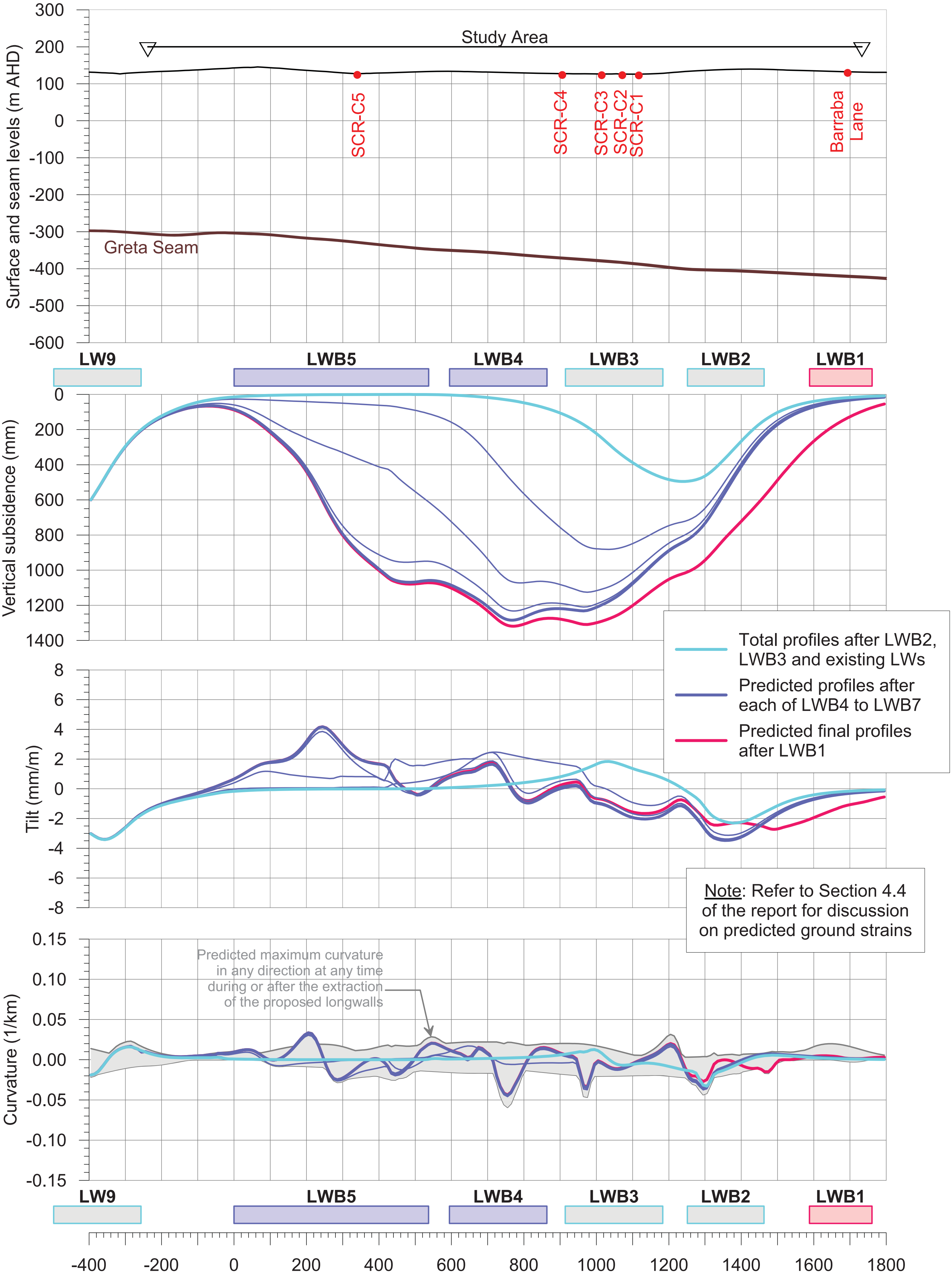
Predicted profiles of conventional subsidence, tilt and curvature along Drainage Line 1 resulting from the extraction of Longwalls B1 to B7



msec

Fig. C.03

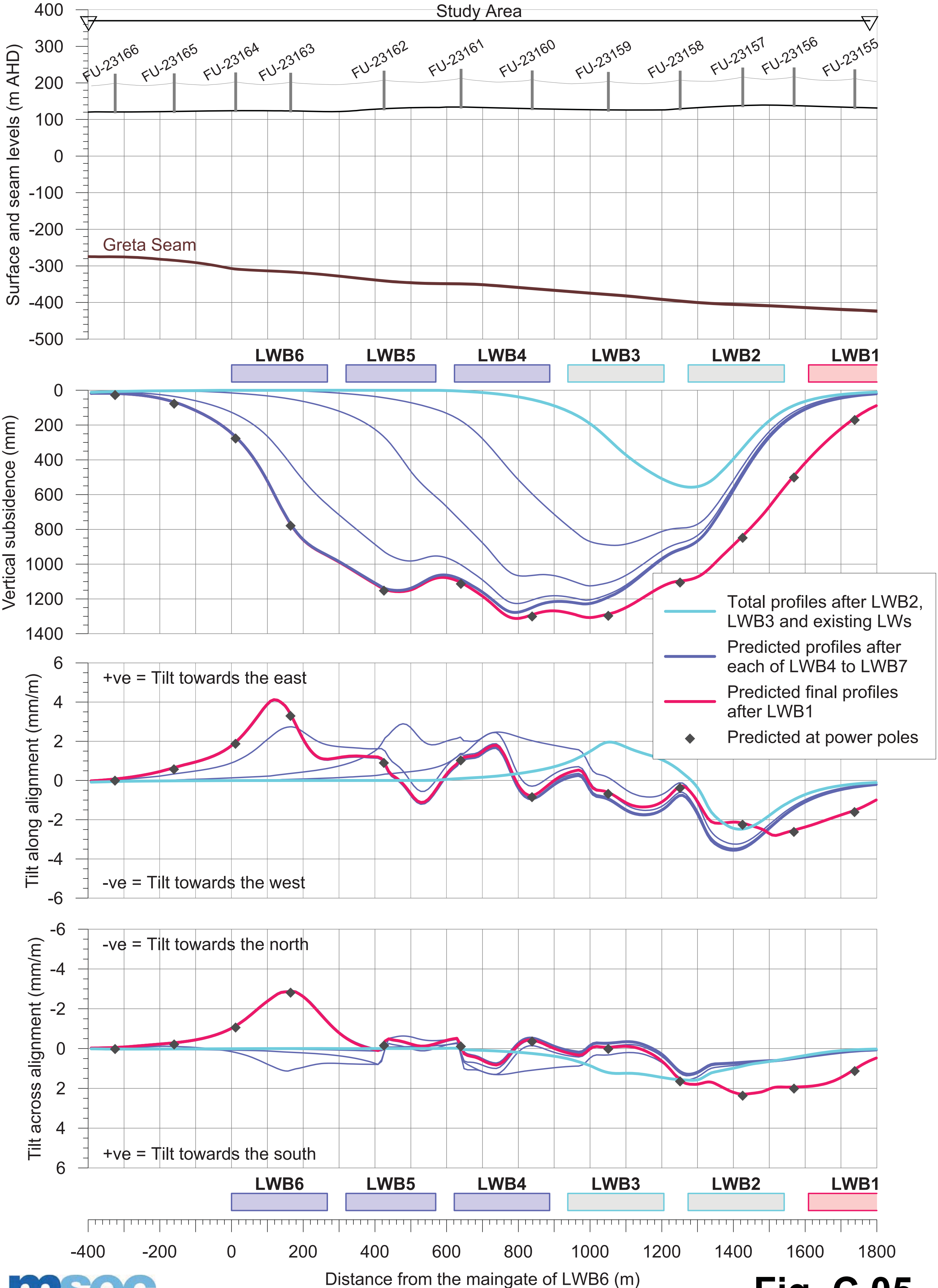
Predicted profiles of conventional subsidence, tilt and curvature along Sandy Creek Road resulting from the extraction of Longwalls B1 to B7



msec

Fig. C.04

Predicted profiles of conventional subsidence, tilt along and tilt across the 11 kV Powerline Branch 1 resulting from the extraction of Longwalls B1 to B7



Predicted Profiles of conventional subsidence, tilt along and tilt across the 11 kV Powerline Branch 2 resulting from the extraction of Longwalls B1 to B7

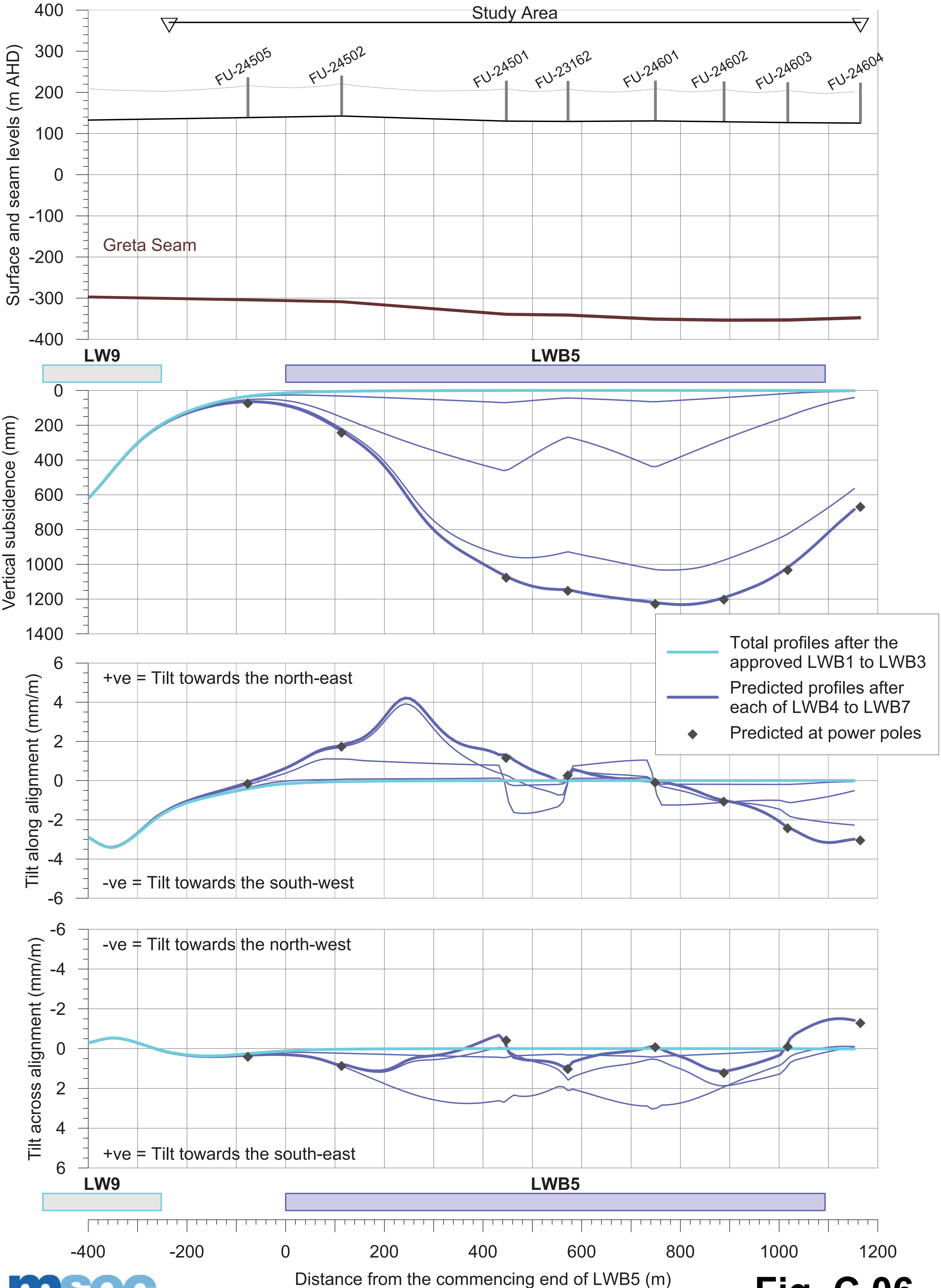


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Fig. C.06

APPENDIX D. TABLES

Table D.01 - Maximum predicted subsidence parameters for the rural structures within the Study Area

Property Reference	Structure Reference (refer to Drawing No. MSEC903-09)	Type	Predicted Total Subsidence after LWB2 and LWB3 (mm)	Predicted Total Subsidence after LWB4 (mm)	Predicted Total Subsidence after LWB5 (mm)	Predicted Total Subsidence after LWB6 (mm)	Predicted Total Subsidence after LWB7 (mm)	Predicted Total Subsidence after LWB2 to LWB7 and LWB1 (mm)	Predicted Total Tilt after LWB2 to LWB7 and LWB1 (mm/m)	Predicted Total Hogging Curvature after LWB2 to LWB7 and LWB1 (1/km)	Predicted Total Sagging Curvature after LWB2 to LWB7 and LWB1 (1/km)
A01	A01j	Shed	40	50	60	60	60	125	1.0	< 0.01	< 0.01
	A01k	Tank	40	50	60	70	70	125	1.0	< 0.01	< 0.01
A02	A02a	Shed	70	80	100	125	125	125	< 0.5	0.01	< 0.01
	A02b	Shed	60	80	100	125	125	125	0.5	0.01	< 0.01
	A02c	Shed	50	400	625	725	725	775	5.5	0.04	0.02
	A02e	Shed	40	375	600	700	725	775	5.5	0.04	< 0.01
	A02f	Shed	60	450	675	750	775	825	5.5	0.04	0.03
	A02g	Shed	20	250	475	600	625	650	5.0	0.04	< 0.01
	A02h	Tank	30	325	525	625	650	675	5.5	0.04	< 0.01
	A02i	Tank	40	325	550	650	675	700	5.5	0.04	< 0.01
	A02j	Tank	40	350	575	675	700	725	5.5	0.04	< 0.01
A06	A06b	Shed	40	90	125	150	150	175	1.0	0.01	< 0.01
	A06c	Shed	40	90	125	150	150	175	1.0	0.01	< 0.01
	A06d	Shed	40	90	125	150	175	175	1.0	0.01	< 0.01
A08	A08r01	Shed	< 20	< 20	30	525	650	650	4.0	0.03	0.02
	A08r02	Shed	< 20	< 20	40	550	725	725	4.0	0.03	0.02
	A08r03	Shed	< 20	< 20	50	600	775	775	4.0	0.03	0.02
	A08r04	Shed	< 20	< 20	80	700	825	825	3.5	0.02	0.02
	A08t01	Tank	< 20	< 20	60	625	750	750	3.5	0.02	0.02
	A08t02	Tank	< 20	< 20	80	700	825	825	3.5	0.02	0.02
B03	B03r07	Shed	225	250	275	275	275	775	2.0	0.01	0.02
	B03r08	Shed	300	350	375	375	375	875	2.5	0.01	0.02
	B03r09	Shed	350	400	400	400	425	925	2.5	0.01	0.02
	B03r10	Tank	275	325	325	325	325	850	2.5	0.01	0.02
	B03r11	Tank	250	275	300	300	300	800	2.5	0.01	0.02
	B03r12	Tank	275	325	325	325	325	825	2.5	< 0.01	0.02
	B03r13	Shed	300	350	350	375	375	875	2.5	0.01	0.02
C01	C01r01	Shed	< 20	250	900	1100	1200	1200	1.5	0.02	0.02
	C01r02	Tank	< 20	250	875	1100	1200	1200	1.0	0.02	0.02
	C01r03	Shed	< 20	150	725	1050	1150	1150	1.0	0.03	0.02
	C01r04	Shed	< 20	225	850	1100	1200	1200	1.0	0.02	0.02
C02	C02p01	Pool	< 20	50	350	975	1200	1200	1.0	0.03	0.03
	C02r01	Garage	< 20	50	325	975	1200	1200	1.0	0.03	0.03
	C02r02	Shed	< 20	50	300	975	1200	1200	1.0	0.03	0.03
	C02r03	Shed	< 20	40	275	950	1200	1200	1.0	0.03	0.03
	C02r04	Shed	< 20	40	275	950	1150	1200	1.0	0.03	0.02
	C02r05	Shed	< 20	40	250	925	1150	1150	1.0	0.03	0.02
	C02r06	Shed	< 20	50	350	1000	1200	1200	1.0	0.03	0.03
	C02r07	Gazebo	< 20	70	450	1000	1200	1200	0.5	0.03	0.03
	C02t01	Tank	< 20	50	325	975	1200	1200	1.0	0.03	0.03
	C02t02	Tank	< 20	50	350	1000	1200	1200	1.0	0.03	0.03
C03	C03r01	Shed	< 20	< 20	< 20	20	30	30	< 0.5	< 0.01	< 0.01
	C03r02	Shed	< 20	< 20	< 20	20	30	30	< 0.5	< 0.01	< 0.01
C05	C05r01	Shed	< 20	< 20	40	70	80	80	1.0	< 0.01	< 0.01
	C05r02	Awning	< 20	< 20	40	80	90	100	1.0	< 0.01	< 0.01
	C05t01	Tank	< 20	< 20	30	60	70	80	0.5	< 0.01	< 0.01
	C05t02	Tank	< 20	< 20	40	70	80	80	1.0	< 0.01	< 0.01
	C05t03	Tank	< 20	< 20	50	90	100	100	1.0	< 0.01	< 0.01
		Maximum	**350**	**450**	**900**	**1100**	**1200**	**1200**	**5.5**	**0.04**	**0.03**

Table D.02 - Maximum predicted subsidence parameters for the farm dams within the Study Area

Property Reference	Dam Reference (refer to Drawing No. MSEC903-09)	Maximum Planar Dimension (m)	Surface Area (m2)	Predicted Total Subsidence after LWB2 and LWB3 (mm)	Predicted Total Subsidence after LWB4 (mm)	Predicted Total Subsidence after LWB5 (mm)	Predicted Total Subsidence after LWB6 (mm)	Predicted Total Subsidence after LWB7 (mm)	Predicted Total Subsidence after LWB2 to LWB7 and LWB1 (mm)	Predicted Total Tilt after LWB2 to LWB7 and LWB1 (mm/m)	Predicted Total Hogging Curvature after LWB2 to LWB7 and LWB1 (1/km)	Predicted Total Sagging Curvature after LWB2 to LWB7 and LWB1 (1/km)	Predicted Total Change in Freeboard (mm)
A01	A01d06	71	1467	40	60	70	80	80	200	2.0	0.03	< 0.01	< 50
A02	A02d01	133	6223	70	70	80	150	175	175	1.5	0.02	< 0.01	< 50
A04	A04d06	83	1806	375	375	375	375	375	375	3.5	0.04	< 0.01	150
A06	A06d01	81	2968	40	175	275	325	350	375	3.5	0.04	< 0.01	150
	A06d02	28	480	60	70	90	90	100	125	0.5	< 0.01	< 0.01	< 50
	A06d03	60	968	80	125	150	175	200	250	2.0	0.03	< 0.01	< 50
	A06d04	9	52	40	70	125	150	150	175	1.0	0.01	< 0.01	< 50
A07	A07d01	80	2464	< 20	40	300	625	675	700	4.5	0.04	< 0.01	200
A08	A08d01	76	2549	< 20	< 20	40	550	625	625	4.0	0.03	0.02	200
	A08d02	40	417	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01	< 50
B01	B01d01	40	956	300	350	375	375	375	900	2.5	0.01	0.01	100
	B01d02	47	879	375	875	1100	1200	1200	1300	1.0	0.02	0.03	< 50
	B01d03	35	1044	40	550	1050	1200	1250	1300	2.0	0.02	0.06	< 50
B02	B02d01	63	1714	125	150	150	150	150	575	3.0	0.01	< 0.01	150
	B02d02	34	718	475	600	625	625	625	825	4.0	0.02	0.02	100
B03	B03d03	82	806	80	90	90	90	90	400	3.0	0.02	< 0.01	100
	B03d04	41	955	80	100	100	100	100	175	1.0	0.01	< 0.01	< 50
	B03d05	8	29	400	450	450	475	475	750	3.5	0.03	0.01	< 50
C01	C01d01	63	1695	60	625	1100	1250	1300	1350	1.5	0.02	0.06	< 50
C03	C03d01	439	46886	70	70	70	150	625	625	4.5	0.04	0.03	500
	C03d02	159	3432	< 20	< 20	< 20	100	475	475	4.0	0.03	0.03	300
C05	C05d01	34	686	< 20	< 20	< 20	30	40	40	< 0.5	< 0.01	< 0.01	< 50
	C05d02	25	405	< 20	< 20	< 20	< 20	20	20	< 0.5	< 0.01	< 0.01	< 50
C06	C06d01	46	1006	50	50	50	60	60	60	< 0.5	0.01	< 0.01	< 50
			Maximum	**475**	**875**	**1100**	**1250**	**1300**	**1350**	**4.5**	**0.04**	**0.06**	**500**

Table D.03 - Maximum Predicted Subsidence Parameters for the Houses within the Study Area

Structure Reference (refer to Drawing No. MSEC903-09)	Predicted Total Subsidence after LWB2 and LWB3 (mm)	Predicted Total Subsidence after LWB4 (mm)	Predicted Total Subsidence after LWB5 (mm)	Predicted Total Subsidence after LWB6 (mm)	Predicted Total Subsidence after LWB7 (mm)	Predicted Total Subsidence after LWB2 to LWB7 and LWB1 (mm)	Predicted Total Tilt after LWB2 and LWB3 (mm/m)	Predicted Total Tilt after LWB4 (mm/m)	Predicted Total Tilt after LWB5 (mm/m)	Predicted Total Tilt after LWB6 (mm/m)	Predicted Total Tilt after LWB7 (mm/m)	Predicted Total Tilt after LWB2 to LWB7 and LWB1 (mm/m)
A02d	50	350	550	650	650	700	0.5	4.0	5.0	5.0	5.0	5.5
A06a	60	80	100	125	125	125	< 0.5	< 0.5	< 0.5	0.5	0.5	0.5
A08h01	< 20	< 20	50	600	700	700	< 0.5	< 0.5	0.5	3.0	3.5	3.5
C02h01	< 20	60	400	1000	1200	1200	< 0.5	< 0.5	3.0	2.0	1.0	1.0
C04h01	< 20	< 20	90	400	450	450	< 0.5	< 0.5	0.5	3.0	3.5	3.5
C05h01	< 20	< 20	40	80	90	90	< 0.5	< 0.5	< 0.5	1.0	1.0	1.0
Maximum	**60**	**350**	**550**	**1000**	**1200**	**1200**	**0.5**	**4.0**	**5.0**	**5.0**	**5.0**	**5.5**

Table D.03 - Maximum Predicted Subsidence Parameters for the Houses within the Study Area

Structure Reference (refer to Drawing No. MSEC903-09)	Predicted Total Hogging Curvature after LWB2 and LWB3 (1/km)	Predicted Total Hogging Curvature after LWB4 (1/km)	Predicted Total Hogging Curvature after LWB5 (1/km)	Predicted Total Hogging Curvature after LWB6 (1/km)	Predicted Total Hogging Curvature after LWB7 (1/km)	Predicted Total Hogging Curvature after LWB2 to LWB7 and LWB1 (1/km)	Predicted Total Sagging Curvature after LWB2 and LWB3 (1/km)	Predicted Total Sagging Curvature after LWB4 (1/km)	Predicted Total Sagging Curvature after LWB5 (1/km)	Predicted Total Sagging Curvature after LWB6 (1/km)	Predicted Total Sagging Curvature after LWB7 (1/km)	Predicted Total Sagging Curvature after LWB2 to LWB7 and LWB1 (1/km)
A02d	< 0.01	0.04	0.04	0.04	0.04	0.04	< 0.01	0.02	0.02	0.02	0.02	0.02
A06a	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
A08h01	< 0.01	< 0.01	< 0.01	0.02	0.02	0.02	< 0.01	< 0.01	< 0.01	0.02	0.02	0.02
C02h01	< 0.01	< 0.01	0.02	0.03	0.03	0.03	< 0.01	< 0.01	< 0.01	0.03	0.03	0.03
C04h01	< 0.01	0.01	0.01	0.03	0.03	0.03	< 0.01	0.01	0.01	0.02	0.02	0.02
C05h01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Maximum	**< 0.01**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**< 0.01**	**0.02**	**0.02**	**0.03**	**0.03**	**0.03**

APPENDIX E. DRAWINGS

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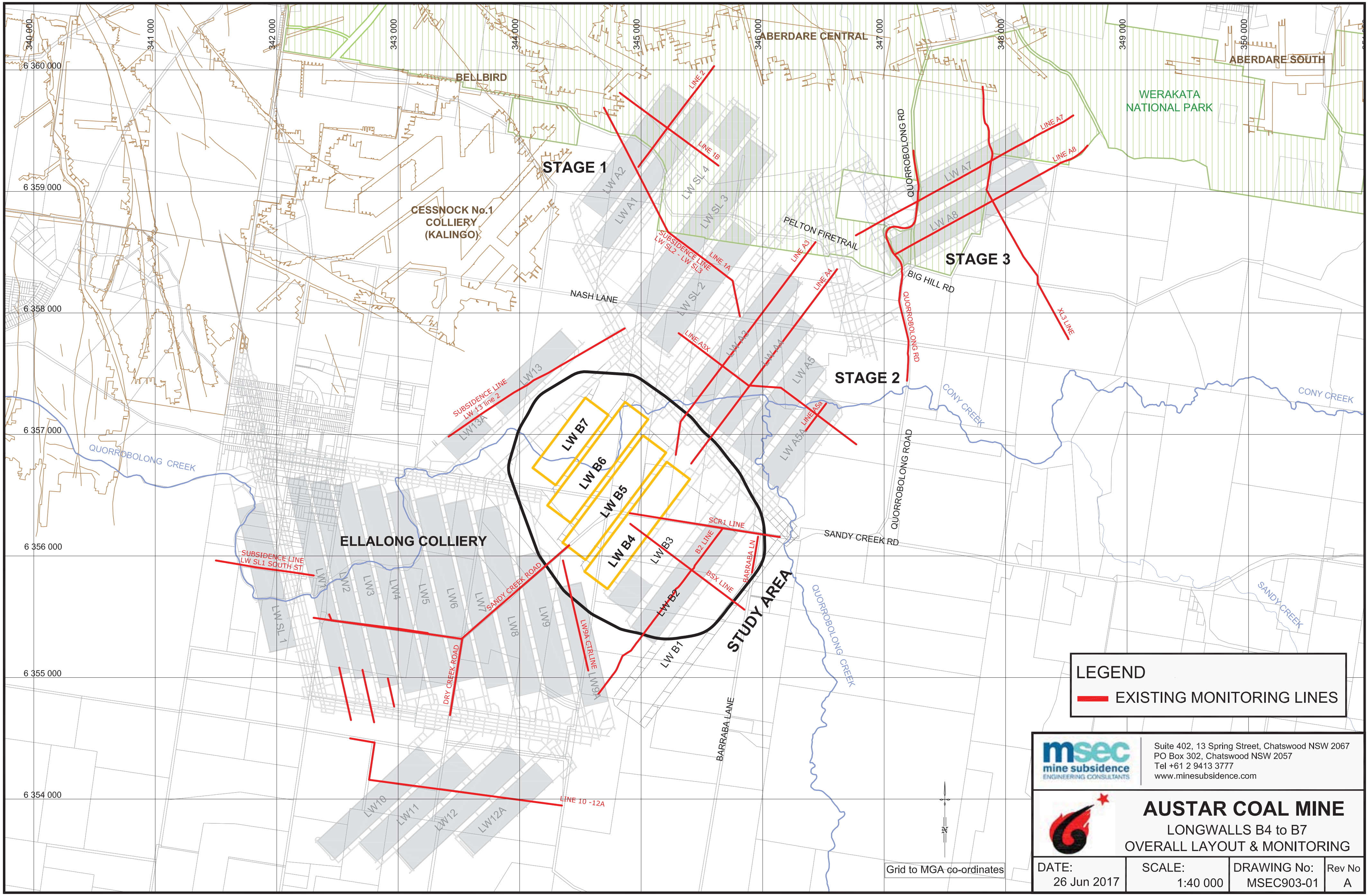

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LONGWALLS B4 to B7
OVERALL LAYOUT & MONITORING

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26 Jun 2017	1:40 000	MSEC903-01	A

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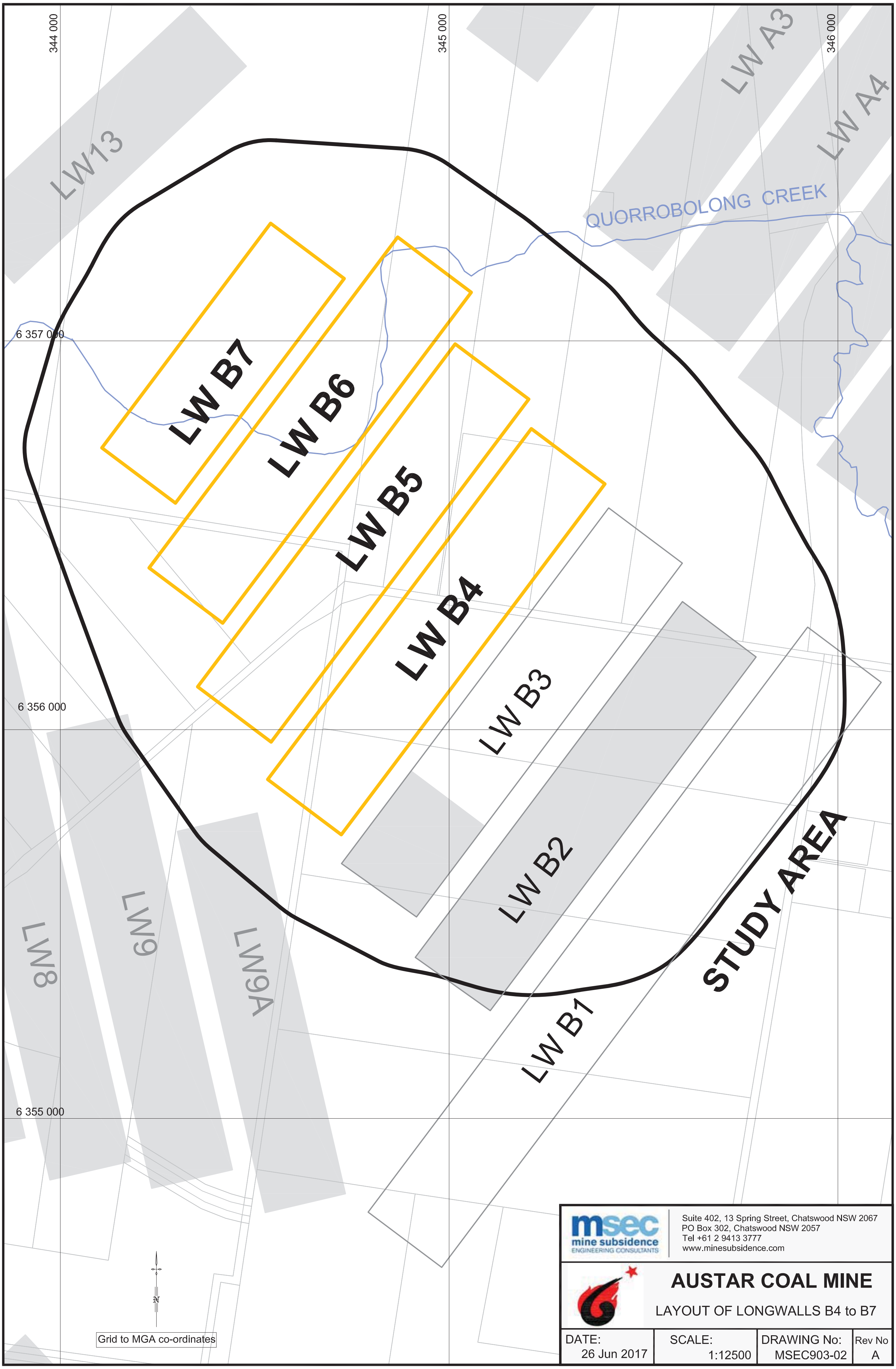

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LAYOUT OF LONGWALLS B4 to B7

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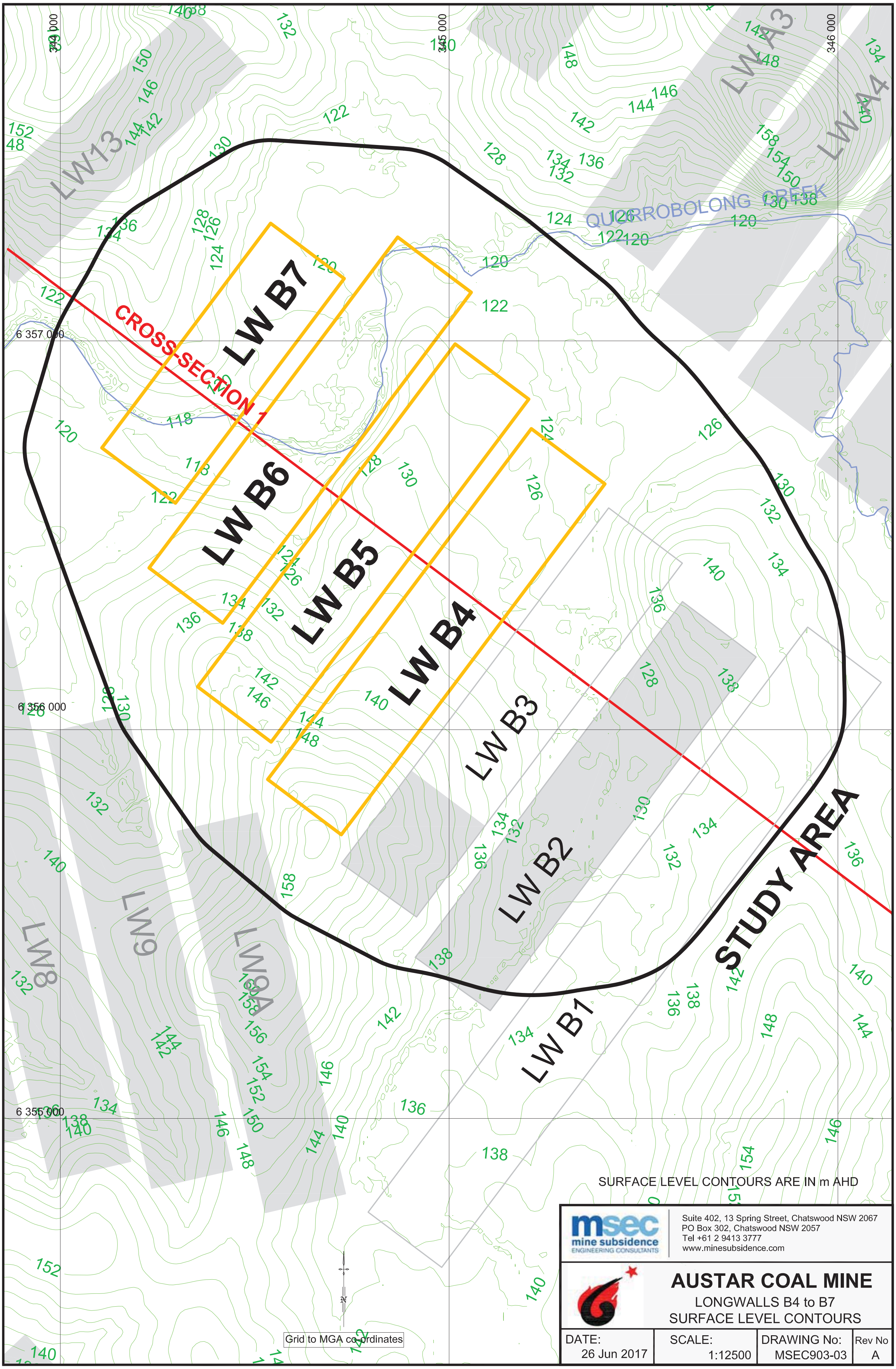

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LONGWALLS B4 to B7
SURFACE LEVEL CONTOURS

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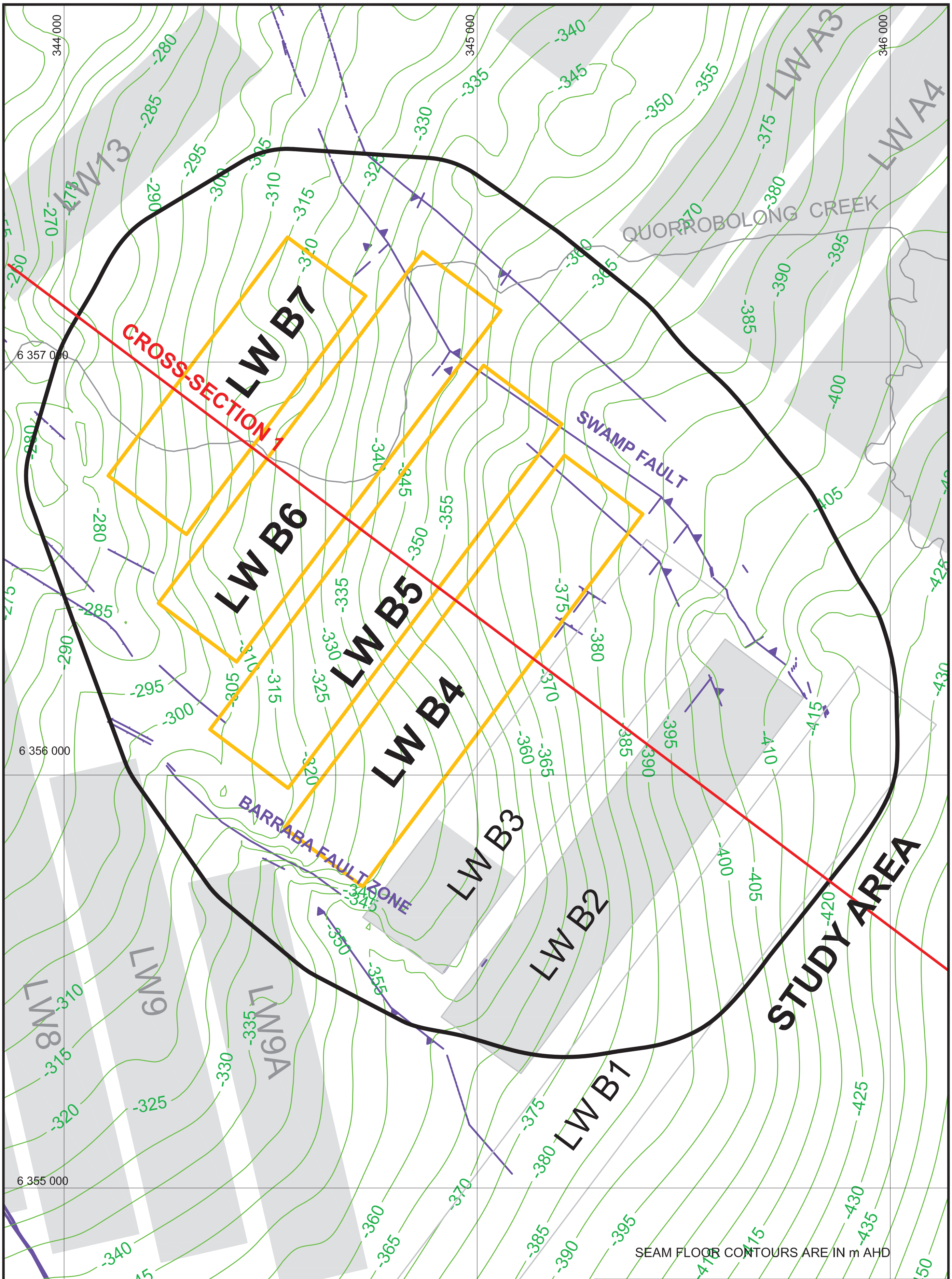

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LONGWALLS B4 to B7
SEAM FLOOR CONTOURS

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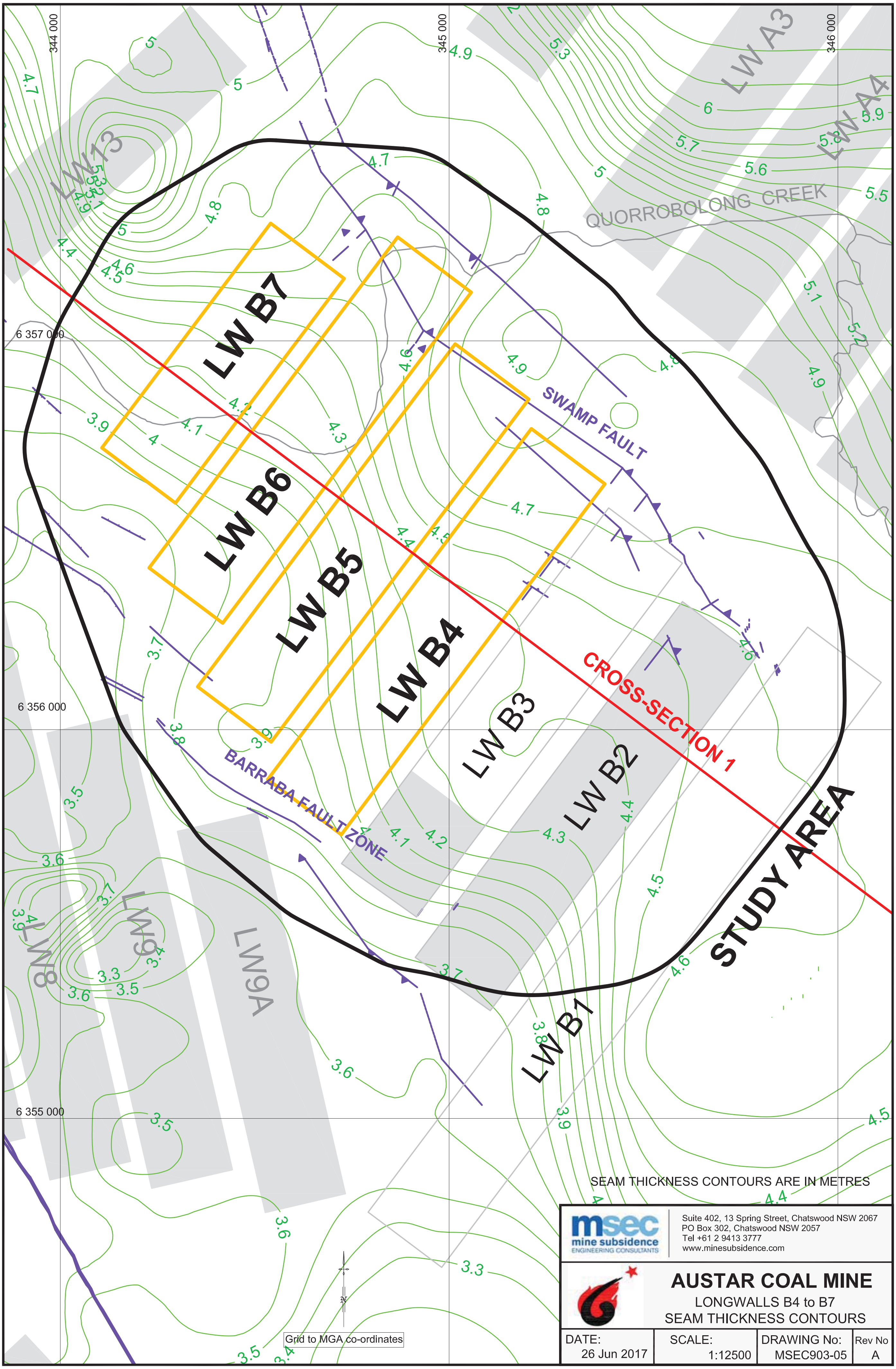

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LONGWALLS B4 to B7
SEAM THICKNESS CONTOURS

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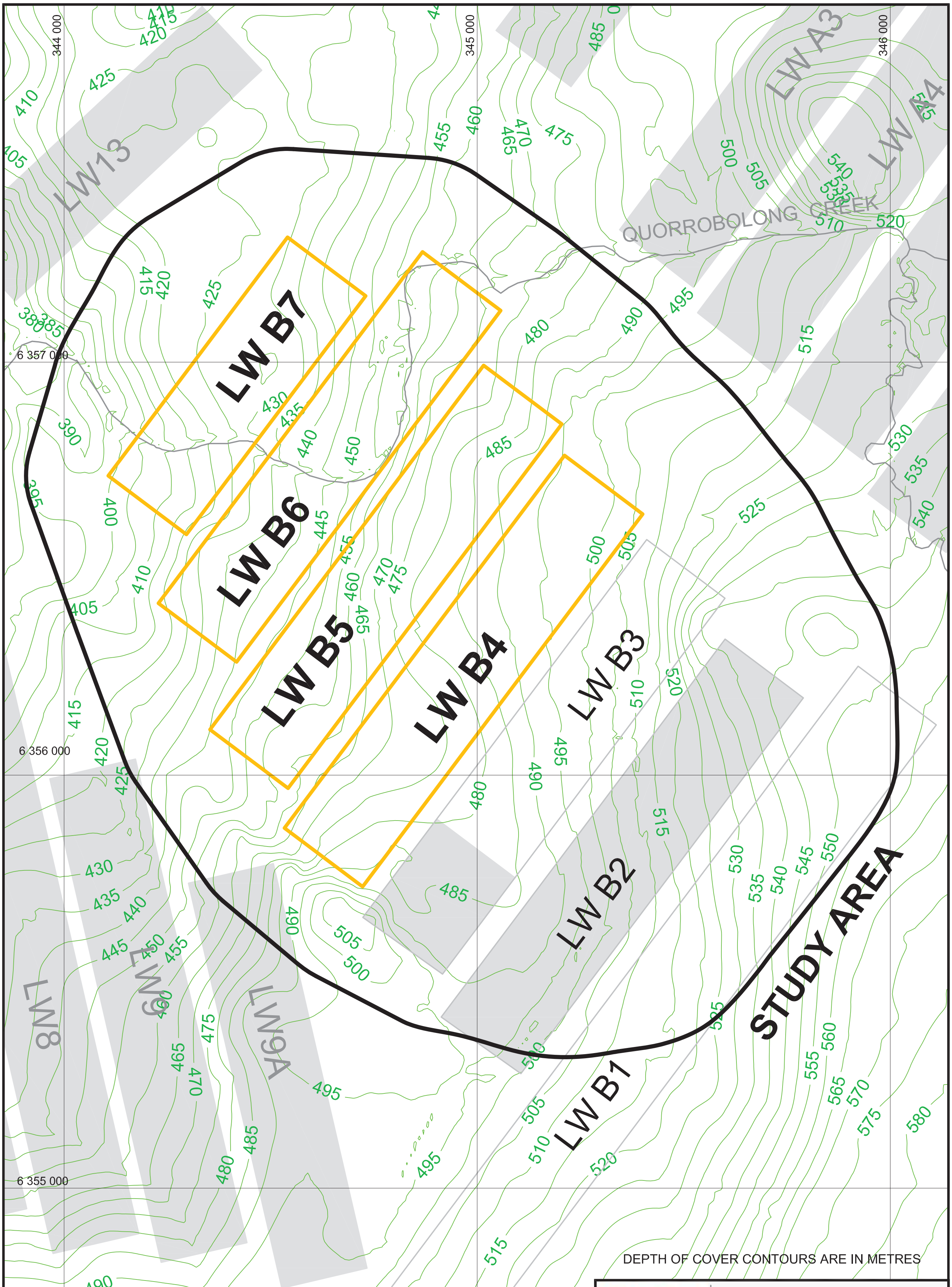

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LONGWALLS B4 to B7
DEPTH OF COVER CONTOURS

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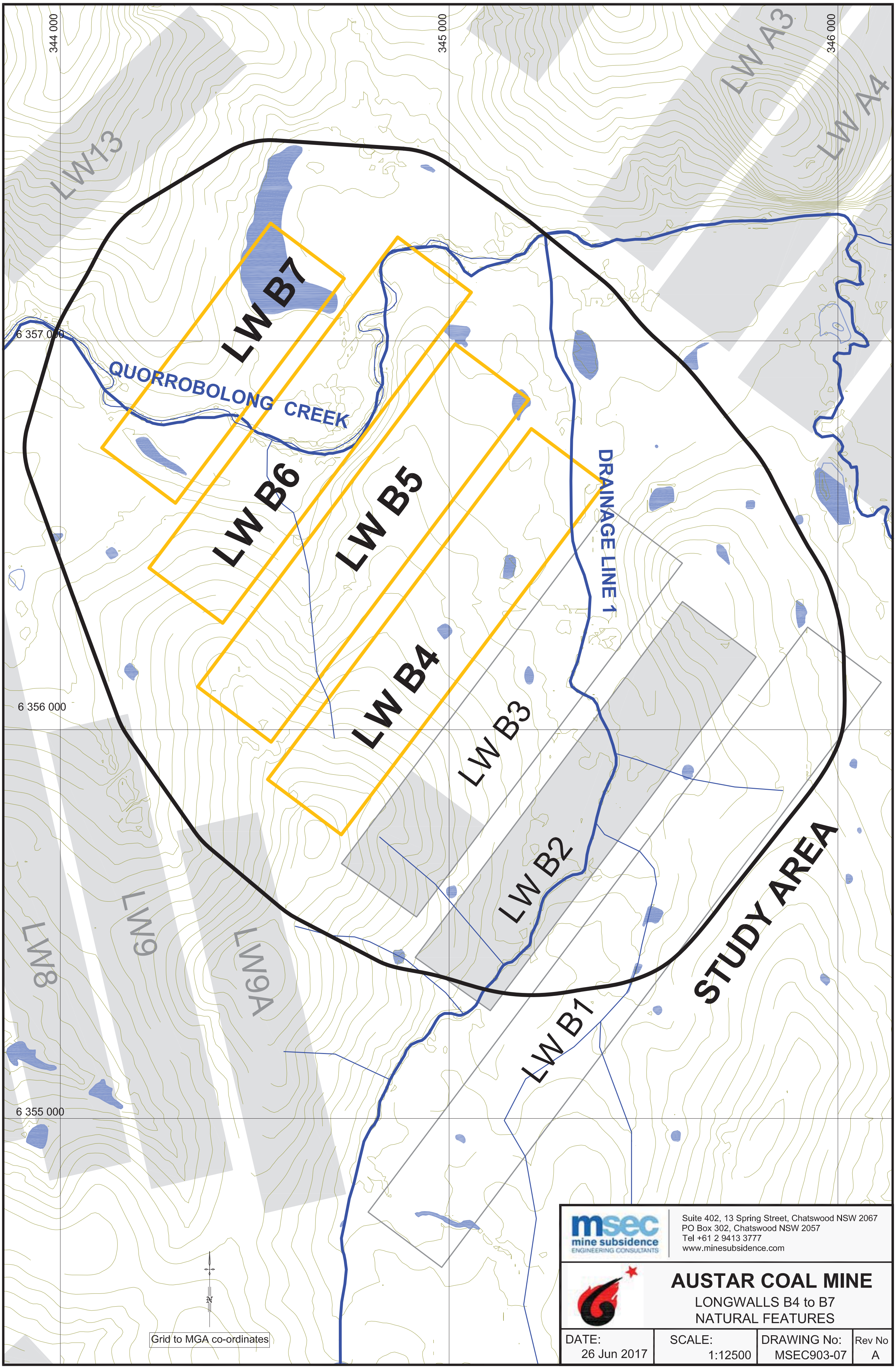

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NATURAL FEATURES

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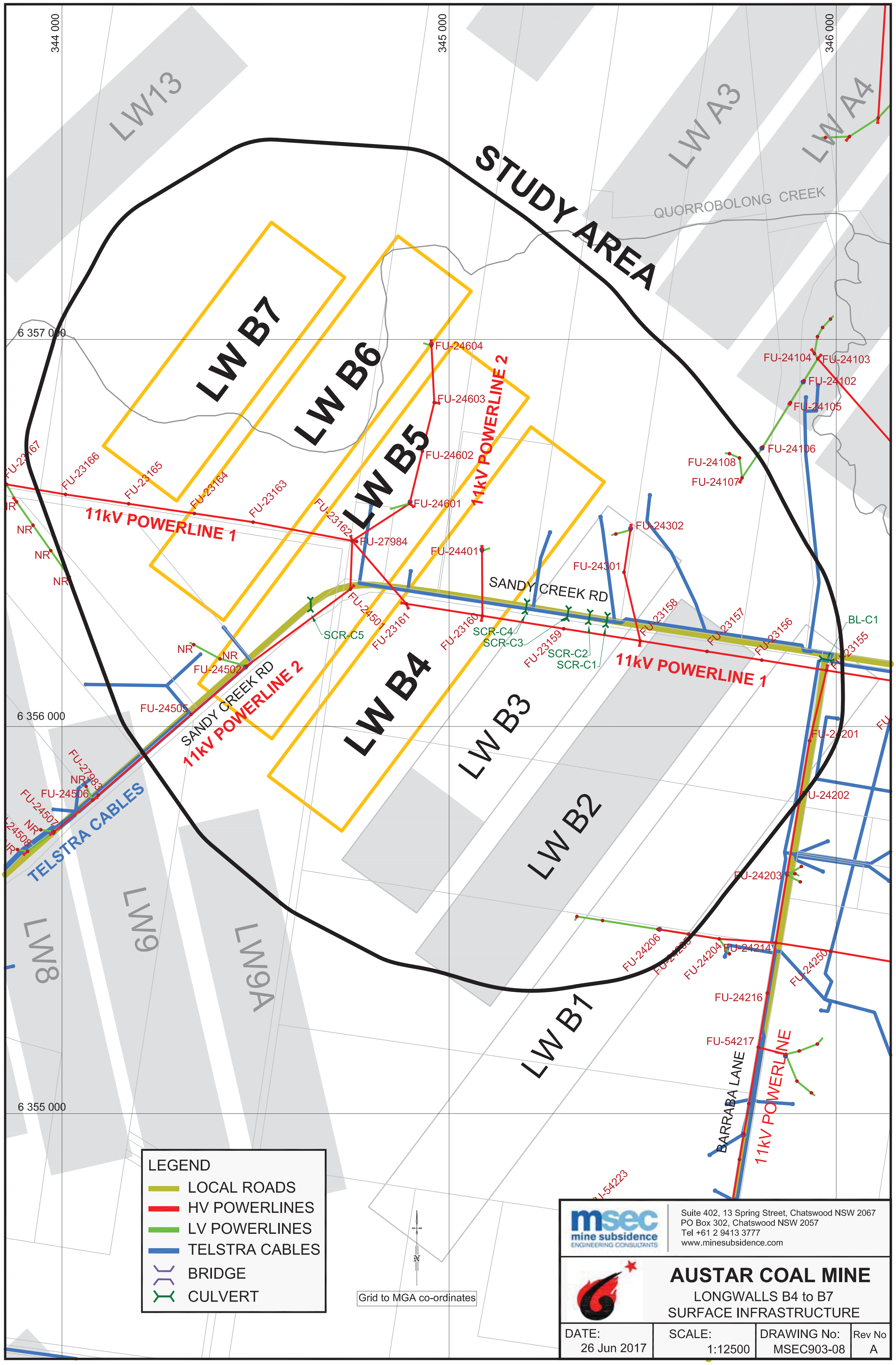

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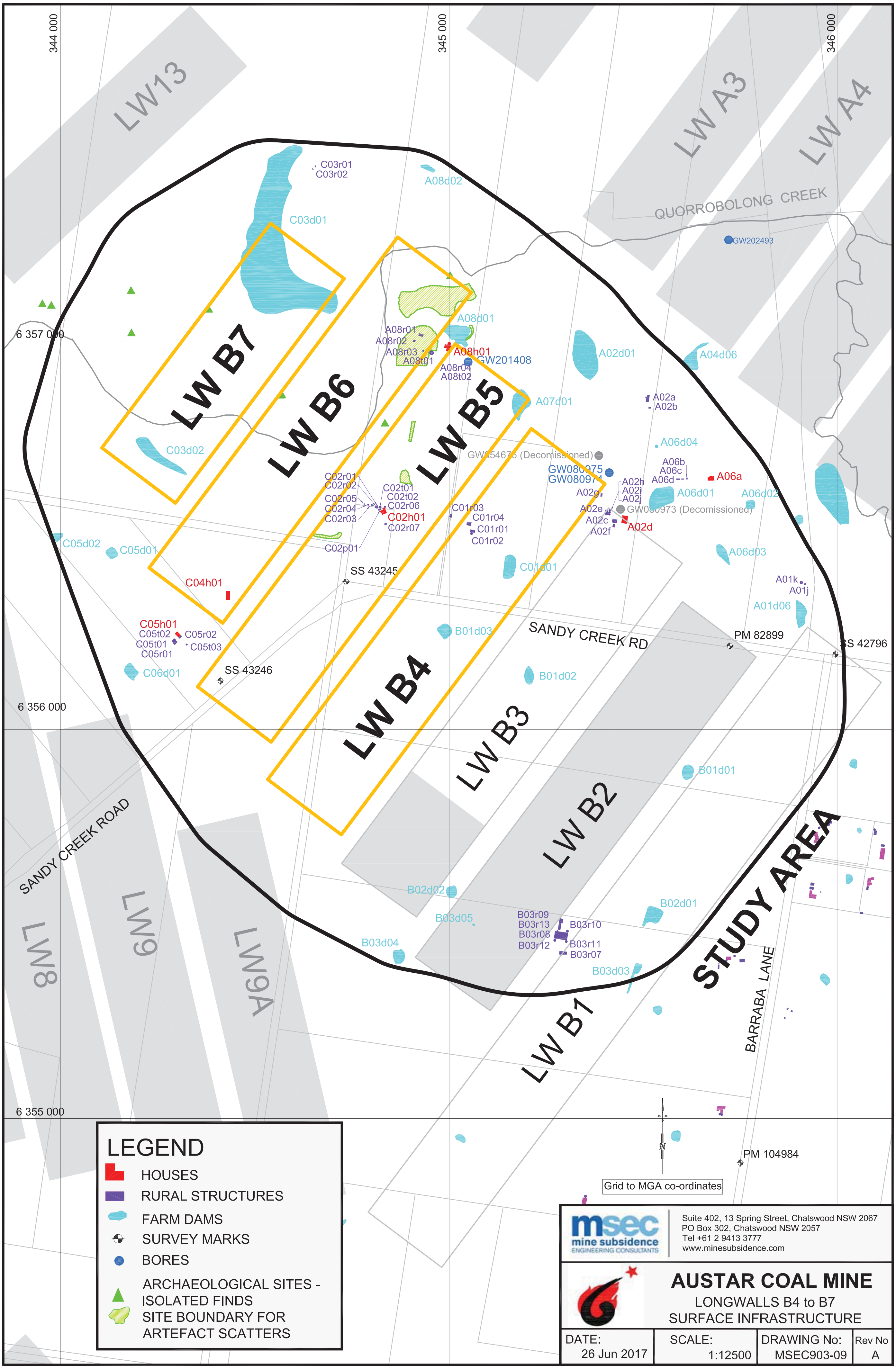

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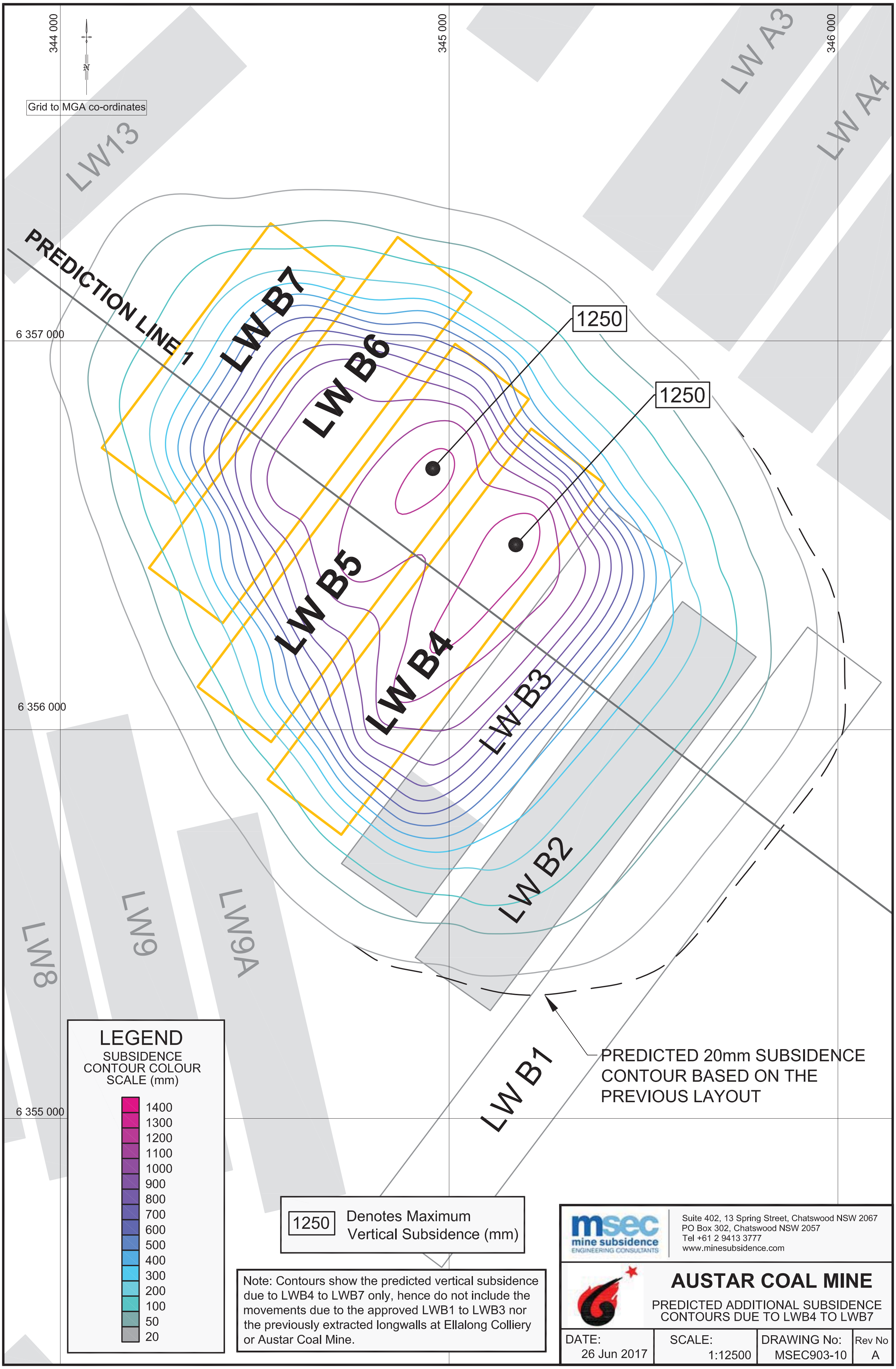

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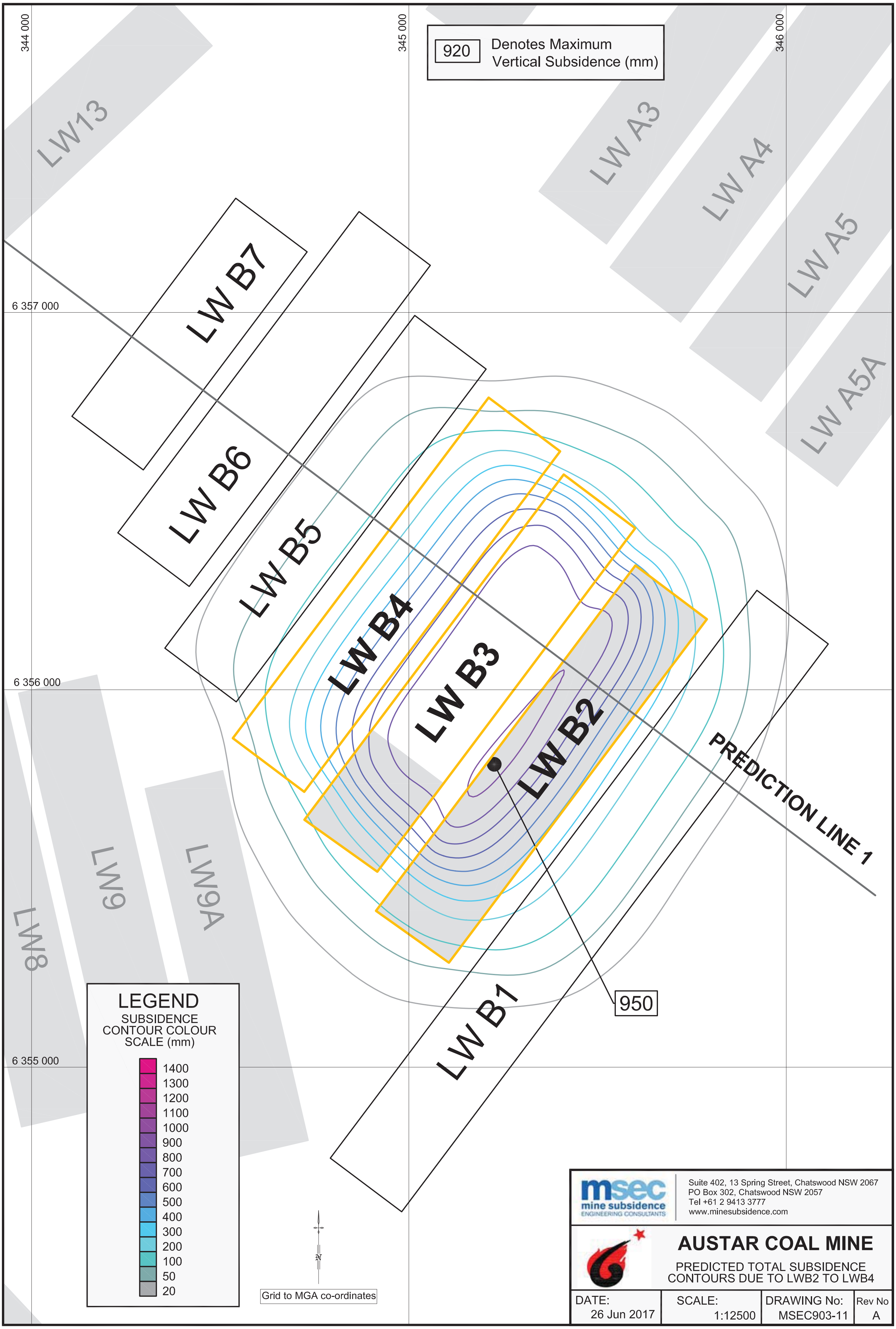

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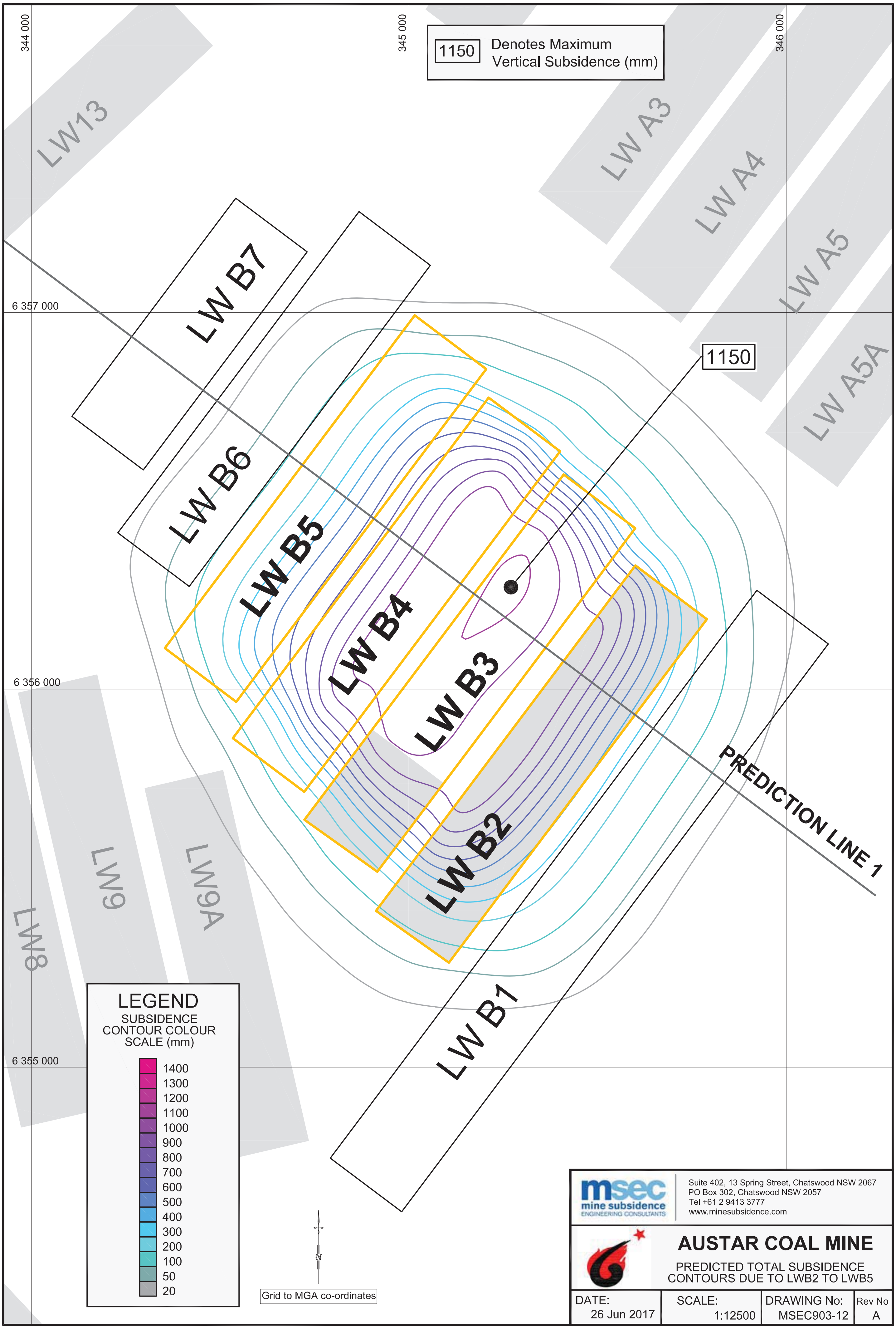

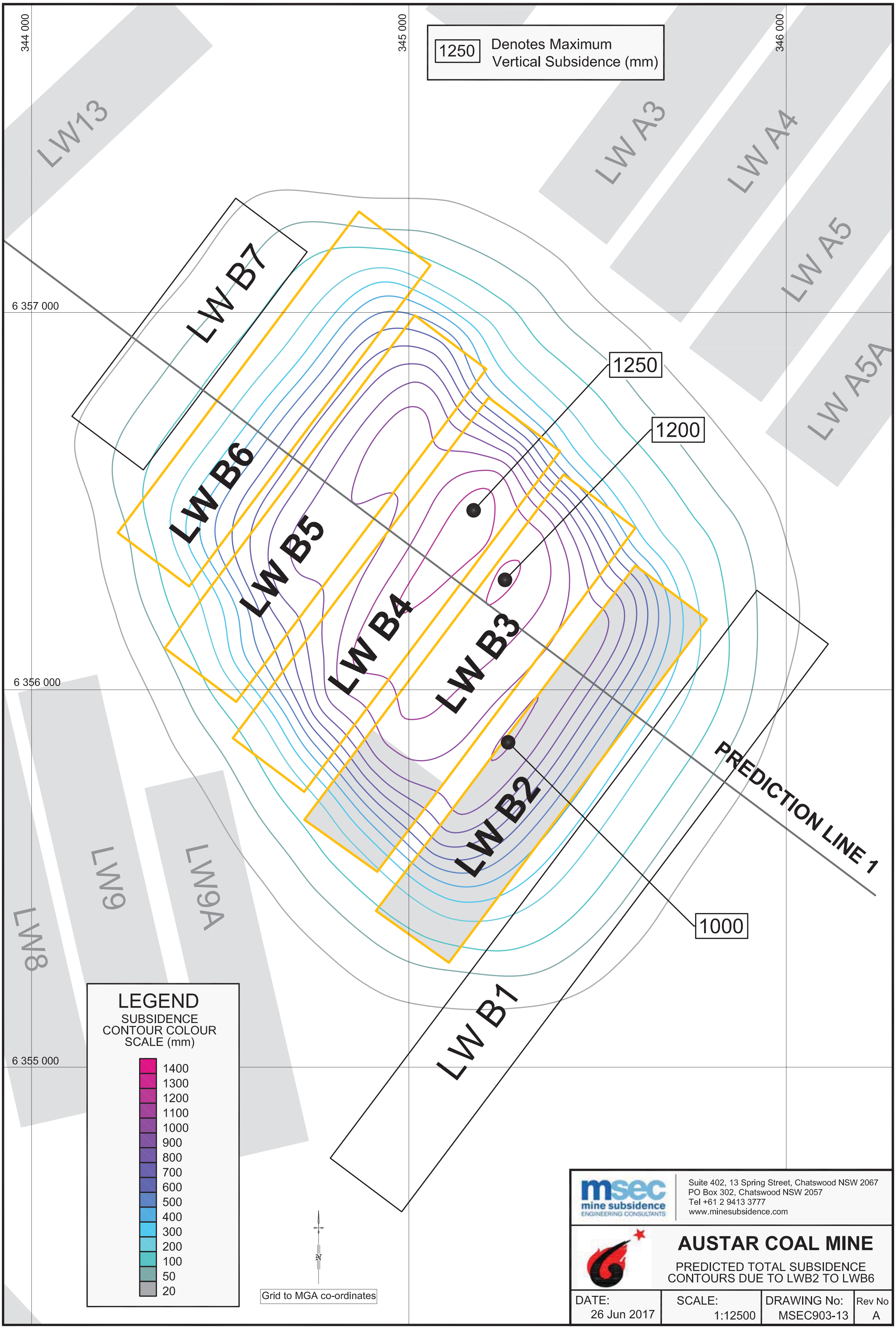

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PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LWB2 TO LWB6

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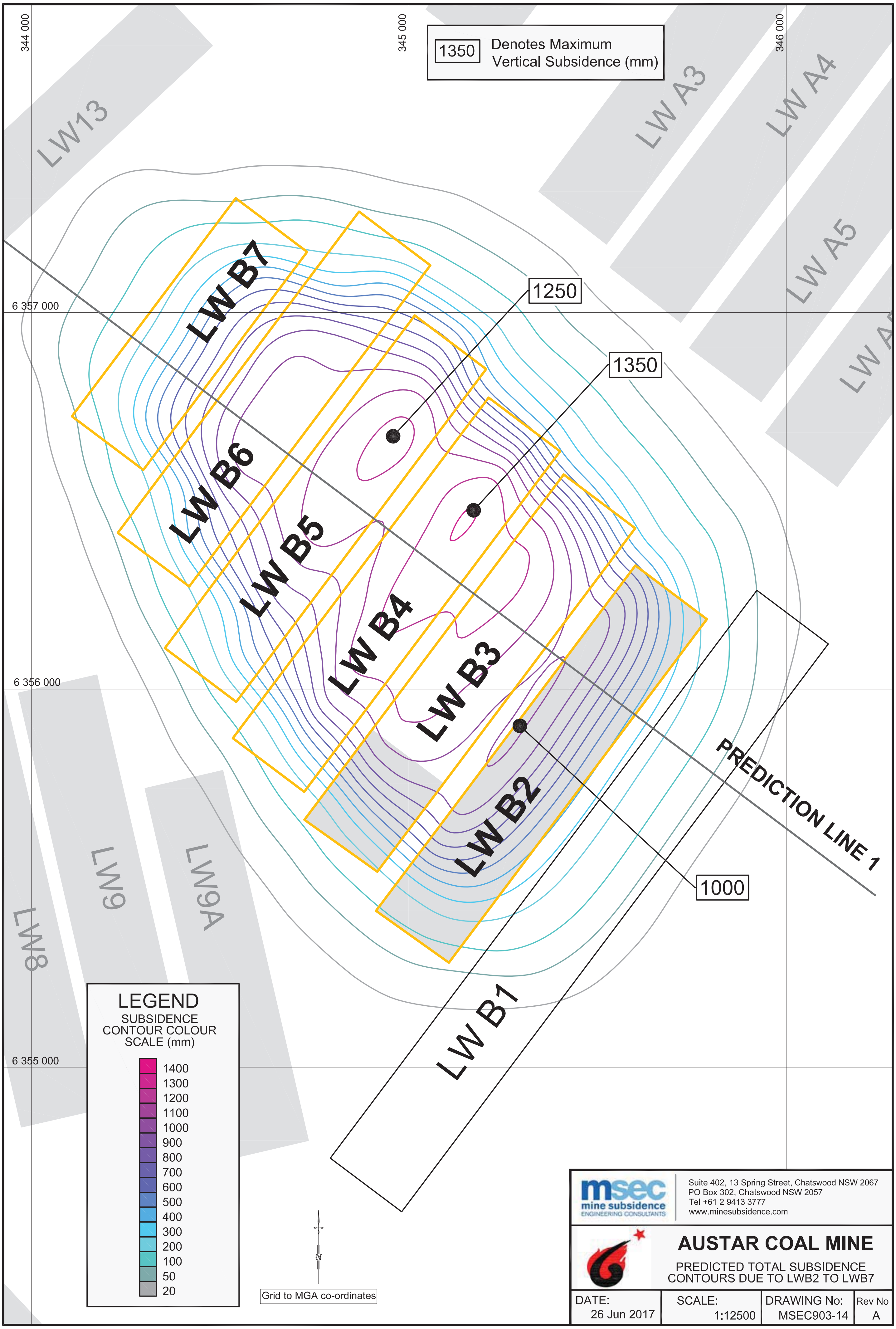
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345 000
346 000
6 357 000
6 356 000
6 355 000
1350 Denotes Maximum Vertical Subsidence (mm)
LW13
LW A3
LW A4
LW A5
LW B7
LW B6
LW B5
LW B4
LW B3
LW B2
LW B1
LW9
LW9A
LW8
1250
1350
1000
PREDICTION LINE 1
LEGEND
SUBSIDENCE CONTOUR COLOUR SCALE (mm)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
50
20
Grid to MGA co-ordinates
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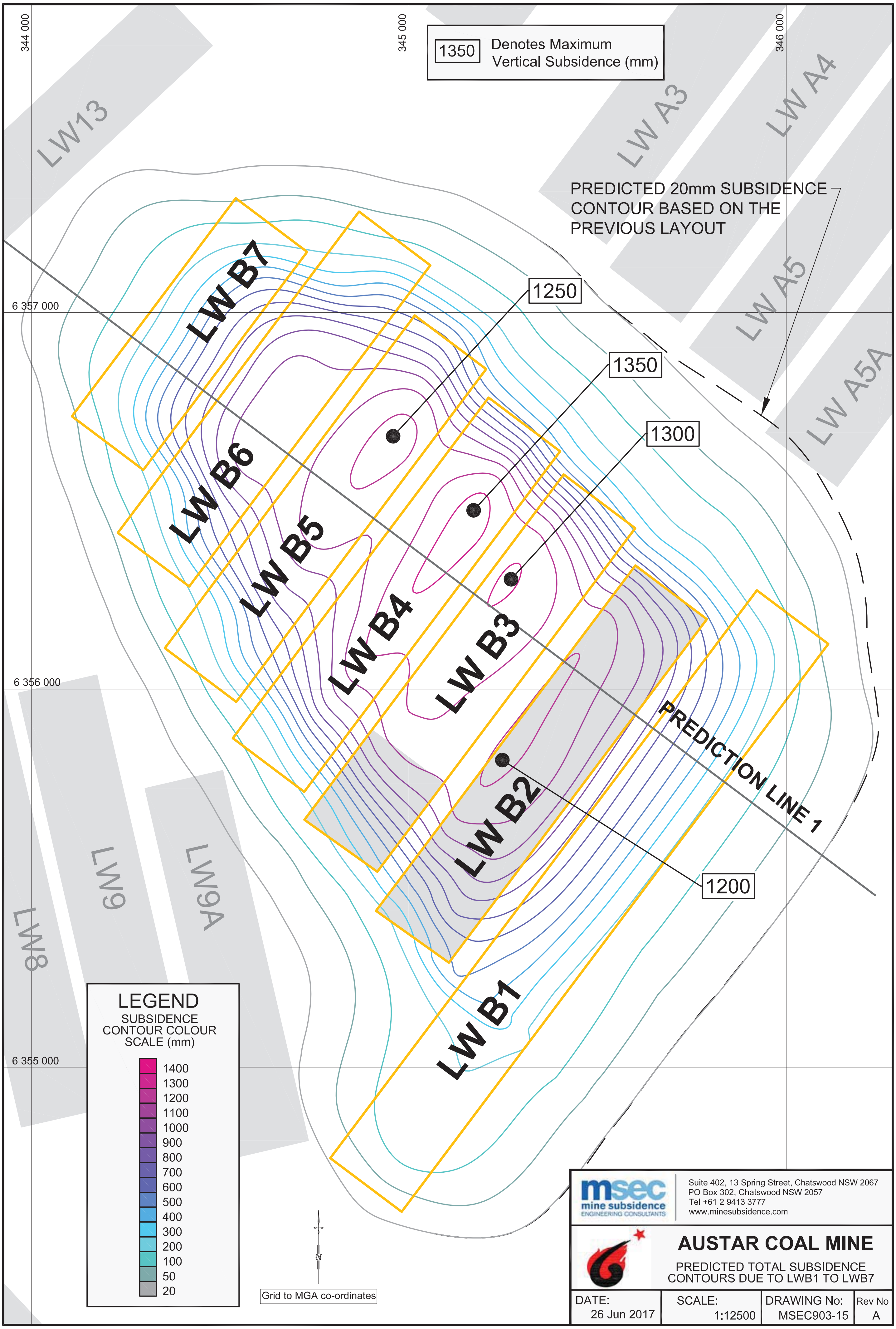

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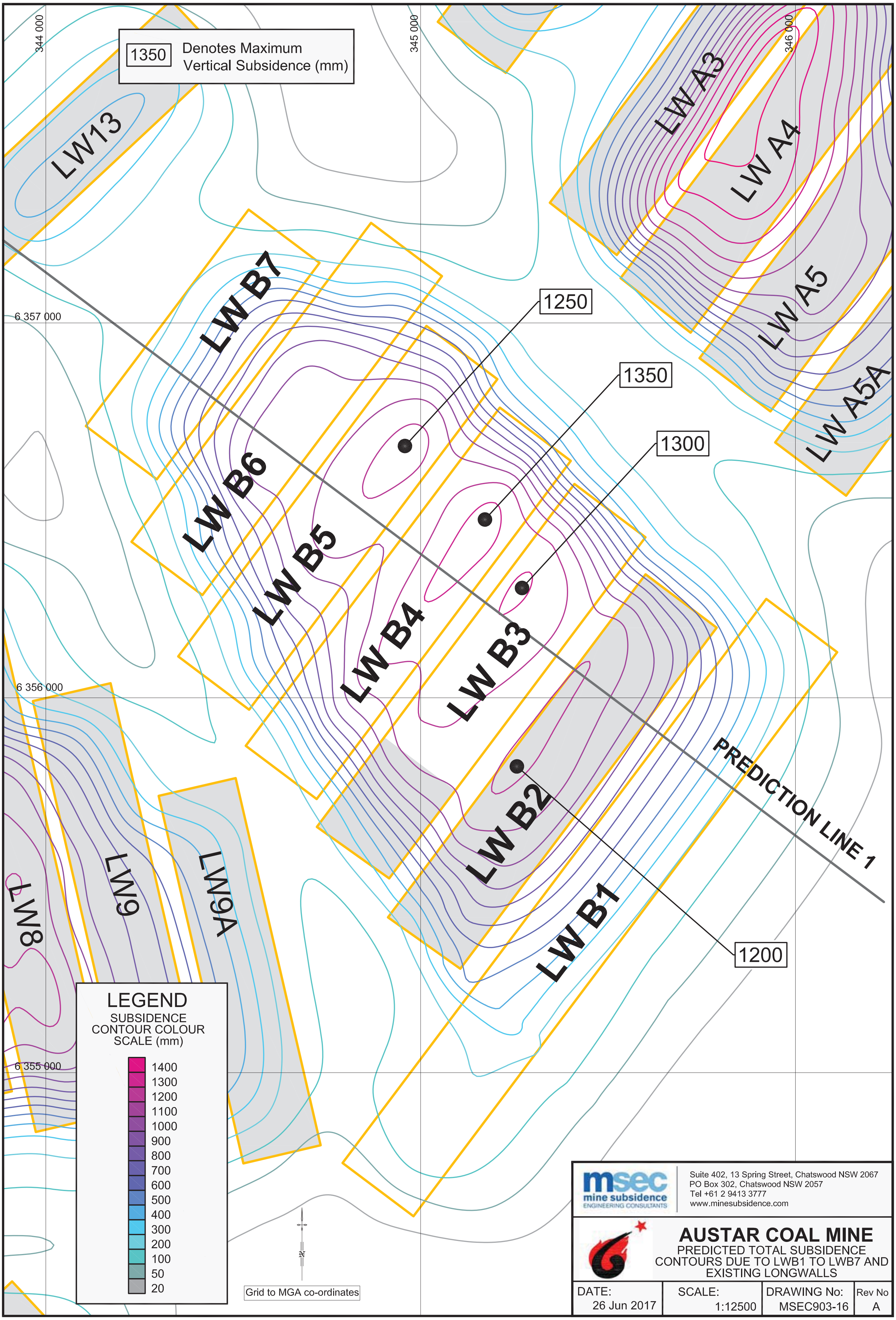

Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

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PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LWB1 TO LWB7 AND EXISTING LONGWALLS

DATE:	SCALE:	DRAWING No:	Rev No
26 Jun 2017	1:12500	MSEC903-16	A